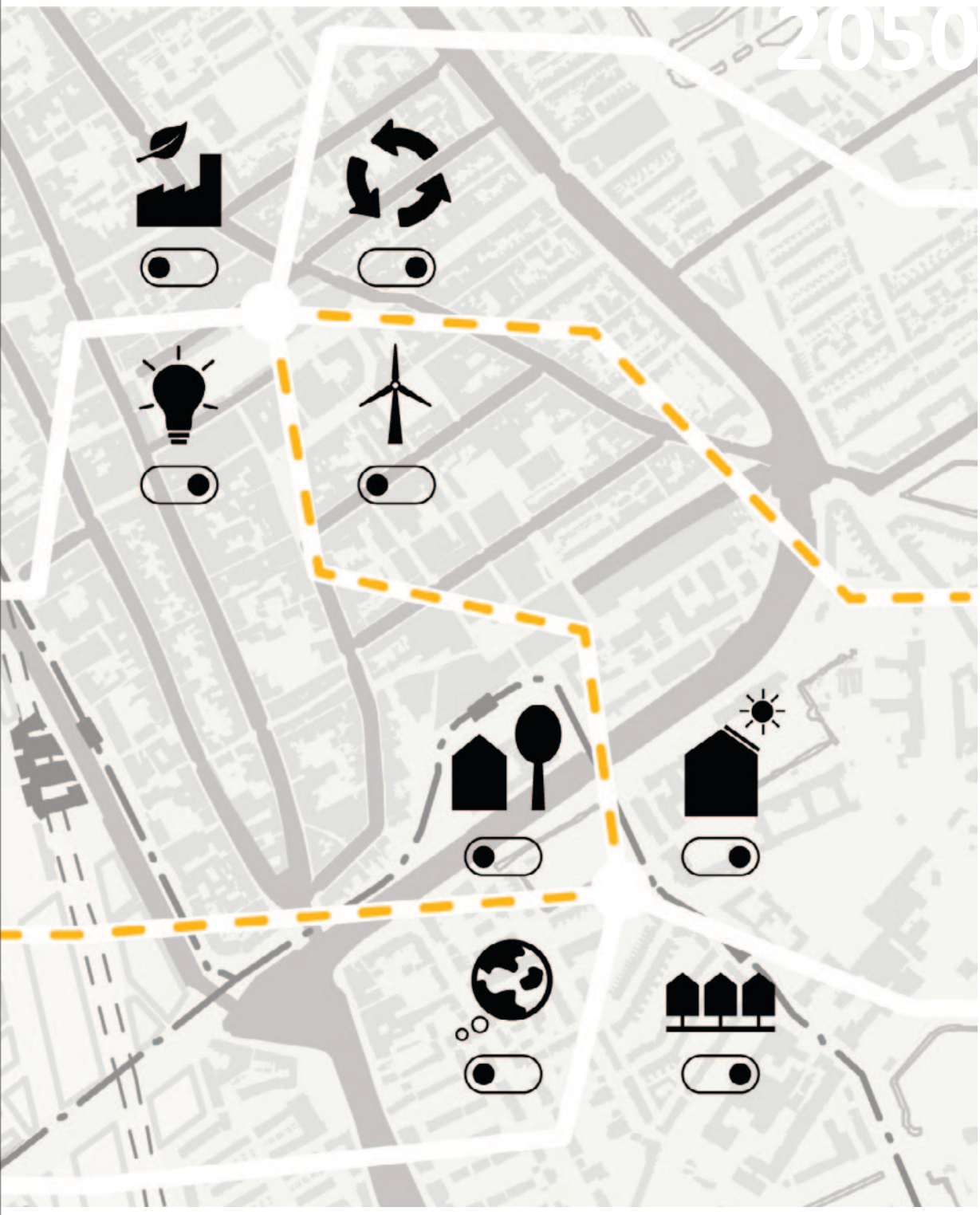
DELFT SMART CITY



KNOWLEDGE ECONOMY ENERGY-NEUTRAL CLIMATE-PROOF

Learning to look at the city in a new way

Cities face considerable social, economic and spatial challenges. The world is urbanising rapidly. Existing services and amenities are under pressure, due to their age, or simply as a result of growing demand. The natural systems on which cities are so heavily dependent are overburdened. Furthermore, their geographical position makes many cities vulnerable to the impacts of climate change. An untenable situation that forces us to shift to an essentially sustainable form of urban development.

The 'smart city' is said to be the answer. But is this not an overly optimistic scenario? Are we again to be seduced into believing in a 'technological fix'? Our era is too complex to simply roll out the latest technology. An efficient city will not, in itself, guarantee capacity for adaptation and self-sufficiency, nor is it a guarantee of social sustainability. In the past I have called for 'smart urban design' based on a much better understanding and better planning of the 'urban metabolism'. This requires an integrated look at the city as a complex of material flows and living environment, which exposes the connections between sources, functions, infrastructure and users. This also requires a broader debate on what kind of city we really want. We have to focus on the big issues currently facing cities – or lying in wait – such as demographic ageing, the need for new healthcare arrangements and for a better match between education and work, and the energy transition. After all, technology is never the solution; it can only be a tool for tackling the issues.

If we define the urban metabolism and set it against these various challenges, we will have a framework for strategic decision-making and a narrative. If the city council can see how to prepare the city for the future, it can share this knowledge with residents, companies and other stakeholders and invite them to participate in solutions which, step by step, will lead to a 'green' economy and an inclusive society. The smart city therefore encompasses, first and foremost, a learning process, a new way of looking at the city, and also a common denominator that can unite parties.

The *Delft Smart City* project was based on this line of thought. It examined the city by means of research by design. One of the products is a sampler of efforts that will be needed to achieve the energy neutrality, climate-resilience and socio-economic development we desire. I applaud the initiative and regard it as an inspiring example for other cities. Let us aim for cities that are stronger through collaboration.

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DELFT SMART CITY

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1 INTRODUCTION

Introduction

Work, prosperity, safety, food, entertainment: the city has lots to offer. Over half the world's population now live in a city, and in some parts of the world migration to urban areas is set to continue for some time to come. Both the global population and the proportion of city dwellers on the planet continue to grow. As a result, city administrators and urban communities as a whole face major challenges: how to handle urbanisation with the prospect of climate change, the need for sustainable energy, and growing social inequality. What is the smart response?

We need smart cities because urban challenges are growing steadily more complex. Delft city council also faces these challenges. What is more, it does so at a time of administrative and social change. The decentralisation of certain central government responsibilities, the need for closer collaboration at regional level and shifting relations between the authorities, the commercial sector and the public all entail new tasks and roles for and make new demands of both the city's administration and public servants. Given all this, how does a local council make smart strategic choices? How can people and resources be used most effectively at a time of austerity? The promise of a Smart City where technology and big data reduce costs and ensure the city functions at its best is attractive. But can a Smart City live up to expectations?

The Delft Smart City project explored recent Smart City developments and what they might mean for Delft. This report presents the findings.

A broad approach was taken in assessing the opportunities of Smart City developments for Delft. The emphasis in the project was not so much on the technological side of Smart City as on the strategy, also known as 'smart urbanism'. Before smart technology is used, it is important to know what goal is to be achieved. Delft Smart City used research by design and a Smart City toolkit to assess three strategic policy goals of Delft city council: an energy-neutral city, a climate-proof city and development of the knowledge economy (as a driver of new jobs).

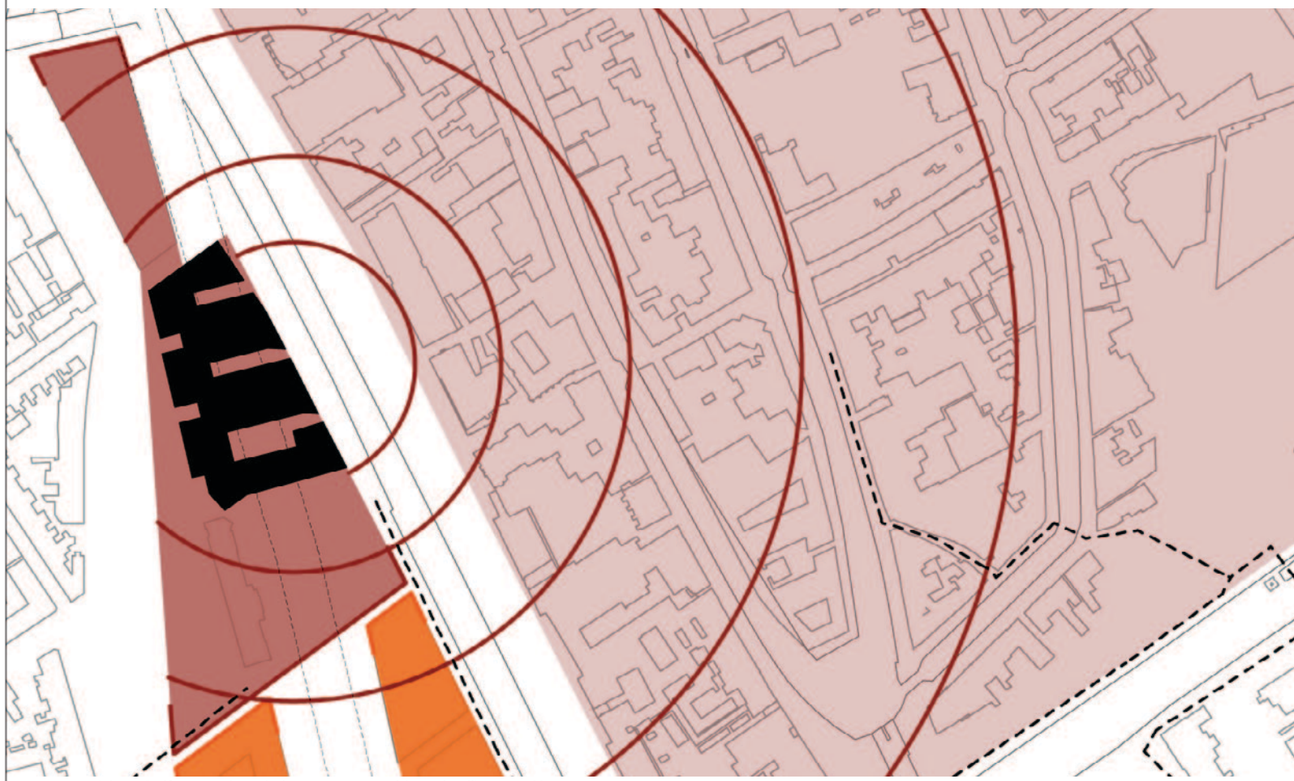
The three strategic goals are the result of a clustering of six original projects/lines of policy. These particular strategic goals (Delft has more, of course) were chosen because these lines of policy already contain elements of the Smart City idea, and a clear long-term goal has been defined, based among other things on national policy and research programmes.

Collaboration with Ministry and TNO

The Smart City idea began to attract attention in Delft in autumn 2013 when, alongside Assen and Amsterdam, Delft featured as a case study in the 'Smart Cities NL' study. This exploration of opportunities and challenges for the Smart City idea in the Netherlands was performed by Ton Venhoeven on behalf of the Ministry of Infrastructure and the Environment's *Atelier Stad* ('City Studio'). Taking a research by design approach, he considered how Delft might better exploit its role as a regional hub. In consultation with the Ministry, Delft city council proceeded to the next step: research by design exploring the concept of Delft Smart City that could be significant for the city itself and for the image of smart cities in general. The Ministry was thus closely involved in the Delft Smart City project, providing both knowhow and resources. At the same time, talks were held with technological research institute TNO. As part of Smart City Flagship, TNO developed a toolkit to support Smart Policymaking. The broad scope of Delft Smart City provided TNO with an opportunity to test and further develop its strategic toolkit.

Two goals

The project had two objectives: to explore a possible approach to long-term challenges and to develop a better understanding of them. Can the Smart City idea be used to develop a strategy for achieving the city's long-term goals? Such a strategy should properly reflect the city's role in the region, and should therefore focus not only on the city council itself but also on other parties in the city. It was for this reason that the project focused on specific challenges facing Delft. Realistic policy objectives can be used to assess whether an approach is likely to lead to results, while at the same time creating a better understanding of the challenges, which the city council and the community can use in tackling them.



Nieuw Delft map > knowledge economy as driver (detail), see p. 68

System analysis

The project developed a systematic procedure for obtaining insight into the intricacies of a challenge, possible solutions and the human and other resources and systems needed to address it. The results give the city council a basis for decision-making and may prompt stakeholders to launch initiatives themselves. The thorough system analysis and exploration of potential strategies constitutes the city council's call for parties to develop initiatives – regional as far as possible – and deploy innovations (technological or otherwise). This approach also allows for initiatives to be 'adjusted' in order to take concrete steps towards achieving strategic goals in the longer term.

The approach gives the city council the opportunity to adopt various positions, depending on the subject at hand. In this sense, this report is not a conclusion, it is merely a beginning. A beginning for all parties that might potentially play a role in getting the city ready for the future.

Guide for the reader

Chapter 2 gives a more detailed description of the concept of Smart Cities and Delft's vision of the concept. Chapter 3 sets out the procedure followed in the project, including the approach taken to the research by design element. Chapter 4 reports on the research by design stage, presenting the result of the analysis of the three themes (*Energy-neutral*, *Climate-proof and Knowledge economy as driver*). The findings are then applied specifically to three locations in Delft. Chapter 5 explains how the TNO Smart City toolkit was used in the project and chapter 6, finally, presents some general conclusions.

A huge range and quantity of knowledge was contributed to and gained from the Delft Smart City project. That knowledge has been recorded in this report. Some aspects are examined very thoroughly, and the results are directly applicable to ongoing projects or lines of policy. In other cases, only an example is given, or a suggestion as to how that aspect might be considered.

2 SMART CITIES

2.1 What is a Smart City?

Network society
Society is rapidly becoming digitised. 'Smart' solutions are being devised and developed in certain sectors – healthcare, water management, energy supply and transport, for example. More and more of these technologies are becoming part of everyday life, and increasingly we live in a network society, where (almost) everything is connected to (almost) everyone.

Physical and digital
The Smart City concept brings the physical and the digital together. It provides a way of addressing global challenges on an urban scale. Regarding the city as a complex system of flows – energy, transport, water, people, services, information, data – within a certain space – the urban environment – to what extent can technology, networks and infrastructures be used to deal with the challenges we face? Can we make the city ready for the future by means of a smart physical, social and digital design?

Smart City definitions
The Smart City concept has been defined in several ways. A lot of the literature on the subject, such as Anthony Townsend's book *Smart Cities, Big Data, Civic Hackers, and the Quest for a New Utopia* (2013) explores the potential role of new technology in urban communities. Townsend defines smart cities as 'places where information technology is combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic, and environmental problems'. He thus emphasises the rise of smart technology. Recent Dutch publications place more emphasis on the intelligence of the city as a whole. In their book *Smart about Cities. Visualizing the Challenges for 21st Century Urbanism*, Maarten Hajer and Ton Dassen call for the smart city concept to be integrated with social issues to give 'smart urbanism'. At a recent debate in The Hague Hajer said 'Local authorities will have to focus on the social issue. Only then will they be able to choose the correct ICT solutions. Thus smart city becomes smart urbanism'.[1]

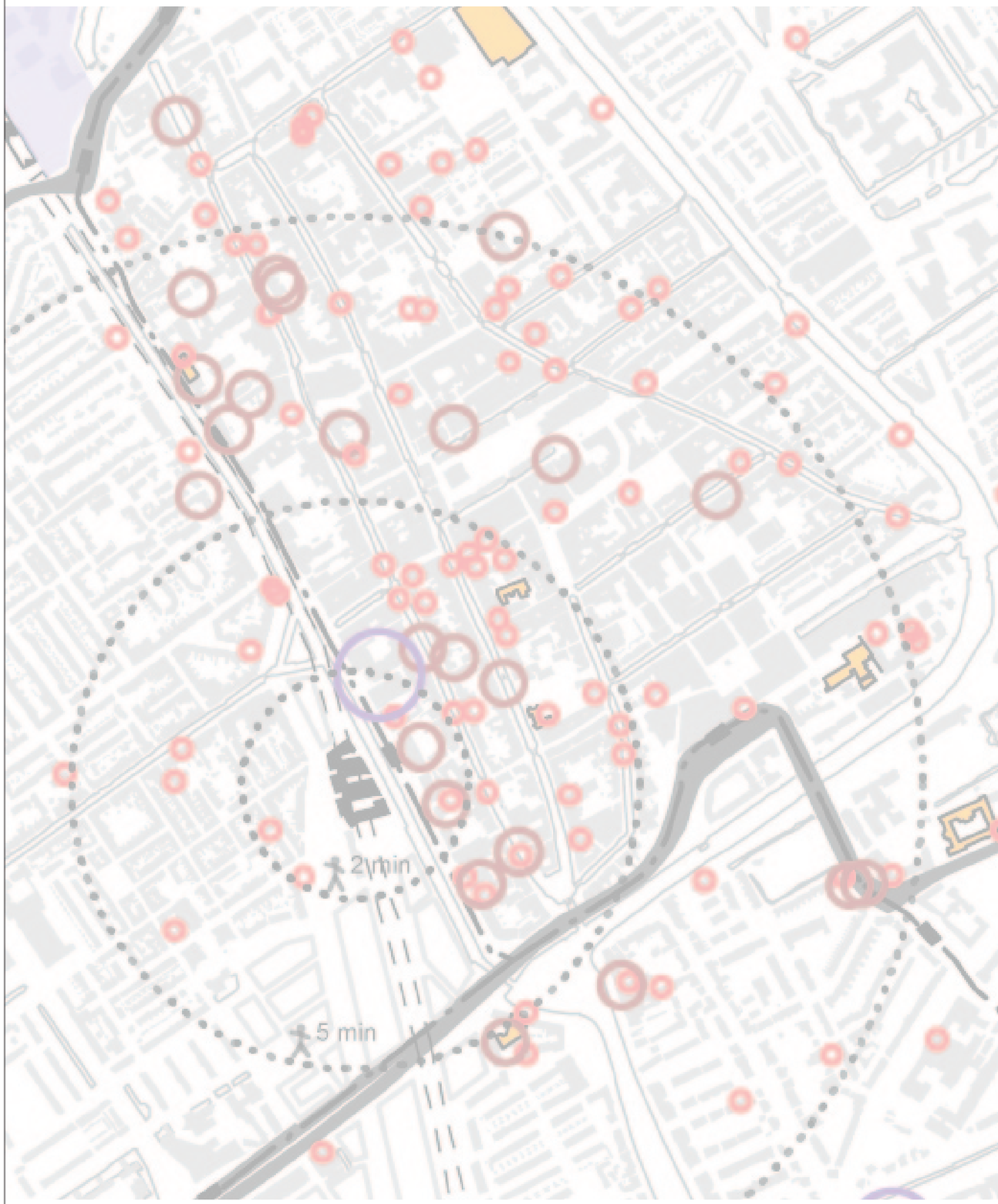
2.2 Europe and the Netherlands

The European Urban Agenda
Europe is also debating the definition of a smart city. The Europe 2020 Strategy focuses on smart, sustainable, inclusive growth. Cities and urban regions will play a vital role in achieving the 2020 objectives. The European Union is joining with national, decentralised and regional authorities to consider how the EU Urban Agenda might develop. The agenda should help the EU foster a joint approach to various policy areas, at various levels of administration (European, national and regional).

Agenda Stad ('City Agenda')
The European Urban Agenda will be presented during the Dutch Presidency of the EU in 2016. The Netherlands is already focusing on urban development and related issues at national level in the form of its '*Agenda Stad*'. *Agenda Stad* is a movement involving central government, cities and urban partners, research institutions, people with urban experience and committed city-dwellers. *Agenda Stad* is the Netherlands' way of anticipating the European Urban Agenda, so that it is able to discuss the knowledge it has gained in its own cities at European level.

Agenda Stad has three aims [2]:

1. To get the major challenges facing cities on the agenda by clearly defining problems and solutions.
2. To act as a catalyst for urban innovation by linking, accelerating and scaling up promising initiatives.
3. To organise coalitions to enable the necessary transitions.



Knowledge economy map > companies (detail), p. 55

2.3 Delft's vision of a Smart City

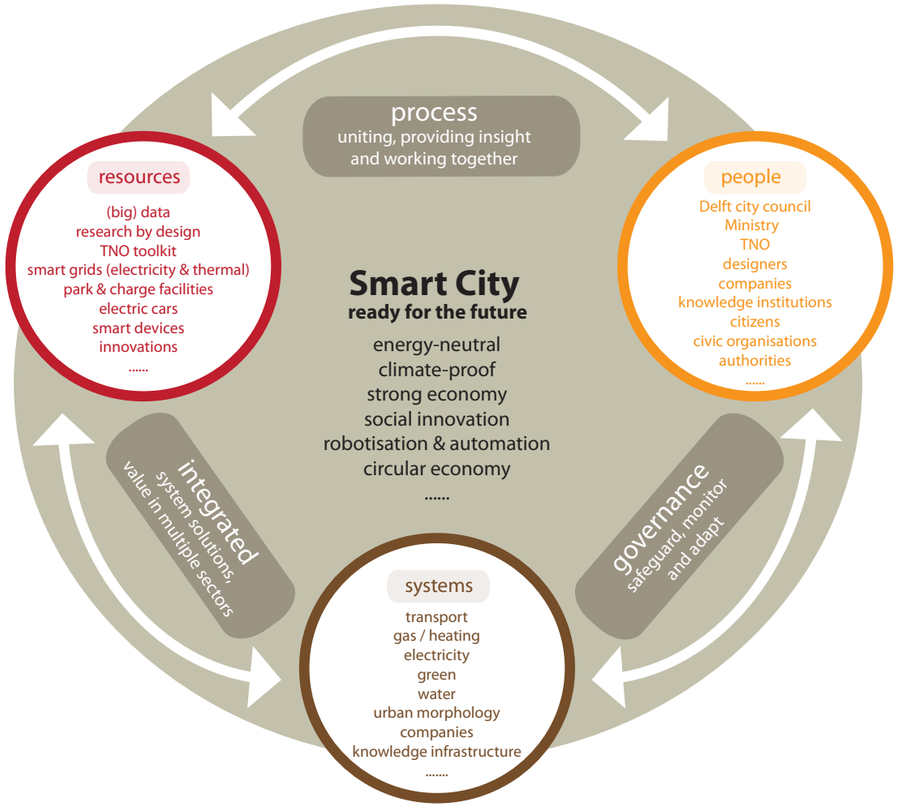
At the start of the project, Smart City was defined not as a final goal, but as an approach whereby new, integrated solutions for making the city ready for the future would be developed, implemented and monitored in collaboration with others. This approach was based on three pillars: systems, resources and people, linked by an integrated approach, bringing parties together and governance. This is illustrated in the diagram below.

Future-proof city
The long-term challenges facing the city – adapting it to climate change, making the transition to renewable energy, and caring for various vulnerable groups differently and better – lie at the centre of the diagram. These challenges are complex, and have different time horizons.

Systems
The city is a complex physical entity through which a number of 'flows' pass: transport, food, waste, data, power, natural resources, people. These flows are possible thanks to certain infrastructures. Surface water, for example, flows from canals in the open countryside and rivers into city canals, waste water flows through the sewers, and pedestrians and cyclists move along footpaths and cycle paths. Digital data, on the other hand, flow through cables or wireless networks. This collection of flows and their associated infrastructures are defined in the Smart City approach as the city's systems.

Resources
Resources can be used to improve systems in order to achieve long-term objectives. The resources in question comprise innovative resources, like the use of big data, smart grids, sensor technology and apps, and existing resources, including better use of the capacity of systems.

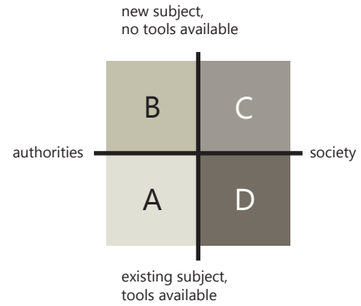
People
People bring about change and ensure that the city as a whole becomes smarter. The energy consumption, climate resilience and economic resilience of the city are matters that concern all members of the urban community. The authorities, employers and civic institutions can encourage people to contribute by organising and supporting parts of the community in a certain way and making resources available.



Integrated
Most long-term challenges involve several systems and therefore require integrated solutions. The challenges are also often so complex that an incidental improvement will not suffice; solutions are needed at system level. Making the spatial impact of solutions at system level clear and specific turns abstract goals into manageable individual challenges for which measures can be put in place and actions undertaken. Sometimes these measures and actions will be sectoral, but insight into the system solution makes it clear how they contribute to the whole (integrated).

Process
Parties in charge of systems or resources that have a bearing on the challenge will not necessarily actively seek to collaborate. This applies both between different parties and within organisations. After years characterised by a sectoral mindset and behaviour, cross-sectoral action does not come naturally. Bringing people or parties from different disciplines together is often a time-consuming process that requires great care. The key thing is to make people understand specific possibilities and the benefits to all of involvement in an integrated challenge that allows parties to bring their own strengths to bear.

Governance
The authorities, as guardians of the common good, can be expected to address and clarify social challenges. If society is expected to contribute to solving problems, it is important that people feel they own the problems. Governance is about how an organisation pursues its policy goals, manages processes and monitors the results. *Good governance* is a form of governance that is effective in the context within which management takes place. In other words: the method of governance and the role of the authorities in it differs from one subject area to another, depending on the goals, the parties involved, the knowledge available and the structures present. This is illustrated in the diagram below.



[source: A. Loeber UvA, R.J. de Graaff ORG-ID]

The horizontal axis indicates who is responsible for the challenge. Is it a responsibility for the authorities (installing sewerage system)? Or is it a job for society (reducing hard surfaces in gardens)? The vertical axis shows whether it is an innovative subject for which tools/policy instruments have yet to be developed, or a known subject for which technology and regulations are already available. The diagram is an aid that can help local authorities decide how to tackle complex issues. Take, for example, the development of Smart Grids. This requires technological and administrative innovation, and therefore more intervention on the part of the authorities than, say, the installation of solar panels. This is a tried and tested technology for which regulations and tools (grants) already exist. In the diagram, solar panels would be in the D quadrant, while Smart Grids would shift from B to C.

Positioning challenges in society
In essence, the long-term challenges a city faces are generally the same as those faced by parties higher up the scale. Many challenges are brought to society's attention by central government, then discussed with commercial and civic partners before measures are adopted. A good example of this is the *Energy Agreement for Sustainable Growth* (2013), progress on which is being monitored by the Social and Economic Council of the Netherlands. These challenges are then passed on to local authorities, so that they do not need to reinvent the wheel. It is good for local authorities to realise which parties have been involved in defining the challenge, so that they can involve local representatives of those parties in the search for local solutions.

Application in research by design phase
The research by design phase started by dissecting the challenges, highlighting in each case how it is positioned in society. After a detailed analysis of the challenge in relation to each of the three themes the findings were summarised in an overview, taking an integrated look at the different systems that have a bearing on the theme. The thorough analysis allowed the systems, resources and people needed to address the challenge to be identified. This was then summarised in a second overview. Both overviews indicate the appropriate governance quadrant for each individual challenge. The overview provides an example of what form governance might take, and defines the roles of the different parties. A possible next step might be to launch a process in which parties become involved in actually addressing the challenges.

3 PROCEDURE

3.1 An intensive process

Many people were involved in the Delft Smart City project. At the start of the project it was already clear that the study would have to be performed with – not for – the city council. This was necessary in order to guarantee sufficient depth in terms of themes and disciplines, and also to ensure the results were fully taken on board. The process of analysing the three themes started in September 2014. A series of interviews were held with policy officers and project staff, people from the Research & Statistics Department and strategic advisers of Delft city council. The research team structured the information obtained from the interviews and a large quantity of existing data on the themes in question and presented them in the form of maps.

The first Delft Smart City workshop was held on 28 October 2014; it was attended by 35 people, including 12 staff from TNO, 3 from the Ministry of Infrastructure and the Environment, 4 from the research by design team and 16 from Delft city council. The morning session was devoted to practising with TNO's Smart City Gameboard. The afternoon session presented the initial results of the research by design phase and the three themes were explored in more depth. The outcome of the workshop was incorporated into the rest of the research by design phase. A spatial analysis of the systems associated with the three themes was produced, the challenges described and potential directions for solutions developed using maps, diagrams and text. The outcome was also discussed with the council staff concerned.

At the second workshop on 11 December the initial results on the energy-neutral city theme were presented, TNO highlighted the potential of Urban Strategy and a Smart City Dashboard was presented, and three workshop sessions were held to enable participants to practise applying the potential solutions to each theme at three locations: Nieuw Delft, Buitenhof and Schieoevers Zuid. There were 31 participants at the second workshop: 6 from TNO, 3 from the Ministry, 4 from the research by design team and 18 from Delft city council. The results that emerged from the research by design part of the project gave rise to this report.

Seven interviews and three preview presentations were held with staff of Delft city council to test and hone the final results.

3.2 Research by design

Research by design is a method for performing analyses, identifying interests, investigating connections and developing scenarios using visual techniques. Research by design includes a co-creation process, generally in the form of a workshop at which parties share their positions and knowledge and jointly develop innovative solutions. The three different themes in Delft Smart City were each subjected to a systematic research by design process, repeating the same steps for each. These steps are described below and also appear as sections in the chapter on research by design.

1. introduction to theme
The background, national and European context of each theme were described, along with the positioning of the challenge in society.

2. developments in the region
A description of the main regional developments with a bearing on the theme.

3. spatial analysis of systems
The systems or flows in the city involved in the theme were described. As much data as possible was gathered on these systems and visualised in maps and diagrams. This included quantitative data such as information from interviews with policy officers and project staff from Delft city council. In the case of 'energy-neutral', the focus was on information from the *Energie in Beeld* database and spatial information. For 'climate-proof' data on the water table, flooding and water quality were incorporated into models produced by Delfland regional water management authority and the city council. Delft Smart City used existing maps on which these data were visualised, rather than the data themselves. The theme 'knowledge economy as driver' drew mainly on data from the council's annual statistics and data originating from the Research & Statistics Department. The challenges and solution alternatives were described for the various systems.

4. overview 1: goals > effort
The challenges and solution alternatives for each system were clearly presented in a diagram until a total overview of each theme had been created. The charts encapsulate the specifics of the key goals for a future-proof city based on the Delft Smart City vision.

Result of workshop session on Schieoevers Zuid

5. overview 2: infrastructure > technology > partners
The analysis of systems and flows provided insight into the relevant infrastructure. A second chart was then produced showing what technology (smart or otherwise) will be needed to achieve more efficient or more sustainable systems, and which partners will help achieve this, thus incorporating the three pillars of Delft's Smart City vision – people, resources and systems – into each theme.

6. summary and conclusions
The analysis was summarised and conclusions drawn for each theme. A map was produced showing which locations will play a role in achieving the long-term objectives.

7. specifics for each location
The final step involved filling in the details of the thematic challenges for three different locations: Nieuw Delft, Schieoevers Zuid and Buitenhof.

3.3 Smart City toolkit

As well as a research by design phase, the project also included experiments with the Smart City toolkit developed by TNO. Various tools were used at both workshops.

Smart City Gameboard
The Smart City Gameboard is a tool for promoting strategic discussion of the integrated long-term development of a policy measure or project.

Urban Strategy
Urban Strategy is an interactive tool for spatial planning which allows the effects of urban developments to be simulated.

Smart City Dashboard
A Smart City Dashboard gives policy advisers, council management teams and city councillors an integrated perspective on the latest situation.

4.1

ENERGY-NEUTRAL

2050: no carbon emissions from fossil fuels within Delft's municipal boundaries

Delft city council aims to be 'energy-neutral' by 2050. This means no CO_2 will be emitted from fossil fuels within its boundaries [3]. This ambition is Delft's response to European, national and regional agreements. The city council is keen to ensure a secure, affordable and clean energy supply for its residents. The three main arguments in favour of a transition to clean energy are: geopolitical urgency (from global dependence to local supply), the depletion of fossil fuel reserves and global warming caused by carbon emissions.

From global to local

A large proportion of the Netherlands' energy requirements are met using imported fossil fuels. Thanks to our natural gas reserves we are not entirely dependent on imported energy. The proportion of energy generated from renewable sources in the Netherlands is still very small. If it were to switch to local power generation from renewable sources the Dutch government could become independent of foreign suppliers. This would shield the energy supply from geopolitical developments and enable the government to ensure energy remained affordable. It would also represent an investment, leading to the generation of power in the local economy, thus creating jobs. The figure on the following page shows the energy flows through the Netherlands, and how they determine our energy supply. Apart from our high degree of dependence on imported fossil fuels, it highlights the fact that three times more fossil fuels pass through the country (some of them processed here) than we actually use. This process is an important pillar of the Dutch economy. A transition from a global to a local energy system would impact on this.

Fossil fuels running out

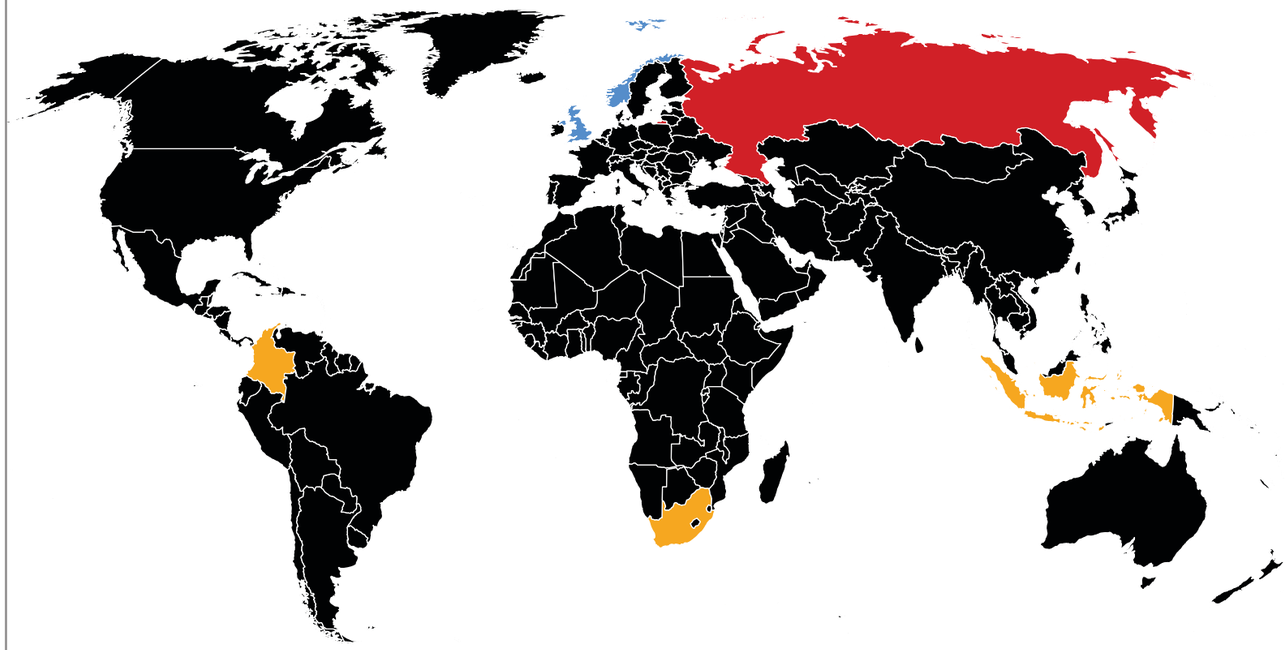
The depletion of fossil fuel reserves is an important reason for switching to renewable sources. However, new fossil fuel reserves are still being found and exploited. The problems associated with global warming due the burning of fossil fuels appear to be overtaking those associated with availability, however. It was recently calculated that, if we are to have a 50% probability of keeping global warming below 2C, the quantity of fossil fuels that we should leave unexploited is some three times higher than the amount we are 'allowed' to burn [4]. The Netherlands' natural gas reserves will run out in the near future. According to Statistics Netherlands, based on the net annual production for 2013, at the end of that year there was enough gas left to last for another 12 years [5].

Global warming

Greenhouse gases like CO_2, methane and nitrous oxide cause the earth to retain heat. This 'greenhouse effect' is causing the average global temperature to increase, accelerating climate change. Since the mid-20th century the burning of fossil fuels has caused a huge increase in carbon emissions, and therefore also of the quantities of greenhouse gases in the atmosphere. Concentrations of these gases have reached levels higher than at any time in the past 800,000 years [6]. A lot of research is being conducted into climate change and its impacts. All over the world, measures are being taken to mitigate unfavourable effects like global warming and sea level rise, and to adapt the human environment to the consequences of climate change. Reductions in carbon emissions are an important mitigating measure.

Positioning the challenge in society

The EU member states have undertaken to reduce carbon emissions in various agreements. Factories and companies that emit large quantities of CO_2 are subject to the European emissions trading system (ETS). Gradual reduction of the emission rights sold should reduce overall emissions [7]. Delft and 6000 other European towns and cities, have signed the 'Covenant of Mayors', in which they committed to raise the bar for CO_2 emission reductions higher than the European Union's 2020 target. The Dutch government has reached agreement with various parties regarding carbon emission reductions. One of the most important of these is the *Energy Agreement for Sustainable Growth*, signed by more than 40 partners, including employers, trade unions, environmental groups and local authorities.



distribution by source

renewable energy

70% biomass
20% wind
4% geothermal
3% ambient heat
1% solar
<1% hydroelectric

import by origin

coal

27% South Africa
32% Colombia
17% Indonesia
2% Australia
2% Poland
10% other

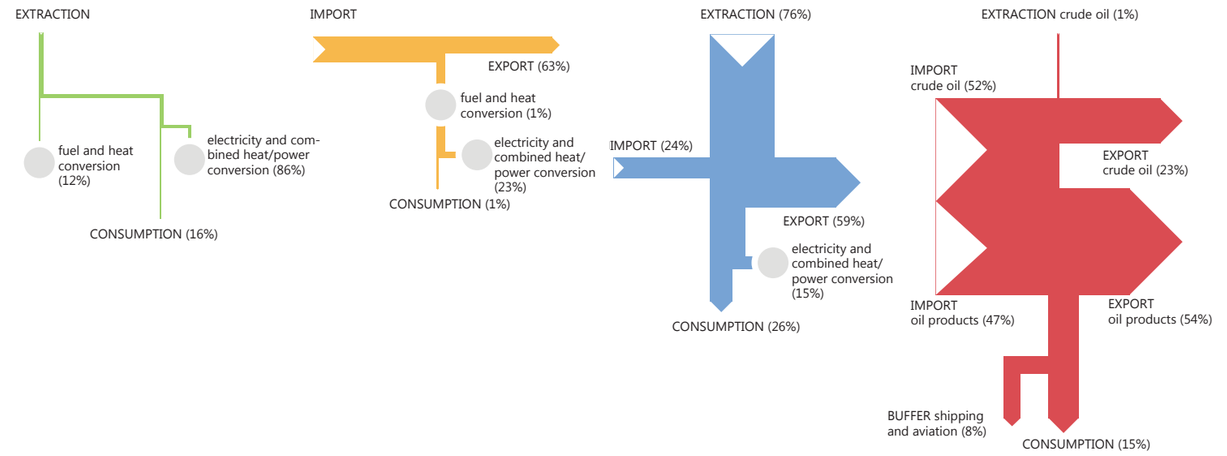
natural gas

50% Norway
27% United Kingdom
10% Russia
4% Denmark
3% Germany

crude oil

34% Russia
12% United Kingdom
12% Norway
8% Saudi Arabia
7% Nigeria
27% other

Energy flows in the Netherlands (2013)



4.1.1 REGION

In 2014 Zuid-Holland provincial authority draw up a policy document in which it announced its plans to step up its energy policy (*Nota intensivering energiebeleid Zuid-Holland*). In 2012 only 2.2% of the energy consumed in Zuid-Holland was renewable; the figure for the country as a whole was 4.4%. The provincial authority is redoubling its efforts to achieve the targets (14% renewable energy by 2020), focusing on the following areas: energy conservation by companies, sustainable heating, wind energy, solar energy, biomass on a regional scale and biobased economy, and renewable energy for transport [8]. More or less all these areas are also important for Delft. A number of them are discussed in more detail below.

Zuid-Holland *Warmterotonde*

According to a national map of residual heat produced by CE Delft in 2011, Zuid-Holland province has the largest supply of residual heat in the country, at over 25 PJ per year, enough to heat 545,000 homes [9]. In order to use this heat, the provincial authorities are working on a regional thermal grid known as the '*Warmterotonde*', with a partnership established specifically for the purpose (*Warmte Koude Zuid-Holland*), involving 25 partners, such as public authorities, companies (including energy companies), banks and grid operators. In November 2014 Zuid-Holland provincial authority and The Hague, Delft, Westland and Rotterdam local authorities started preparations for the western section of the *Warmterotonde*. The *Warmterotonde* will comprise a network of heating pipes connecting industry, greenhouses and households in Zuid-Holland province. The network will first be supplied with residual heat from the industry in and around Rotterdam. Other sustainable energy sources can then be connected to the *Warmterotonde* in due course [10]. By 2020, the network could supply 350,000 homes and 1000 hectares of commercial greenhouses in Zuid-Holland [11]. The *Warmterotonde* gives Delft an opportunity to heat a considerable proportion of its homes using hot water rather than gas. Section 4.1.4 HEATING further explores the potential for a thermal grid in Delft.

Geothermal

Zuid-Holland has a major potential source of geothermal energy, as well as a large amount of residual heat. This combination makes the installation of regional thermal grids an attractive prospect. The thermal grids are already efficient thanks to the use of residual heat, and can be supplied by geothermal heat in the future. The residual heat from industry in and around Rotterdam does not come from renewable sources, but from power stations fuelled mainly by coal and gas. In the long term, these power stations can be replaced by sustainable sources of energy (geothermal). New geothermal energy wells will need to be dug and connected to smart thermal grids in order to make the transition to sustainable heating in the future. In Delft, plans for a geothermal energy well in the university district (TU Delft) are at an advanced stage. This could supply all the heating for the TU campus and Nieuw Delft, and as a TU Delft research facility it could make a major contribution to the enhancement of knowledge of geothermal energy and smart thermal grids.

Wind energy

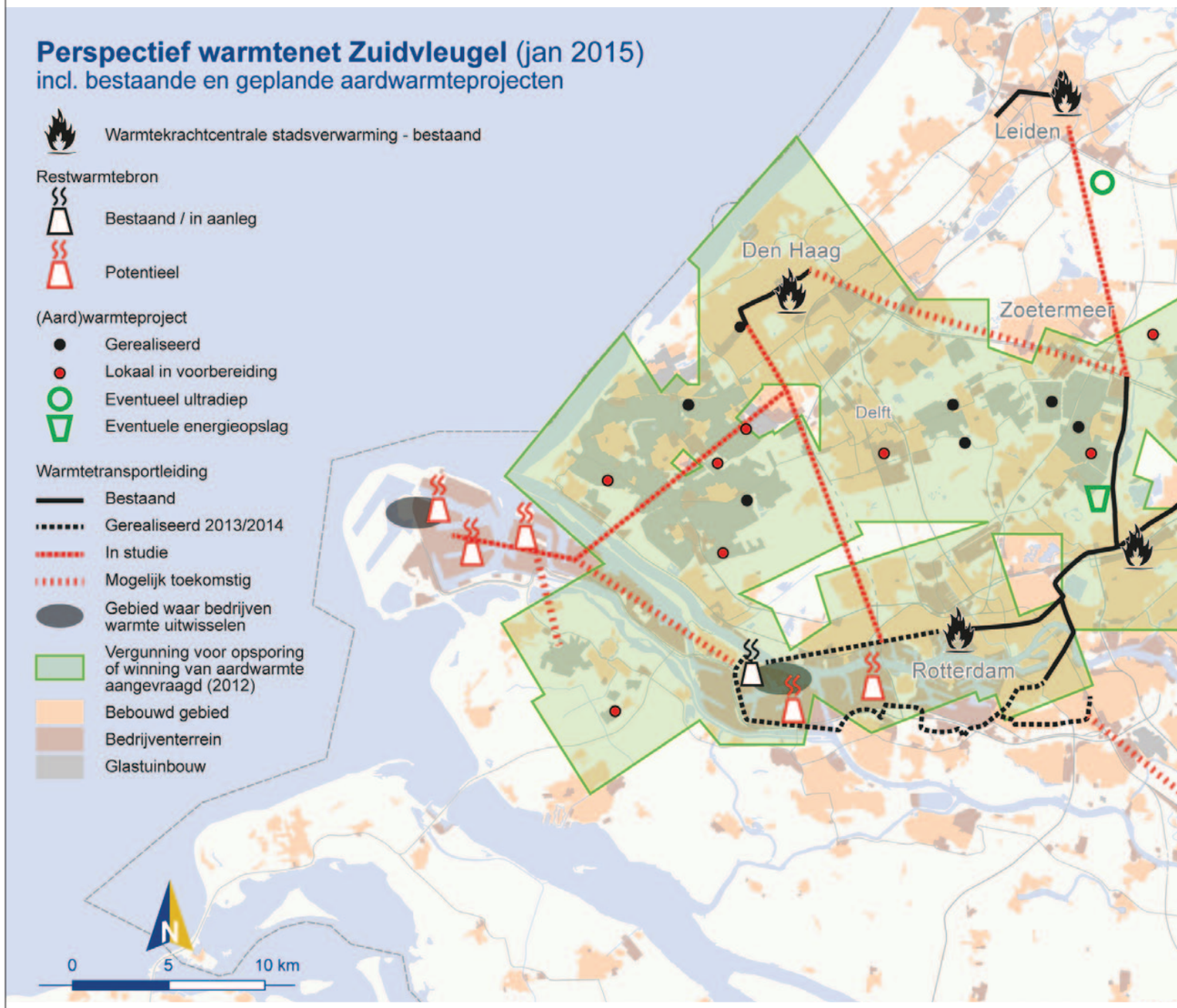
Thanks to its geographical position, Zuid-Holland province has the potential to generate wind power both on land and at sea. Terrestrial wind power is more cost-effective in the coastal provinces than in other provinces because they have more wind. It is almost impossible for Delft to build wind turbines within its boundaries, however, because of the height restrictions associated with Rotterdam The Hague Airport.

Solar energy

Zuid-Holland provincial authority encourages and supports use of solar energy, and over the past few years has helped bring about a considerable number of large-scale solar projects, such as the solar panels on the new Rotterdam Central Station building. The authority focuses mainly on large-scale applications for solar panels, and how they can best be blended into the environment. It currently provides grants for famers wishing to replace an asbestos roof with solar panels [12].

Energy conservation by companies

The provincial authority encourages companies to conserve energy in two ways: by better enforcement of compliance with regulations, and by collaboration with sector organisations. The national *Energy Agreement for Sustainable Growth* defines energy conservation targets for companies. These developments are interesting for Delft because they provide a springboard for talks with companies about energy conservation and because lessons learnt in various sectors can also be applied in Delft.



map: Zuid-Holland provincial authority cartographic service 14.1110/2

4.1.2

ENERGY

CONSUMPTION IN DELFT

In order to reduce carbon emissions we will have to consider our **energy consumption**. The top chart shows carbon emissions in Delft (2013), and the bottom chart shows energy consumption (2013). The charts clearly differ. Gas consumption in Delft, for example, accounts for 64% of all energy consumption, but produces only 43% of carbon emissions. The figures come from the overview *Energie in Beeld*, in which grid operators Enexis, Liander and Stedin monitor and present figures for energy consumption. The energy consumption of large-scale consumers who are directly linked to the Tennet and Gasunie grids is not included.

To make energy consumption in Delft clear, it is useful to distinguish between two aspects. One is the purposes for which energy is used; the other concerns commercial and domestic consumption.

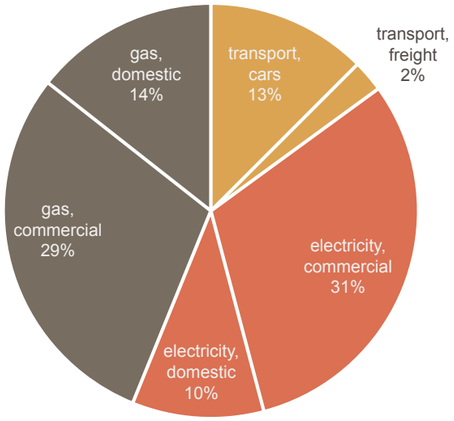
Use of energy

Energy is used for a range of purposes. We distinguish here between three: transport, heating and electrical power. We transport ourselves and our goods by car, bus, truck and other modes of transport, powered by burning oil-based fuels such as petrol and diesel. We use energy to heat buildings and water; in Delft, this is almost always by gas. We also cook largely on gas. Factories use gas in industrial processes. We have grouped all this together and called it heating. We use electrical power to operate machines and equipment. Electricity is generated mainly in coal- and gas-fired power stations.

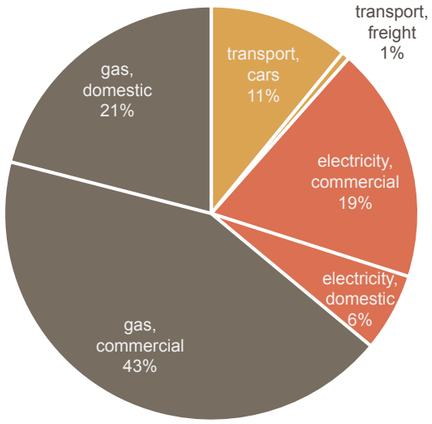
Commercial and domestic consumption

Commercial energy consumption is two or three times greater than domestic consumption. For instance, some two-thirds of all gas and around three-quarters of electricity is consumed commercially. The maps show how energy consumption is distributed across the city. Figures for domestic consumption are available at neighbourhood level, and for commercial consumption at district level.

The sections below take a closer look at transport, heating, domestic energy consumption (heating and power) and commercial energy consumption (heating and power). We also suggest how our energy consumption might be made more sustainable.



Carbon emissions in Delft in 2013: 389 kton

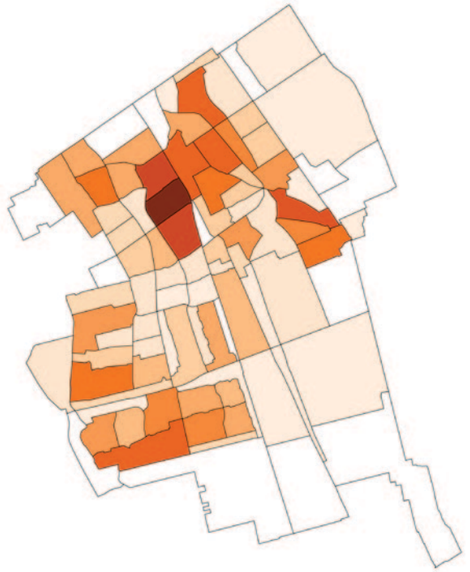


Energy consumption in Delft in 2013: 5,27 PJ

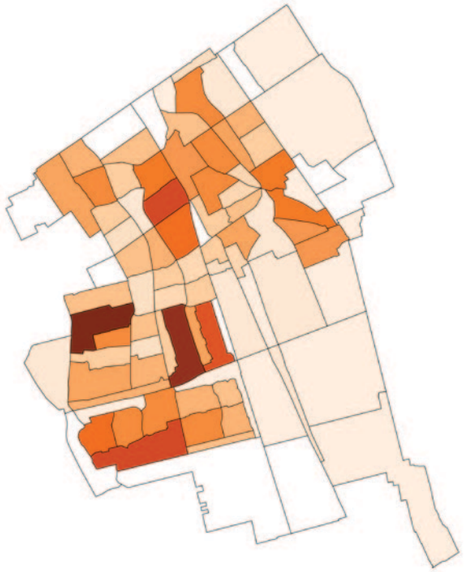
Three steps to sustainability

Trias Energetica is a commonly used method of making energy consumption more sustainable. The original three steps were: reduce, make sustainable, make cleaner (applies to generation using fossil fuels). This last step is not energy-neutral however, and the use of residual flows has been added, as a result of which the three steps now look like this:

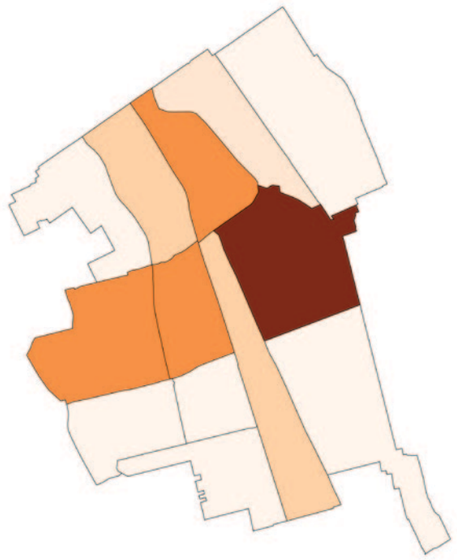
1. **conserve energy (reduce demand)**
2. **reuse residual flows**
3. **sustainably generate to meet remaining demand**



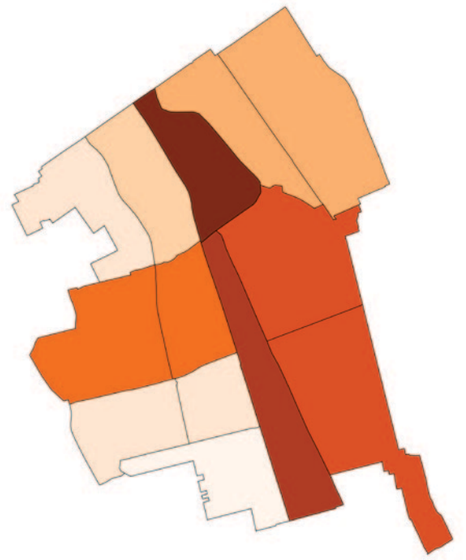
Domestic gas consumption by neighbourhood in Delft in 2013: approx. 31 million m³ of natural gas.
Westerkwartier stands out for its high consumption. This neighbourhood has a high density of older homes, which are probably poorly insulated.



Domestic electricity consumption by neighbourhood in Delft in 2013: approx 89 million kWh.
The neighbourhoods where there are lots of high-rise apartments, and therefore a lot of homes, have the highest figures. Correction for density produces a more even picture.



Commercial gas consumption by district in Delft in 2013 (excluding large-scale consumers): approx. 64 million m³ of natural gas.
Gas consumption is highest in Wippolder, where there are lots of companies on Delft Tech Park and along Rotterdamseweg.



Commercial electricity consumption by district in Delft in 2013 (excluding large-scale consumers): approx. 269 million kWh.
The highest commercial consumption is in the city centre, where density is high, and there is a mix of shops, bars and restaurants, offices and amenities.

4.1.3 TRANSPORT

Sustainable mobility

Infrastructure management agency *Rijkswaterstaat* uses a variation on Trias Energetica for mobility, which it calls Trias Mobilica [13]:

1. **Reduce**: less mobility, through spatial planning and smart working, for example.
2. **Change**: encourage people to switch to public transport, cycling, walking, car sharing.
3. **Make more sustainable**: encourage people to buy sustainable vehicles and fuels, like electric cars and green gas.

Optimising the modal split

Delft is a compact city that is well suited to handling slow traffic and, given its central position in the southern Randstad conurbation, is easily accessible by public transport. The distribution of people and goods between different modes of transport, known as the 'modal split', is already quite good in Delft. The new station and surrounding area and the four railway lines that will serve the city in the future will make Delft's public transport system even more attractive. The challenge will be to make better use of public transport and enhance the accessibility of parts of the city further away from the station. Various measures could be taken, including customised parking policies, information provision and changes to the layout of public spaces. Facilities for car sharing and flexible working, near the new station for example, could also help reduce car use.

Electric cars

Transport accounts for 12% of all energy consumption in Delft. Carbon emissions from vehicles represent 15% of the total. Electric cars have two positive effects. They use less energy per kilometre because an electric engine is up to three times more efficient than an internal combustion engine. If the electricity is generated sustainably, no extra carbon is emitted. Electric cars are interesting in terms of energy-neutrality, but they are not yet a natural choice for people, or in a technological sense. The action radius of most electric cars is still too limited for many motorists. A network of charging points is also needed, supplied with sustainably generated power. Solar energy would be an obvious choice.

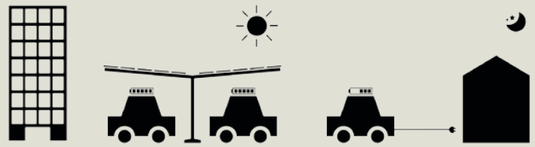
In 2012 245 million kilometres were driven on Delft's roads (excluding the A13 motorway) [15]. The energy consumption of electric cars depends on the type of car. The Volkswagen e-Golf, for example, uses 127 kWh/100 km [16]. If all the kilometres driven in Delft were driven by this type of car, some 31 million kWh of sustainable electricity would be needed. With a potential average generation of 123 kWh/m^2 [17], approximately 250,000 m^2 of roof-mounted solar panels would be needed. The public and private car parks in Delft have a joint surface area of approx. 400,000 m^2. Installing solar panels above two-thirds of these car parks would generate enough solar power for all the kilometres driven in Delft. However, this would require a smart electricity grid to match supply and demand.

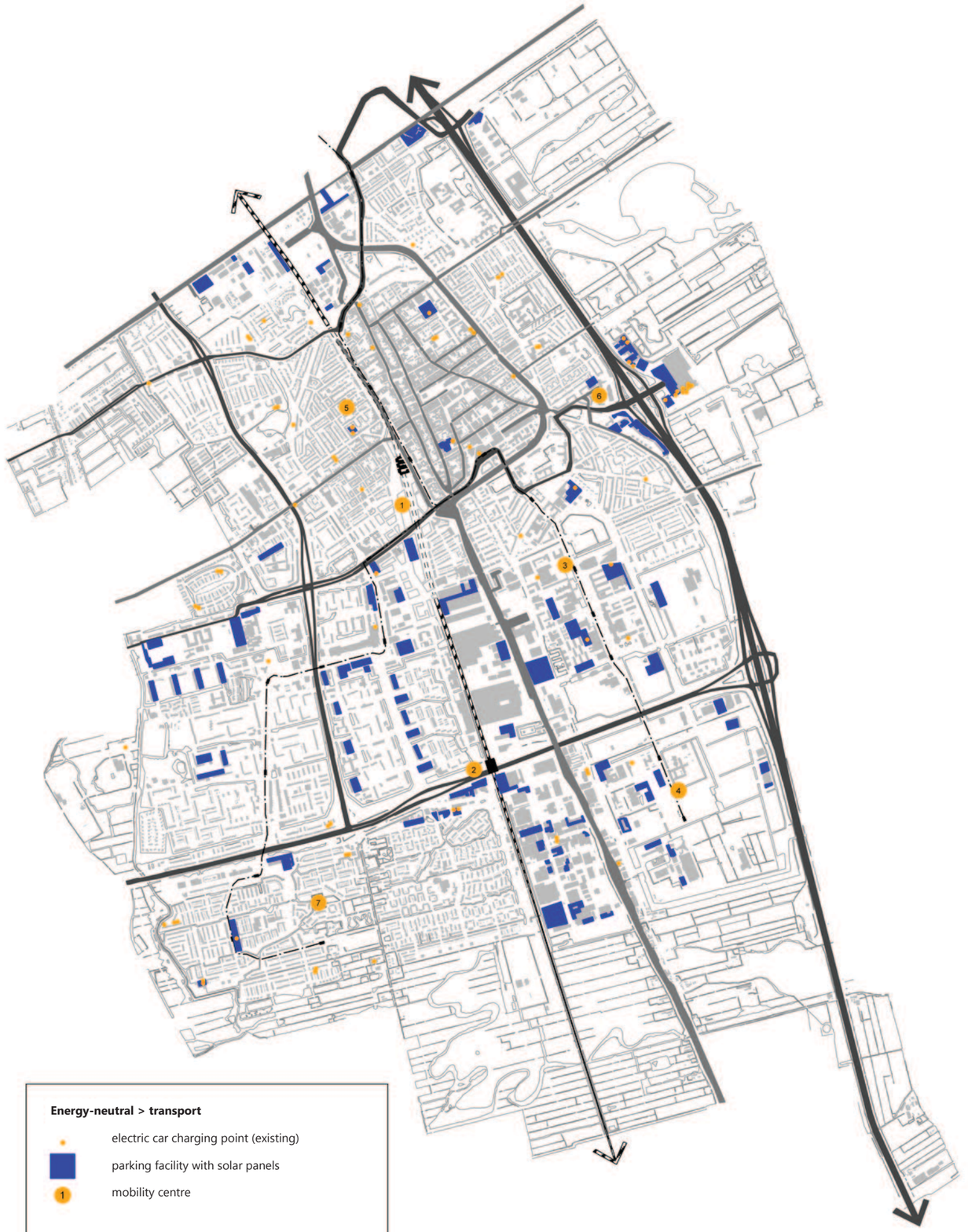
Mobility centre

The city council is developing a 'mobility centre' in the Nieuw Delft area. This is a physical facility near the new station which will focus on sustainable mobility, showcasing shared use, facilitating an optimum shift in transport modes, and encouraging various forms of sustainable mobility, such as electric cars. The idea is to set up several 'mobility centres' in Delft where users can borrow various types of vehicle.

Park & Charge

Electric cars can be charged at Park & Charge facilities: parking spaces with solar panels. Such facilities do not yet exist in the Netherlands, but TU Delft has developed concepts for them, for locations including Schiphol and Rotterdam's city ports [14]. The battery in an electric car that runs on solar power can be linked to a smart grid. The electricity stored in the battery could for example be supplied to the home in the evening. Parking near offices and companies is highly suitable for Park & Charge facilities because cars can charge up there with solar power during the day.





4.1.4 HEATING

What is a thermal grid?

In most homes, the hot water that heats radiators is supplied by a gas central heating boiler. A system that supplies hot water to homes instead of gas is known as a thermal grid. One well-known type of thermal grid is district heating. There are various ways of heating the water. Often, residual heat from power stations and waste incineration plants is used. The use of residual heat cuts gas consumption.

Warmterotonde

Most of the residual heat from the port of Rotterdam remains unused. Rotterdam's local thermal grid mainly uses heat from the AVR waste incineration plant in Rozenburg. A number of parties, including Delft city council, are working on a '*Warmterotonde*' that will allow the heat from the port to be used. The western section of the *Warmterotonde* will carry the residual heat from Rotterdam via pipelines to the horticultural greenhouses in the Westland area and the urban areas of Delft and The Hague. One of the pipelines might even be laid close to or right through Delft, thus supplying a considerable proportion of the city with residual heat.

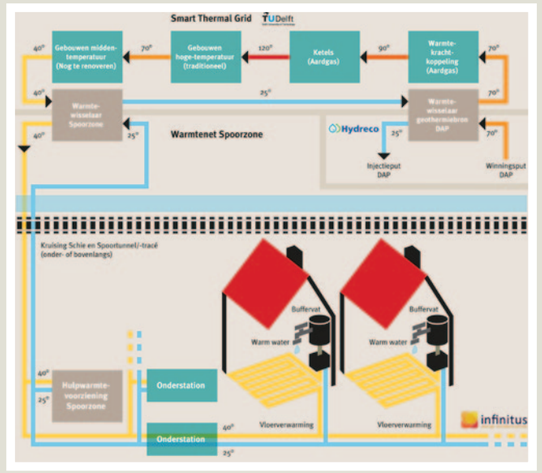
Thermal grids in Delft

Several (small) thermal grids are operational in Delft. Most are supplied by gas-fired power stations. The thermal grid at Harnaschpolder is heated by residual heat from the sewage treatment plant. Thermal grids will soon be an interesting option for homes without a central heating boiler, which are currently connected to a collective heating system, such as flats in apartment blocks. All it takes to switch from gas to residual heat is some adjustments to the building's central boiler. In individual homes, however, every connection and boiler needs to be replaced. Depending on the temperature of the thermal grid, this can entail considerable costs. If the *Warmterotonde* really does pass close by or through Delft, so much heating will be supplied that thermal grids will also be an interesting option for individual homes in the longer term.

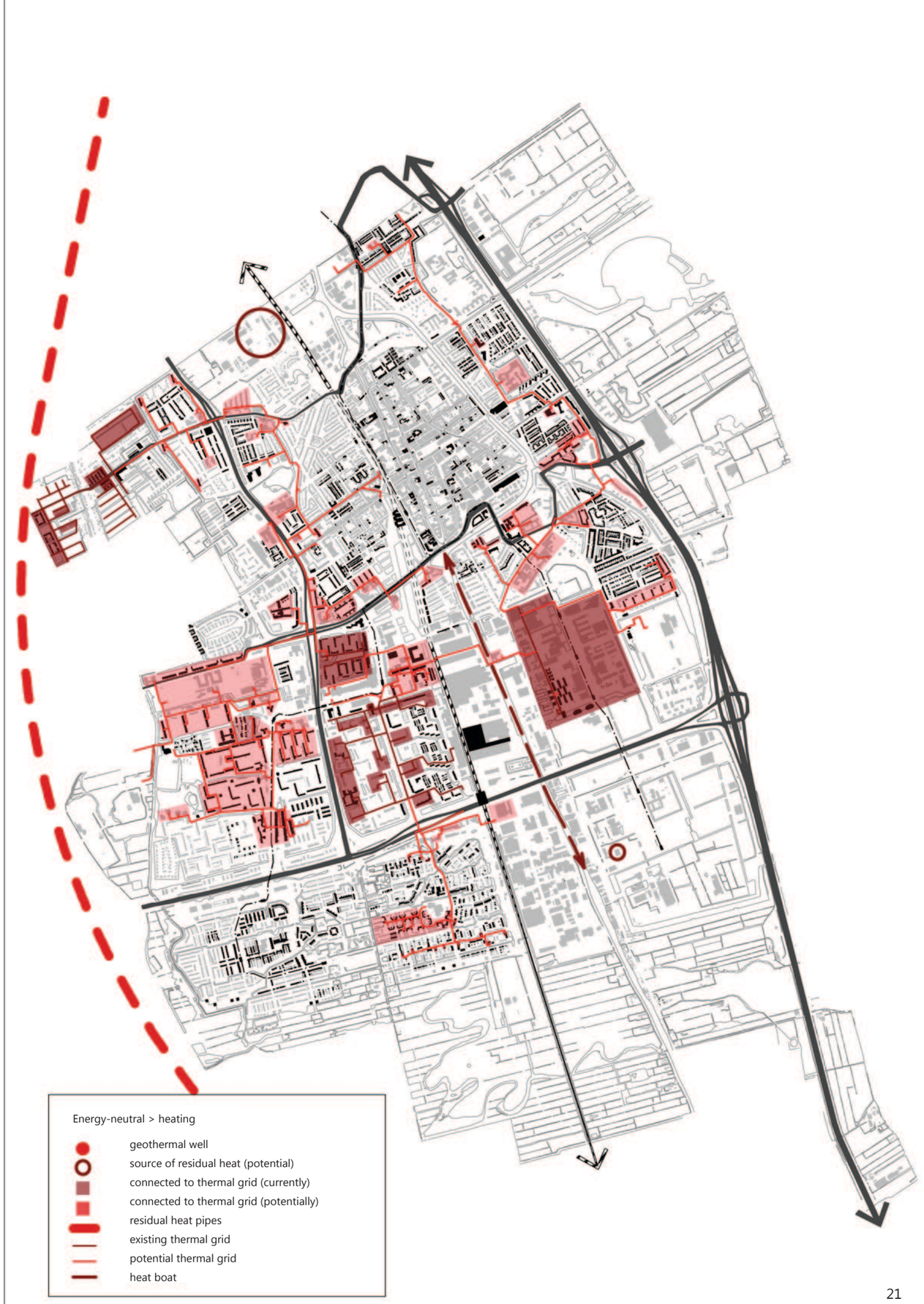
The map shows where there is potential for use of residual heat in the near future. Voorhof and Buitenhof, in particular, have lots of apartments owned by housing associations which are suitable for switching from gas to residual heating. The information comes from a map for a potential thermal grid drawn up by former heating company Warmtebedrijf Eneco Delft.

Smart Thermal Grid

Thermal grids supplied largely by residual heat can eventually also be supplied by other sustainable sources. The temperature of the heat source and the required supply temperature of the heat distribution systems in buildings are not always the same, however. The thermal grid will therefore have to become a Smart Thermal Grid that is able to make optimum use of the available energy by efficiently transferring heat (cascading), and using heat exchangers and additional heating from sustainable sources. One good example of this is TU Delft's plan for the use of geothermal heat which, after use, could then be passed on as residual heat for homes in the Nieuw Delft district. Circumstances have currently brought this initiative to a halt, highlighting the fact that it is not always easy to put smart solutions in place.



[design for Nieuw Delft geothermal heating facility
image taken from *Nieuw Delft Integraal Ontwikkelingsplan 2015*]



4.1.5 **DOMESTIC**
ENERGY CONSUMPTION

Conserving heat in homes

Domestic gas consumption in Delft was 314 million m^3 in 2013, 21% of total energy consumption in the city. Gas consumption in people's homes can be divided into consumption for heating (75% = 23.5 million m^3), for hot water (20% = 6.3 million m^3) and for cooking (5% = 1.6 million m^3) [18]. We have identified three steps to making gas consumption for heating more sustainable:

1. Conserve: consumption awareness and insulation
2. Replace gas by residual and sustainable heat
3. Use solar energy

Consumption awareness

Conserving heat in homes is a matter of raising awareness of the value (reducing carbon emissions) and benefits (smaller energy bills) of reducing energy consumption. The development of smart meters and apps that monitor energy consumption are useful tools.

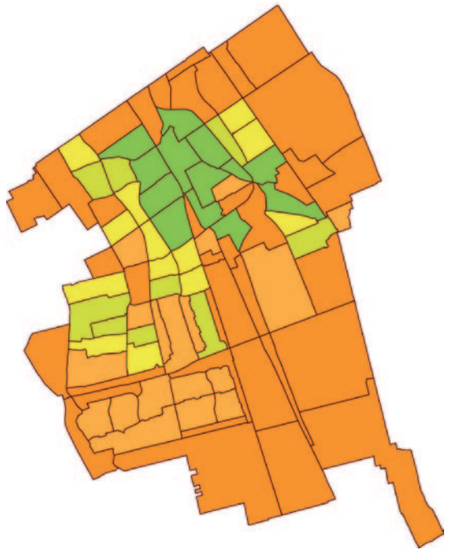
Insulating homes

The EPC (energy performance coefficient) for new homes was further reduced to 0.4 in January 2015. Homes now being built therefore require very little energy for heating. The biggest challenge thus lies in insulating the existing housing stock where, as a general rule, the older a home the poorer the insulation. The figure below shows the conservation potential in each neighbourhood of Delft, based on the energy labels in the neighbourhood and the number of homes there (see appendix 1a). We can see that districts with older housing (the centre and the surrounding areas) have the greatest potential for energy conservation. If all homes in Delft were insulated to the standard of energy label A this would produce a 50% saving on domestic gas consumption for heating. That is equivalent to 11.8 million m^3 a year (50% x 23.5 million) (see appendix 1b).

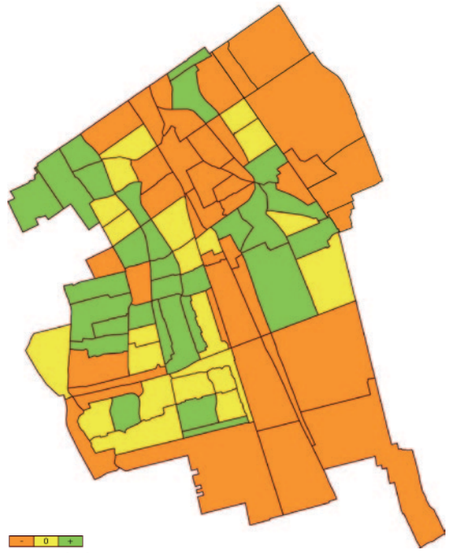
Replacing gas with piped heat

Secondly, we can look at the possibility of replacing gas with piped heat in each neighbourhood, using the potential thermal grid map drawn up by former heating company Warmtebedrijf Eneco Delft. The figure shows the potential for piping heat instead of gas. A 2006 study by Delft city council found that over 17,500 homes could be connected to the thermal grid. Some 5000 of these are new, and around 11,500 will be eligible for major renovation work or a new boiler in the foreseeable future. Connecting this group of homes to the thermal grid would reduce gas consumption by 8.2 million m^3 a year (see appendix 2).

It is also interesting to reverse steps 1 and 2, so to look first at the potential for a thermal grid and then at insulating homes. The thermal grid could produce a saving of 8.2 million m^3 of gas, leaving 23.5 – 8.2 million = 15.2 million m3. The homes that could not be connected to the thermal grid could be insulated to the standard of energy label A, reducing the remaining demand by 50%, or 7.6 million m^3 of gas.



potentie energiebesparing per buurt



potentie inzet restwarmte per buurt

Use of solar power

We then considered the possibility of heating homes with solar power, which involved looking at the 'PV potential' (PV = photovoltaic) of all the roofs of homes in Delft. In other words, how much room there is for solar panels. In 2014 the Netherlands Environmental Assessment Agency (PBL) estimated the average available roof space for solar panels for various types of homes built in certain years [9]. It assumed that a terraced house has a roof area of 32.5 m^3. Experience shows that the actual space available for solar panels differs from the available roof area. Bearing this in mind, we applied the PBL data to Delft. The figure below shows the average available roof area in different neighbourhoods. After correction for the pitch and angle of the roof, the PBL study assumes a potential average power generation of 123 kWh/m^2 of available roof area. Using this as a basis, we found that potential power generation of electricity using solar panels mounted on the roofs of all homes in Delft was 124.6 million kWh (see appendix 3a).

How much of this power would be used for heating would depend on how much electricity were needed to heat water, cook and power appliances (see appendix 3b).

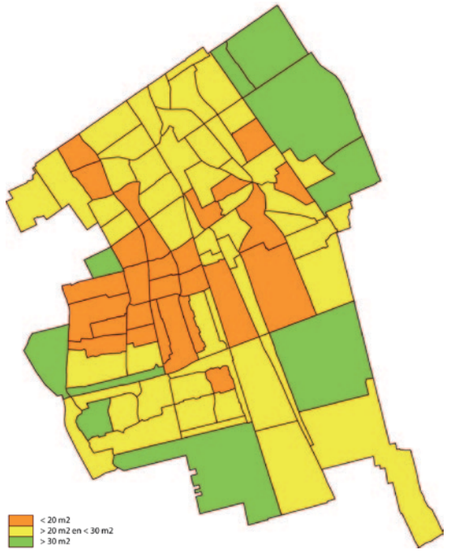
The table summarises the calculations above. It shows that, of the 124.6 million kWh PV potential, 6.3 million remains for electric heating. This could replace 2.6 m^3 of gas (see appendix 3c).

domestic 2013	**gas consumption: 31.4 million m^3**	**electricity consumption: 89.3 million kWh**	**PV potential: 124.6 million kWh**
saving due to consumption awareness	unknown	unknown	
gas > piped heat from thermal network	- 8.2 million m^3		
other homes > label A standard	- 7.6 million m^3		
solar-powered heating	- 2.6 million m^3		- 6.3 million kWh
elec. consumption by appliances		- 89.3 million kWh	- 89.3 million kWh
hot water	- 6.3 million m^3		- 20.5 million kWh
cooking	- 1.6 million m^3		- 8.5 million kWh
total	**5.1 million m^3**	**0**	**0**

The figures above show that domestic energy consumption (gas and electricity) can be made largely energy-neutral if:

1. the potential of the thermal grid, as indicated in the council's study, is used to the full
2. any homes that are not connected to the thermal grid are insulated to energy label A standard
3. all homes in Delft are fitted with solar panels. This would require a smart electricity grid to match supply and demand

It is important to remember that this is a theoretical exercise, intended to obtain a sense of the spatial potential for energy-neutrality in the Delft local authority area. The exercise has shown that there is no single fast track to 'energy-neutrality', but that any number of routes lead there, and that decisions concerning goals and means will have to be taken along the way. A good understanding of the scale of the challenge and the possibilities can help.



gemiddeld beschikbaar dakoppervlak op woningen

4.1.6

COMMERCIAL
ENERGY CONSUMPTION

Commercial consumption

According to the figures in *Energie in Beeld* commercial consumption of gas and electricity accounts for 43% and 18% of total energy consumption in Delft respectively. Commercial consumption is therefore some two to three times higher than domestic consumption.

Large-scale consumers

Energie in Beeld does not provide any information about the energy consumption of large-scale consumers. They are connected directly to the national gas and electricity grids. DSM is a large-scale commercial consumer in Delft. It is responsible for additional carbon emissions amounting to some 50 kton a year [15]. In terms of gas, this is approx. 28 million m^3, almost as much as the gas consumed by all the homes in Delft. DSM is obliged to participate in the European emissions trading system, which aims to reduce the carbon emissions of large-scale consumers.

Large-scale consumers like DSM, and other parties in the municipality, like TU Delft, have a relatively large carbon footprint. Measures to make their energy consumption more sustainable are defined mainly by national and European regulations. The city council has the opportunity to enter into agreements with these consumers concerning the use of residual heat and scaling up interesting applications like smart thermal and electricity grids. The TU Delft campus is a national testbed for ways of transforming the current thermal grid into a smart thermal grid that delivers heat at different temperatures, from various (sustainable) sources of heat and cold.

Making commercial energy consumption more sustainable

We have identified three steps to make commercial energy consumption more sustainable:

1. Conserve: consumption awareness and insulation
2. Replace gas by residual and sustainable heat
3. Use solar energy

Consumption awareness and insulation

The EPC for non-residential buildings varies according to their function: from 0.8 for offices to 1.7 for shops. New non-residential buildings are becoming more and more energy-efficient, but progress is slower than for homes. As with residential buildings, however, the biggest challenge lies in the existing stock. Production processes will also have to be made more sustainable. The *Energy Agreement for Sustainable Growth* includes arrangements that might further these efforts, including more stringent enforcement of the Environmental Management Act, which stipulates that energy conservation measures must be taken if the costs can be redeemed within five years.

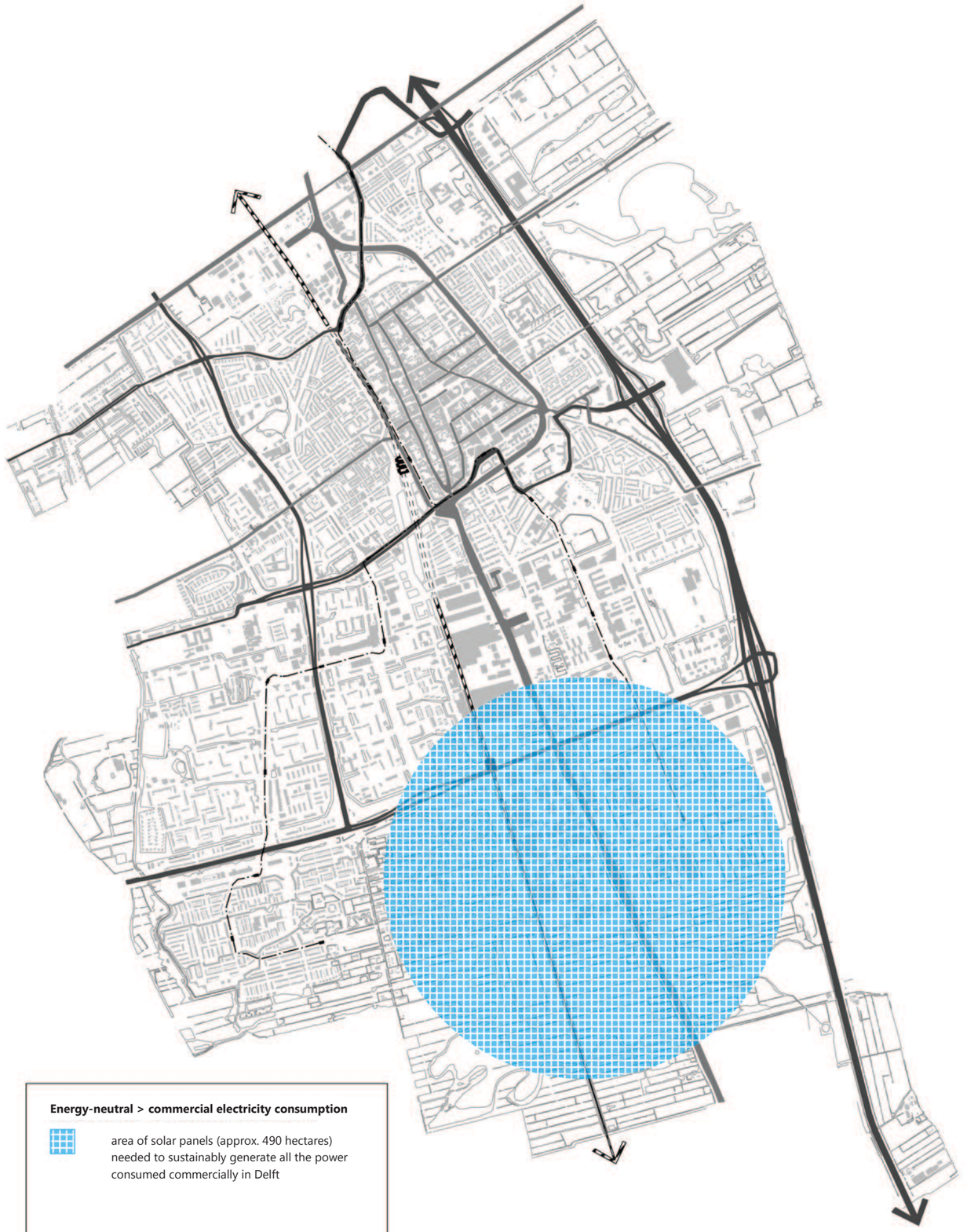
Replacing gas with piped heat

The section on domestic energy consumption looked in depth at the potential of thermal grids supplied by residual heat or geothermal energy. A thermal grid would also be an interesting prospect for commercial consumers. The depletion of the Netherlands' gas reserves, and reductions in the amount of gas extracted, will lead to higher gas prices for Dutch consumers. Connection to a thermal grid could therefore be beneficial from a financial point of view. The smarter the use of residual heat with a gradual reduction in temperature (cascading), the more profitable this will be. Experiments with ways of making the thermal grid more sustainable at TU Delft offer the prospect of lower gas consumption, and provide an opportunity to gain practical experience and learn lessons that can be applied in other parts of the city. A thermal grid supplied by sustainable heat on the neighbouring business park along the river bank (Schieoevers), for example, would help to considerably reduce commercial gas consumption in Delft.

Use of solar power

Fitting solar panels on the roofs of all non-residential buildings would allow an annual total of 69.4 million kWh of electricity to be generated (see appendix 4). This represents around a quarter of commercial consumption in Delft. Unlike in the domestic sector, where an individual household can generate its own electricity supply using solar panels, installing solar panels on all commercial premises will not be enough to make commercial consumption sustainable. To illustrate how many solar panels would be needed, the map shows what area of solar panels would be required to supply all electricity consumed commercially in a sustainable manner. It is based on the solar farm planned for Ameland: approx. 5.5 million kWh from 10 hectares [19]. Commercial energy consumption in Delft in 2013 was approx. 269 million kWh. This would require approx. 490 hectares of solar panels.

It is also unclear how demand will develop in future. The switch to low-energy lighting, for example, will reduce consumption. But the automation of production processes will cause a rise in consumption. Making commercial consumption more sustainable requires efforts at several levels: legislation and innovation at national level; thermal grids, wind and solar farms at regional level; and cooperation and energy exchange between companies at local level.

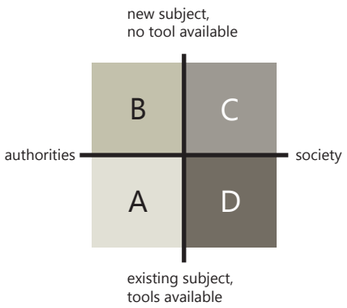


Energy-neutral > commercial electricity consumption

area of solar panels (approx. 490 hectares) needed to sustainably generate all the power consumed commercially in Delft

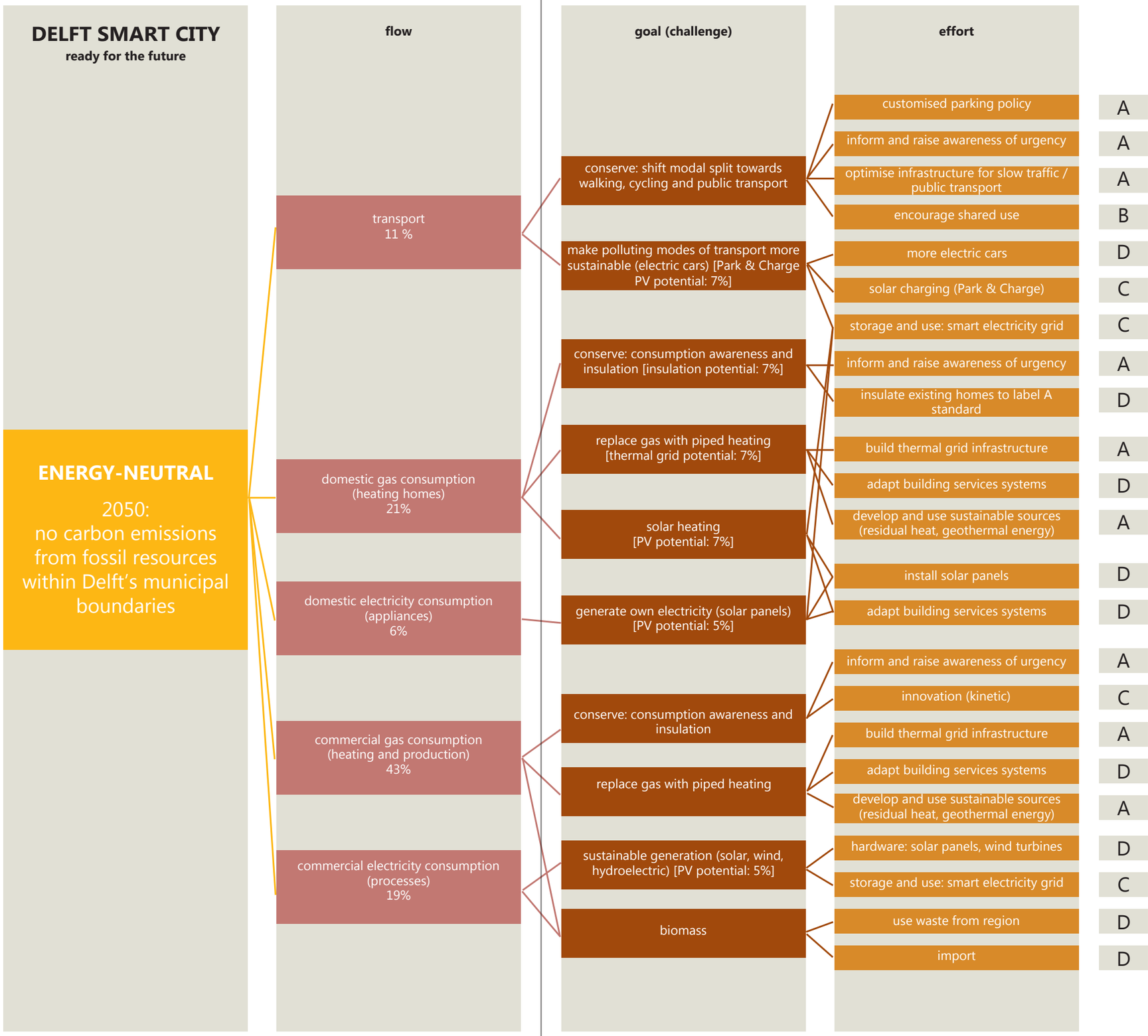
4.1.7 OVERVIEW
GOAL > EFFORTS

The chart summarises the analysis presented above. The challenge associated with each flow (or partial flow) is indicated, plus the efforts that will be needed to achieve the goal. The appropriate governance quadrant for each of these efforts is also indicated. Categorisation into governance quadrants is a preliminary exercise designed to give a sense of the role of the authorities and society in addressing the challenge.



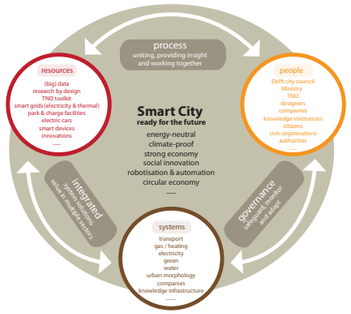
The chart shows that a significant proportion of the energy challenge lies beyond the scope of the city council. Residents and companies choose their energy supply and mode of transport. They will therefore have to decide whether to conserve energy, or choose the more sustainable option. The authorities (local or otherwise) cannot do much more than inform and encourage, possibly with grant schemes. Perverse incentives also exist. For example, fossil energy prices do not reflect the costs of pollution. Furthermore, the more energy is used the less it currently costs. National and European legislation is needed to abolish these perverse incentives, tax pollution and curb waste.

Local and regional authorities need to prompt the market to ensure that an infrastructure for sustainable heating and power is built. However, this requires the right tools. Currently, for example, a thermal grid does not have the same status as an electricity, gas or water grid.



4.1.8 OVERVIEW INFRASTRUCTURE > TECHNOLOGY > PARTNERS

The second chart refers to the circular diagram depicting Delft's vision of a Smart City. All three pillars have been completed for 'energy-neutral'. Here, too, the overview is not exhaustive, but merely intended as an exercise that provides an insight into the resources (both new and existing) and partners that will be needed.



One striking feature of the diagram is the development of smart electricity and thermal grids, where all the lines from infrastructure meet and then fan out to all kinds of partners. This immediately makes it clear that developing and implementing such grids is a complex matter.

Local energy cooperatives and producers are disruptive in a certain sense, because they change the system. The involvement of such partners requires technical adjustments (selling back to the grid and irregular supply) and a different form of governance. One example is net metering of electricity by residents' associations.

A huge number of partners are involved in the energy challenge. E-deals with companies, members of the public, knowledge institutions, energy suppliers and other partners are a good way of meeting the common challenge.

DELFT SMART CITY
ready for the future

ENERGY-NEUTRAL
2050:
no carbon emissions from fossil resources within Delft's municipal boundaries

flow	infrastructure	(smart) resources	people
transport	road network	optimum use of existing networks A/B	national grid operators: Tennet, Gasunie
	public transport network		
	(electric) vehicles	self-charging vehicles, optimise supply to grid C	local grid operators: Stedin, Liander
	charging points		national energy suppliers and energy producers: Eneco, Nuon, Greenchoice etc.
electricity	electricity grid (above and below ground)	**smart electricity grid** to coordinate supply and demand supply: solar and wind power use: systems / appliances / cars supply to grid net metering B/C	local energy cooperatives and energy producers: public, companies and authorities
	electrical storage capacity		
	power stations / combine heat and power systems		energy users like property owners and consumers: people associations companies institutions authorities
	solar panels / systems		
	windmills / wind turbines	increase yield C	
	systems and appliances that run on electricity	systems and appliances that decide when they should charge D/C	developers of knowledge: knowledge and research institutions
heating / gas	gas supply network	build A	developers of new products and services: (innovative) companies
	thermal grid	seek + exploit B/C	(energy) advisers and designers: consultancies
	residual heat sources	find, drill, exploit + gain more knowledge C	
	geothermal sources	**smart thermal grid**: use energy as efficiently as possible through cascading, heat exchangers and additional heating from sustainable sources B/C	construction companies
	local heat generators (solar boiler, heat exchanger)		companies hoping to find, extract (and use) geothermal energy
	heat distribution systems in buildings	switch to piped heat instead of gas D	financiers / investors / venture capitalists

4.1.9

SUMMARY
AND CONCLUSIONS

Energy-neutral by 2050

An energy-neutral city means that by 2050 no carbon emissions resulting from the use of fossil fuels may be generated within Delft's city limits. Reducing carbon emissions is a challenge that affects everyone. Global carbon emissions will have to be seriously reduced if we are to limit global warming to 2ºC. The goal is therefore clear, but how to achieve it remains a big question. Many local and regional authorities are now working towards the 2020 targets, but what is to happen afterwards is unclear to many. This report has therefore attempted to make the overall challenge clear for one city – Delft. By dissecting, visualising and calculating the challenge quite specifically, step by step, we have given an insight into the complexity of and summarised the details of the challenge for the authorities and for society.

Delft's challenge
Delft's energy challenge falls into three parts: transport, domestic gas and electricity consumption, and commercial gas and electricity consumption. Commercial gas consumption is twice as high and commercial electricity consumption three times as high as domestic consumption. In Delft's case, the construction of a Zuid-Holland *Warmterotonde* is important, as it should give the city access to residual heat from Rotterdam's port area.

Transport
Car use can be kept to a minimum by continuing to focus on Delft as a city of cyclists, walkers and public transport. Remaining car use can be made energy-neutral by switching to electric cars, which consume less energy than petrol or diesel cars, provided the energy required is sustainably generated, free of carbon emissions.

Domestic
In the case of domestic gas consumption, the main focus is energy conservation and insulation in existing homes. The development of the *Warmterotonde* would also make it feasible to switch from gas to sustainable piped heating. Solar cells will have to be installed on all homes so that they can generate their own power. By connecting 12,000 homes, mainly in apartment blocks, to the *Warmterotonde*, upgrading the insulation of all remaining homes to energy label A standard and installing solar panels on all homes in Delft, it would in theory be just possible to make Delft's domestic energy consumption energy-neutral. Clearly, this will be no simple matter, and it will involve major investments.

Commercial
Commercial energy consumption is not only much greater than domestic consumption, we also know less about the potential for conservation, and regulation (such as the energy performance coefficient) lags behind that applying to housing. The *Energy Agreement for Sustainable Growth* represents a first step towards encouraging companies to take energy conservation measures. If solar panels were fitted on all the commercial premises in Delft, approximately a quarter of their current energy consumption could be made sustainable. Much lower, therefore, than the potential improvement in domestic consumption. Other additional solutions will thus be needed. The switch from gas to sustainable piped heating thanks to the *Warmterotonde* also offers companies an opportunity to make their energy consumption more sustainable. Local cooperation between companies to ensure a smart energy supply, for example by exchanging energy and cascading heat, will become more popular as the price of energy rises in future. Given the scale of the challenge and the low level of awareness regarding potential solutions, the issue of making commercial energy consumption more sustainable should be high on the agenda.

Smart grids
In terms of innovation, the biggest challenge is to create smart electricity and thermal grids. These will be needed because the supply of energy will fluctuate more and supply and demand will have to be better coordinated in order to supply the energy people need when they need it. Innovation will not only involve technology. Perhaps even more important is the question of how to organise cooperation and responsibilities between all the parties that supply, purchase, transform, buffer and manage energy.

Cross-overs with economy and climate adaptation
The energy transition will require manpower. Insulating homes, installing solar panels and smart monitoring and control systems is mainly a matter for the construction and building services sectors. If local companies manage to position themselves well on the local market in Delft, this will create local jobs. Knowledge-intensive sectors can also benefit from the chance to innovate in the energy system. There are cross-overs with climate adaptation on several levels. The energy and climate challenges are similar in terms of governance. In both cases the authorities have only limited influence, and limited funding. This applies even more to energy-neutrality than to climate resilience. Both also require interventions in the physical environment, entailing links with other measures. Finally, the two challenges can also be linked in practical terms. Examples include energy conservation achieved with green roofs and living walls, and more planting around the home, and the generation of energy from natural processes.

4.2

CLIMATE-PROOF

2050:
a city that can cope with the consequences of climate change, which include flooding, drought and heat

Global warming is changing the world's climate. This will affect all countries, including the Netherlands. How can we adapt our environment in order to mitigate or prevent the negative effects of climate change, such as localised and major flooding, heat stress and drought? How can we make Delft climate-proof?

Future scenarios

The IPCC (Intergovernmental Panel on Climate Change) studies climate change all over the world and draws up scenarios for the future. The Dutch meteorological service KNMI translates these scenarios to the situation in the Netherlands. In its KNMI'14 Climate Change Scenarios it sets out four possible scenarios for the future of the climate in the Netherlands around 2050 and 2085, based on the most recent insights. The KNMI concludes that:

1. sea level rise will continue and the pace will increase;
2. rainfall and extreme rainfall will increase in the winter;
3. the intensity of extreme rainfall in the summer will increase, while two of the four scenarios also predict drier summers;
4. the temperature will continue to rise, and mild winters and hot summers will become more common.

To give an impression of the possible range of climate change in the future, the table gives the values for various indicators in the scenarios with the lowest (G_L) and highest (W_H) temperature rise and changes to air flow patterns, alongside the natural variation.

change	scenario G_L around 2050	scenario W_H around 2085	natural variation
sea-level rise	+15 to +30 cm	+45 to +80 cm	±1.4 cm
ave. rainfall in winter	+3%	+30%	±8.3%
max. hourly rainfall/year, summer	+5.5 to +11%	+22 to +45%	±14%
rainfall deficit during growing season	+4.5%	+50%	±13%
temperature rise	+1.0°C	+3.7°C	±0.16°C
no. of days of frost, winter	-30%	-80%	±9.5%
no. of days of summer weather (max. temp.>25°C)	+22%	+130%	±13%

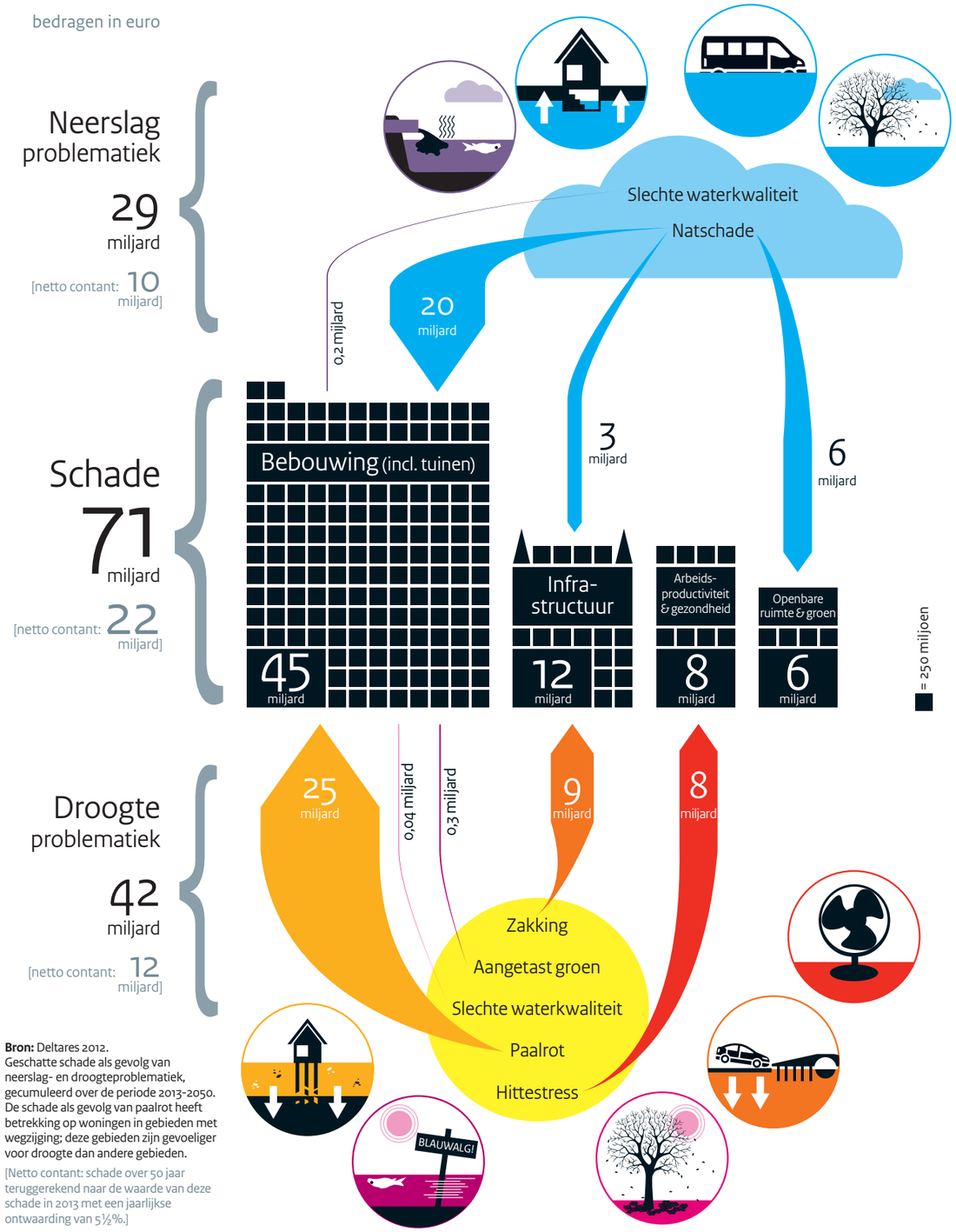
[source: KNMI'14 Climate Change Scenarios for the 21st Century – A Netherlands perspective]

Damage caused by climate change

Climate change produces a higher risk of flooding, heat stress, subsidence, siltation and excessively high or low water tables, which can lead to damage. In 2012 Deltares identified the likely scale of this damage in the Netherlands. In a densely-populated region like Zuid-Holland the damage that might occur if no adaptation measures are taken is potentially huge, and the impact of climate change could disrupt both the economy and daily life.

De Klimaatbestendige stad

Opgaven



Bron: Deltares 2012.
Geschatte schade als gevolg van neerslag- en droogteproblematiek, gecumuleerd over de periode 2013-2050. De schade als gevolg van paalrot heeft betrekking op woningen in gebieden met wegzijging; deze gebieden zijn gevoeliger voor droogte dan andere gebieden.

[Netto contant: schade over 50 jaar teruggerekend naar de waarde van deze schade in 2013 met een jaarlijkse ontwaarding van 5½%.]

[Deltares infographic taken from Climate-proof City Manifesto (2013)]

4.2.1 REGION

Delta Programme 2015

The fifth Delta Programme (DP2015) is an important national framework for climate adaptation. It sets out proposals designed to improve protection from flooding and water shortages. Such decisions concern flood risk management, the freshwater supply and spatial planning. The 'delta decision' Spatial Adaptation describes measures for climate-proof and flood-resilient spatial design [21]. All authorities have formalised their ambition to ensure that the infrastructure and spatial design of the Netherlands is as climate-proof and flood-resilient as possible by 2050. This ambition is to be translated into regional and local frameworks by 2020 at the latest. Local and regional authorities are therefore analysing the flood- and climate-resilience of their own planning area, drawing up an adaptation strategy with specific targets, and ensuring it is reflected in policy and regulations [21].

Positioning the challenge in society

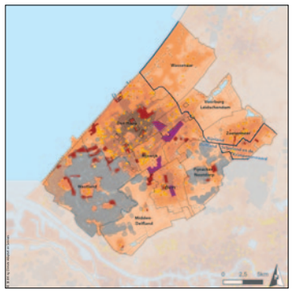
The Spatial Adaptation decision sets out proposals that should make the spatial design of the Netherlands climate-proof and flood-resilient by 2050. This is mainly a challenge for regional and local authorities, which will set to work addressing it from 2020 in collaboration with commercial partners, NGOs and knowledge institutions. This is the result of an innovative process, whereby a large number of public and private partners have prepared for and committed to the necessary steps. This collaboration has been formalised in the Spatial Adaptation Declaration of Intent (2014), which reaffirms the Climate-proof City Manifesto (2013) drawn up by public and private partners. The ambitions and agreements in the delta decision will be put into practice over the coming years as part of this programme. Implementation will be in the hands of a growing number of local and regional partnerships acting on the basis of local and regional climate adaptation strategies.

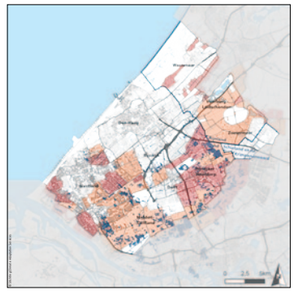
Climate adaptation strategies

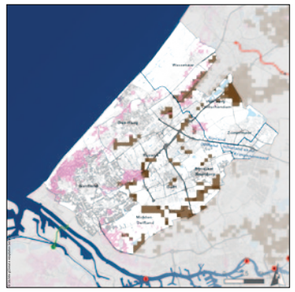
Many local and regional authorities have now begun drawing up climate adaptation strategies for their areas. Authorities in the vulnerable southern Randstad have taken the lead. The Haaglanden Regional Climate Adaptation Strategy (RAS, 2013) sets out the results of a survey by nine local authorities, Zuid-Holland provincial authority, the Delfland and Rijnland water authorities and a number of knowledge institutions on the implications of climate adaptation for the region. The RAS describes the challenges and strategies for three characteristic area types in the Haaglanden region: greenhouse, grassland and urban areas. The table below shows the aspects of climate change, consequences and measures that are particularly important in urban areas. The sections below applies them specifically to Delft, focusing on three systems that are vital for a climate-resilient city: water, green spaces and urban design.

Change	Resulting in	Adaptation strategy
sea-level rise	risk of major flooding	multi-layered flood risk management
increased rainfall (quantity and intensity)	localised flooding	retain, buffer, drain water
	excessively high water table	sufficient surface water, drainage, structural measures
rainfall shortage	drought and siltation	seasonal buffering
	subsidence	adapted weir management, structural measures
	low water table	sufficient infiltration
temperature rise	heat stress	adapt design of urban areas
	decline in water quality	natural purification, prevent sewage overflow

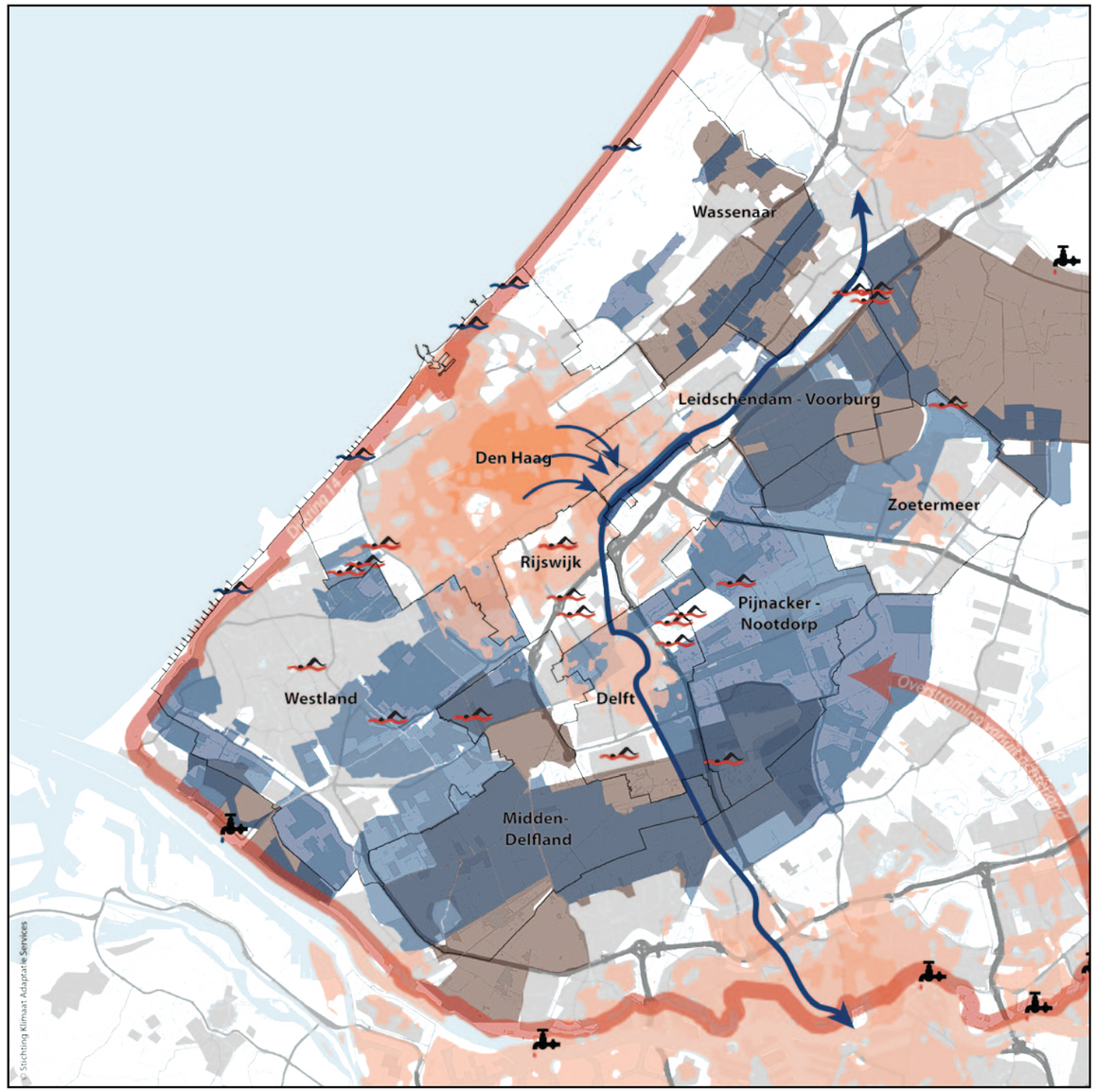

Flood risk management


Heat


Localised flooding


Drought and siltation

[maps on this and following page by Stichting Klimaat Adaptatie Services, taken from Haaglanden Regional Climate Adaptation Strategy, 2014]



Klimaat kwetsbaarhedenkaart Haaglanden

Kans op hittestress

Hittestress komt voor bij een periode van uitzonderlijk warm weer en wordt versterkt door het hitte-in-de-stad of urban heat island effect (UHI). Het UHI effect is het fenomeen dat de temperatuur in een stedelijk gebied gemiddeld hoger is dan in het omliggende landelijk gebied. Door het UHI worden problemen tijdens hittegolven, zoals hittestress, verergerd. Het effect treedt met name 's nachts op als de warmte in de stad wordt vastgehouden en de stad onvoldoende kan afkoelen. De kaart toont de gebieden die kwetsbaar zijn voor het optreden van hittestress.

Kans op wateroverlast

Klimaatverandering leidt tot een toename van de intensiteit van piekbuien. Of deze toenemende intensiteit ook daadwerkelijk leidt tot meer wateroverlast hangt vooral af van lokale factoren en maatregelen. De kaart toont die gebieden die op basis van NBW toetsing kwetsbaar zijn voor het optreden van wateroverlast. Afwatering van de stedelijk gebied van Den Haag naar de Vliet zorg er bovendien voor dat deze watergang kwetsbaar is.

Kans op bodemdaling

Met name veengebieden zijn door oxidatie kwetsbaar voor bodemdaling. Dit is een autonoom proces dat wel versterkt wordt door klimaatverandering. Het zorgt er bovendien voor dat deze gebieden gevoeliger worden voor het optreden van andere klimaateffecten zoals wateroverlast en overstroming.

Kans op overstroming

Klimaatverandering kan op diverse manieren het risico op overstromingen vergroten. Ten eerste door zeespiegelstijging: hogere waterstanden vergroten de kans op dijkdoorbraken en vergroten het landoppervlak dat binnen het bereik van een (tijdelijk extreem hoge) waterstand valt. Door veranderde neerslagpatronen en toename van kortstondige, maar extreme neerslag neemt het risico op overstroming van rivieren toe. Ook opstuwing door harde wind vergroot de kans op een overstroming. Voor de dijkring die Haaglanden beschermt tegen het buitenwater geldt een overschrijdingsfrequentie van 1/10.000. Het op orde houden van deze veiligheidsnorm is een opgave binnen het Deltaprogramma.

Kans op blauwalg

Hogere temperaturen leiden tot een grotere vraag naar openlucht recreatie en zwemwateren. Een hogere luchttemperatuur en verhoogde instraling kunnen namelijk leiden tot een hogere watertemperatuur waardoor de kans op blauwalgproblematiek toeneemt. Piekbuien kunnen daarnaast leiden tot stijgende stikstof- en fosfaatconcentraties in het oppervlakte water door uitspoeling en oppervlakkige afstroming. Dit kan algenbloei verder stimuleren.

Kans op zoetwatertekort

Bij een lage rivierwaterafvoer en een stijgende zeespiegel kan zout zeewater makkelijker stroomopwaarts komen waardoor het chloride gehalte in het oppervlaktewater toeneemt. Inlaatpunten kunnen dan onbruikbaar raken, waardoor een zoetwatertekort kan ontstaan.

De Klimaat Kwetsbaarhedenkaart brengt globaal de belangrijkste effecten in beeld. Meer informatie en detail is te vinden in de interactieve klimaateffectatlas van de Regio Haaglanden

4.2.2 FLOOD RISK MANAGEMENT

Major flooding from sea or rivers

Flood protection is based on the concept of 'multi-layered risk management'. To achieve the optimum situation, flood risk management needs to be seen as a multi-layered issue, and adequate measures need to be taken at all levels – prevention, infrastructure and design, and control.

1. prevention of flooding thanks to strong levees
2. smart urban design with compartments within levee systems and protection of vital infrastructure and vulnerable objects
3. disaster control

Strong levees

Sea-level rise increases the likelihood of major flooding. Delft is situated in levee system 14, a contiguous system of flood defences between The Hague, Amsterdam, Utrecht and Rotterdam. Levee system 14 is a primary flood defence which protects the area from flooding, both from the sea and from the major rivers. The Delta Programme includes measures to ensure that adequate flood risk management is achieved in levee system 14 [22].

Urban design and disaster control

Delft local authority area lies largely below Amsterdam Ordnance Datum, or NAP. This means that, in the event of major flooding, the ground floor of a large proportion of the buildings in Delft would be partially or completely flooded. This can mean that essential functions like energy supplies are lost, and also that people who are infirm are unable to escape to safety in time.

Multi-layered risk management requires integration of flood risk management and urban design, both within and between public authorities. To keep problems to a minimum during a flood event, it is wise to identify the risks (loss of a function or inaccessibility of an area), to consider how they can be limited or prevented, and to prioritise measures for this purpose in the short and long term. How the measures should actually be put in place can then be considered together with the owners of the infrastructure or object at risk. Policy or policy recommendations can also be drawn up detailing how to incorporate flood risk management into new urban developments. In this respect, it is vital that spatial planning and urban design are linked. If flood risk management is considered at an early stage of planning, it need not entail any additional costs.

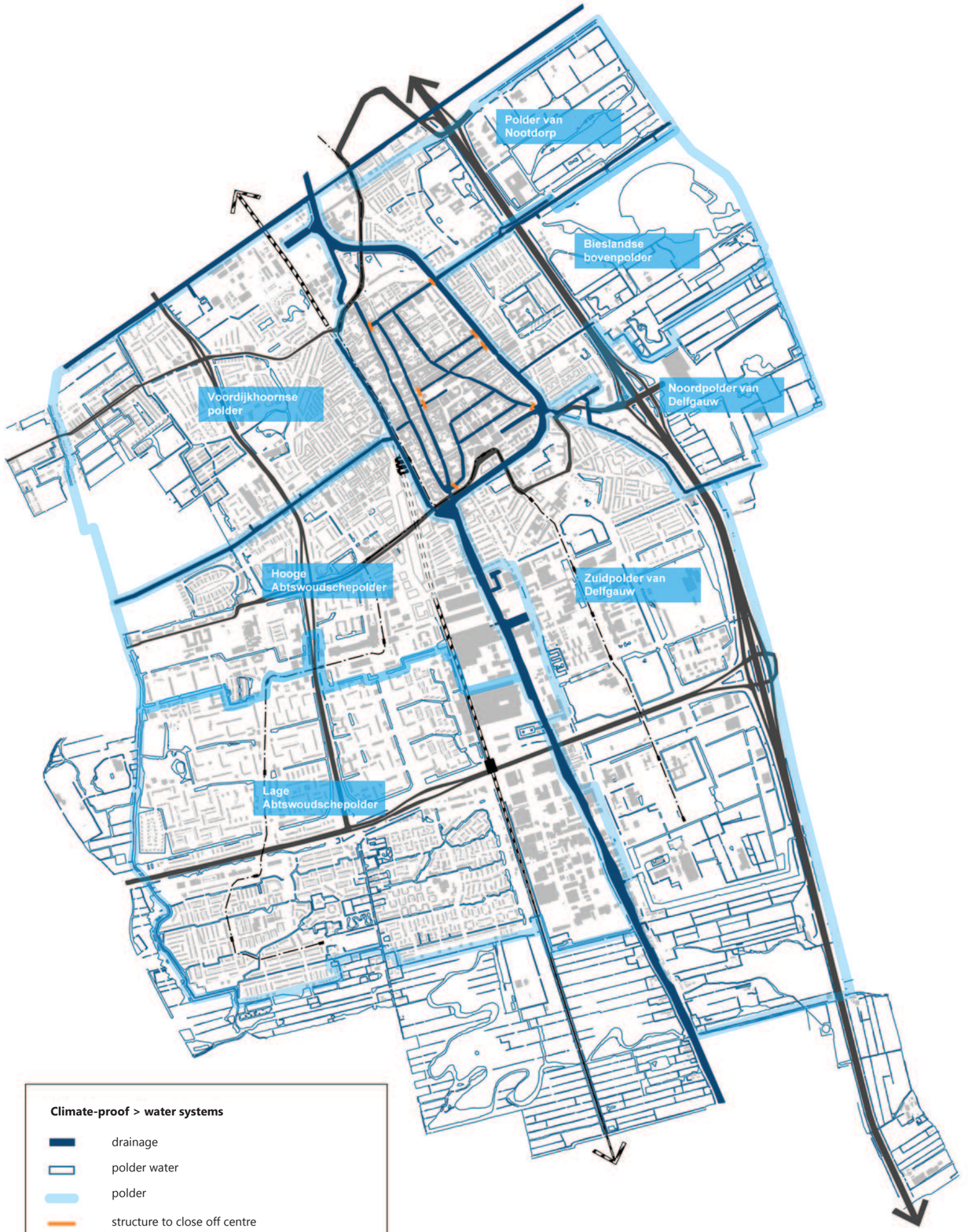
Disaster control, finally, is about informing people what they should do in the event of flooding. Here, a specific education and information programme is important: where can people seek refuge, for example? This has to be based on a survey of risks and risk areas. The regional public safety authorities are responsible for preparing for and responding to crises like major flooding, and for advising the authorities and informing the public [23].

Flooding from drainage channels

Levee system 14 encircles many polders that are separated by levees or embankments along drainage channels.
The Delft local authority area encompasses a number of polders: Polder van Nootdorp, Bieslandse Bovenpolder, Voordijkhoornsepolder, Hooge Abtswoudschepolder, Lage Abtswoudschepolder and the Zuidpolder van Delfgauw. Water is pumped from the polder to the higher-lying drainage channel, which eventually drains into the sea or one of the major rivers.

The Schie, the Pijnacker canal, the Buitenwatersloot, the Tweemolentjeskade and the city's canals are all part of the drainage channel system. Delft city centre is not on a polder, but a drainage area, and it is therefore at the greatest risk of flooding. In the event of heavy rainfall, the water level in the drainage area can rise. Since the ground surface is only just above the water level in the canals in many parts of the city centre, a total of eight shutter weirs have been installed in the centre that can be used to close off some of the canals to prevent the water from rising any further in the centre. This innovative solution is managed dynamically: the canals are closed off only if the water level is expected to rise too far. However, progressive subsidence, particularly in the east of the city centre, means the canals are eventually likely to have to be permanently closed off from the Schie to prevent streets and homes from flooding.

More intense rainfall and more or longer periods of drought have an impact on the stability of regional flood defences. They will therefore have to be strengthened at certain points over the coming years [22]. Zuid-Holland provincial authority recently set new safety standards for these flood defences.



4.2.3 LOCALISED FLOODING

Overspill and standing water in the street

More and heavier rainfall can lead to more localised flooding. There are two types of localised flooding: overspill and flooded streets. Overspill occurs when the surface water system cannot drain the excess rainwater quickly enough (via the pumping station to the drainage channels), as a result of which the water level in watercourses and ditches rises and water eventually spills over into the street. In older systems, rainwater often drains via the sewerage system rather than the surface water system. If the capacity of the sewerage system cannot handle the quantity of rainwater, the sewers will fill and water can no longer drain away, leaving it standing in the street.

The water buffering capacity required for an area is generally determined on the basis of guide numbers. The norm for urban areas is 325m^3/hectare. Since the soil structure and sewerage system have a bearing on localised flooding, in addition to the surface water system, it is important to consider the entire system. Delfland water authority and Delft city council performed two studies that modelled the entire system and calculated where localised flooding might potentially occur. The models also incorporated the KNMI scenarios. The city council then presented the results of the studies and other data on a map showing potential troublespots. The map shows that there are still several places in Delft where localised flooding might occur. The strategy of retention, buffering and drainage can be used to address these troublespots.

1. Retention

The rain that falls in an area remains there if it is absorbed by the soil (or green roofs). Grass and other vegetation, or permeable hard surfaces, can be used to replaced paving and impermeable surfaces, and green roofs can be installed in order to allow this to happen.

2. Buffering

Water can be temporarily buffered in the area so that it can be drained away later. New watercourses and lakes can be dug, wildlife-friendly banks and green or paved ‘water squares’ can be created to buffer excess water.

3. Drainage

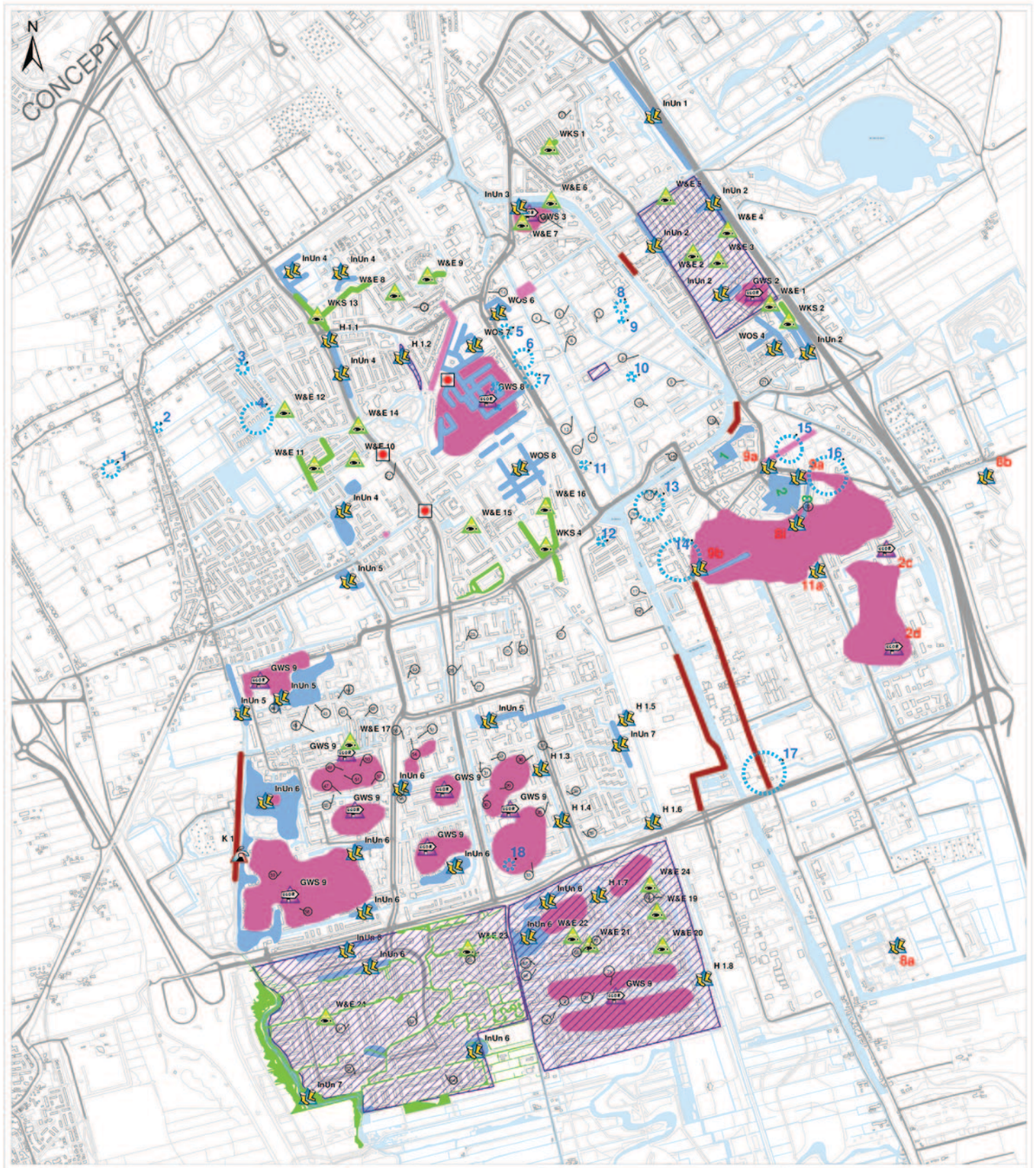
The throughput and robustness of both the surface water system and the sewerage system can be improved by installing new culverts and links with open water, or enlarging existing ones.

Another issue is who is actually responsible for alleviating localised flooding. Under the Water Act, all landowners are individually responsible for the retention, infiltration and, if necessary, drainage of rainwater that falls on their land. Furthermore, we have to consider whether the problem justifies the costs to society. Standing water in the streets will occur more and more frequently in future. If it lasts for only a short time and causes no damage, is major investment in adaptations to the sewerage system really necessary? Such decisions must be taken on the basis of collaboration and consultation between all parties in the area. The ‘Green-Blue Southeast Delft’ project has successfully developed an approach for improving the water and green infrastructure of an area in collaboration with all stakeholders, using a predictive map. The emphasis is on investing in places where the money can be used most effectively. The approach could also be applied in other parts of the city.

Groundwater

Changes to rainfall can cause either an excessively high or an excessively low water table. The rainfall predicted in the KNMI’14 scenarios varies sharply, which makes it difficult to predict what will happen to the water table. It is already very high in some parts of Delft. The current troublespots are shown on the map opposite. The reduction in groundwater abstraction at the DSM site will also cause a significant rise in the water table, potentially leading to problems in places where groundwater levels are already high.

A high water table can cause a range of problems. Groundwater can seep into crawl spaces or cellars that are not watertight, and rise into the walls. This can cause mould to develop, which in turn can lead to health problems. A high groundwater level in gardens and public spaces leaves the ground soggy and unusable. Certain trees and shrubs cannot survive such wet conditions. A high water table can also lead to damage to roads and reduced buffering capacity in the soil, making localised flooding more likely. It is not easy to tackle the problem of excessively high groundwater levels. Homes can be made watertight by taking structural measures. Drainage can be installed in public spaces. However, these are technical measures that entail considerable costs. More natural measures in public spaces, such as creating more room for urban water and specifically opting for green spaces, might help address the problem. Trends in the water table are monitored very closely in Delft. Testing the effectiveness of more natural measures in pilot projects and test facilities might help develop a broader strategy for tackling high groundwater levels.



[map: Delft city council]

4.2.4 HEAT
AND RAINFALL SHORTAGE

Heat stress

Higher ambient temperatures can cause health problems. When temperatures are high the body has to use a lot of energy to maintain a stable temperature. A rising body temperature can lead to dehydration, fainting and even heat stroke, which can cause death in extreme cases. Babies and elderly people are particularly vulnerable to heat stress.

Urban heat island effect
Heat stress is often associated with the 'urban heat island effect'. This is the phenomenon whereby temperatures in urban areas are higher than those in rural areas, partly because stone buildings and paved streets absorb more heat and retain it for longer. In addition, more heat is produced in urban areas, by industry, heating systems and traffic, for example. Heat radiation and reflection between buildings and reduced air circulation means cities stay hot for longer. The temperature difference between towns and cities and the surrounding area is greatest at night. Studies have shown that the average temperature difference caused by the urban heat island effect is as big as the temperature change predicted in the scenarios for 2050 [20]. Heat stress will therefore occur much more frequently in urban than in rural areas in the future.

Impact on economy and energy consumption
Rising temperatures are not always seen as a problem. Many people regard a more Mediterranean climate in the Netherlands as an attractive prospect. However, the Mediterranean culture and living environment are designed to cope with heat (and keep indoor environments cool). Narrow streets and arcades provide shade, and thick white stone walls and small windows keep it relatively cool indoors. A Dutch open-plan home with large windows soon heats up and is designed to retain heat rather than release it. If the temperature rises by several degrees in the Netherlands, we will need to adapt our physical living environment to keep it comfortable and healthy. If urban areas are not properly designed for heat, they may become less attractive for tourists and for companies. Commercial and domestic energy consumption for cooling will also rise, which will not help achieve the energy targets.

Hotspots in Delft
The surface temperature on a summer's day gives an impression of where heat stress might occur in Delft. High surface temperatures are particularly prevalent along the north-south axis between DSM, the city centre and the banks of the river Schie (Schieoevers). Measures to curb heat stress are most urgently needed where heat could potentially have a negative impact on health, the economy and energy consumption.

Subsidence

Higher temperatures cause peat to break down more quickly, which leads to subsidence in peat areas. Besides the desiccation of peat, the weight of buildings and infrastructure in urban areas with a weak subsurface can also cause subsidence. In Delft, the ground is subsiding particularly rapidly in the southern part of the city, in the Tanthof, Buitenhof and Voorhof districts. Subsidence, the potentially high water table and increasing rainfall have reduced the water buffering capacity of these districts, and areas that currently have sufficient buffering capacity will not have enough capacity in the longer term. Considering future subsidence and adapting the water and water buffering system accordingly might help avoid the need for major investments in the future.

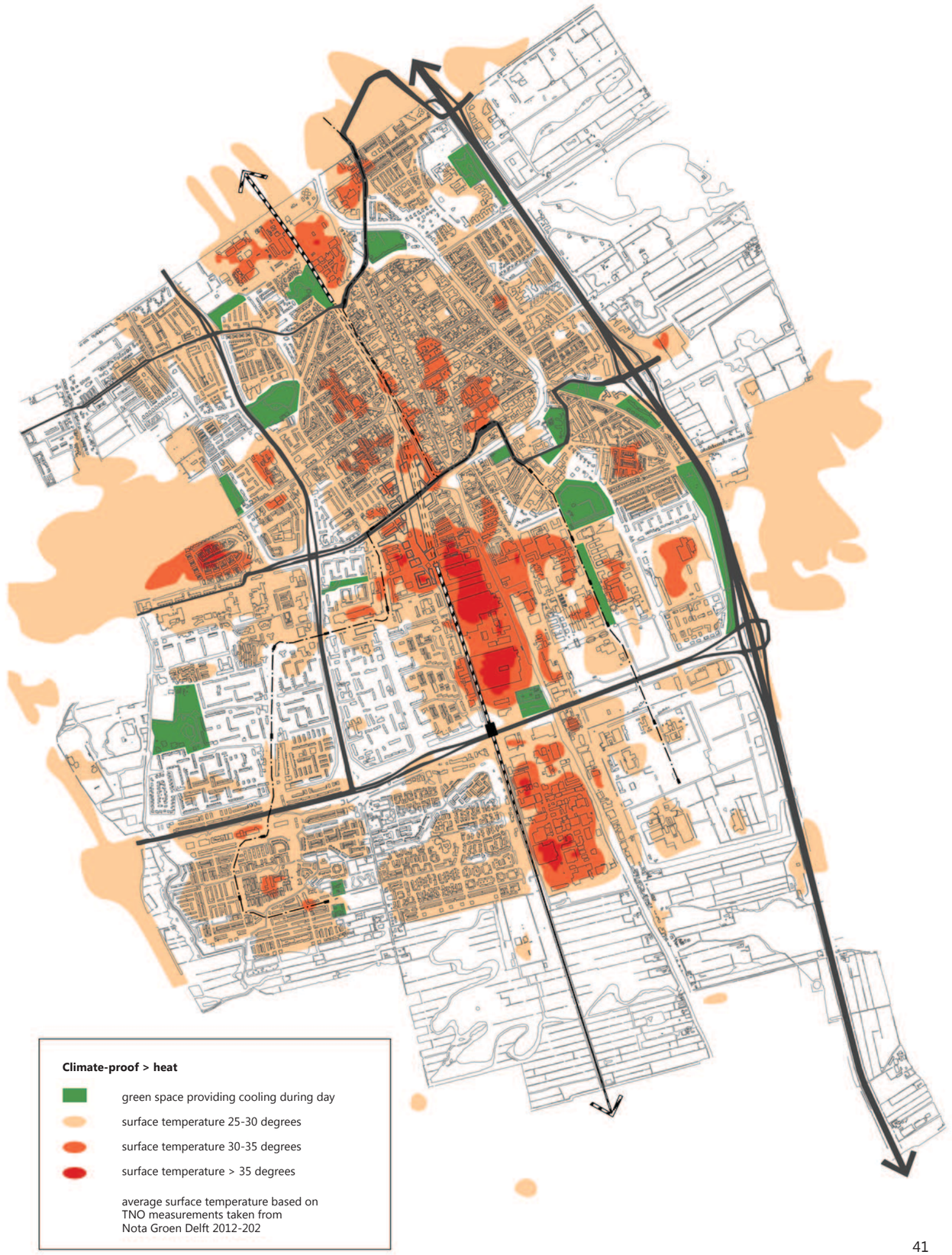
Declining water quality

Higher temperatures increase the demand for recreational facilities where people can swim, like the water parks in the Delftse Hout area. However, high temperatures also increase the risk of algal blooms, which can make water unsuitable for swimming. Lots of measures are being taken but they are not always effective. The problem of excessive nutrient levels in the water is highly persistent. If the water for swimming in Delft becomes inaccessible on a more regular basis, people will turn to alternative forms of leisure activity or other locations. If this reduces the number of people visiting Delft for recreational purposes, it will have an impact on the local economy.

The rising temperature and excessive nutrient levels in water will mean that ditches and canals are covered in duckweed earlier in the season [24]. Duckweed deprives aquatic plants and fish of oxygen and causes a deterioration in water quality. It is therefore a growing problem. There is little that can be done to stop the growth of duckweed. Natural measures such as eco-friendly banks, helophyte filters and floating islands can help improve water quality in general and make the aquatic ecosystem more robust.

Low water table and desiccation

A shortage of rainfall in the summer months can lead the water table to fall below the desired level. This in turn can cause wooden pile foundations to rot and buildings to subside. Delft has almost no buildings on wooden piles. Desiccation of the soil can lead to instability in flood defences, particularly peat dikes. Expanding the water system, practising more flexible water level management and creating seasonal buffers could all help make the water system more resilient and better able to accommodate the rainfall shortage.



4.2.5 GREEN SPACES AND URBAN DESIGN

Functional green spaces

The infrastructure and design of a city play an important role in curbing or preventing the negative effects of climate change, such as flooding and heat stress. Green spaces play a key role, providing better infiltration and water buffering, and reducing problems caused by a high water table. Vegetation can also reduce the formation of smog, which can happen more frequently as temperatures rise. Ozone and fine particulates are the most harmful constituents of smog. Vegetation lowers the air temperature and filters the air (particularly fine particulates), thus limiting the potential harm. Green spaces combined with a good urban infrastructure can also reduce urban warming and provide some cooling.

Cooling during the day
Green spaces cool the surrounding environment in two ways: through transpiration and shade. Transpiration is an active cooling process, as the energy needed for moisture in leaves to evaporate is taken from the surrounding air, causing the air temperature to fall. How effective this manner of cooling is depends on the amount of water available to the vegetation. Green spaces also provide passive cooling, by providing shade for people, hard surfaces and buildings that would otherwise be exposed to the sun. The amount of shade provided depends on the shape and density of the canopy. Densely vegetated parks, and also trees in gardens and along streets can be very effective at providing cooling in summer. A good example of this can be found on Beestenmarkt square in Delft.

The creation of the park in Nieuw Delft will be an opportunity to provide an attractive cool place in the middle of the city that could be valuable not only for the neighbourhood itself but also for the city centre and the Westerkwartier neighbourhood. However, 'cooling' must be included as a prerequisite in the specifications for the park. As well as parks, internal courtyards in blocks of buildings can also provide a significant amount of cooling. The distances between blocks in the city centre are large enough for trees. In many residential areas, however, gardens are paved and trees are not welcome. Awareness raising and joint efforts by neighbours to make their block climate-proof can improve matters.

Cooling at night
Very little transpiration occurs at night, and shade is of no use then. Large open green spaces (diameter > 6 times the height of the surrounding edges), such as fields and parks with few trees do however cool the surrounding environment at night because they radiate a lot of heat to the open air. The temperature difference between such green spaces and the rest of the city causes circulation, drawing cooler air into built-up areas. The outskirts of the city and the larger parks and open-air sports facilities provide cooling at night in Delft. As the map shows, they are situated mainly on the edges of the city.

Urban design

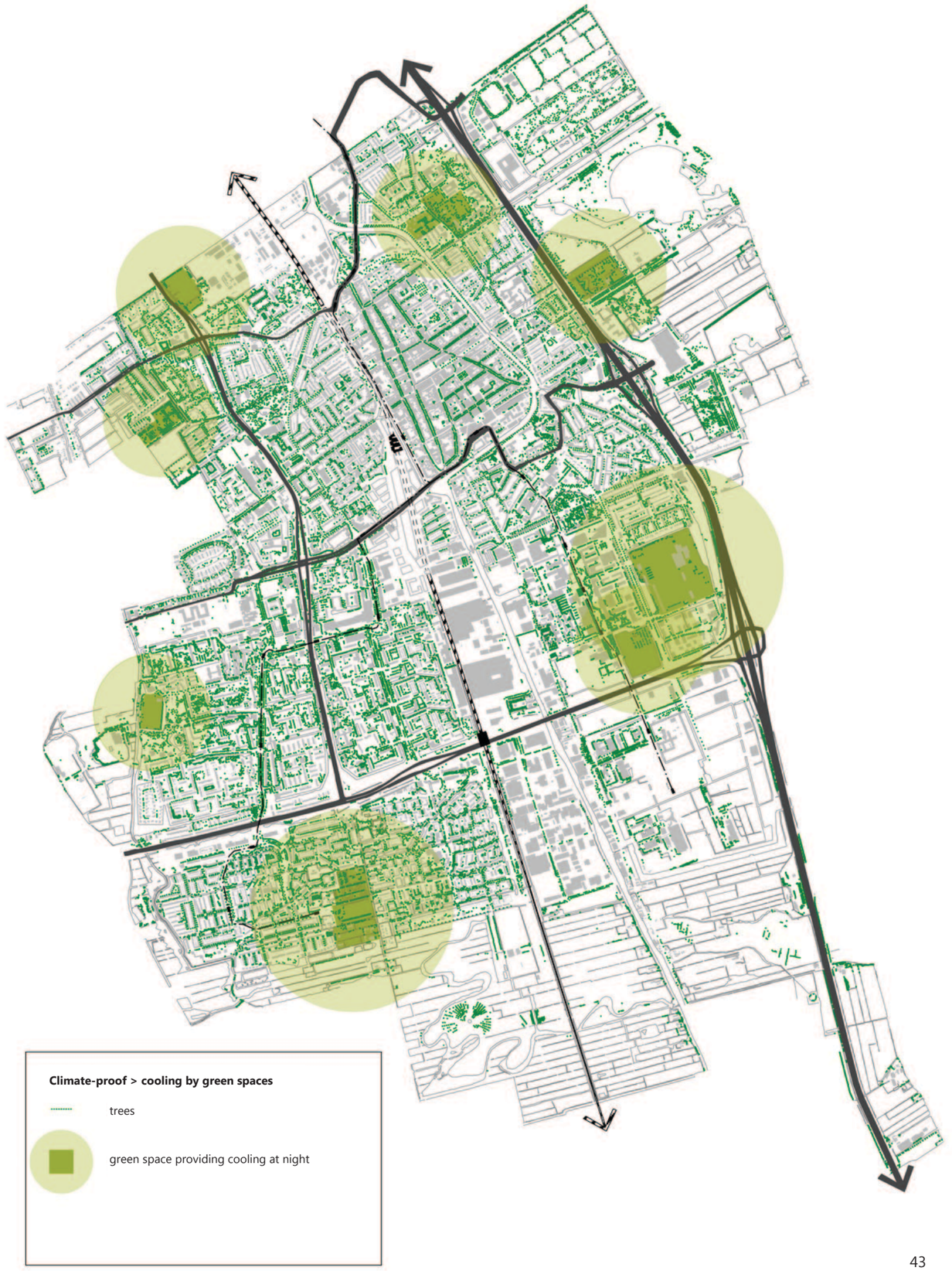
Wind cooling
Wind can replace hot, humid air with cooler air. Wind also cools the body by helping the skin lose heat. It is possible to enhance the cooling effect in certain places by positioning open spaces in such a way that they catch the wind, or by siting tall buildings at strategic spots that guide wind towards the ground. However, it is important to avoid excessive wind in cooler seasons. Wind corridors – long, wide passages with as few obstacles as possible – can help draw wind from outlying areas into the city. Since the wind in Delft generally comes from the west-southwest, streets oriented east-west can help with this. This could be used as a criterion when redesigning such streets.

Street furniture
Street furniture – pergolas covered in vegetation, flysheets and awnings, screens, fountains and taps – can also help relieve heat stress. Such solutions are particularly suitable for densely-built areas like the city centre and the Westerkwartier neighbourhood.

Hard surfaces and materials in buildings
Manmade materials like asphalt, concrete, brick and steel absorb more heat than natural materials like clay and wood. They then radiate this heat back at night. Light-coloured building materials and paving help to considerably reduce the amount of heat absorbed. Semi-paving is a good option, as it allows transpiration from the interlying soil/vegetation. A different choice of materials could be particularly useful in reducing heat stress at the DSM, Schieoevers and Technopolis business parks.

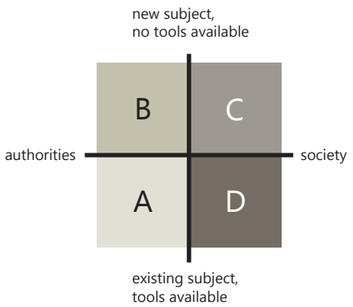
Biodiversity and climate change

Climate change also has implications for the natural environment. Species endangered by climate change need green corridors that enable them to move between areas that have become separated. A large diversity of plant species and habitats can help enhance the resilience of the ecosystem [25]. The species of plants chosen for urban green spaces is therefore important.



4.2.6 OVERVIEW
GOAL > EFFORTS

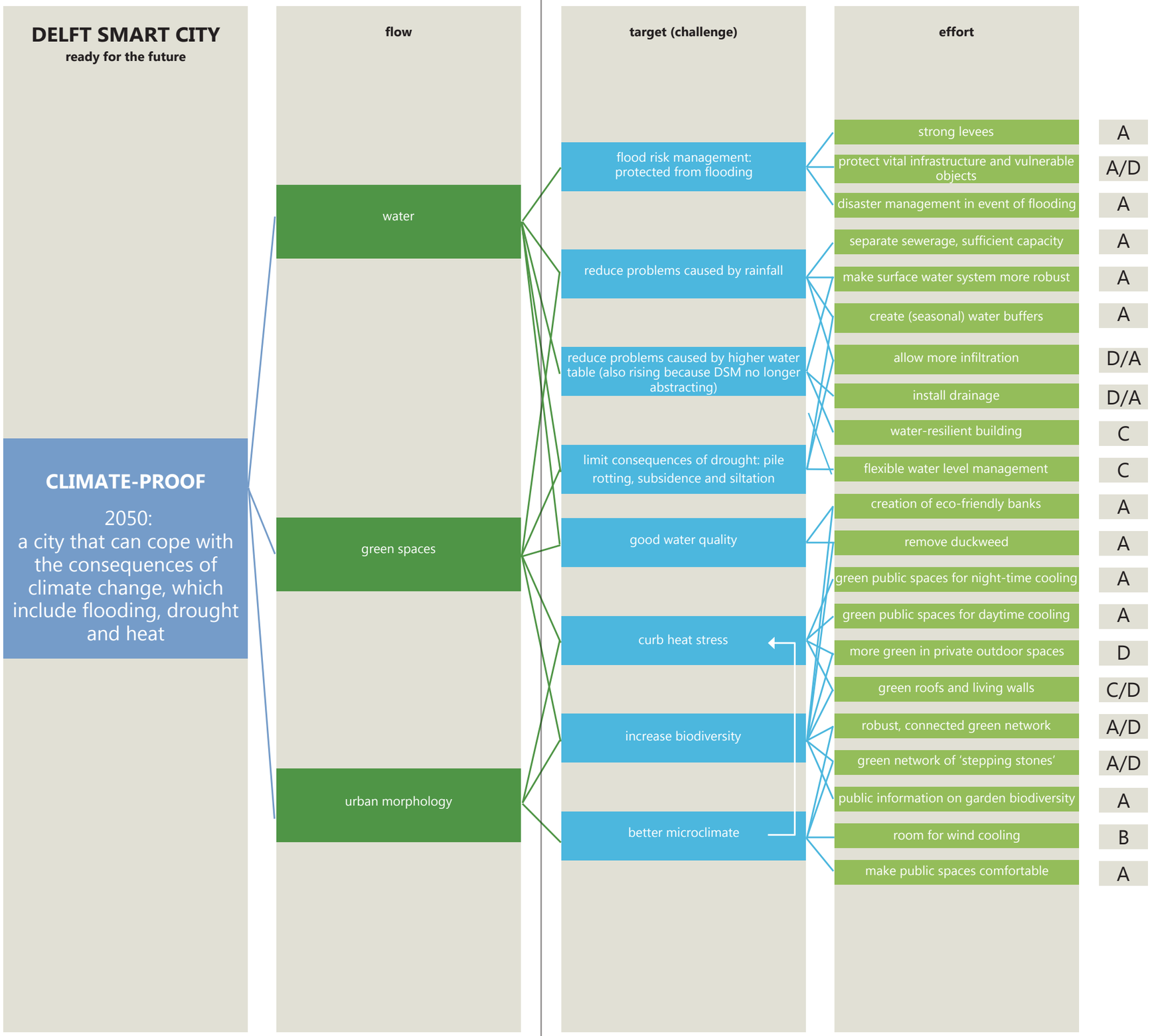
The chart summarises the analysis presented above. The challenge associated with each flow (or partial flow) is indicated, plus the efforts that will be needed to achieve the goal. The appropriate governance quadrant for each of these efforts is also indicated. Categorisation into governance quadrants is a preliminary exercise designed to give a sense of the role of the authorities and society in addressing the challenge.



Unlike in the energy challenge, local and regional authorities such as the city council and water authorities have the resources to contribute to a climate-proof city. They share responsibility for the water system. Linking efforts to procedures for residential developments, sewerage replacement and management of public spaces, for example, will require an integrated approach involving several sectors and organisations.

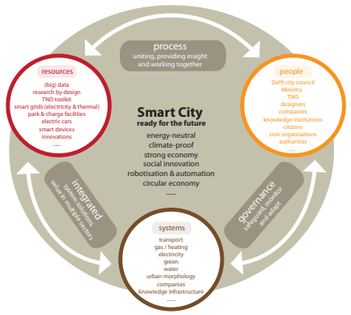
Both commercial parties and the public authorities regard innovative solutions (for water buffering for example) as promising, but regulations often hamper their implementation. One example is water buffering under the street. Since a water authority has no powers over the street – these powers lie in the hands of the city council – this method of buffering cannot be included in the system.

The chart shows that it will take relatively little effort to achieve a joint approach by the authorities and society. The challenge is to develop appropriate governance models.



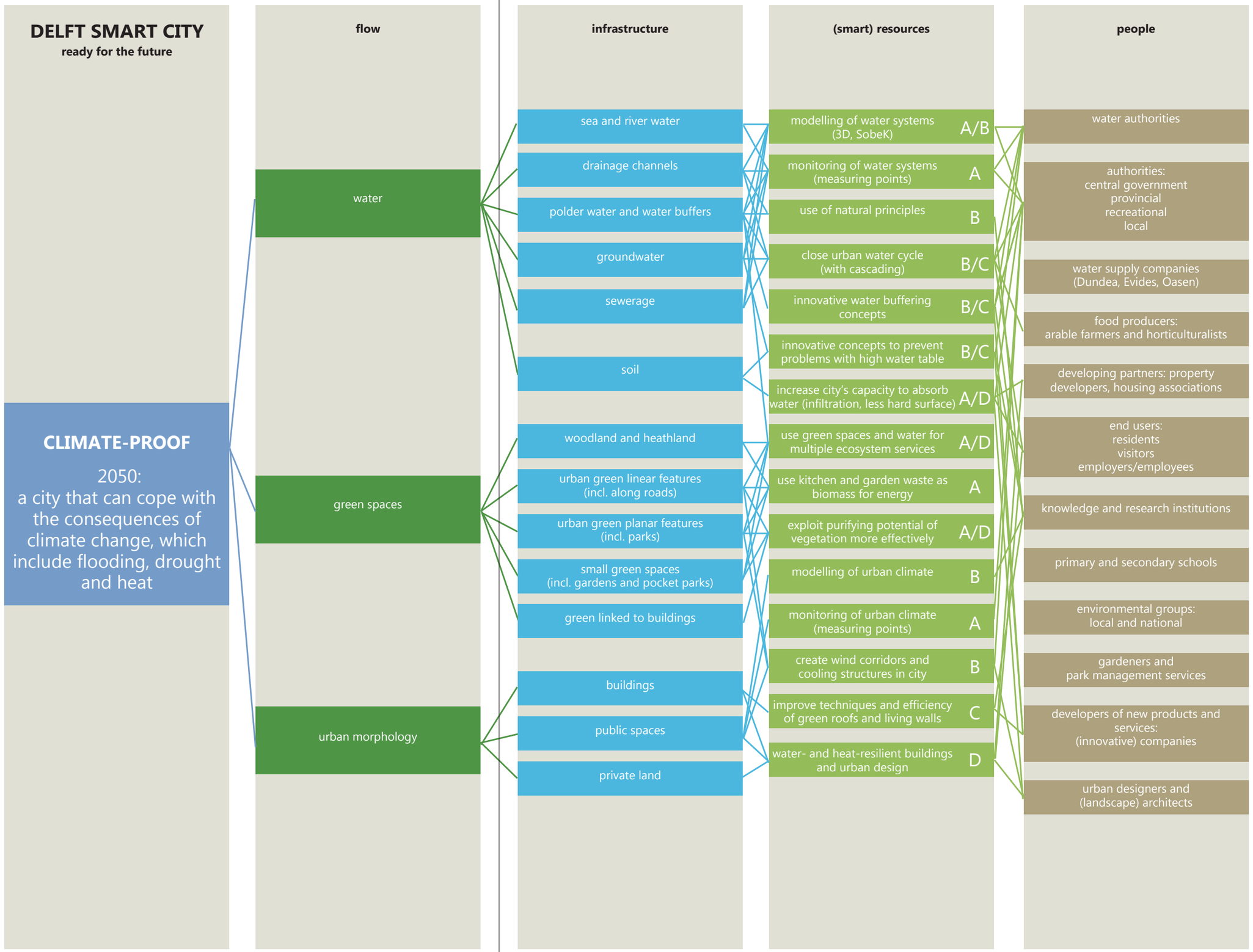
4.2.7 OVERVIEW INFRASTRUCTURE > TECHNOLOGY > PARTNERS

The second chart refers to the circular diagram depicting Delft's vision of a Smart City. All three pillars have been completed for 'climate-proof'. Here, too, the diagram is merely intended as an exercise that provides an insight into the resources (both new and existing) and partners that will be needed.



The resources (smart or otherwise) needed to make the city climate-proof focus on two aspects. One is monitoring and modelling, a practice that is already experiencing rapid development, but still has the potential for further improvement. What measures are effective in combating urban heat stress, for example? Where should they be applied? The other is the prospect of using nature and natural principles to make the city more climate-resilient. A great deal of literature has been written about this, but application is proving difficult. A project like the Sand Engine clearly shows that nature can help us if we are prepared to think out of the box.

Although the challenge in terms of spatial adaptation lies with the local and regional authorities, central government can also be expected to develop legislation for use by local authorities. One good example of this is a law recently adopted in France stipulating that new commercial buildings must be roofed at least partially with vegetation or solar panels.



4.2.8 SUMMARY AND CONCLUSIONS

Delft Climate-proof

Climate change increases the likelihood of localised and major flooding, heat stress and desiccation, potentially causing damage and disrupting daily life. We can mitigate or prevent the consequences by adapting the city, a process known as spatial adaptation.

Major flooding
In the event of major flooding, the ground floor of a large proportion of the buildings in Delft would be inundated. There must be sufficient opportunity for people – including vulnerable, immobile people – to evacuate the affected area and flee to upper floors or higher ground.

Localised flooding
Localised flooding can be expected in various parts of Delft as a result of heavy rainfall. This can be caused by overspill from watercourses and by water that is unable to flow away and thus remains in the street. The best way of deciding which measures to mitigate localised flooding would be most effective is to look at the area as a whole. This leads to a local approach, identifying how all parties can contribute and the potential for measures linked to investments in, for example, infrastructure or the living environment. Standing water in the street is likely to become more common over the coming years. If the situation lasts for only a short while and no damage is caused, are measures really necessary?

High water table
High groundwater levels occur in various places. The problems associated with this might grow worse as the abstraction of groundwater at the DSM site is reduced. Apart from damaging buildings, an excessively high water table can also be harmful to health as mould forms in wet cellars and on walls. The existing technical solutions are expensive. Research into use of more natural measures might provide more options for dealing with high groundwater levels.

Heat stress
Heat stress will become more common in the city, with implications for the economy, public health and energy consumption. Delft's hotspots are concentrated mainly in the older neighbourhoods, such as the city centre and the Westerkwartier neighbourhood, and in the industrial areas like the DSM site and Schieoevers. Measures to combat heat stress are needed most urgently in places where lots of elderly people live (vulnerable groups) and places where lots of people are often on the street, such as the city centre (attractive to tourists). Adequate information campaigns on heat stress (in collaboration with the city health service) can help prevent or reduce health problems. Green spaces significantly help to reduce heat stress. Wind and careful use of materials in public spaces can also make a difference. Such measures are not necessarily complex or costly, but their value is not fully acknowledged.

Climate-proof urban design
Urban climate adaptation requires different skills from everyone working to make the city better. The project brief is changing, and so is the challenge for urban designers. Civil engineering (water) and physical elements (heat and wind) are becoming more important. Urban design is first and foremost about achieving spatial cohesion and ensuring spatial systems function better. Obviously, the details of the solution have to be worked out by experts, and it has to contribute to the aesthetics of the living environment. In our efforts to make the city climate-resilient, the impacts of climate change must be the starting point for addressing any spatial challenge, be it large or small.

Cross-overs with economy and energy
Climate change and climate adaptation have an impact on other sectors. Damage, and measures to prevent damage, cost money. Heat stress and a high water table can impact on public health. Higher temperatures increase energy consumption (for cooling systems). On the other hand, however, warmer winters will reduce the energy consumed for heating. Adapting the city to climate change could have a beneficial effect on the economy and on social welfare. People like to live and work in or visit a city with a lot of green spaces. Greening can also increase labour productivity. Investment in climate-resilience directly benefits the urban economy, creates extra jobs and reduces energy consumption.

4.3

KNOWLEDGE
ECONOMY AS DRIVER

2030: enough jobs at all levels, thanks to a strong knowledge economy

With its academic institutions and knowledge-intensive companies, Delft is a real knowledge-based city. Development of the knowledge economy is a focal point for the city council, not least because of the likely benefits to employment in the city. This study considered the spatial aspects of Delft's knowledge economy and the likely impacts.

Positioning the challenge in society

Delft is regarded as a city with two faces. It is a knowledge-based city with a highly educated working population of knowledge workers (largely technical), and it has a lot of residents on low incomes in social housing. The question of whether investments in the knowledge economy will help close this gap regularly features in policy documents and council debates. The previous council shifted from incidental investment in the knowledge economy to structural investment. During the current council's period in office (2015-2018) the focus is on creating new jobs at all levels. In view of the plan to structurally invest in the knowledge economy, it is useful to consider the extent to which it actually generates jobs.

Working population

In 2013 Delft had a working population of 45,000, 2% fewer than in 2012 [26]. Delft's working population is relatively highly educated: 52% have a degree, 34% have a secondary qualification and 14% are low-skilled. The figures for the Haaglanden region as a whole are 44%, 38% and 18% respectively [26]. Compared with the wider region, therefore, a smaller proportion of Delft's working population are low-skilled, and a larger proportion are highly educated.

Number of jobs

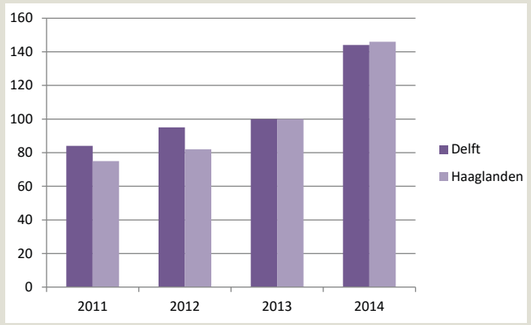
On 1 January 2014, companies and institutions in Delft employed 49,579 individuals, 43,017 of whom worked more than 12 hours a week. This was 907 fewer than on 1 January 2013. The number of jobs in Delft has been declining steadily for several years, and is now 4% lower than in 2009 (6% lower in the Haaglanden region). Most companies and institutions are located in the city centre (1557). However, most jobs are in the Wippolder district (incl. Schieweg and Ruiven). In this district, where TU Delft is also situated, 16,319 people are employed: 38% of the total number of working persons [26]. Lots of people also work at the Reinier de Graaf Gasthuis hospital and at the Schieoevers business park.

Knowledge-intensive jobs

The number of people working full-time in the knowledge-intensive sector was 16,392 on 1 January 2014, 119 more than a year earlier. As a result, the proportion of people working in this sector increased to 38%.

Unemployment

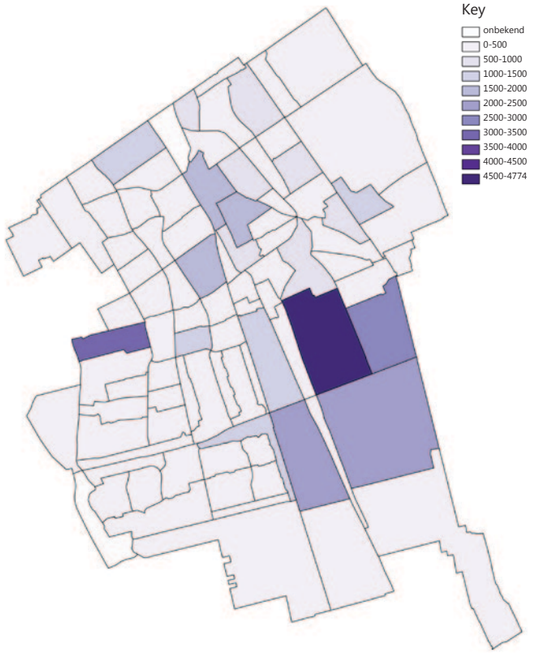
Unemployment in Delft and the surrounding region rose sharply in 2013. According to benefits agency UWV, on 1 January 2014 there were 5229 out-of-work jobseekers in Delft, 44% more than on 1 January 2013. In the Haaglanden region unemployment rose by 46% in 2013. Almost half the unemployed people in Delft (48%) are low-skilled. The proportion of low-skilled people among the unemployed has increased [27].



indices out-of-work jobseekers [27]

jobs in Delft on 1 January 2014, by sector	
healthcare and welfare services	9102
education	8309
consultancy, research and other specialist business services	7220
wholesale, retail, car repair	6954
information and communications	2732
industry	2688
hotel and catering	2456
public administration, government services and compulsory social insurance	2065
construction	1544
transport and storage	1378
movable goods rental and other business services	991
culture, sport, leisure	968
water abstraction and distribution, water and wastewater management and purification	827
other services	660
financial institutions	528
production, distribution and sale of electricity, natural gas, power and cooled air	549
property sales and rental	536
farming and fisheries	72
Total (full-time and part-time)	49,579
knowledge-intensive sectors	

[source: Delft city council annual statistics 2015, table 4.2]



number of people working at companies and institutions on 1 January 2014 [26]

Employment effects

On 1 January 2014 full-time jobs in the knowledge-intensive sector accounted for 38% of the total number of jobs in Delft. A large proportion of them are jobs for people with a higher technical qualification. The city council's goal is to ensure the strong knowledge-driven economy helps create jobs at all levels, including in other sectors. A number of potential employment effects of the knowledge economy are listed below, and examined in further detail in the rest of this chapter.

More highly-educated technical knowledge workers
The cluster of knowledge-intensive companies and institutions could attract other knowledge-intensive companies and institutions, creating new jobs for highly-educated technical and other knowledge workers.

Low- and mid-level technical jobs
An increase in the number of knowledge-intensive companies could also lead to an increase in jobs for people with lower or intermediate technical qualifications. People with such qualifications are in particular demand among high-tech instrument makers and manufacturers.

Growth in consumer services
When more highly-educated people live in a city, this creates more work for people with a low level of education, since highly-qualified workers spend money on consumer services. This is known as the trickle-down effect.

Growth in business services for companies
Besides an increase in consumer services due to an influx of highly-educated residents, there might also be growth in business services for companies. This includes things like cleaning, security, catering and courier services.

Epicentre of knowledge economy

Delft's position in the region was examined by the Louter consultancy in a 2013 study (*Delft in regionaal perspectief*). The illustration opposite shows the number of jobs in knowledge-intensive sectors (technical or otherwise) per square kilometre [34]. A contiguous area can clearly be seen stretching from Technopolis (Delft), via Plaspoelpolder (Rijswijk) to Utrechtsebaan and Binckhorst (The Hague). The clustering of companies in this area is good for the economy and employment in Delft and in the region. However, it also means that companies have a large choice of locations.

Company premises

Dedicated office developments – monofunctional office locations and large concentrations of offices at business parks – dominate the supply of commercial premises in the region. Central locations are locations near or forming part of a town or city centre. Such locations are lively, multifunctional and easily accessible by public transport. They are mainly are located in The Hague and Rotterdam [28]. In Delft the majority of office premises are in dedicated developments. The development of the area around the current railway station (Spoorzonegebied) will give Delft a central location for offices and companies. Nieuw Delft will expand the supply, and is expected to attract companies with a different profile from those at the existing locations.

Knowledge clusters in Delft

A large number of knowledge institutions are based in Delft. In spatial terms, the city has three knowledge clusters with a regional function:

1. TU Delft and Technopolis

The TU Delft campus and Technopolis science park lie to the southeast of the city centre. They are by far the largest knowledge cluster in the city. Apart from the faculties of TU Delft, the area is also home to branches of the HE colleges Haagse Hogeschool and Hogeschool Inholland, research institutions like TNO and Deltares, various companies and the incubator YES!Delft. On 1 January 2014 9908 individuals worked in the area as a whole (including Delftechpark and the TNO site) [26].

2. Delft – DSM Biotech Campus

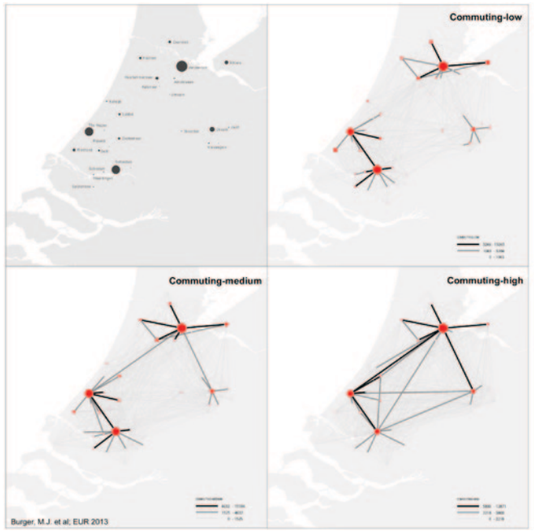
To the north of the city centre lies the DSM site, which includes DSM Biotechnology Centre and the Bioprocess Pilot Facility. This testbed offers companies and research institutions the opportunity to test their ideas for feasibility on an industrial scale. Over the coming years, the DSM site is to be further developed into a park for industrial and R&D activities in the biotechnology and life sciences sector, where other companies will also be able to locate their operations [29]. On 1 January 2014 1061 individuals worked at this location.

3. Reinier de Graaf Gasthuis

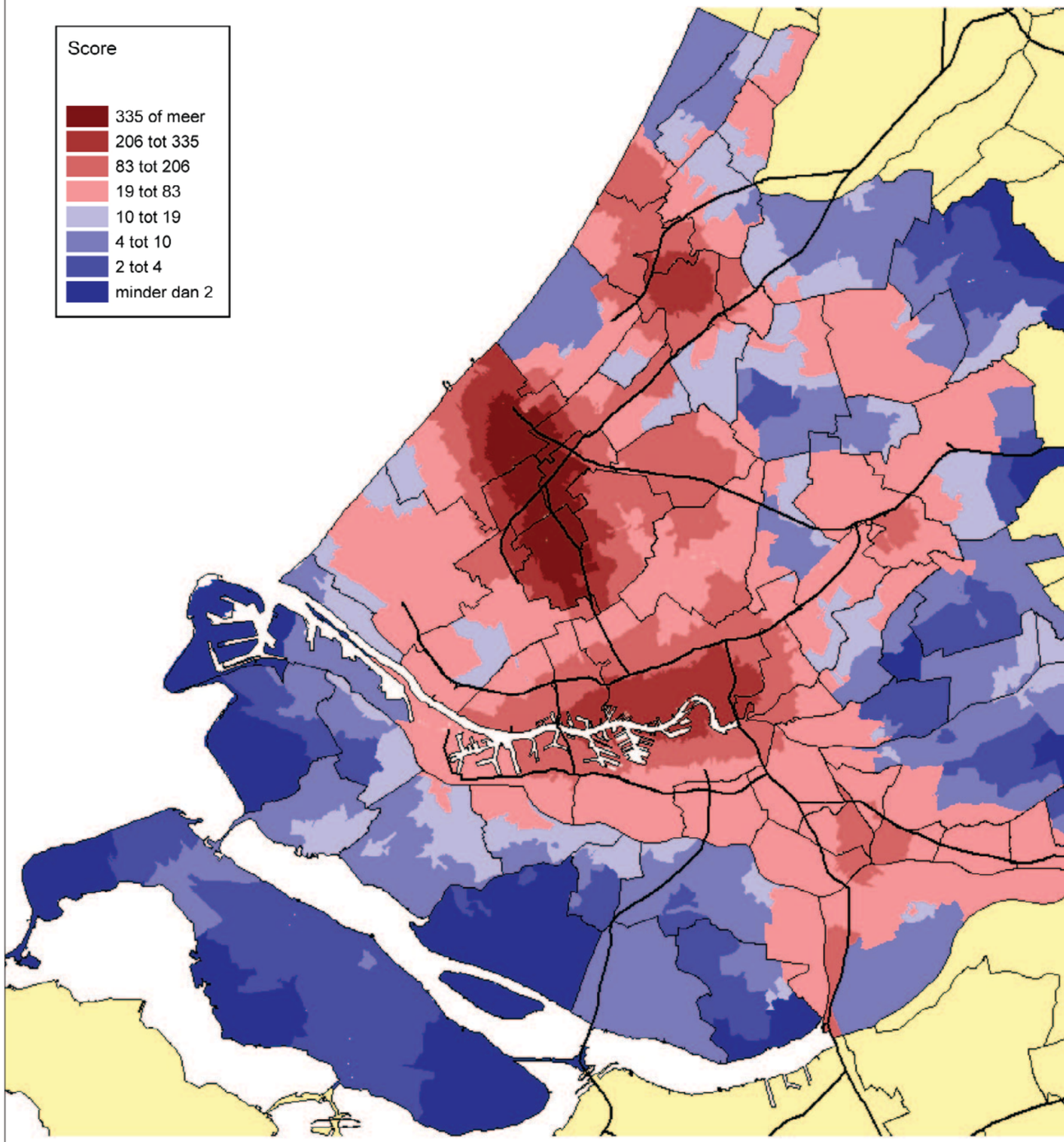
The Reinier de Graaf Gasthuis hospital is a leading clinical teaching hospital. When its new building is complete, the hospital will be the most sustainable in the Netherlands [30]. To optimise patient care, it recently entered into a partnership with Philips for innovative medical technology, clinical IT and services [31]. Space will become available on the site when the new building opens. On 1 January 2014 3231 individuals worked at the site [26].

Commuting

The higher a person's qualifications and income, the further they are likely to travel to work [33]. Highly-educated knowledge workers who work in Delft's knowledge clusters do not necessarily live in Delft. Fewer than half of Delft's residents with a university degree actually work in the city. Highly qualified knowledge workers can potentially live and work anywhere in the region, or even the entire Randstad conurbation. Things are different for people with lower qualifications. Almost two-thirds of people with no qualifications, or lower qualifications, work in Delft itself. If we include Rijswijk, Westland, Midden-Delfland and Pijnacker-Nootdorp, we find that around 80% work in Delft and the surrounding area [32]. Local jobs are therefore particularly important for people with a low level of education.



relationship between labour market and commuting [maps by M.J. Burgers et al., from *ATLAS Metropoolregion Rotterdam Den Haag* (2013)]



Number of jobs in (technical) knowledge sectors per square kilometre.
[map by P. Louter et al., from *Delft in regionaal perspectief, economische en fysiek domein* (2013)]

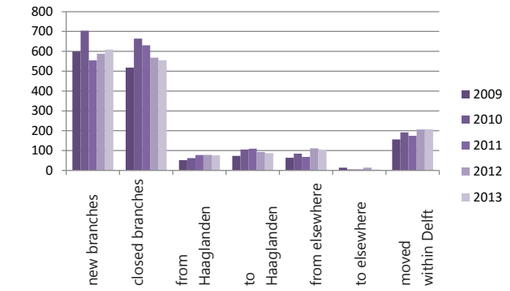
4.3.2 KNOWLEDGE-INTENSIVE COMPANIES

General

More companies, fewer jobs
In recent years, the number of branches of companies and institutions in Delft has risen steadily. Compared with 2009, there has been an increase of 5% (the Haaglanden region has also seen a 5% increase). However, the number of people working at these companies and institutions has been declining for years. On 1 January 2014 there were 5778 company branches and institutions in Delft, 140 more than on 1 January 2013, but they employed 907 fewer staff (full-time) [26].

Turnover of companies
If we look at the turnover of companies over a number of years, we see that the number of start-ups is structurally higher than the number of companies closing, but the difference is only slight. The number of companies moving from Delft to Haaglanden is slightly higher than those moving in the other direction, but again the difference is only small. By contrast, however, the number of companies moving to Delft from outside the region is much higher than the number of companies moving from Delft to elsewhere in the country. Delft therefore seems to be an attractive location for companies outside the Haaglanden region. In 2013 775 companies with 1311 employees moved to or were launched in Delft. In the same year, 635 company closed branches or moved to another location; they employed 1871 people. Of the total reduction of 907 employed persons in Delft in 2013, 560 were therefore accounted for by companies that left the city or closed their branch there. A city council can do little to stop companies shedding jobs. It can however influence where new companies decide to locate.

Annual turnover of companies



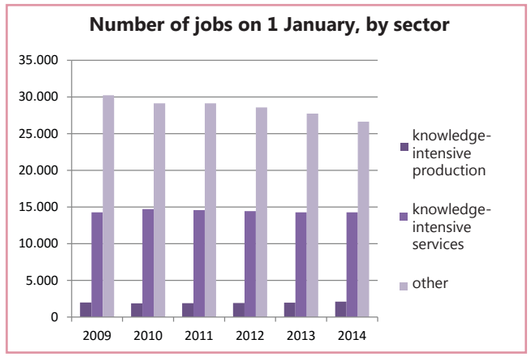
Company locations
Delft has 20 business parks and office locations. They are mainly dedicated office developments which are easily accessible from the motorway. Only Tanthof-Oost is situated close to a railway station (Delft Zuid), as well as being accessible by car. On 1 January 2014 Delft's business parks and office developments were home to 771 company branches, employing 15,950 people [26]. the locations are shown on the map.

Knowledge-intensive

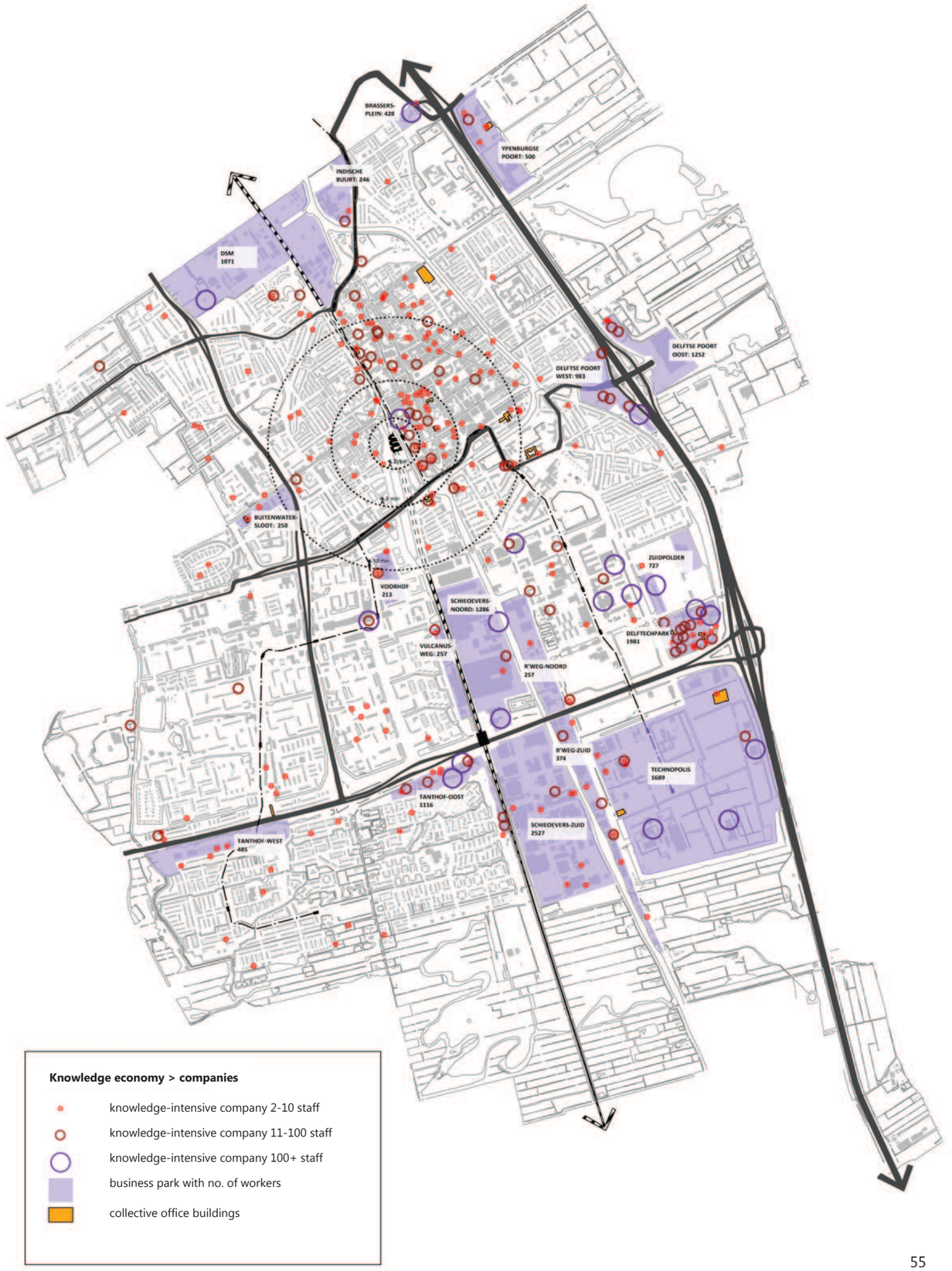
More companies, same number of jobs
The number of companies in the knowledge-intensive sector is also growing. Here, however, there has been no decline in the number of jobs, but rather a stabilisation or a slight increase. The number of jobs in the knowledge-intensive services sector remained the same in 2013. In knowledge-intensive production, approximately 140 new jobs were created [26].

The number of jobs has fallen by approx. 1030 in other sectors. The loss of jobs is not therefore occurring in the knowledge economy sectors. Depending on the economic situation in the country, the current stabilisation may turn into growth. When large companies open in or leave Delft hundreds of jobs can be involved. In 2014, for example, 3M opened at Technopolis, creating around 200 new jobs. In 2015, some 500 jobs will be lost when TNO moves its headquarters out of Delft.

Number of jobs on 1 January, by sector



Locations for knowledge-intensive companies
The map shows where knowledge-intensive companies (apart from nonemployers) are located. They tend to be concentrated in east Delft. Most knowledge-intensive companies employing more than 100 staff are in the southeast, on the TU Delft campus, Technopolis and Schieoevers. Many knowledge-intensive companies are on business parks or in office developments. The major exception to this is the city centre, where approximately a third of knowledge-intensive companies are located. The city centre and the area around it also has the most collective office accommodation.



4.3.3 KNOWLEDGE AND EDUCATIONAL INSTITUTIONS

Knowledge development and transfer

Knowledge 'flows' through Delft via the many research and educational institutions to which the city is home. This involves both the development and transfer of knowledge, which occurs at certain places and with the help of certain resources: the knowledge infrastructure. The link between education (knowledge development) and the labour market is important for mid- and low-level jobs in the technical sectors. Valorisation (making knowledge available to society and actually using it) can create more work for highly educated technical people.

1. Knowledge infrastructure

The physical knowledge infrastructure consists of teaching and research facilities such as lecture halls, study areas, workshops, laboratories and test facilities. Innovations are displayed and developed in various testbeds and 'living labs'. The city also has institutions focused more on transferring knowledge to the public, such as the Botanical Gardens, the Science Centre, TU Delft Library and DOK library. There are also facilities for conferences and events. The lion's share of this physical infrastructure is on the sites of the three regional knowledge clusters. The exceptions are secondary vocational schools and general secondary schools located in or near the centre and a number of facilities in the city centre.

2. Link between education and labour market

A strong knowledge economy is expected to help increase the number of jobs for people with secondary vocational or higher professional qualifications. Coordinating the courses on offer with the needs of companies can help young people find a job more quickly, and will make Delft a more attractive location for companies looking for well-trained technical staff.

Technical education
The city council and Delft's educational institutions are keen to offer technical education at all levels. Besides the technical degrees taught at TU Delft and at the Haagse Hogeschool and Hogeschool Inholland HE colleges, the secondary vocational courses Green Tec and Mechatronics are now also available. Technical education at pre-vocational level will be offered at the new SC Delfland site in Nieuw Delft.

High Tech Centre Delft
High Tech Centre Delft was established on 1 January 2015. Here, educational institutions at all levels, industry and the authorities will work together to match education to the needs of the labour market. The High Tech Centre Delft is located next to Haagse Hogeschool's Betafactory ('Science Factory'). The partners in the High Tech Centre are shown on the map. It can be seen that a large proportion are companies located on the Schieoevers. Many Delft youngsters attend the schools involved in the venture, so High Tech Centre is expected to have an impact locally as well as regionally.

3. Knowledge valorisation

Transforming knowledge into new products and services can create more jobs. Improving existing companies' access to knew knowledge is one way of encouraging valorisation. Facilities like YES!Delft help new companies develop and market innovative ideas. Various organisations and partnerships facilitate these developments. The TIC network and Zorg&Techniek ('Care&Technology') were discussed as part of the Delft Smart City project.

TIC network
The TIC network was established by Delft city council, TU Delft and twelve knowledge partners in 2012. The aim is to bring knowledge partners together to invest in Technological Innovation Campus Delft. The network has since been expanded to include a number of large companies, and the focus has now shifted to involving SMEs. TIC has two main focuses: raising the profile of Delft (and the TIC partners) as the heart of the regional knowledge economy in order to attract investment and jobs to Delft and Delft companies and knowledge institutions – a regional role, in other words; and a local role in stimulating developments like High Tech Centre and the Betafactory. TIC supports its partners in several sectors, including water and delta technology, biotechnology, ICT and the creative industries.

Zorg&Techniek
Zorg&Techniek is a network of healthcare providers, knowledge institutions, tech companies and end users that focuses on healthcare technology innovation and implementation. The network has organised meetings to articulate the need for new products and services more forcefully and to draw attention to the supply of new technology. The network has also supported PhD, graduation and student projects. The innovation broker matches the supply of technology (students) to demand for care (healthcare institutions and end users).

The TIC network shows that, by acting together, parties can have more impact, helping them all to achieve their aims. This could also be a useful strategy for healthcare institutions. Zorg&Techniek has shown that bringing partners in the same field together also leads to the implementation of new products and services in Delft. This might prove an interesting way for TIC to follow up on themes like 'climate-proof' and 'energy-neutral'.

4.3.4 RETAIL, HOSPITALITY, CULTURE AND LEISURE

Trickle-down in other sectors

More work for highly-educated knowledge workers can lead to more work for people with lower qualifications. This applies not only to the knowledge-intensive sector.

Consumer services

When more highly-educated people live in a city, more work is created for low-skilled people, as the highly educated spend money on consumer services, such as retailing, the hospitality industry, culture and leisure, as well as domestic and personal services. The trickle-down effect has been shown to occur in the hospitality industry and the culture and leisure industries. One percentage-point more highly-educated residents in a city leads to an average of 0.31% more jobs for less well-educated residents. Assuming the housing stock remains the same, in Delft this means that for every one hundred additional highly-educated residents, almost eight extra jobs will be created for people with lower qualifications [35].

When highly-educated people work but do not live in a city, they may still spend more money on consumer services there, thus creating jobs. In this case, they mainly spend their money at lunch rooms, cafés and coffee bars. Whether this actually occurs has never been proven. When asked, people currently working at the TU campus or Technopolis indicated that they rarely visit cafés and restaurants in Delft.

Business services

Business services are support services that companies provide for other companies: cleaning, security, catering, courier services. A growth in the number of knowledge-intensive companies is also likely to bring about a growth in demand for business services. However, no specific information is available on the extent to which this is likely to occur.

Conference tourism

Both leisure tourists and conference tourists visit Delft. In 2008 66,000 people visited Delft on business. They were mainly individual business travellers [36]. Since 2011 the city council has been actively involved in conference acquisition, which resulted in 13,750 man days related to conferences in Delft in 2014. If the number of conferences in Delft increases, there might be a rise in the number of business tourists staying there, which could lead to more jobs in Delft city centre, particularly in the hospitality industry, because that is where most of the hotels are located. Making sure hotels are located in and around the city centre helps ensure the potential trickle-down effect actually occurs.

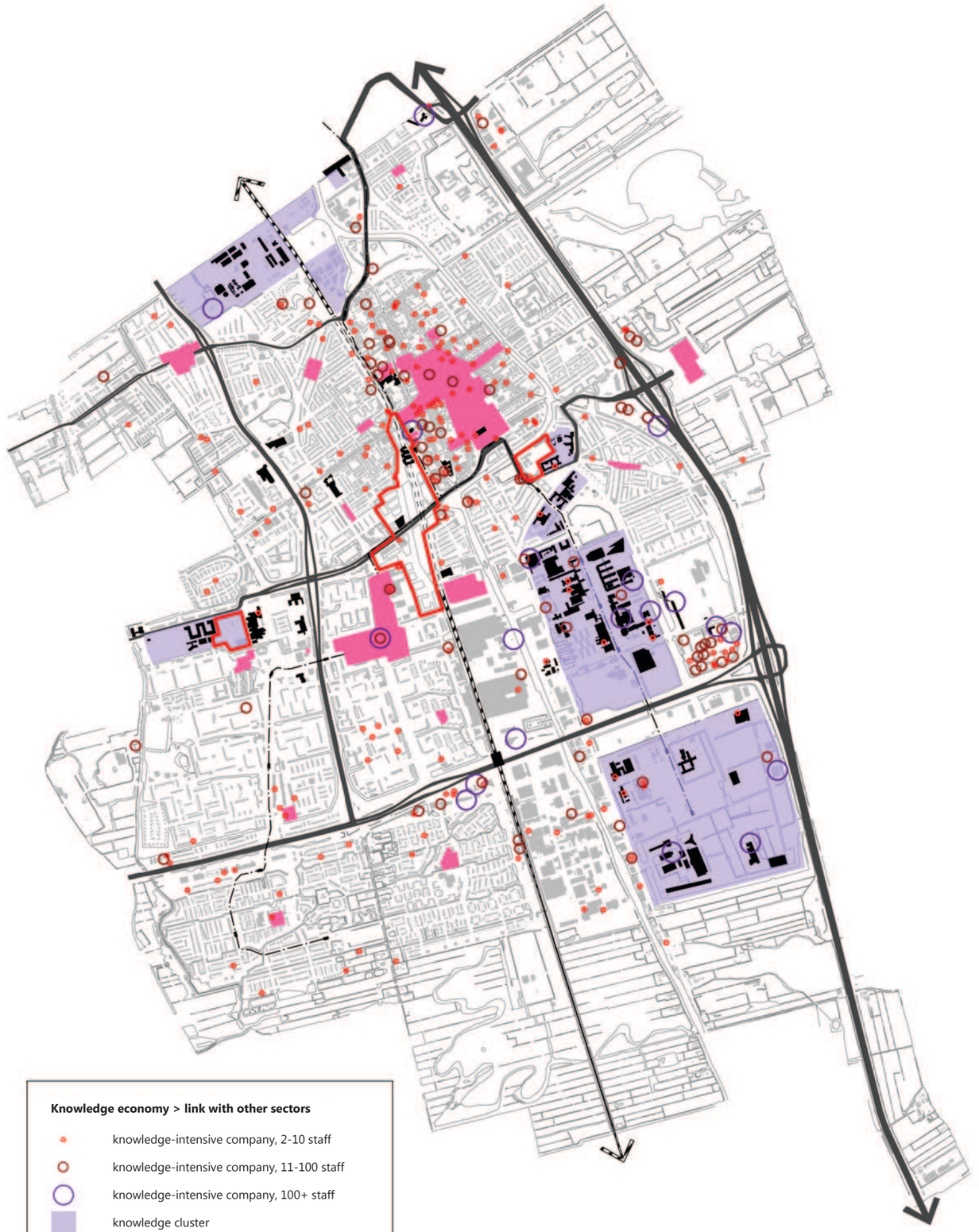
Physical connection with hospitality industry and amenities

The map shows the locations of hospitality and cultural facilities, the knowledge infrastructure and knowledge-intensive companies. There is clearly overlap between knowledge-intensive companies and hospitality and cultural facilities in the city centre and in the De Hoven Passage shopping centre. The knowledge infrastructure does not overlap with hospitality and cultural facilities. The question is therefore to what extent the trickle-down effect actually occurs. There are three places that could play a potential role in creating spatial connections between the knowledge infrastructure and other sectors.

Nieuw Delft
All the employment effects we have described might potentially occur in Nieuw Delft. New jobs for highly-educated knowledge workers can be created if new companies open there. Technical jobs for people with mid- and low-level qualifications could be generated by offering space for technical manufacturing companies in the vicinity of Nieuw Delft, and linking these companies with the educational institutions in the area: the pre-vocational and vocational schools, the High Tech Centre and the Betafactory. An increase in consumer services around the area could come about as people go to work and live there. An increase in business services could follow on from the clustering of companies with similar demands. The chapter on locations examines this in more depth.

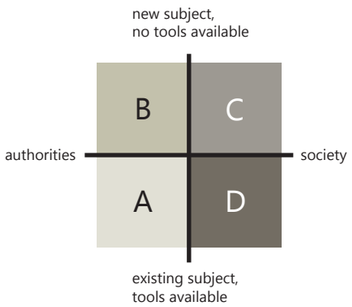
TU Noord
Student housing association DUWO is developing an International Student house with bars and restaurants and other amenities at TU Noord. The historic building at 2B Kanaalweg is also being renovated, and will house both PhD students and the offices of DUWO itself. There are plans to develop number 4 Kanaalweg into an incubator for start-ups. In view of the current business activity at the Science Centre and the Dynamohal, and given the tourist and educational function of the Botanical Gardens and the Science Centre, this area could develop into a very attractive multi-purpose residential, work and leisure environment, where all three flows come together. In spatial terms, the area could link TU Delft and the city centre, as it is in walking distance of both the university faculties and the centre.

Reinier de Graaf Gasthuis
When the new premises of the Reinier de Graaf Gasthuis hospital open space will become free on the site. The development of this area could create a link with the shops in Buitenhof on the other side of the water. This is examined in further depth in the chapter on locations.



4.3.5 OVERVIEW
GOAL > EFFORTS

The chart summarises the analysis presented above. The challenge associated with each flow (or partial flow) is indicated, plus the efforts that will be needed to achieve the goal. The appropriate governance quadrant for each of these efforts is also indicated. Categorisation into governance quadrants is a preliminary exercise designed to give a sense of the role of the authorities and society in addressing the challenge.



Many of the efforts concern known issues, for which tools are already available. Responsibility lies first and foremost with society, with a role for the authorities in facilitating the growth of companies and knowledge institutions, which could in turn create new jobs.

The development of living labs and the associated expansion of the knowledge infrastructure through research and innovation programmes are efforts requiring innovative governance.

In efforts to enhance the impact of the knowledge economy on the support economy (trickle-down effect) it is important that the support economy be given enough opportunity to benefit from highly-educated knowledge workers. Such opportunities range from visibility, physical proximity and reduced regulation to training and access to finance.

DELFT SMART CITY
ready for the future

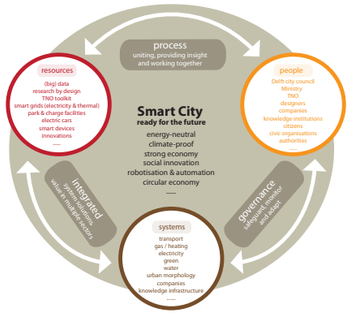
KNOWLEDGE ECONOMY
2030:
enough jobs at all levels, thanx to a strong knowledge economy

flow	goal (challenge)	effort	
knowledge-intensive companies (services and industry)	attract companies from elsewhere	attractive location for companies	A
		attractive place for staff to live	A/D
		good supply of cultural, hospitality and leisure facilities	A/D
		network of potential clients and investors	A
	facilitate growth of existing companies	automation of production processes (smart industry)	C
		supply of commercial premises	A/D
	promote new companies (start-ups)	city council as launch customer	A
		Delft as living lab for testing of innovations	B/C
	facilitate strong knowledge institutions	adequate supply of student housing	D
		good accessibility	A
		attractive city (incl. internationally)	A/D
knowledge and educational institutions	attract new knowledge institutions	interaction with other knowledge institutions: knowledge clusters	D
		national and international lobby	A/D
	expand knowledge infrastructure	national and international grant and development programmes	B/C
		shared use of services and facilities	D
	knowledge valorisation	enhanced access to knowledge in companies (via networks)	A/D
		physical work places for young entrepreneurs	A/D
	match education to labour market	training places in tech companies	D
		contact between colleges and labour market: work/study interaction environment	D
		expand supply of technical (pre-) vocational courses	D
		technology programme for primary schools	D
retail, hospitality, culture and leisure	enhance impact of knowledge economy on support economy (trickle-down)	provide opportunities: visibility, physical proximity, fewer rules	A
		stimulate CSR	A
		entrepreneurship	D

valorisation

4.3.6 OVERVIEW: INFRASTRUCTURE > TECHNOLOGIE > PARTNERS

The second diagram refers to the circular diagram depicting Delft's vision of a Smart City. All three pillars have been completed for 'knowledge economy as driver'. Here, too, the diagram is merely intended as an exercise that provides insight into the resources (both new and existing) and partners that will be needed.



A lot of the infrastructure and resources (smart and conventional) focus on knowledge valorisation. This requires collaboration between various parties, and all will have to look beyond their own field. The TIC network facilitates collaboration between the authorities, companies and knowledge institutions (Triple Helix). In the Zorg&Techniek partnership the focus is on linking new technology with end users to take steps towards actual implementation of new technologies. Involving users in the Triple Helix is also referred to as the Quadruple Helix. Open data, marketplaces (incl. online) and brokers are resources that can be further developed and deployed to link new technology and users.

In addition, space to experiment is needed – testbeds and living labs where innovations can be put to the test. Often legislation hampers the testing and application of innovations, however. Examples are an electricity network supplying direct current and the production of one's own drinking water. Zones with reduced regulation are needed to allow for experimentation with new technologies.

DELFT SMART CITY
ready for the future

KNOWLEDGE ECONOMY
2030:
enough jobs at all levels, thanx to a strong knowledge economy

flow

knowledge-intensive companies (services and industry)

knowledge and educational institutions

retail, hospitality, culture and leisure

infrastructure

company premises on business parks beside motorway
company premises in cities/close to public transport hubs
collective office buildings (for start-ups)
production processes (manufacturing)
development of new services and products (services and consultancy)
meeting and video-conferencing facilities
flexible work and meeting places (seats to meet)
shared service workspaces: 3D printing, appliances and devices
faculties and buildings
laboratories, equipment and workshops
test facilities
testbeds, living labs
educational facilities (library, Science Centre, Botanical Gardens)
conference facilities
shops
cafés, restaurants, hotels
theatres, cinemas, VAK arts centre, museums, music venues and events

(smart) resources

services to companies A
smart industry C
open data B/C
marketplaces and brokers: link user demand with innovations B/C
wi-fi and mobile data network D
visible and open for shared use (for knowledge development) D
reduced regulation zones A
organise collaboration and responsibilities B/C
smart retail (integrate offline and online shopping) C
marketing and information provision D

people

knowledge-intensive companies:
large companies (multinationals)
SMEs
start-ups
authorities:
central government
provincial authority
city council
end users of products and services:
consumers
clients
telecom companies and wi-fi providers
research and educational institutions
visitors
companies in retail, hospitality and leisure industries
cultural institutions

4.3.7 **SUMMARY**
AND CONCLUSIONS

The knowledge economy as driver

Ensuring there are sufficient jobs at all levels is a key priority in the policy of Delft city council. Since 2008, both the Dutch economy and the global economy have been in difficulty, resulting in a decline in the number of jobs. Though the number of companies is increasing, the number of people they employ is falling. In Delft, however, the number of people in the knowledge-intensive sector has remained stable or increased slightly. The question is whether the knowledge economy can act as a driver of employment. This study defined four employment effects of a strong knowledge economy, two of which concern growth in knowledge-intensive sectors, and the other two growth in other sectors.

Spatial organisation
The employment effects were studied by visualising the spatial impact of the relevant systems in the city and investigating the links between them. A spatial divide can be seen in Delft, with knowledge-intensive companies and institutions to the east, and residential areas to the west. This is the result of years of planning policy focused on separating functions. The shift from an industrial economy to a service economy requires a mixing of functions, however. At the moment Delft's knowledge economy hotspots are not physically well connected with the rest of the city.

Regional or local effects
Highly educated knowledge workers do not always live and work in the same place. For them, the region, even the entire Randstad conurbation, is a potential place to live and work. A strong knowledge economy in Delft will therefore have a positive impact on the region. People with lower qualifications are less likely to travel to work, and local jobs are important for them.

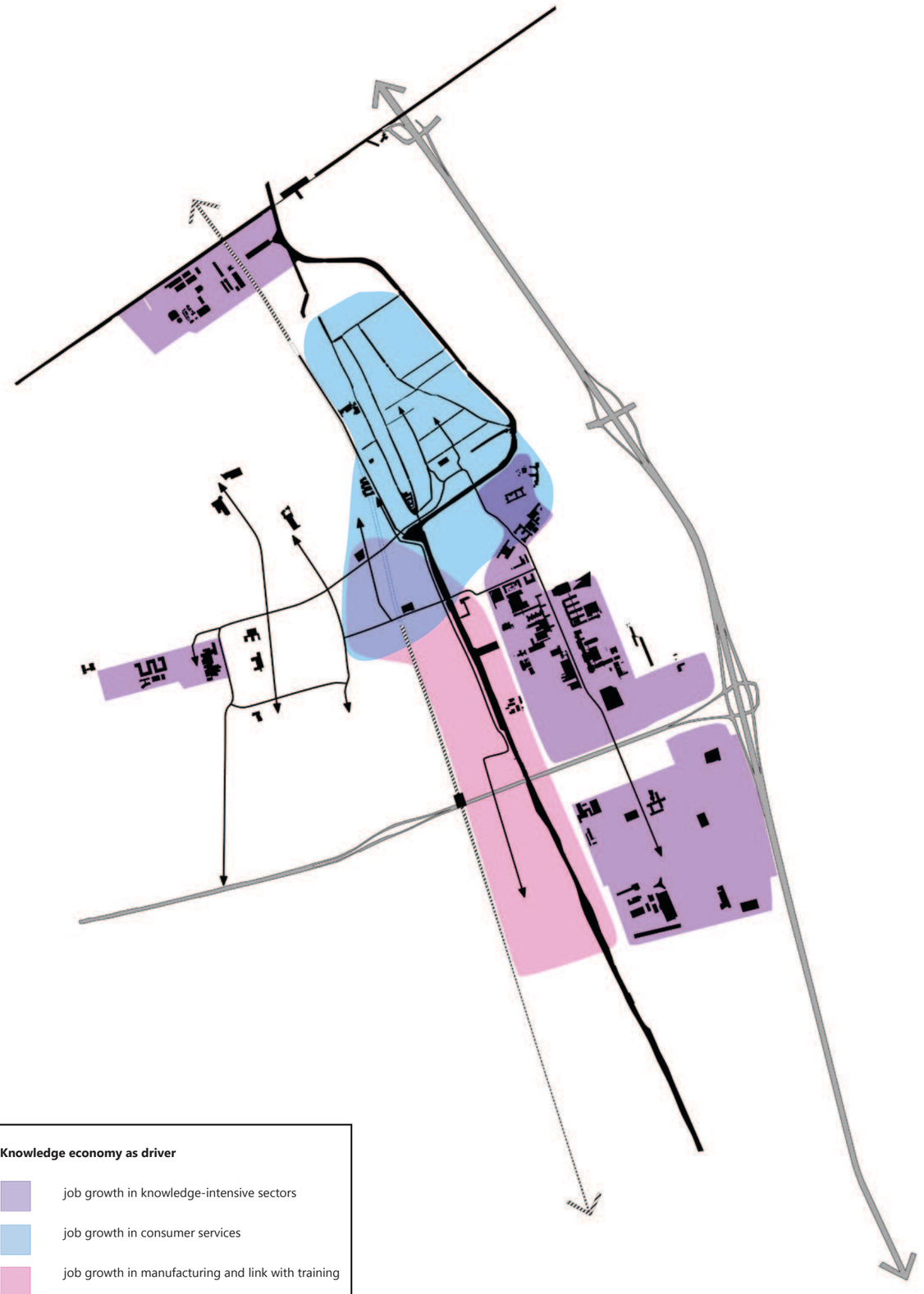
Job growth in knowledge-intensive sectors
An increase in jobs at all levels in the knowledge-intensive sector depends on various factors, such as an attractive climate for business, opportunities for companies to grow and the degree of access to and valorisation of knowledge. The match between education and the labour market is also important. A good match ensures people are more eligible for employment and makes them more attractive to companies. Promoting Delft in the region through the TIC network will help attract companies and create jobs for people with higher qualifications, in particular. The High Tech Centre focuses on connecting Delft youngsters with local and regional companies, and in this sense can play an important role in creating jobs for people with mid- and low-level qualifications and in strengthening local business (at the Schieoevers business park, for example).

Job growth in other sectors
A strong knowledge economy is expected to create jobs in consumer services, such as the hospitality industry, retailing and cultural amenities. This is known as the trickle-down effect. In spatial terms, however, there is no overlap between the location of consumer services and the knowledge infrastructure, which is situated mainly in the city's three regional knowledge clusters. Consumer services are concentrated mainly in and around the city centre. The extent to which the trickle-down effect will actually occur is therefore uncertain.

Physically linking the knowledge economy with other sectors
The spatial links between the knowledge infrastructure and support sectors can be strengthened in a variety of ways. Useful developments are already occurring in Nieuw Delft, TU Noord and on the Reinier de Graaf site. More opportunities could be offered to businesses in the hospitality and amenities sector at knowledge economy locations like the TU Delft campus.

Nieuw Delft as a hotspot for new jobs
Nieuw Delft could play a key role in providing jobs for the entire city. All four employment effects might potentially occur there, and have a knock-on effect in the city centre, Voorhof and Schieoevers. Nieuw Delft is important to the economic vitality of the city, even at times of economic decline. Economic growth and employment are expected to improve again, though there have been studies that suggest that automation and robotisation could lead to a loss of two to three million jobs in the Netherlands [37]. A multifunctional urban environment (homes, work and amenities) in Nieuw Delft could ensure that an adequate base is retained to support the amenities in the city centre. In this respect, Nieuw Delft should perhaps be given priority as a location for companies, over and above locations in the city that have a less important role to play in the local economy.

Cross-overs with energy and climate adaptation
The energy and climate challenges both provide opportunities for job growth. Opportunities for companies lie in the implementation and sale of products and services associated with making homes more sustainable, making the city climate-proof, and in the transition to electric vehicles. There will also be opportunities for companies and knowledge institutions involved in research, consultancy and product development in these areas. The *Energy Agreement for Sustainable Growth* includes the goal of creating at least 15,000 jobs over the coming years. The Delta Programme, with a budget of at least €15 billion up to 2028, will also provide a considerable investment in the Dutch economy. With its huge reserves of knowledge and human capital, Delft should be able to profit from this investment.



4.4

LOCATIONS

Nieuw Delft
Schieoevers Zuid
Buitenhof

Specifics at certain locations

Now that the three challenges have been examined and visualised at the level of the city as a whole, it is useful to consider what exactly a challenge will entail at neighbourhood or district level. What opportunities will there be for parties to contribute to an energy-neutral or climate-resilient city at a certain location? Or to boost the economy and create jobs? The research by design project looked at the specifics of three long-term challenges at three locations: Nieuw Delft, Schieoevers Zuid and Buitenhof. Several challenges come together at each of these locations, and it might be possible to create cross-overs. Again, the systems were first analysed and then the efforts required were considered on the basis of the goal, to identify where we can implement smart, integrated solutions.

Nieuw Delft

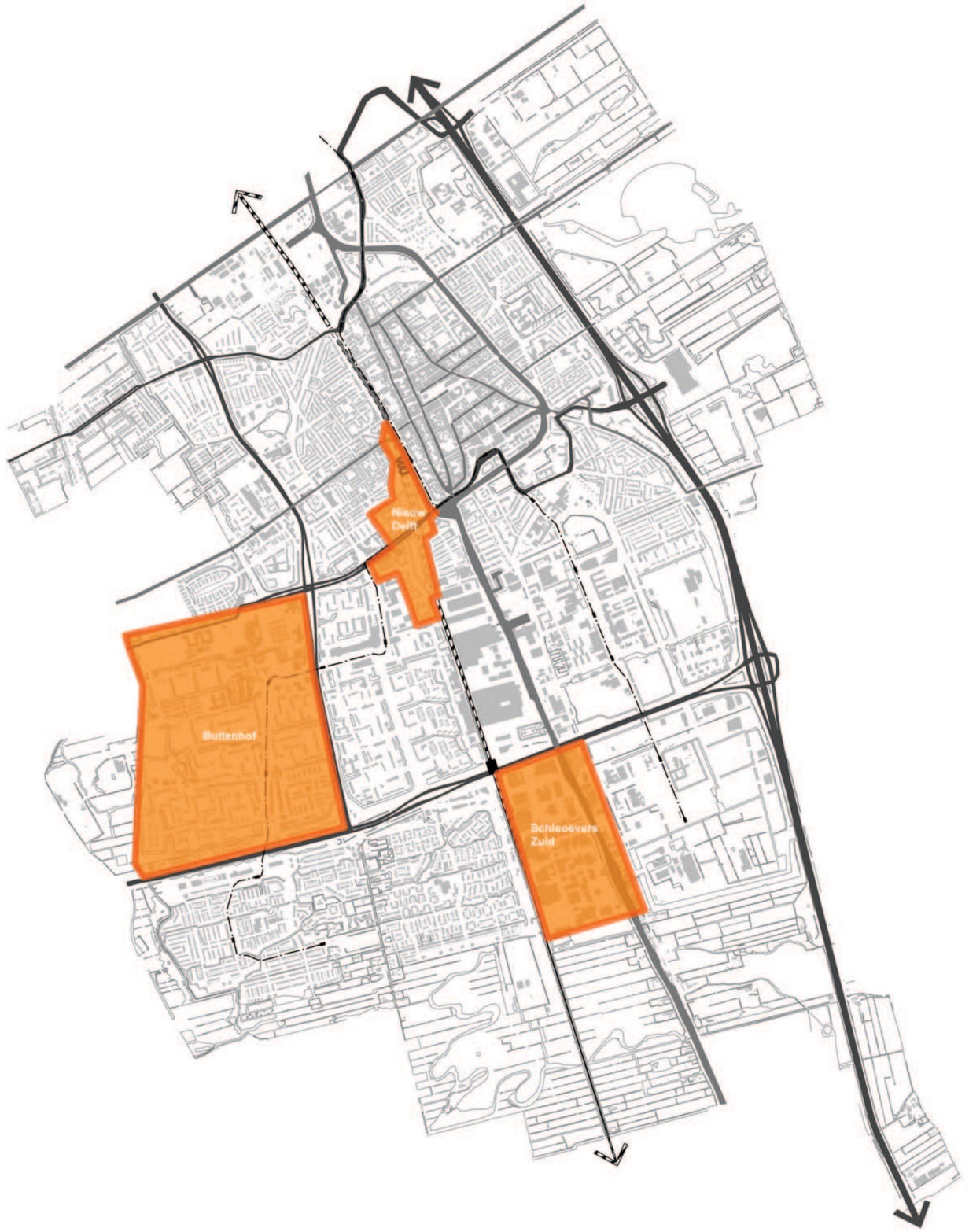
Nieuw Delft was in our sights as an interesting location from the outset. This area earmarked for development lies in the heart of the city, and the plans include proposals for a sustainable neighbourhood and a considerable number of Smart City solutions: sustainable heating, decentralised sanitation and a mobility centre. Interviews with the project managers identified two information needs. Is it possible to indicate the extent to which the proposed efforts will contribute to the goals, particularly in view of the possible scaling down of sustainability ambitions for cost reasons? And secondly: what companies are likely to find the area interesting? What profile should Nieuw Delft adopt? And how will Nieuw Delft as an office and commercial location relate to other locations in the city?

Schieoevers Zuid

The business park Schieoevers Zuid was identified as a location in the research by design phase. A number of issues come together at this site. The large proportion of hard surfaces and lack of green spaces in the area lead to high temperatures in summer. Energy consumption is also high in the area. Consideration of the ‘energy-neutral’ theme identified reducing commercial consumption, or making the supply more sustainable, as the main challenge. Schieoevers Zuid would be an excellent pilot location. The area is also important in terms of jobs, including for people with mid- and low-level qualifications. Declining investment and growing numbers of vacant buildings threaten to force the area into a downward spiral, causing a loss of jobs.

Buitenhof

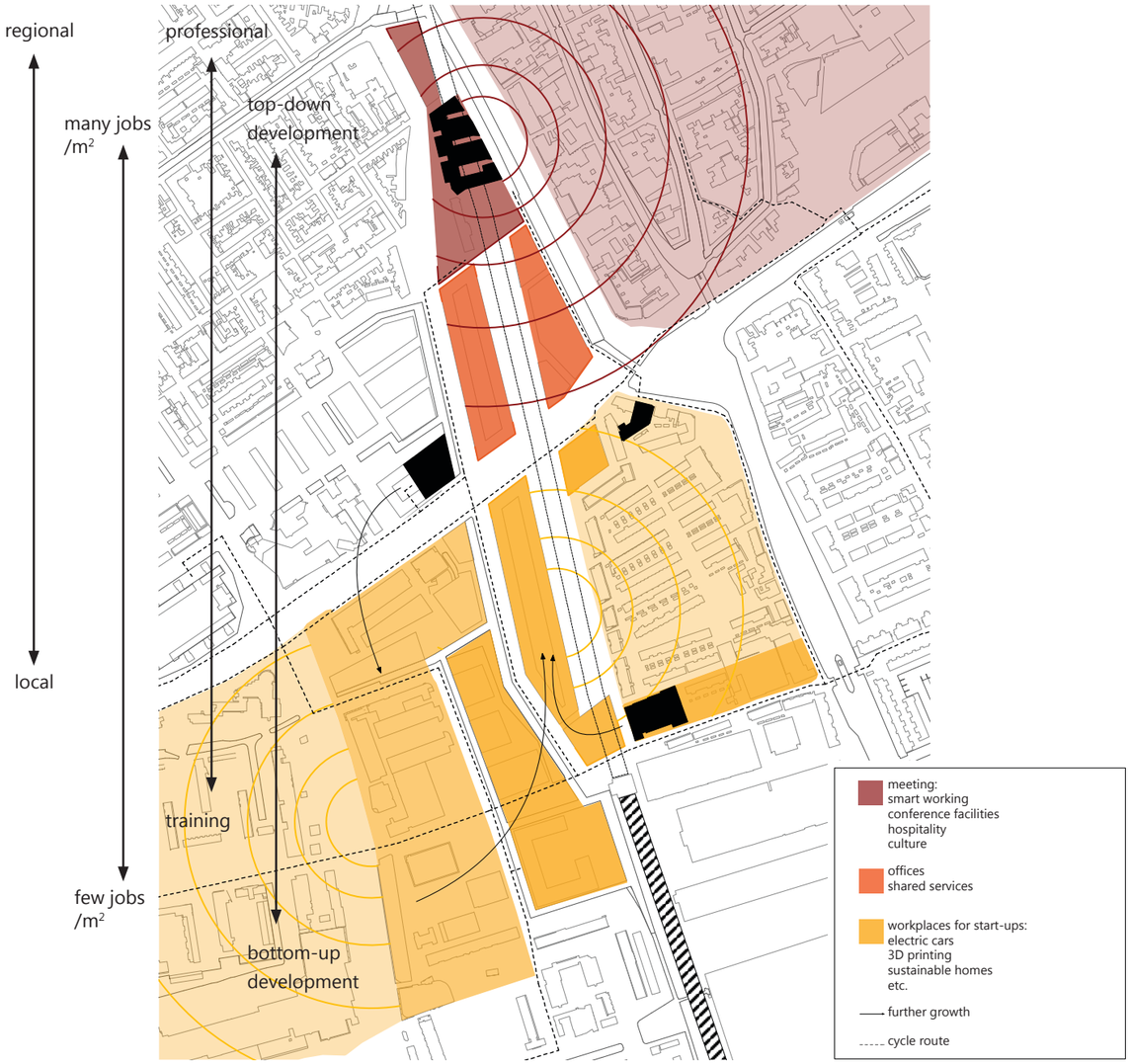
Buitenhof is an interesting location because of the demand for use of the current green infrastructure for sport and leisure, and the question of whether Delft’s knowledge economy can help reduce the high unemployment in the area.



4.4.1 NIEUW DELFT

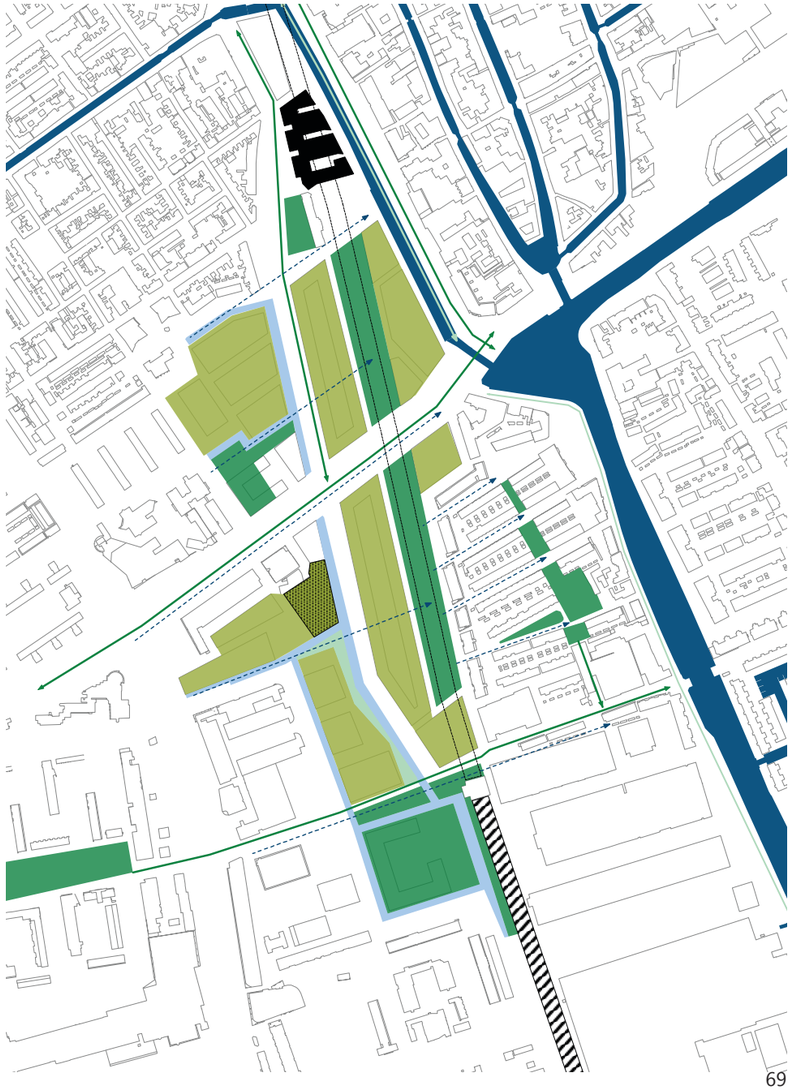
Knowledge economy as driver

Nieuw Delft provides an opportunity for the development of a mixed residential and working environment, with effects on jobs that could benefit both the city centre, and the Voorhof, Buitenhof and Schieoevers districts. Various types of companies and amenities could play a role. The area around the station is probably most suited to companies providing places where people can come together, such as cafés, restaurants and hotels, conference and meeting facilities, culture and smart working. The northern part of the Van Leeuwenhoekkwartier neighbourhood is more suitable for knowledge-intensive companies that require close proximity to public transport and a lively city centre. These are often companies employing lots of young people, in ICT, the creative industries and the sustainability sector, for example. Developing these parts of the area in this way would connect it to the old city centre, the outskirts of which and the creative canals area offer similar functions. In the southern part of the Van Leeuwenhoekkwartier, space could be created for companies that need their own (or a shared) workplace, such as start-ups and combined work/study facilities. Here, students on (pre-)vocational courses, the High Tech Centre and the Betafactory could work as trainees or even start their own company. Possibilities include companies involved in high-tech instrumentation, manufacturing, the sustainability industry, and monitoring and control devices for sustainable systems. The area between Nieuw Delft and Papsouwselaan would also be an interesting location for such companies. There is space for 2000-3000 new jobs in these areas.



Climate-proof

There is potential for combating heat stress in Nieuw Delft. The heat map shows that high surface temperatures occur in the area. The park in Nieuw Delft can provide cooling for residents in the area and in neighbouring areas, if robust vegetation including large trees is chosen, which will provide shade and cool the air through transpiration. Various types of vegetation can guarantee a healthy subsoil that retains water. Plants release the water to the air when it is hot, creating a good microclimate. Both public and private green spaces can help reduce heat stress. To use private green spaces for this purpose, those purchasing plots of land in the area could be subjected to certain conditions relating to restrictions on hard surfaces in gardens, water-resilient building and separation of rainwater. This type of measure can reduce hard surfaces in urban areas and thus prevent excess heating in inner courtyards. Extra vegetation, either waterborne or in cavities, can improve water quality and increase biodiversity, particularly along hard embankments. The various east-west links in the area could function as wind corridors.



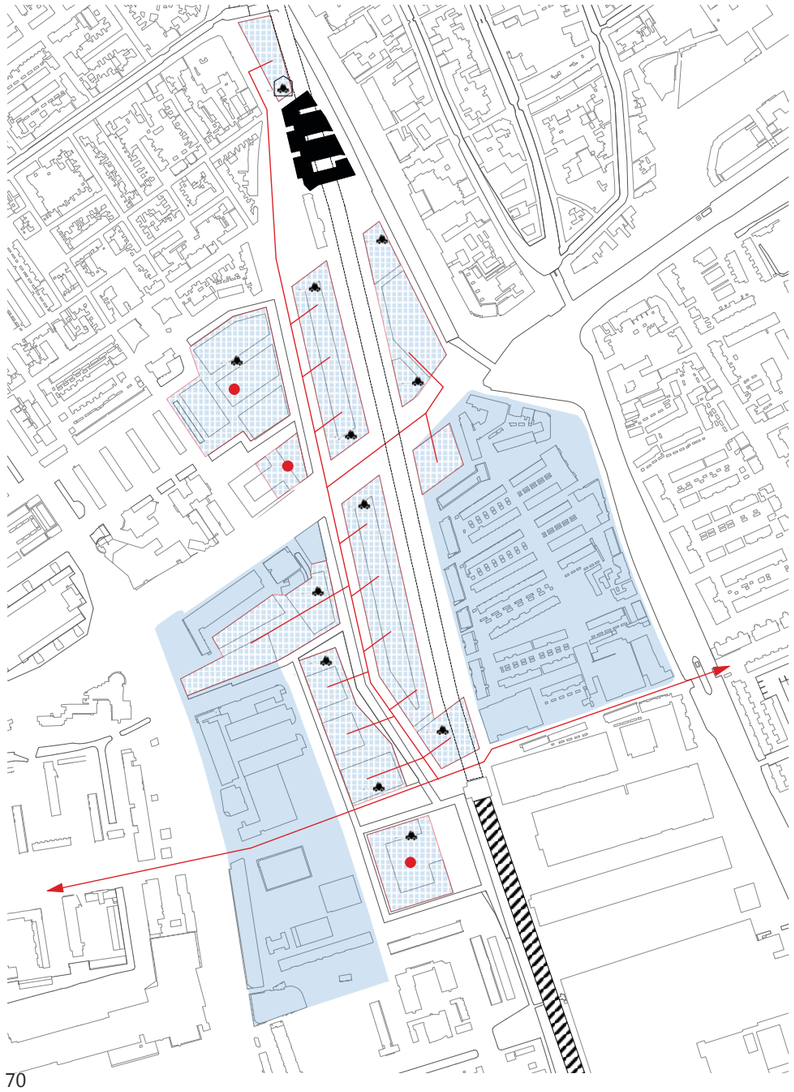
4.4.1 NIEUW DELFT

Energy-neutral

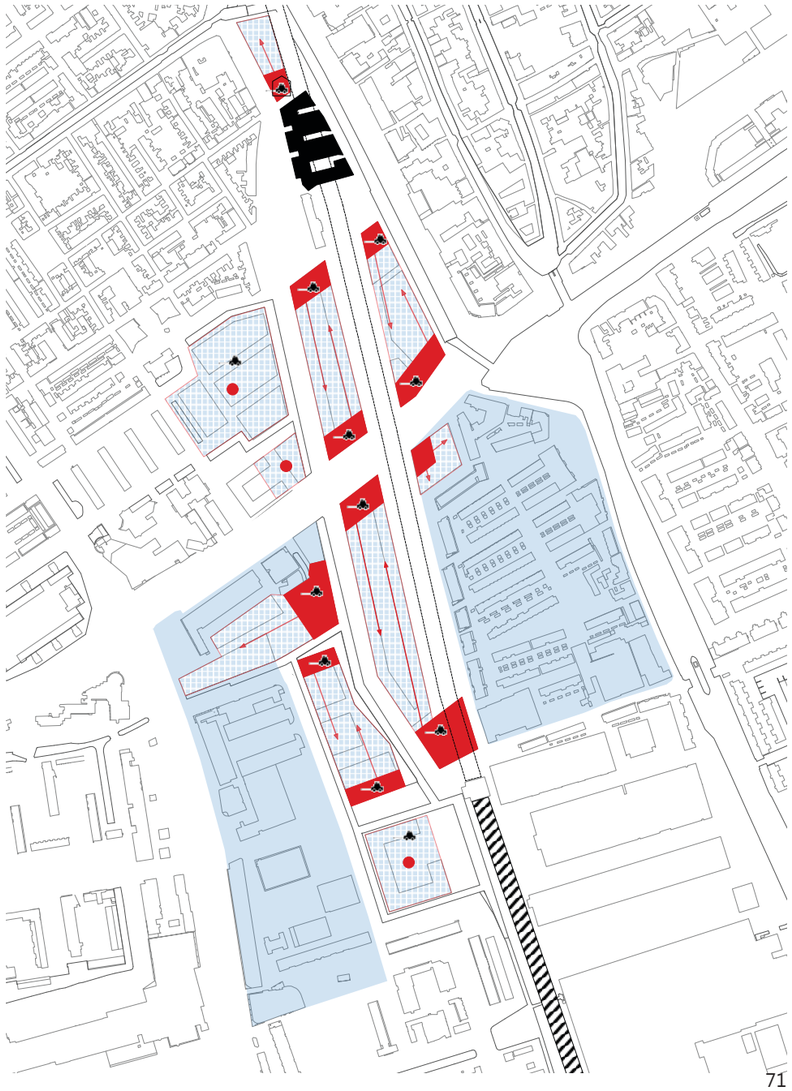
Two scenarios have been devised for Nieuw Delft. In the first, the area will be connected to a thermal grid if the plan to use residual heat from the geothermal well in the TU Delft neighbourhood goes ahead, or if residual heat is supplied by the Warmterotonde. The second focuses on use of residual heat in the area and exchange of heat between functions there. The heating needs of homes can be met by including functions that generate residual heat, such as supermarkets or greenhouses. And of course, the more energy-efficient the homes and utilities that are built there, the less heating will be needed. Solar panels could be fitted on all the buildings in the area to give it an energy-neutral power supply, too. Car ownership in Nieuw Delft is likely to be lower than in other parts of the city because of the immediate proximity of public transport links. Park&Charge facilities could be installed in various places to help facilitate electric vehicles, by coordinating supply and demand.

Cross-overs

Combining housing, education and the development of new products and services in a single area should allow progress to be made in all these fields. 'Energy-neutral' and 'climate-proof' are themes on which combined measures can be taken, by combining green roofs with solar panels, for example. This would lead to a higher yield from the panels, while helping to retain water and cool the area. Cross-overs between these two themes and jobs may potentially occur thanks to specific measures in the area itself and as a result of the clustering of companies around sustainable issues combined with, for example, the mobility centre, the High Tech Centre and the Betafactory. The green profile of Nieuw Delft and the proximity of the Westland and Oostland horticultural regions could help attract companies working on innovations for greenhouses. A test greenhouse in Nieuw Delft would allow companies to trial new systems and allow local residents to grow food. The greenhouse could supply residual heat to homes in the area. An organic fruit and vegetable garden (the Delftse Proeftuin) in the city is already raising the profile of urban agriculture. Furthermore, more jobs in Nieuw Delft will probably improve the modal split, and create fewer new journeys than if the jobs were sited on the city periphery.



- connection to thermal grid
- solar panels on roof as condition of purchase
- encourage solar panels on roof
- heat/cold storage + heat pump
- mobility centre
- electric charging and supply

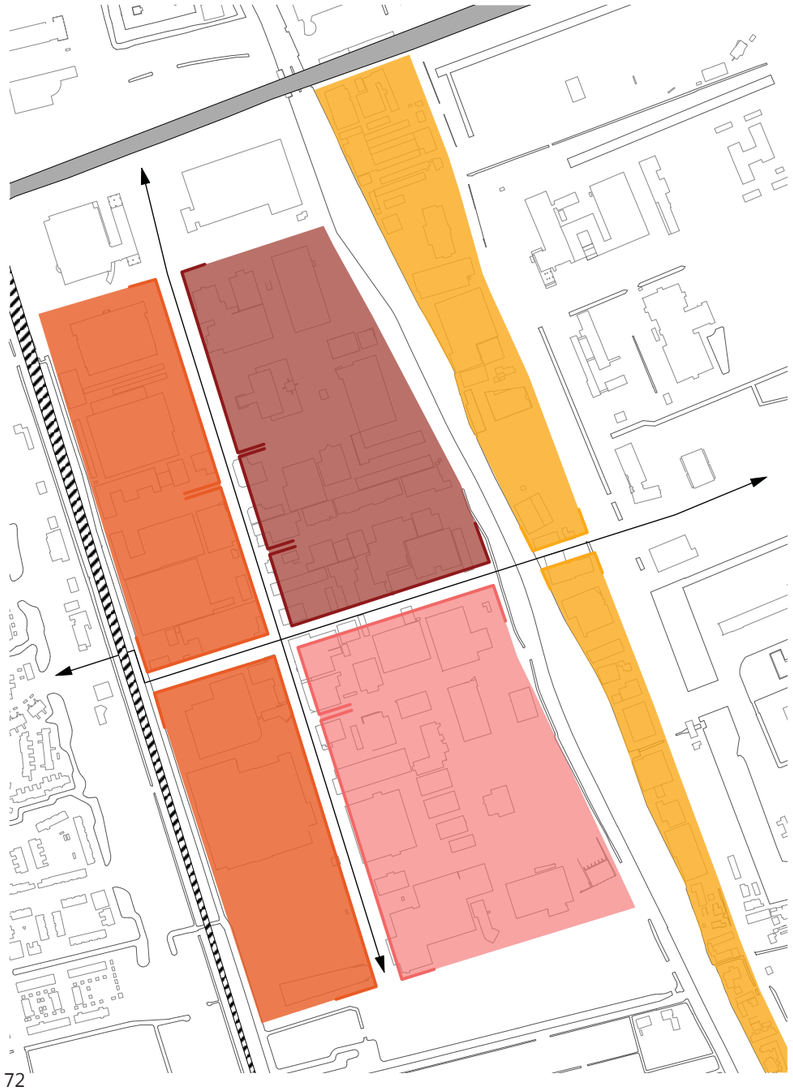


- residual heat supply (supermarket, greenhouse, datacentre)
- solar panels on roof as condition of purchase
- encourage solar panels on roof
- heat/cold storage + heat pump
- mobility centre
- electric charging and supply

4.4.2 SCHIEOEVERS ZUID

Knowledge economy as driver

Schieoevers Zuid is an extensive business park with room for companies up to environmental category 4. More and more buildings are falling vacant in the area and investment is declining. The various types of company in the area fall roughly into four categories: food, transport, construction, and the creative industries and technical manufacturing. Apart from food, all these companies could tie in well with developments in the city to make the area economically more viable. The companies related to construction could focus on jobs created by efforts to address the energy and climate challenges. A training and promotion programme in collaboration with De Bouwcampus would be a good start. The switch to electric vehicles might present new opportunities for the companies related to transport. Manufacturing companies could benefit from the developments associated with the High Tech Centre. Finally, the warehouses and empty commercial premises could provide room for creative minds and start-ups with grand plans but few resources. The area is highly suited to test and pilot facilities, but is barely used for such purposes. The regeneration of Faradayweg (as described in a document setting out a future vision for the area in 2030, Gebiedsvisie Schieoevers 2030) would create opportunities for exchange of knowledge and goods with Technopolis. This new east-west connection could support initial developments in the area and act as a 'cross-section', where the different categories of companies in the area could be showcased. The well-organised Schieoevers business association would be a possible first port of call in efforts to work out ideas for the area in more detail.



- transport-related companies
- building maintenance and repair companies
- food-related companies
- creative and manufacturing industries

Climate-proof

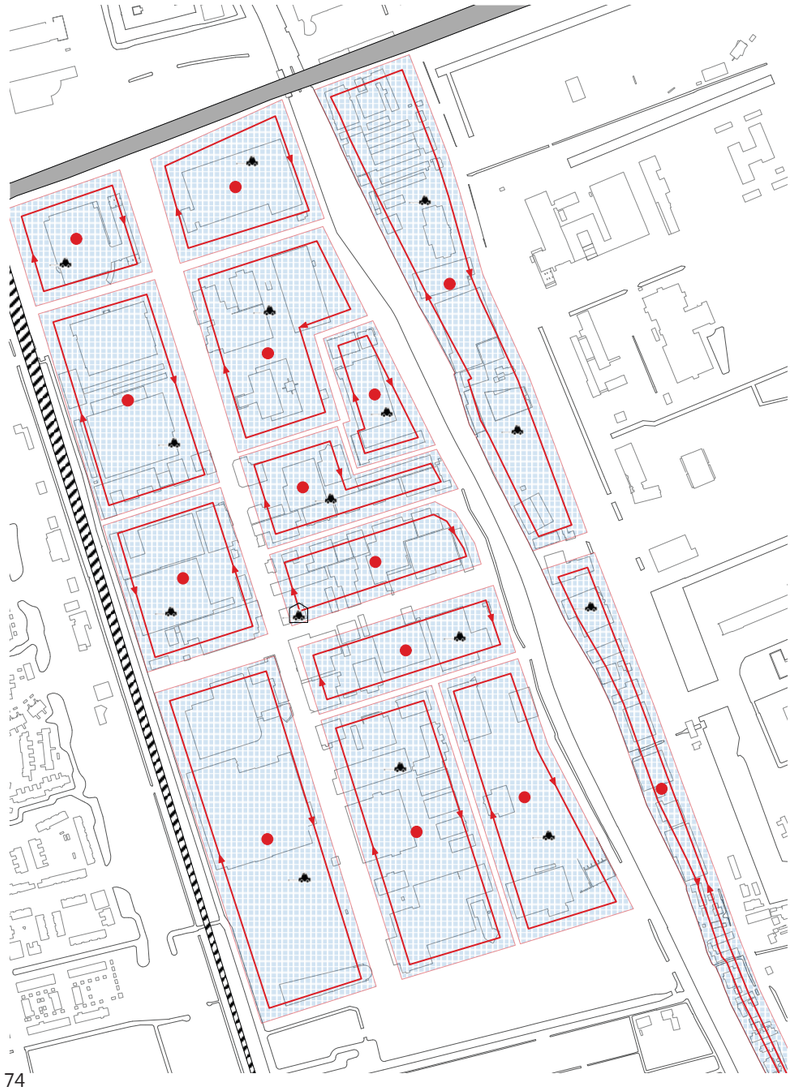
Much of the area has a hard surface. The temperature can therefore rise to high levels there, and rainwater is not yet retained in the area. Creating partially paved car parks could help improve water absorption in the soil. Green pocket parks could also be created in some places to provide cooling locally, ensure water drains more slowly, and act as a meeting place for workers and as a mini-biotope for animals and plants. If such pocket parks were created along the redeveloped Schieweg a robust green infrastructure could slowly but surely take shape in the area. The same applies to the banks of the river Schie. Planting more trees would create a shady route that could provide some cooling on hot days. Green roofs on buildings would help slow the drainage of rainwater, bring the air temperature down, increase biodiversity and provide insulation. The load-bearing structure of existing buildings often makes green roofs impossible, but new buildings could be designed with green roofs (perhaps combined with solar panels).

- green banks for biodiversity and slow traffic
- green 'pockets' for water absorption and cooling
- semi-paved car parks and paving with increased reflection coefficient
- green corridor

4.4.2 SCHIEOEVERS ZUID

Energy-neutral

An individual system and a collective system were explored for Schieoevers Zuid. In the individual system, companies would use as much heat and cold as possible from the shell of the building and from outdoor spaces. The high proportion of hard surfaces in this area means that a lot of heat is retained in the facades of buildings and in road surfaces. This scenario would also require heat and cold storage and a heat pump for each cluster of companies. The collective system would be based on a thermal grid fed by geothermal energy or residual heat from the *Warmterotonde*. Another possibility would be to use heat from the river Schie, which would provide heat and cold storage for the entire area. Serious consideration would have to be given to energy conservation measures, particularly insulation, in both the individual and the collective system. As many solar panels as possible would have to be installed on all roofs so companies could generate their own power. Park&Charge facilities could be installed at all parking spaces. A mobility centre for vehicle sharing would help reduce car use.



- heat/cold storage from surface + heat pump
- encourage solar panels on roof
- mobility centre
- electric charging and supply

Cross-overs

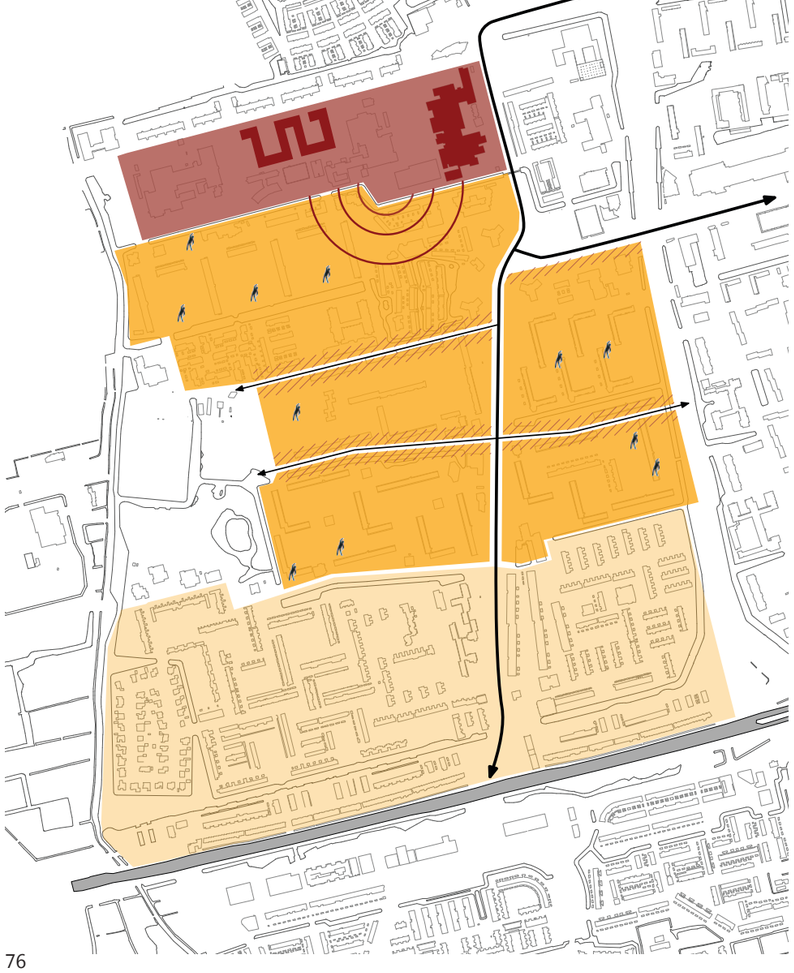
A cross-over between jobs and greater sustainability could be achieved in Schieoevers in the same way as in Nieuw Delft. Jobs would be created thanks to efforts to create more sustainable commercial premises and outdoor spaces. Ideally, companies would address this challenge themselves and integrate the knowledge gained into their operations. The following model would be one way of achieving this: construction-related companies receive training in ways of making buildings more sustainable and, in return, put what they have learned into practice at their own company premises. Car companies could be encouraged to switch to sustainable mobility in a similar way.

- connection to thermal grid
- encourage solar panels on roof
- geothermal well
- heat/cold storage
- mobility centre
- electric charging and supply

4.4.3 BUITENHOF

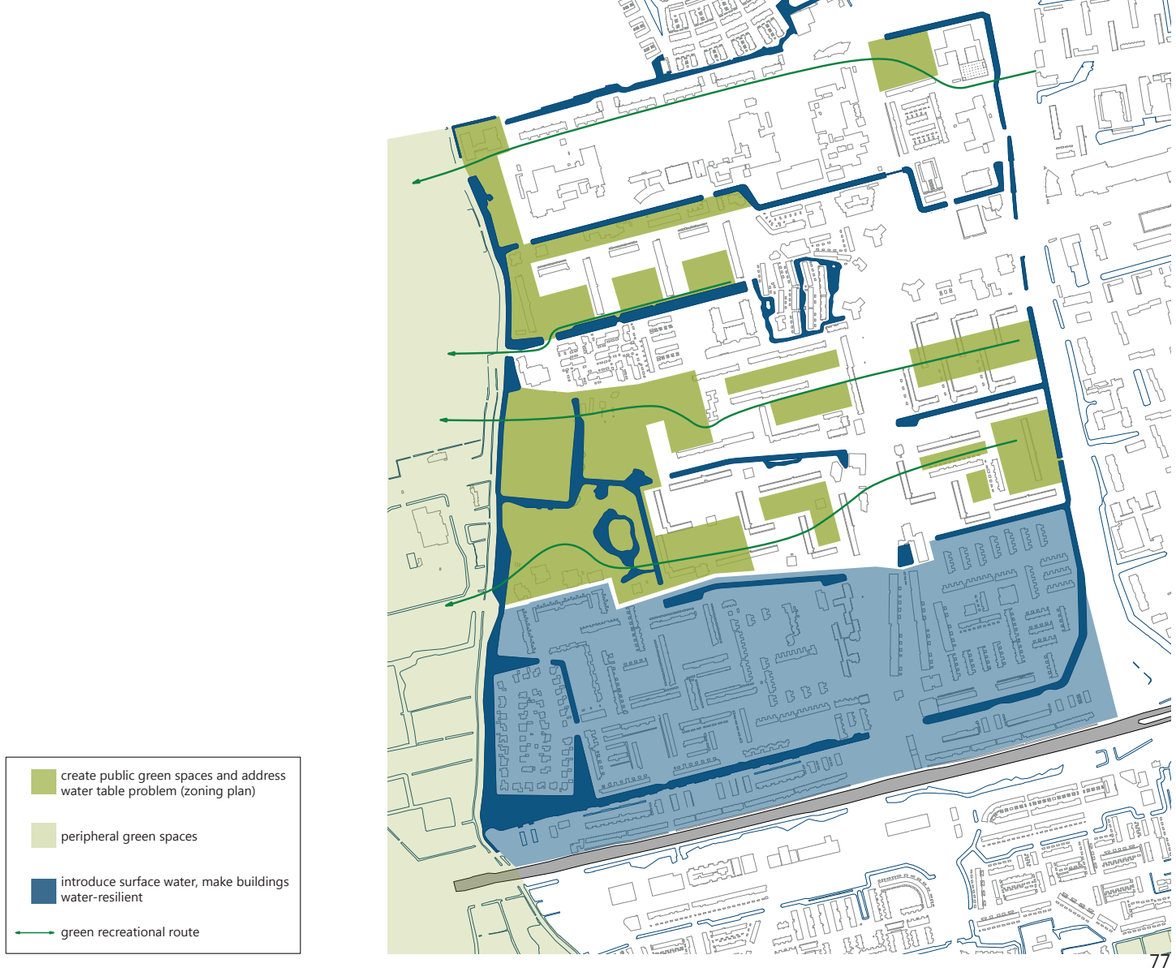
Knowledge economy as driver

Buitenhof provides several opportunities for job creation through links with the knowledge economy. The site that will become available next to the new Reinier de Graaf hospital building could help with the formation of a 'healthcare campus', which could provide new jobs at medical technology start-ups and at existing companies that move there. Local employment in an area where many people have only low-level qualifications could also receive a boost from this. Firstly, a physical relationship between the new healthcare campus and the existing shopping centre might create new opportunities for cafés and restaurants and other support services (such as childcare centres, hairdressers). Secondly, housing and care could be combined, so that care could be provided and coordinated locally. Siting functions related to healthcare in the neighbourhood might encourage more contact between residents and create new jobs due to elderly people's need for transport, places to meet and other services; a local 'care economy', in other words. Thirdly, the link between companies in manufacturing, building services and construction is an interesting one because such companies employ people with mid- and low-level qualifications. These companies are now concentrated mainly in the Schieoevers area. Nieuw Delft and the area around Papsouwselaan could provide a bridge between these companies and jobseekers in Buitenhof. This will apply particularly to young people and to schoolchildren, because they will come into contact with such companies through pre-vocational and vocational education programmes, like those on offer at High Tech Centre.



Climate-proof

Redesignating green spaces in the neighbourhood to make them eligible for other functions (sport and play, food production) could help promote health and prevent illness. This would tie in well with the demand for healthcare in the neighbourhood. Linking these green spaces with others outside the area would create a robust green infrastructure that would encourage people to use green spaces in and around the city. The neighbourhood has problems with a high water table, and green spaces could help address these problems, too. Sufficient consideration must be given to this double function when green spaces are designed, so that they remain usable during wet periods. This can be ensured by creating height differences and working with different types of subsurface and vegetation. The priority in the southern part of Buitenhof is to make existing buildings water-resilient and introduce extra surface water.



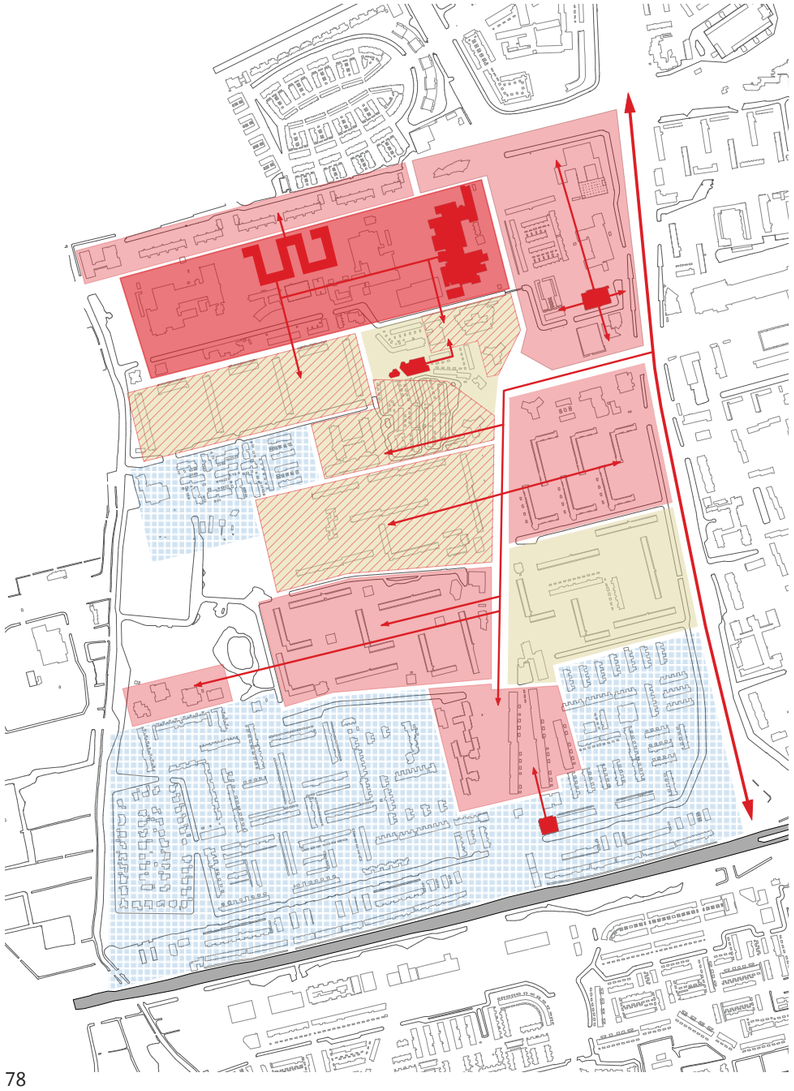
4.4.3 BUITENHOF

Energy-neutral

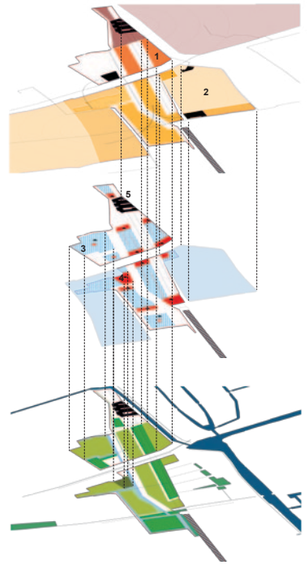
There are various options for reducing energy consumption in the different neighbourhoods in the Buitenhof district. A number of neighbourhoods could be connected to a thermal grid fed by the Warmterotonde without the need for too much structural work. The Reinier de Graaf hospital and the surrounding healthcare campus could benefit from geothermal energy. The residual heat from this site could then be used in the surrounding neighbourhoods. The supermarkets and the crematorium in the area are also potential suppliers of residual heat. A focus on energy conservation (particularly through insulation) would yield particular benefits in some neighbourhoods. Homeowners could be encouraged to install solar panels in neighbourhoods with a high rate of owner-occupancy.

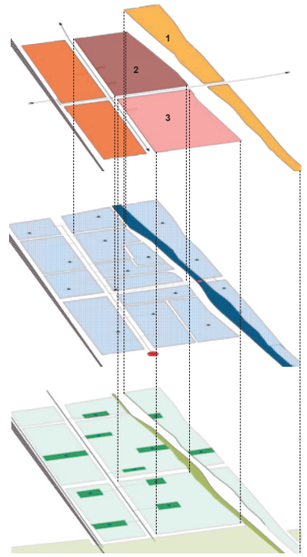
Cross-overs

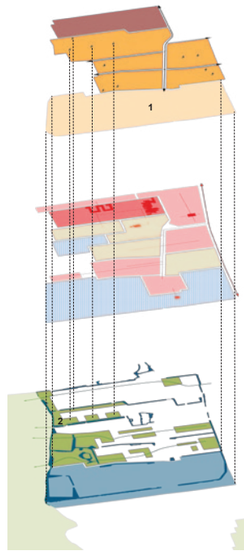
In the Buitenhof area, too, making the housing stock more sustainable could create jobs for local construction companies. This cross-over is particularly evident in the southern part of the district. Another cross-over concerns green spaces. Companies focusing on health and sport could be sited on the edge of green spaces and thus contribute to the function of the space.



4.4.4 OVERZICHT
CROSS-OVERS







Nieuw Delft

1. Jobs, housing, education and development of new sustainability products and services will help to make the district energy-neutral and climate-resilient – and vice versa (applies to all plots) > general
2. Sustainability developments in Nieuw Delft could create trickle-down effects in construction and renovation in surrounding districts > general
3. The combination of green roofs and solar panels will increase the yield of the panels and help retain water and cool the environment (applies to all plots) > specific
4. An urban greenhouse could supply residual heat to homes > specific
5. More jobs near the station in Nieuw Delft could reduce car journeys in the city > specific

Schieoevers Zuid

1. Creative and technical sustainability innovations can help to make the business park energy-neutral and climate-resilient – and vice versa (applies to all plots) > general
2. Car companies in the area could help with the switch to sustainable mobility > specific
3. Construction and building services companies in the area could help reduce heat stress and retain rainwater in the area > specific

Buitenhof

1. Making the existing housing stock energy-neutral and climate-resilient would create work for local construction companies > general
2. Green spaces would help address the water challenge and create jobs in the district by providing space for companies focusing on health and sport > specific

Tools for a smart city

In 2013 and 2014 TNO ran a Smart City Flagship project to develop tools to deal with the complexity of the city and make it easier to develop and apply integrated policy. The tools would be designed to show how resources could be used most effectively to achieve the city's long-term goals. Both Delft Smart City workshops successfully used the Smart City Gameboard. The Urban Strategy and Smart City Dashboard were also presented.

Smart City Gameboard

The Smart City Gameboard provides an overview of connected variables for a sustainable and economically vital city that offers good quality of life. They are classified into six components based on the theories of Boyd Cohen: Environment, Governance, Living, Economy, Mobility and People. The Mobility component, for example, includes the variables accessibility, parking facilities and car ownership. The relationships between the variables are identified as negative or positive, and the speed of the effect and strength of the relationship are also indicated. The Smart City Gameboard can be used as a tool for a strategic discussion of the integrated impact of a policy measure or project.

Workshops

The Gameboard was used at both Delft Smart City workshops. The projects/policy lines TIC Delft, Zorg&Techniek, Nieuw Delft, Delft Energy-neutral 2050 Implementation Programme, Waste Policy, Green Spaces and Water Policy were subjected to the following steps:

1. Discuss the long-term goals of the project and translate them into variables.
2. Discuss the achievements or efforts of the project/ policy and translate them into variables.
3. See whether there is a relationship between the effort variables and the goal variables, and how it works (directly or via other variables).

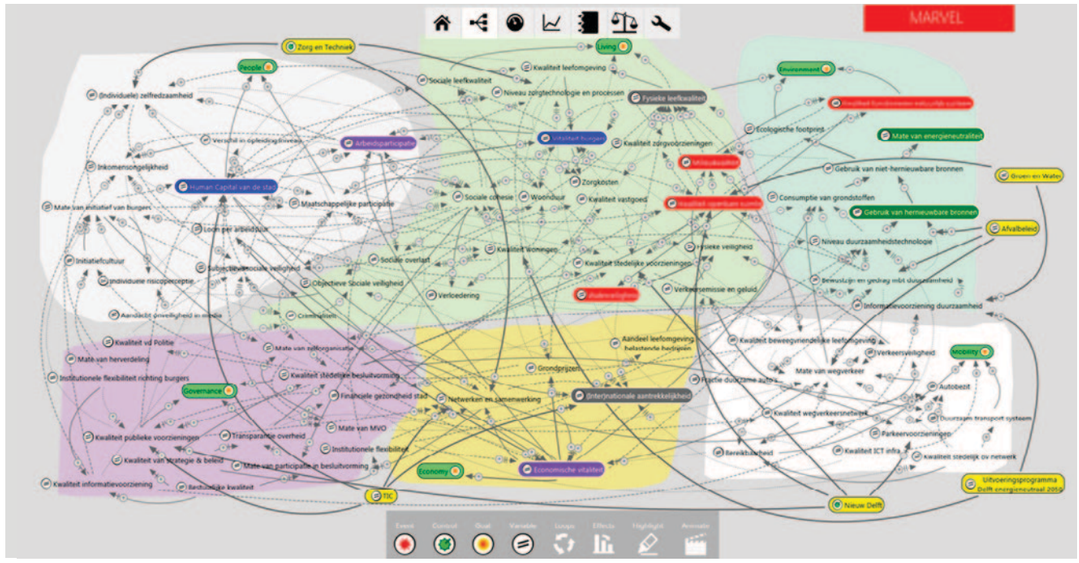
Example 1
The Delft Energy-neutral 2050 Implementation Programme has 'degree of energy-neutrality' as its goal variable. One of its effort variables is 'provide information on sustainability'. The relationship between these two variables is not direct, but proceeds via two other variables:

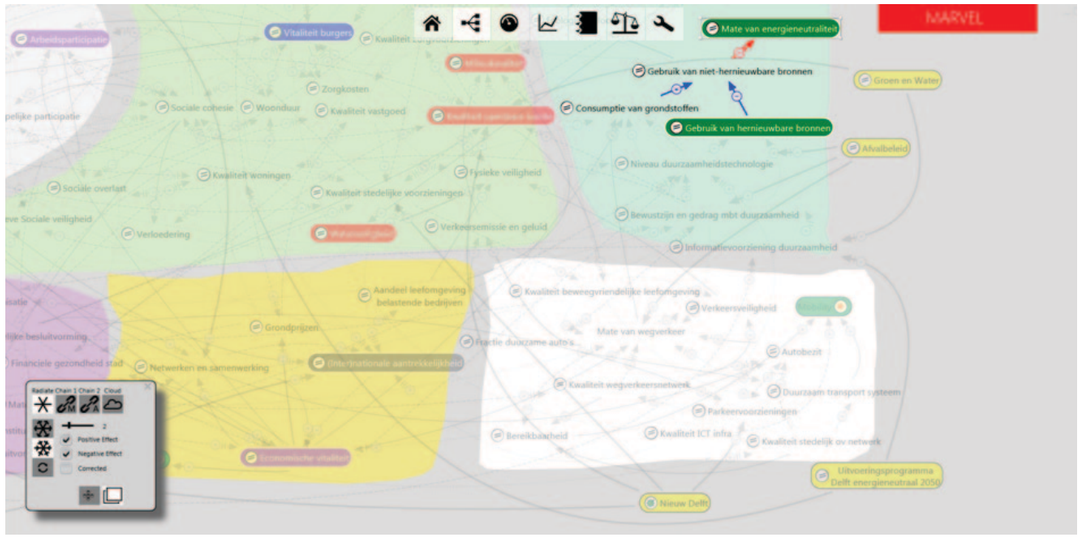
Information provision on sustainability > awareness and behaviour concerning sustainability > use of renewable sources > degree of energy-neutrality.

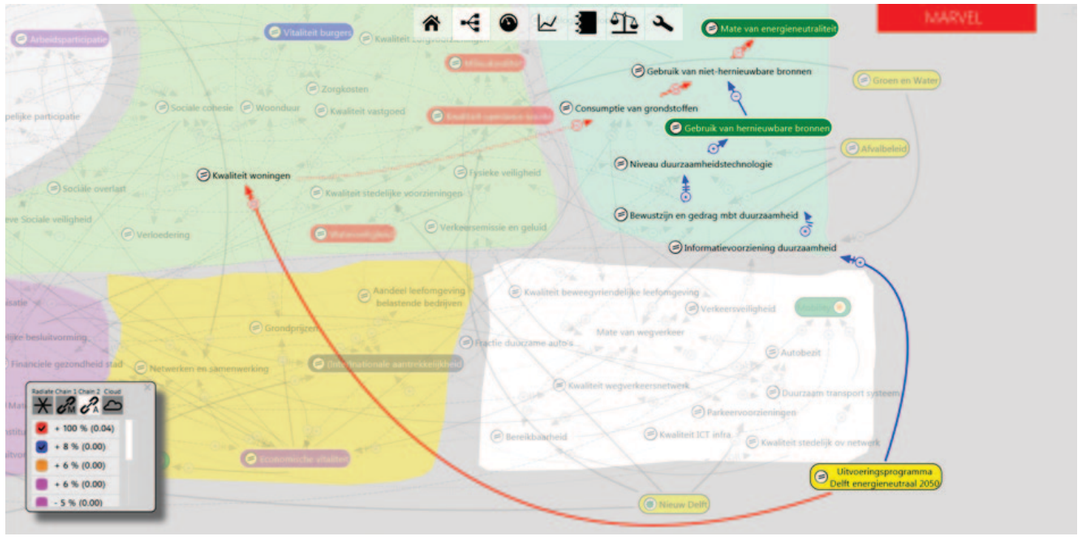
This is a predictable route. It is more interesting to note that, besides staff working on the Delft Energy-neutral 2050 Implementation Programme, those concerned with Waste Policy, Green Spaces Policy and Water Policy also mentioned 'provide information on sustainability' as an effort variable. There might therefore be potential for a joint approach.

Example 2
A second finding of the Gameboard session was that when considering the effort variables of Zorg&Techniek and TIC Delft, it was found that both projects made efforts concerning the components People, Economy, Governance and Living, but that neither touched Environment or Mobility. Since these components present particularly big challenges (energy-neutral, climate-proof), it might be useful to expand the network approach of Zorg&Techniek and TIC Delft to or focus it more on the components Environment and Mobility.

Gameboard as discussion tool
Workshop participants were positive about the Gameboard. The fact that it was possible to work with it in real time showed the quality of the software and the operators of the model. The Gameboard allows users to think at a high level of abstraction about goals, policy and efforts. Because it reveals relationships between different components, it also highlights potential cross-overs. The drawback of the Gameboard is that the relationships identified are not given a value, so the extent to which the variable contributes to the goal remains unclear. Nor does it provide a complete picture of all variables needed to achieve a goal. This means there is a risk that the Gameboardconfirms choices already made without providing a good impression of the context in which the relationship arises. It is therefore mainly a discussion tool, rather than a decision tool.







[Smart City Gameboard screenshots]

Smart City Dashboard

TNO designed a Smart City Dashboard for the Delft Smart City project. The dashboard can be used to present information for use at various policy levels.

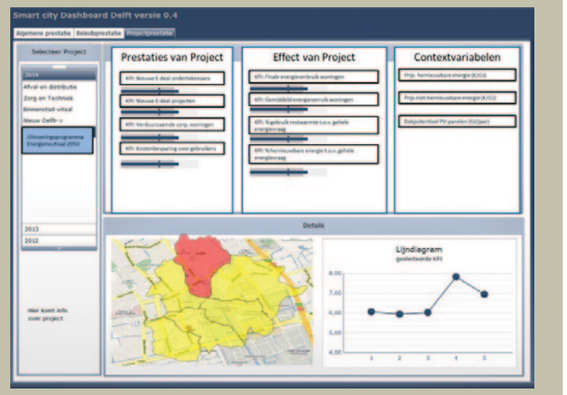
General performance
The general performance dashboard consists of a summary based on a generic set of indicators. It can also be used for comparison with other similar local authorities on the basis of a benchmark for these indicator
s. This information can be used to identify problems during policy preparation.

Policy performance
Every local authority has its own priorities which it translates into specific policy goals. The policy performance dashboard provides an insight into these indicators and allows devel-opments in them to be monitored. This information can be used in policy evaluation to propose adjustments to policy.

Project performance
The project performance dashboard provides an insight into the performance of a project in terms of its objectives and strategic goals. This information can be used to monitor and adapt the project in the policy implementation phase.

TNO believes there is potential for further developing this toolkit in collaboration with other cities and authorities (local and regional), and intends to seek partners and stakeholders for such a venture in the near future.

[general performance dashboard screenshot]



[project performance dashboard screenshot]

Urban Strategy
Urban Strategy is an interactive tool for spatial planning which incorporates many of TNO's models for the urban environment. For example, Urban Strategy allows the user to model future air quality in the event that a new road is built. Several sessions were held with TNO to assess the possibility of using Urban Strategy for Delft Smart City. It could for example be used to analyse the relationship between measures for and the costs of 'energy label', 'roof area' and 'potential for thermal grid'. At the second workshop TNO showed how this might work. It was not however possible to work with actual data from Delft within the scope of the project.

[Urban Strategy screenshot]

6 CONCLUSIONS

Delft Smart City

What might recent ‘Smart City’ developments mean for Delft? We considered this in light of the growing complexity of the challenges facing the city, changing relationships in society, the role of the local authority and its need to use the resources available to it as efficiently as possible. This question gave rise to the Delft Smart City project, which deliberately chose to view the Smart City concept as a strategic issue. There are plenty of smart technical solutions, but what problems do we actually need to solve? In other words: the key thing is to find the smartest answers on the basis of the challenge you face.

Delft’s vision of a Smart City, as defined for this project, is a future-proof city resting on three pillars: systems, people and resources. These pillars can be linked by means of an integrated approach, bringing parties together, and governance.

What are the benefits?

The project developed a procedure for making the city ‘future-proof’. The basis of the procedure is research by design, combined with other methodologies. During the process, new insights were developed concerning the themes and locations examined.

Research by design
Three of the city’s long-term objectives – energy-neutral, climate-proof and the knowledge economy as driver – were each examined in the same systematic way. In each case, the relevant systems in the city were analysed and visualised. This was used as a basis to separate the challenge into goals and efforts, and indicate the systems, people and resources needed.

‘Energy-neutral’ and ‘climate-proof’ are both themes that manifest themselves spatially, and have often been the subject of research by design. This is not the case when it comes to ‘knowledge economy as driver’. This project showed that research by design can also produce interesting findings on non-spatial themes. Secondly, it showed that the knowledge economy does in fact have a spatial manifestation, particularly in terms of the employment effects likely to be brought about by an increase in consumer services, which require a physical link between consumer and service. The shift from an industrial to a service economy in which networks are increasingly important and the boundary between public and private is becoming increasingly blurred will require adaptations to the physical space. In the current debate on unemployment, research by design can provide a bridge between economists’ research reports and actual measures on the ground, not only in Delft but also in other cities.

Cross-overs
The substantive findings on the three themes and their application at three locations are described in chapter 4. The cross-overs identified at various scales provide prospects for action by various parties in the city, and starting points for policy. The consequences of climate change, such as flooding and heat stress, bring a risk of damage to the economy and to public health. Energy-neutrality is of course the most important way of curbing further climate change due to carbon emissions and limiting its adverse consequences. Both the energy transition and climate adaptation provide job opportunities. Besides creating jobs climate adaptation can also indirectly contribute to the economy by improving the climate for business, as well as helping to reduce energy consumption. A strong economy also gives people and companies the financial scope to take measures themselves that help make the city energy-neutral and climate-proof.

Governance
The flows, infrastructure, people and resources associated with all three themes have been described. The systems that are relevant to ‘energy-neutral’ and ‘climate-proof’ function largely in the same way. Infrastructure is managed and products and services are delivered to end users.
One important difference between the various systems is the transition of ownership from the public sector to the commercial market. In the case of water, this will happen at the last moment, while the market for energy comes fairly early in the system. When it comes to the economy, the public authorities have no ownership, and can only have an indirect influence. Responsibility for the challenges is also devolved from central to local government in different ways. In this context, the local authorities must represent the interests and achieve the objectives on their own territory as effectively as possible. It is becoming increasingly apparent that these interests and objectives extend beyond local authority boundaries. Regional collaboration is therefore gaining in popularity. The regional scale is large enough to ensure knowledge and resources are used more efficiently, and small enough not to lose sight of local issues.

Switchboard
The local authority faces a changing playing field in each challenge. It must consider what direct influence it can have on the basis of its core responsibilities, what support it can derive from national policy and what initiatives exist in the city and region. Add to this the complexity of the challenge itself and it becomes clear how difficult it is to define a particular sequence of steps that can be used to address the challenge. It is better to compare the process with a switchboard. We know the situation at the outset and we know where we want to end up. On the way there will be developments over which the local authority has influence, and some over which it has none. These developments can be seen as switches on a switchboard. It is not yet possible to identify the switch through which the route will eventually pass. By keeping an up-to-date overview of the challenge and the changing playing field, it is possible to substantiate the choices made.

What is the potential?

This study provides an insight into the details and the complexity of the challenges arising from Delft city council’s three strategic policy goals. It also suggests directions the council might take in its search for solutions, where there is potential for an integrated and efficient approach, and what parties, resources and systems will be needed. This information can be used in various ways.

Smart use of people and resources
The city council can use this information to make clear choices concerning the use of resources and capacity for the themes and locations studied, in order to play its role in the region to the best of its ability. After all, the forces at play differ from one challenge to another. The exercise with the governance quadrant can serve as a tool for clearly defining the city council’s role on the various themes.

Measuring and monitoring
The schematic overviews for each theme are ideal for comparing with the measurable administrative programme, making clear the extent to which the efforts in the programme contribute to addressing the overall challenge. A short exercise was performed for this purpose during the project; this could be worked out in further detail in a follow-up study. It also ties in well with the exercise in conjunction with TNO to develop a Smart City Dashboard. To take this a step further, measurable quantitative indicators are needed that can reveal the relationship between goal and effort. The two schematic overviews for each theme could serve as a basis for this.

Apply method to other policy objectives
The method developed can be applied to other objectives of Delft city council. The analysis of the knowledge economy as driver shows that it is suitable not only for themes that have a strong relationship with the spatial element. Other possibilities might include ‘social innovation’ and ‘accessibility’.

Down to work with new insights
The new insights on the three themes and the locations studied can be incorporated into policy and used in the implementation of policy and projects. One example is the potential role of Nieuw Delft in creating jobs and the proposed changes to the types of company in the area. This information can be used as a starting point for discussions or workshops with companies and knowledge institutions for the purpose of jointly devising a growth model for the area in which each party can define its own role.

Integrated approach
The study shows that the efforts needed to achieve the long-term goals extend across several sectors. Take climate adaptation, which involves three sectors: water, green spaces and spatial planning. A focus on one’s own (sectoral) efforts is important, but it may be even more important to understand the greater (integrated) whole of which those efforts form part. The information in this study can help broaden people’s view and enable them to see how their own role relates to the shared challenge. This applies not only to local authority staff, but to all parties who might potentially play a role in making the city ready for the future.

Activate society
An understanding of the scale and complexity of the city’s long-term goals is useful for all the parties who make a city: the authorities, the public, and also knowledge institutions, schools, companies and organisations. This thorough analysis is the city council’s call for parties to develop cross-sectoral integrating initiatives – focused on entire areas where possible – and to deploy technological and other innovations. Since it does not offer a blueprint solution, but information on what exactly the challenge is, it leaves parties free to use their own strengths and expertise to come up with solutions. Together, they can decide how they want to tackle the challenge and achieve interim and final goals. By first sharing the information in this study the city council is fostering a general understanding of the long-term goals. The second step is to get together with stakeholders to translate the goal to a challenge for the area, focused on the operations or objectives of the parties concerned.

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APPENDICES

Appendix 1a > notes on potential energy conservation figure

The conservation potential is a qualitative approach based on data available on energielabelatlas.nl, an initiative of the Meer Met Minder energy conservation partnership. The atlas indicates the energy label for each building, based either on the label if one has been awarded, or on the type of home and year of construction. When the conservation potential was determined, a third of homes in Delft had an energy label. The potential per neighbourhood was determined in a qualitative sense on the basis of the average energy label and the number of homes in the neighbourhood. A large number of homes with a poor average energy label means there is a large energy conservation potential, while a small number of homes and/or a good energy label means there is little energy conservation potential.

	certificate		certificate + estimate	
label	number	percentage	number	percentage
A	363	2%	5145	10%
B	1525	9%	3887	8%
C	3794	22%	12,870	26%
D	6099	35%	8805	18%
E	2897	16%	6360	13%
F	1774	10%	11,293	23%
G	1111	6%	1692	3%
	17,563		50,052	

Appendix 1b> 50% energy saving on heating by insulation to energy label A standard

The potential energy saving achievable by improving homes to energy label A standard can be quantified by determining what benefit would be gained if each of the homes were to achieve energy label A standard. The saving is based on the theoretical energy consumption associated with an energy label, not the actual consumption. The theoretical energy consumption of a home with a certain energy label was assumed on the basis of the average theoretical consumption. All homes with energy label D, therefore, have a theoretical energy consumption of 1.8 GJ/m^2, the average of the mid-point between labels C and D. The average floor area of all buildings in Delft used primarily or solely for residential purposes was taken as the floor area; this figure is 89.3 m^2.

energy label	max. est. consumption [GJ/m^2]	ave. est. consumption [GJ/m^2]	ave. fall in consumption due to label change [GJ/m^2]	no. of homes per energy label [certificate + estimate]	total floor area per energy label	total theoretical consumption based on energy label [GJ]	
						current situation	scenario – all homes label A
A++	< 0.5	-	-	-	-	-	-
A+	< 0.7	0.6	-	-	-	-	-
A	< 1.05	0.875	0.1375	5145	459,449	402,017	3,910,938
B	< 1.3	1.175	0.15	3887	347,109	407,853	-
C	< 1.6	1.45	0.1375	12,870	1,149,291	1,666,472	-
D	< 2.0	1.8	0.175	8805	786,287	1,415,316	-
E	< 2.4	2.2	0.2	6360	567,948	1,249,486	-
F	< 2.9	2.65	0.225	11,293	1,008,465	2,672,432	-
G	< 2.9	-	-	1692	151,096	-	-
					sum	7,813,576	3,910,938

This brings the theoretical saving to ((7,813,576 GJ - 3,910,938 GJ) / 7,813,576 GJ) = 50%.

Appendix 2> saving from use of residual heat

The neighbourhood in which 11,500 homes are located is known. The absolute saving was calculated by dividing the demand for heat between neighbourhoods on the basis of the data in Energie in Beeld. This took account of the specific differences in the demand for heat in, for example, a house and an apartment.

Neighbourhood	No. of homes	ave. gas consumption (m^3) acc. to EIB2013	total current gas consumption (m^3)	proportion of homes eligible for renovation	potential saving on total consumption by neighbourhood (m^3)
Harnaschpolder Delft	1800	-	-	-	-
Westerkwartier	1200	1154	1,384,800	1	1,384,800
Voorhof	4143	190	787,170	1	787,170
Buitenhof	3124	694	2,027,476	1	2,027,476
Poptahof	1446	299	432,354	0.5	216,177
Spoorzone	1746	-	-	-	-
Land van Altena	30	1256	37,680	0	0
Reinier de Graaf	330	702	231,660	0	0
TU North *)	1968	1764	3,471,552	1	3,471,552
TU Wippolder district	1328	808	1,073,024	-	-
TNO Zuidpolder	350	-	-	-	-
Bomenwijk	295	954	281,430	1	281,430
total (Delft)	17,760	-	-	-	
					8,168,605

Appendix 3a> PV potential of homes

The roof area available for solar panels per household is based on a study of the housing stock in Utrecht (Vreugdenhil, 2014). In this study, the roof area per building was analysed on the basis of information in the database on the height of objects in the Netherlands (Object Hoogtebestand Nederland). An average available roof area was derived for each type of home and year of construction, taking account of obstacles (fascia, chimney etc.) and the pitch of the roof. The results of this study were projected on the housing stock in Delft, using an overview of the number of homes by type and year of construction in each neighbourhood. This gave a total available roof area of 1,037,242 m^2. 95% of the homes in Delft were included in the estimate of the total available roof area. Since the type of the other homes was not known, they were not considered. After correction for pitch and angle, the study (Vreugdenhil, 2014) assumes a potential average generating capacity of 123 kWh/m^2 of available roof area. This was the basis for determining that the potential generation of electricity from photovoltaic cells installed on the roofs of all homes in Delft is 124.6 million kWh. NB: If the year of construction is not considered in the calculation the potential turns out barely any higher, at 127.6 million kWh.

Appendix 3b> consumption for hot water and cooking

On average, 20% of 31.4 million m^3 = 6.3 million m^3 of gas is used to heat water in Delft. This is equal to 0.22 GJ, or 61.5 million kWh. Water can also be heated by an electric combined heat pump. This requires (at a COP of 3 for water) 61.5 million kWh / 3 = 20.5 million kWh of electricity. COP stands for coefficient of performance, the ratio between the amount of heat emitted and the amount of energy consumed. Use of photovoltaic energy to heat water can be reduced by 50% if all homes have a solar boiler. This requires a solar collector of 2.8 m^2 to be installed on the roof. In Delft, an average of 5% of 31.4 million m^3 = 1.6 million m^3 of gas is used for cooking. Switching to cooking on electricity would require some 8.5 million kWh.

Appendix 3c> saving on gas from electric heating

The use of an electric heat pump with a COP of 4 could convert 6.3 million kWh of electricity into 90,720 GJ of heat. This would save 2.6 million m^3 of gas.

Appendix 4> PV potential of commercial premises

The available roof area on commercial premises was derived from TNO data on the footprint of non-residential buildings (company premises, office buildings and shops). The footprint of 794,587 m^2 was translated directly to roof area. As with the calculation for homes (appendix 3a), the PV potential of these roofs was determined by deriving the available roof area by applying a correction for obstacles and the pitch of the roof (Vreugdenhil, 2014). This leaves 71% of the roof area available for solar panels. At a potential average generating capacity of 123 kWh/m^2
, this gives a total generating capacity of 69.4 million kWh.

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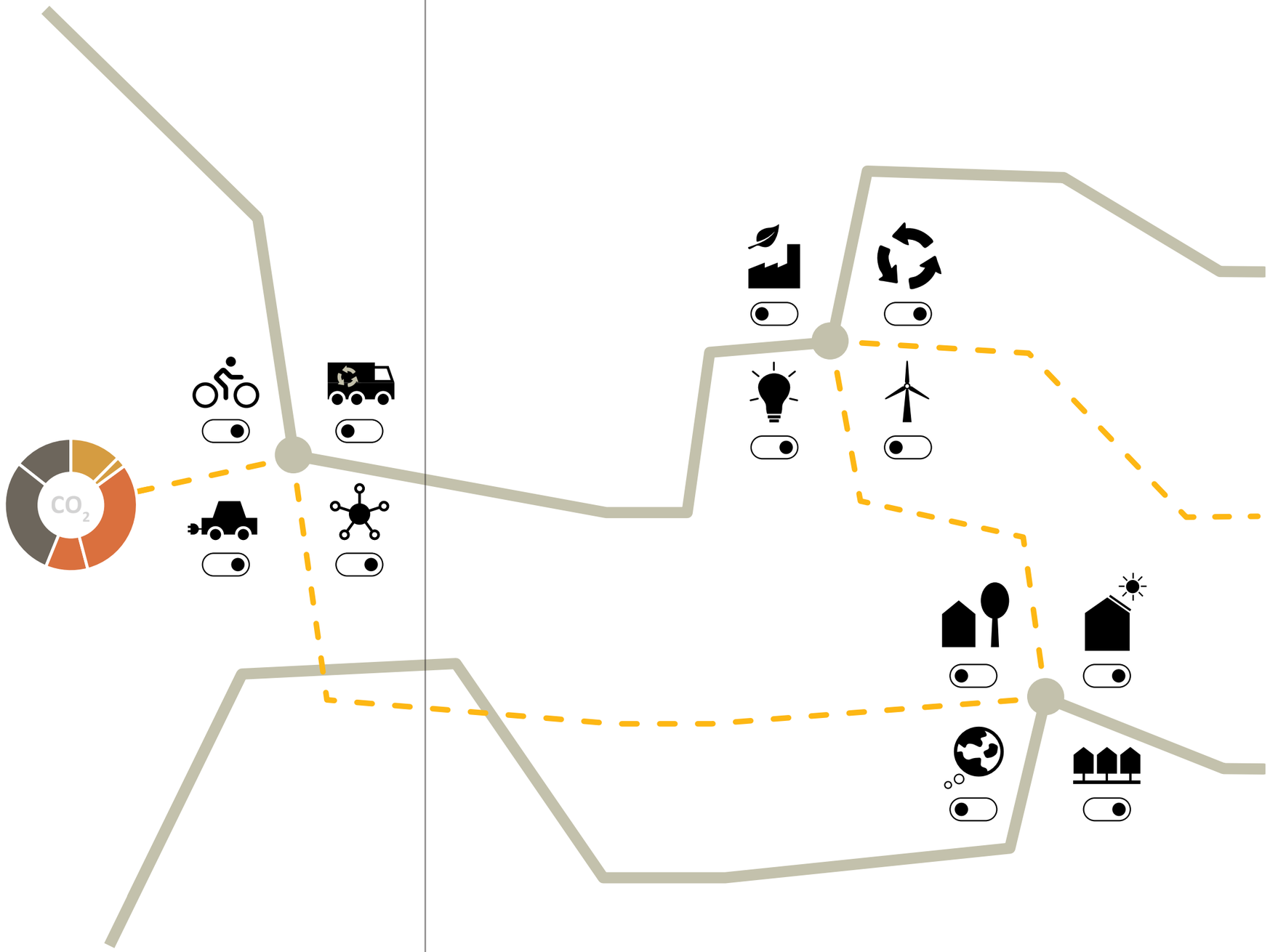

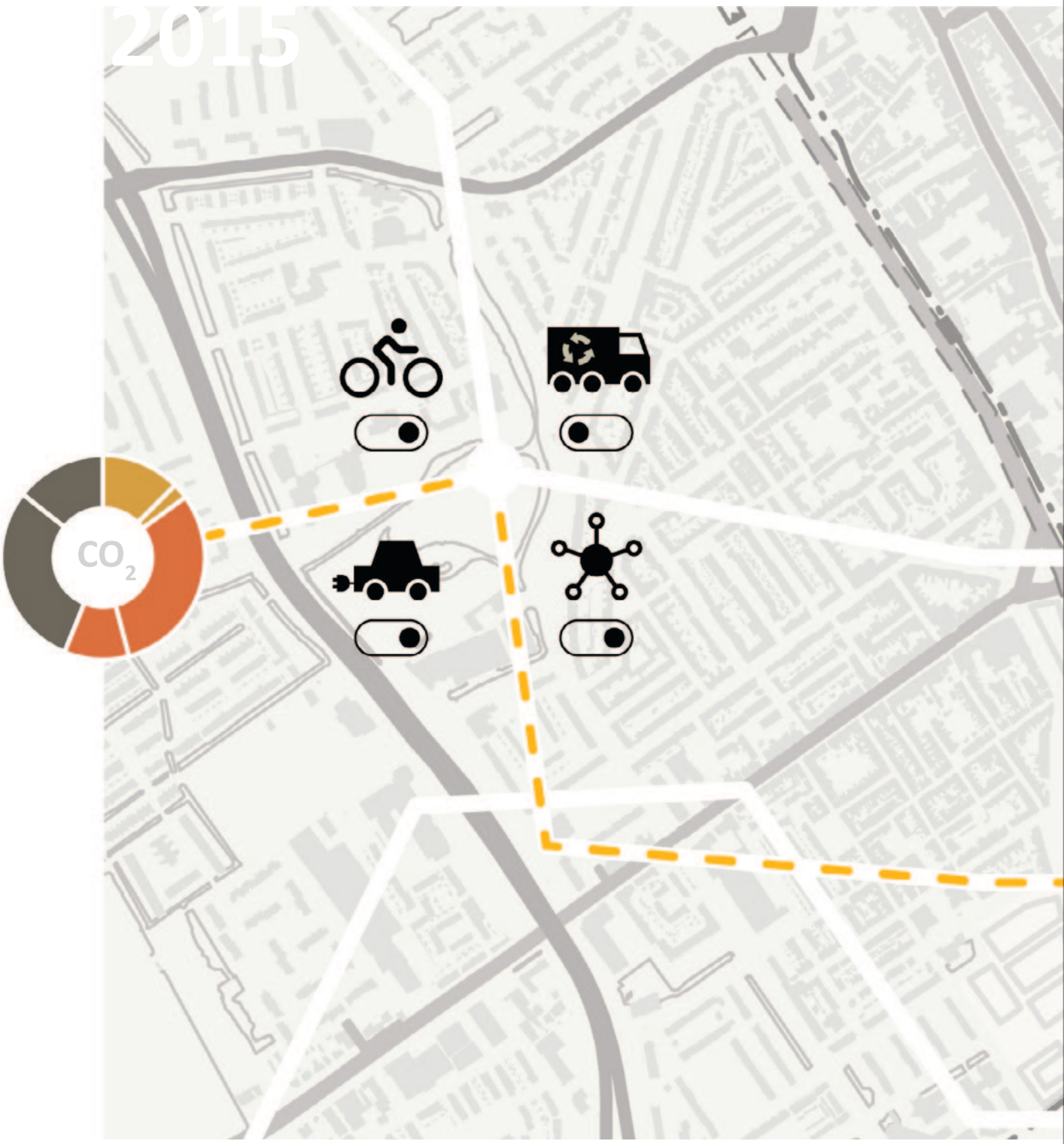

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