energy planning for the unknown

On the potential of adaptive planning
to guide the development of a
future-proof energy system for the
case of Schieoevers Noord, Delft

Linda Vos, 2020

◄ The cover shows one of the characteristic facades of the Schiehallen: this industrial complex used to be home to an old cable factory and currently houses several small enterprises and creates room for sports and leisure. How will the future shape this industrial ensemble of buildings? (Kondor Wessels Vastgoed, 2019)

energy planning for the unknown

On the potential of adaptive planning to guide the development of a future-proof energy system for the case of Schieoevers Noord, Delft

Linda Vos, 2020

Energy planning for the unknown
On the potential of adaptive planning to guide
the development of a future-proof energy system
for the case of Schieoevers Noord, Delft

Master thesis January 2020

Linda Vos
4215990

Graduation project for a double degree in
MSc Architecture, Urbanism and Building Sciences
Track Building Technology

and

MSc Science Education and Communication
Track Science Communication

To be publicly defended at 30 January 2020, at 15:30

Committee Building Technology
Prof.dr.ir. Andy van den Dobbelsteen
Dipl.ing. Ulf Hackauf (Urbanism)
Ir. Huib Plomp (delegate Board of Examiners)

Committee Science Communication
Dr.ir. Steven Flipse
Drs. Caroline Wehrmann
Prof.dr. Marc de Vries

An electronic version of this thesis is available at
http://repository.tudelft.nl/

TU Delft

Preface

The energy transition:
a societal transformation intersecting with anyone's life;
a complex issue puzzling policymakers;
a question without the one answer;
a challenge to be approached from multiple perspectives;
a system change full of uncertainties;
a context which asks for adaptivity.

In a joint graduation project between the master tracks of Building Technology and Science Communication at TU Delft, I have had the opportunity to study the above.
A research process in which disciplines and perspectives have come together, and have strengthened each other.

The city of Delft has been my experimental garden – the industrial area of Schieoevers Noord in particular. This area full of potential, yet full of conflicting interests, is moving towards an interesting future. How this future will look? That is unknown. Although the research question for this thesis finds its origin in the development plans for Schieoevers Noord, bridging theory and practice has been a challenge for me over the past year. The proximity of the case study area has helped me closing this gap since the experimental garden has also been my "back yard" for years now. While running through the area to clear my mind, theory could literally land.

With this thesis, I hope to inspire people to embrace uncertainties while making plans for the energy transition.
I hope to give the tools to incorporate adaptivity in planning processes – to people with naturally adaptive personalities and to those with a rather control-oriented nature like me.

Linda Vos
Delft, January 2020

Acknowledgements

During the process of graduating, I have had the opportunity to follow my own curiosity while being able to learn from inspiring people and to discover many perspectives.

Firstly, I want to thank my mentor team of four: Andy for being a source of inspiration, for the opportunity of setting up my own research, and the trust you gave me for doing that; Steven for his pragmatism, for being a large support in the start-up phase of the project, and for being a self-confidence booster; Ulf for the enthusiasm, the eagerness to collectively learn, for your sharp questions and the ability to "think the other way around"; and Caroline, for always giving me the idea that I worked on a valuable project, for asking the right questions, and for being the "adaptive expert" in the team.

Then I want to express my gratitude to my interviewees, on behalf of the Municipality of Delft, on behalf of the Bedrijvenkring Schieoevers, and on behalf of project developer Kondor Wessels. These interviews have enriched my view on the case of Schieoevers and deepened my understanding of the interests and perspectives that are present in the area development trajectory of Schieoevers Noord.

I want to thank the Fiction Factory – Steven and Arjan - for providing me with insights and numbers on the energy consumption of a "making hall": a building typology and type of enterprise of particular importance for the future energy balance of Schieoevers Noord.

A thesis is best written in good company – thanks to all of my fellow students of the "afstudeerhok" for being great sparring partners, for our lunch and coffee breaks, for advice and feedback, for offering a different perspective, and for just being the company I needed.

Thanks to my family for your trust, support, and love throughout my entire studies. Special thanks to my mum for always asking me if everything is alright, and to my dad who took up the courageous effort to read through my thesis with laymen eyes.

A very warm thanks to all of my close friends, for pulling me out of the graduation bubble now and then – which has been hard sometimes. I enjoyed every single coffee, dinner, "borrel", running event, and (weekend) trip.

A last word of thanks is for Maarten, for being my everyday sparring partner and late-hour study buddy, for your endless support, for your belief in me, and for being my adaptive half.

Summary

The Netherlands has a strong tradition of blueprint planning in spatial design. The financial crisis of 2008 has been an impulse for the Dutch planning paradigm to shift towards more open-ended and small-scale approaches to urban development. Now, in 2020, the economic crisis is over, a large housing shortage exists in the Netherlands, and society has to respond to large sustainability challenges – of which the energy transition is the challenge of focus in this study. As a response to (amongst others) the housing shortage and the energy transition, the new paradigm aims to steer developments into a favourable direction yet without the creation of blueprints.

Industrial area Schieoevers Noord, situated in Delft, is developed with the rationale of this new paradigm. The Municipality of Delft has an urgency to stimulate densification, yet not the intention nor financial means to take an active executing role. Developing gradually at the initiative of multiple parties, the area could provide an answer to the housing demand of Delft (+15,000 houses by 2040), to strengthen the position of Delft as "capital of technology and innovation" and the economy by adding jobs, but also to contribute to the municipal sustainability ambitions (energy neutral by 2050). The area of Schieoevers Noord is envisioned as a lively, mixed-use urban area. The Municipality of Delft describes the development approach as “adaptive”; the area development is open-ended and the final programme, density, and resulting energy demand of the area are unknown.

With the complex challenge of the energy transition ahead, this newly evolving paradigm in area development, asks for a complementary approach - an adaptive approach to energy planning - to be able to direct to energy-neutrality in 2050. The research question answered by this study, has been formulated as: *"How could an adaptive approach to energy planning enable the Municipality of Delft to guide the development of a future-proof energy supply (heat and cold supply) for Schieoevers Noord?"*; the defined scope for the research is the transition path low-temperature heat (and cold) since this part of the energy transition is most interwoven with the built environment. A design-

based research approach has been adopted, in which the area development of Schieoevers Noord was used as a case study. Multiple research methods have been used to provide an answer to the research question.

Firstly, the concept of "adaptivity" has been defined, based on literature, as: "*the characteristic of a system or pathway to adapt or be adapted by system actors, as a response to changing (unforeseen) future conditions*". A need for adaptive approaches roots in the presence of ontic uncertainty: a category of uncertainty rooting in the inherent variability present in human and natural systems. Six characteristics are identified that jointly describe an adaptive process; an adaptive process (1) explores and embraces uncertainty; (2) connects long-term visions with short-term actions; (3) treats a process of systemic change as experiment; (4) focuses on conditions for development; (5) spreads responsibility for decision-making over the system; and (6) integrates the diverse knowledge of those involved.

In literature, a multitude of planning approaches exists, that is concerned with the planning of urban or regional energy transitions. Six of these approaches have been analysed on the presence of the aforementioned characteristics of adaptivity. The characteristics most clearly present, are the connection between long-term visions and short-term actions, as well as the involvement of stakeholder-knowledge. Not enough emphasis is given to the exploration of uncertainties, the element of learning and iterating, and the focus on conditions rather than actions.

An analysis of the area of Schieoevers Noord has studied a practical perspective on adaptive development. The three main stakeholder groups are dependent on each other – land-owning companies, project developers, and the Municipality of Delft. Next, the scale at which the development plan should be adaptable is defined – being the "plot", a subarea of which 15 are identified in the area. Furthermore, requirements and ambitions concerning sustainable energy for Schieoevers Noord are defined: each plot *must* develop energy-neutral for the building-related energy consumption, a maximum contribution to the municipal sustainability ambitions is an *ambition*. Among all sustainable energy potentials, Aquifer Thermal Energy Storage

(ATES) systems are stated to fit the adaptive development trajectory best. They offer independence as well as a promising heat and cold potential.

A design brief has been formulated after this analysis: a stepped approach for adaptive energy planning is to be designed, which includes tools for exploring and accepting uncertainties, for iterating and adapting the development process, and for shaping favourable conditions for developments. The last aspect is answered by the creation of design guidelines, corresponding to the steering mechanism of the current practice.

The *Schieoevers Noord approach for adaptive energy planning* provides the team of planners at the municipality that is concerned with Schieoevers Noord – and specifically the energy planner(s) – with a stepped approach and several tools to incorporate adaptivity in their planning process for sustainable heat and cold supply in the unfolding area development. The approach consists of five steps, building further on current methods:

1. Analyse the *present state of the area* and its context (energy, societal system, stakeholders);
2. Analyse concrete *plans for the near future*;
3. Define a desired sustainable *future vision*;
4. *Explore and explicate uncertainties*, coming from (far-) future scenarios and interdependencies between stakeholders;
5. (a) Create an *adaptive roadmap*, consisting of strategies, no-regret actions and conditions for development;
   (b) Define the points in time and/or *triggers for iteration* of these strategies, actions and conditions.

The tools able to guide the first three steps are described in existing methods. *Step 4* is guided by a set of questions, aiming to explicate which uncertainties exist, to map which barriers for taking actions they create, and to create a perspective on how to act and/or remove the barrier. For *step 5b*, a bi-annual rhythm is proposed, as well as trigger values: the initiation of new developments.

The study paid attention in particular to the creation of favourable conditions for the (energetic) development of different plots in Schieoevers Noord, being part of *step 5a*. Favourable conditions in the scope of aiming for sustainable heat and cold supply target the assurance of energy-neutrality for each step of the area development process, while not hindering following developments concerning their local energy potentials. As an example, the energy balance of the "Kabeldistrict" – one of the plots at which a high-density neighbourhood should be realised – is studied, leading to the following conclusions. When ATES systems are used as the primary source of heating (and cooling), the study shows that either the desired density and function mix of living and working at several plots could not be realised, or much more energy is needed than the local conditions can supply. So, either the maximum energy consumption of each building unit should be restricted to far below the current and planned building decree or different sources of energy are needed. In the last case, energy retrieved from outside the plot would create interdependencies and thereby uncertainties and/or it will impact the following developments.

Four parameters form the base for the energy balance of each development within the area: building density, programme mix, energy demand, and (local) energy capacity. For each plot, it should be considered whether one or more of these parameters should be steered upon, to guarantee both the living quality in the area as well as a future-proof energy strategy. In the case of the Kabeldistrict, it is proposed to use a design guideline that dictates the energy system which is used - preferably an ATES system. It is up to the developer to make the most out of the available energy, by adopting measures as a more optimal function-mix or energetic implants, both stimulating direct heat and cold exchange. Exactly this balance between freedom and guidance creates valuable learning points for following developments and serves as input for adaptations to the development plan.

Content

1.
Introduction

Note to the reader
All images in this thesis have been created by the author, unless stated otherwise

"An urban transition is not a matter of simply matching problems to solutions; it is a complex and multi-faceted endeavour. Reflecting on the past may show us what it takes to get moving and what we are likely to encounter on the way; transitions are never going to be easy. People will push back, vested interests will resist, and some solutions will not work out. But cities will always continue to develop." (Hajer & Dassen, 2014)

This citation points out two elements that are in tension and synergy with each other at the same time: the complexity of urban transitions and the continuous development of cities. While energy is part of the metabolism of a city, unpredictability in city dynamics makes it hard to plan out the energy transition. What if we learn to move along with city dynamics to foster positive change in the transition to renewable energy? A system change is needed to succeed in a transition from fossil to renewable sources of energy, a change reaching from supply to infrastructure and demand, all embedded in our cities and countryside.

1.1. Context

For the Netherlands, the mitigation of climate change by the reduction of carbon emissions as written down in the Paris Agreement (compared to 1990, a 49% reduction by 2030, 95% by 2050), mainly is an energetic challenge. Eighty per cent of the Dutch CO_2 emissions are related to different functionalities of energy – being high- and low-temperature heat (respectively 19 and 18%), power (26%), and transport and mobility (17%); see also Figure 1 (Ministery of Economic Affairs, 2016; Rijksoverheid, n.d.).

The system change to renewables is characterised by a big difference between fossil and renewable sources of energy: their energy density. Coal has an energy content of about 6.7 kWh/kg, natural gas can deliver 14.9 kWh/kg. In comparison, one square meter of solar panels generates about 1.4 kW, corresponding to 4-5 Wh/day (Sijmons, 2017) – so, large solar fields would be needed to replace these energy-dense sources. Hence, in addition to being a socio-economic and technical challenge, the energy transition is a spatial transition.

In our future, energy will take up space, space that is currently devoted to different functions and people. Energy will be harvested over large surface areas – either above ground, for example by wind parks and solar fields, or underground by strategically positioned geothermal wells – where geothermal energy is available. Next to the space taken up by

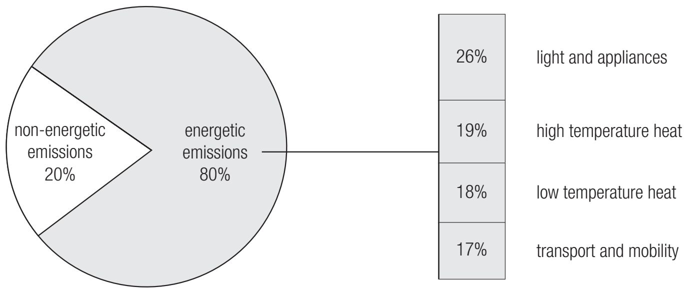


Figure 1: Ratio of CO_2 emissions for the functionalities of energy (Ministery of Economic Affairs, 2016)

supply, on the demand, side this spatial challenge is shaped by the need for reduction in energy demand. For each building typology, a reduction in energy demand has a spatial implication: insulating a façade from the inside implicates the downsizing of usable floor area, whereas insulating at the outside will create a different visual perception (Posad Spatial Strategies et al., 2018). In conclusion, energy will impact our physical environment from landscape to housing scale.

The research presented in this thesis focuses on the relation between urban development and the planning process for the "transition path" of low-temperature heat, also called "*heat transition*". According to Sijmons (2017), the built environment in the Netherlands is responsible for the use of 646 PJ of heat each year – the total annual heat usage being about 1,324 PJ. Characteristic for this heat transition is its relation to the built environment: to cities, urbanism, or spatial development – on a physical and technical, but also on a policy level. The scale on which this transition will be planned and executed is on a regional or local scale; municipalities are given the responsibility to make decisions concerning the (local) heat transition (Ministery of Economic Affairs, 2016). At a local and regional level, it could best be assessed which energy-saving measures and sustainable alternatives are most suitable to provide for the heat demand of the town, city or region, as well as the suitable speed of taking transition measures. Furthermore, the impact on the living environment of citizens will be large, asking for an organ capable to open up a dialogue with local parties: the municipality.

Next to the challenge of the energy transition, the field of area development is evolving. Prior to the economic crisis of 2008, the Dutch spatial planning tradition was characterised by its large-scale and integral approach: project-based, developed by large organisations, with a clear image in mind. Organic development – on the other side of the spectrum – creates several opportunities, that are – mainly in times of economic crises – more beneficial. The involvement of the end-user, phased developments, and the focus on handling uncertainty; organic development is process-oriented (Buitelaar et al., 2012). At the moment of publishing this thesis, the financial crisis is over, and the shortage of housing in cities is large. Furthermore, city planners face large challenges as the energy transition, the need for climate change adaptation measures, but also concerning mobility, for example.

Helleman (2018) describes the search for a planning paradigm fitting these new circumstances – after a period of classical area development, and organic area development. It is stated that although pure organic development is not suitable for the challenges of today, the focus on process rather than project should stay. Four concepts asking for a new perspective in this phase of "area development 3.0" are time, scale, actors, and values. Time asks for a notion of dynamics: a cyclic process instead of a linear one, allowing to respond to the economic climate. Scale asks for the perspective focusing on the dynamics and metabolism of an area, rather than a functional label as "industrial area". Actors – government, developers, business, knowledge institutions, and citizens – should all be involved. The concept of values represents a shift from making money, to a wider perspective on added value for an area: social, economic or physical.

So, a new planning paradigm is developing; a paradigm in which the current housing shortage plays an important role, as well as the transition to renewable energy. One specific area development which has just started, takes place in Schieoevers Noord - the case study for this thesis. Here, it is sought to ways of steering the area development - more directive than pure organic approaches, more gradually than traditional approaches.

1.2. Case study

Inspired by the development plan of Schieoevers Noord, Delft – the aforementioned tension between (new forms of) area development and the development of energy strategies is studied. The city of Delft has a multitude of goals for the upcoming years: the desire to become "capital of technology and innovation", but also the more tangible goal of adding 10,000 jobs to the market and 15,000 houses to the building stock. Furthermore, the Municipality of Delft aims to be energy-neutral by 2050, while the increase in jobs and housing only adds to the current energy demand. Without space to grow as a city within the municipal boundaries, the only solution path results in a densification challenge (Gemeente Delft & KuiperCompagnons, 2018).

Figure 2: Location of case study area Schieoevers Noord: situated between the inner city (north), TU Delft campus (east), and industrial aea Schieoevers-Zuid (south), crossed by the railway and canal Schie.

The area of Schieoevers Noord is pivotal in the realisation of these ambitions, because of its strategic location (see Figure 2), opportunities for densification, presence of public transport facilities, current activities and the area's identity. Currently, the industrial area houses a range of functions: businesses – from heavy industry, to transport companies, waste facilities, start-up and scale-up companies – to places for leisure and sports, and a couple of houses. The aim is to create a lively mixed-use area involving places for living and working (focus on the "making" industry) and utilities to complement (Marco Broekman, 2019).

Striking in the case is the distinct choice for an "*adaptive*" or "*organic*" development trajectory: setting out a spatial framework as perspective for the long term, which allows for multiple programmatic infills and development tempos. Factual, after each partial development, the unfolded trajectory could either end, or trigger new developments. A course is chosen, the endpoint undefined (Broekman, 2018).

Energetically, the developments of Schieoevers Noord aim to be energy-neutral developments, concerning the building-related energy demand. However: how many buildings will be present in 5, 10 or 50 years? Which functionalities will they accommodate? And which industrial processes will be worked on by the making industry? All unknown, but prerequisite to be known, to be able to create a sustainable energy strategy. The tension between adaptivity in spatial and functional planning, and the explicit desire to build energy-neutral, did strike the authors curiosity.

1.3. Problem statement

Open-ended area development trajectories, unfolding in the timespan of the energy transition to an energy system based on renewables, face many uncertainties and have to cope with complexity. The municipality of Delft is facing this situation in the specific case of Schieoevers Noord. Based on the generic problem, as well as on the specific case of Schioevers Noord, the following problem statement is defined.

The Municipality of Delft has the aim to develop the industrial area of Schieoevers Noord towards a lively mixed-use area, following a development strategy with an open ending: an organic development trajectory. This development should contribute to the needed rise in jobs and housing. At the same time, the Municipality of Delft set the ambition to be an energy-neutral city in 2050 and to build only energy-neutral buildings during each of the developments within Schieoevers Noord. Development parameters such as the functional programme and the amount of square meters that will be built, are important input factors to define the energy demand of the future state of the area (the quantitative energy demand (amount of Joules) and the qualitative demand (e.g. water temperature for space heating)). With the future developments being unknown, uncertainty is created for the planners (project team Schieoevers Noord at the Municipality of Delft). The planners currently lack an approach enabling them to take decisions regarding suitable energy strategies and thereby guide the (interrelated) spatial, functional and energetic plans created by developing parties.

1.4. Hypothesis

The concept of adaptivity is hypothesised as being a crucial factor in planning processes characterised by a high level of uncertainty or unpredictability. In the case of planning an energy strategy for an urban area of which the future state – users, programme, amount of square meters, and building density – is unknown, or at least unsure, an adaptive approach to this process of energy systems planning potentially is stated to offer a valuable strategy. The project does not aim to reject or support the hypothesis by quantifying the value of adaptivity in planning processes; however, it seeks an understanding of how adaptivity can contribute to planning under uncertainty.

1.5. Project aim

This study aims to create an approach that enables planners at the Municipality of Delft to make decisions on the future energy strategy for Schieoevers Noord, while the end state of the area development trajectory is unknown: a framework for adaptive planning. Four subobjectives have been formulated, supporting the main research aim:

(1) to create a perspective on planning under uncertainty, for which the concept of adaptivity is explored;
(2) to operationalise the concept of adaptive planning, enabling the Municipality of Delft to incorporate this way of doing in daily practice;
(3) to visualise the interdependency of energy demand and energy supply, and functional and spatial planning, and thereby generate a framework for adaptive development for Schieoevers Noord; and
(4) to create an overview of sustainable energy sources and technologies that fit an adaptive approach to energy planning within the physical context of Schieoevers Noord.

1.6. Research questions

Based on the problem statement and aim of the study, the following main research question (MRQ) is posed, supported by a set of five sub-questions (SQ).

MRQ: How could an adaptive approach to energy planning enable the Municipality of Delft to guide the development of a future-proof energy supply (heat and cold supply) for Schieoevers Noord?

Five sub-questions (abbreviated as SQ1 to SQ5 in the remainder of the report) support the main question:

SQ1. Which drivers and barriers for adaptive (spatial) planning and adaptive (energy transition/climate) policy-making do exist according to literature?

SQ2. Which drivers of adaptivity are present in current, academic approaches for energy planning?

SQ3. How do locally (or regionally) available sources of heat and cold fit the adaptive area development of Schieoevers Noord?

SQ4. Which design guidelines for plot developments could be used by the Municipality of Delft, concerning the (local) energy balance of the plot, to establish adaptivity and energy-neutrality in the spatial and functional design of Schieoevers Noord?

SQ5. What are the implications of these guidelines for existing spatial and functional design proposals for plot developments within Schieoevers Noord?

1.7. Research set-up

The research process of which this thesis is the result, has been a process in which the graduation research for the master tracks Building Technology and Science Communication have been integrated. One main research question has guided the process, and the answer on this research question aims to contribute to the research fields related to both master tracks.

The research set-up has been a design-based research approach, allowing the author to firstly create a deep understanding of the problem statement, after which a design brief is formulated, and solutions for the problem are developed. A mixture of methods is used for both the analyses of the problem and the ideation of solutions, based on social research methods as well as (technical) design and analysis. A constant movement between theory and practice is made, in which the shortly described case study of Schieoevers Noord is representing the practice and is used to understand and add on theory from both of the research fields. The research approach and the research methods that are used are discussed in Chapter 3; the case study is further elaborated upon in Chapter 2.

1.8. Reading guide

The report is structured in 12 chapters. Chapters 1, 2, and 3 form the introductory part of the thesis – the introduction, case description, approach and methodology. Chapters 10, 11, and 12 form the closing part – by the conclusion, discussion, and reflection. The body of the study is written down in chapters 4 up to 9; this structure is also shown in Figure 3. Chapters 4, 5, and 6 present analyses, coming together in Chapter 7, in a design brief. Chapters 8 and 9 present the "design" part: the design of solutions for the design brief

Chapter 1 has been introducing the study – the context, problem statement, objectives and research questions. Chapter 2 proceeds with a more in-depth description of the case study Schieoevers Noord and sheds more light on emerging area development paradigms and the energy transition within the city of Delft. Chapter 3 describes the research approach and the used methods.

Chapters 4 to 6 together build up towards the design brief (Chapter 7). Chapter 4 – the theoretical framework – studies the relation between the theoretical concepts of uncertainty, complexity, and adaptivity, and searches for a definition, drivers and barriers for the concept of adaptivity. Chapter 5, dedicated to existing approaches to (sustainable) energy planning, studies which of the drivers found for adaptivity are present in these existing approaches. Chapter 6 is closer to reality, studying the case of Schieoevers Noord; the analysis including a spatial analysis, an analysis of the development plans, a stakeholder analysis, and an analysis of the energy potentials for the area. All together, the analysis of theory on adaptivity and the practice of Schieoevers Noord lead to a design brief: what knowledge and what decision-framework is needed to adaptively make decisions concerning the development of space, programme, and, most importantly energy within Schieoevers Noord.

Chapter 8 and 9 use the design brief in the development of an adaptive approach to energy planning. Chapter 8 focuses on the interrelations between energy, space, and programme – to create insight in the bottlenecks as well as opportunities in their interrelations for sustainable area development and energy planning. The chapter results in a proposal for energy-based design guidelines for Schieoevers Noord. Chapter 9 synthesises the technical knowledge on energy-related decision-making with process insights retrieved from interviews at the Municipality of Delft and theoretical knowledge on adaptive processes, resulting in a proposal for the "*Schieoevers Noord approach for adaptive energy planning*".

Chapter 10 answers the main research question; Chapter 11 discusses the limitations of the study, presents opportunities for further research, and searches how the results can be extrapolated towards other cases of area development and/or (the scientific field of) energy planning. Lastly, Chapter 12 reflects among others on the research process, the relation between research and design, the evolution of the concept of adaptivity throughout the project, and a view on the developing paradigm in the sector of area development.

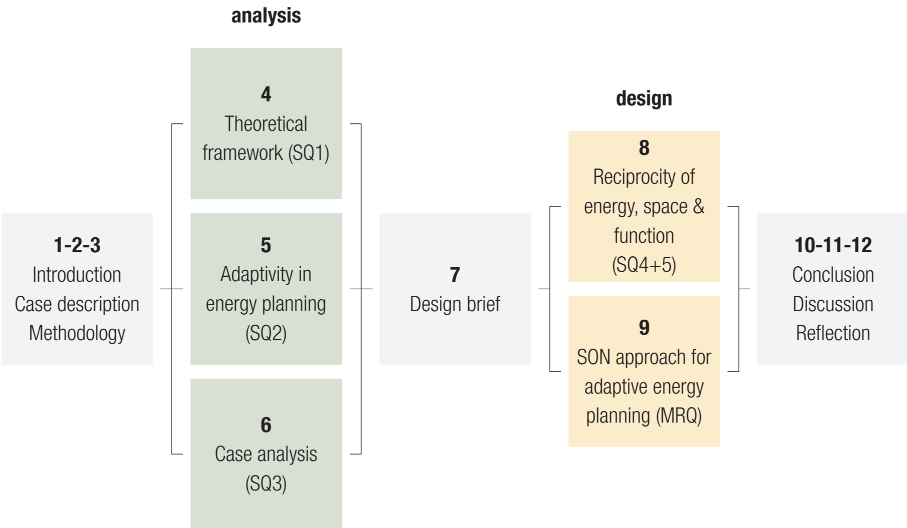


Figure 3: Visualisation of the report structure: the chapters directly leading to answers on the research questions are coloured (the analysis chapters in green, the design chapters in yellow), the grey chapters are supporting chapters

2.
The case of Schieoevers Noord

city of Delft

industrial area Schieoevers Noord

organic area development

energy transition

As described in the introduction, this study is initiated through the inspiration by the area development planned for the industrial area Schieoevers Noord; this area development trajectory is used as a case study throughout the project. This chapter provides more insight into the case study. What is the urgency driving the area development? What kind of area is Schieoevers Noord? What kind of development process is planned? What is organic area development actually? And what challenges of the energy transition are faced within this area development process?

2.1. Densifying the city of Delft

The city of Delft is growing – both its population and companies the city houses. As a result, the city has the ambition to add about 15,000 houses and create about 10,000 job opportunities by the year 2040. About half of the houses are already built or planned, for the other half, space has still to be found. To point out the magnitude of this growth – the total housing stock of Delft will grow with thirty percent, and the amount of jobs with nineteen percent (Figure 4). The province of South-Holland copes with a housing challenge of 240,000 houses in total. The urbanisation of Delft is of importance for the economic power of Delft and for the position of Delft in the region; Delft has an important role in the regional knowledge-based industry (e.g. TU Delft and TNO) as well as an important physical position as being the link between Rotterdam and The Hague. However, according

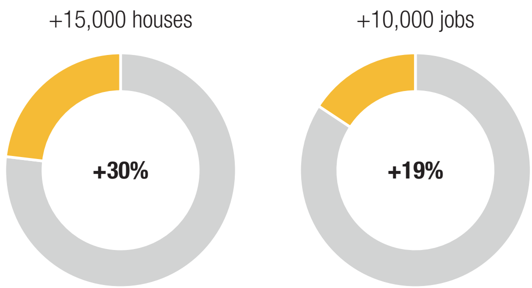


Figure 4: Magnitude of the densification challenge of Delft; grey indicates the current housing stock and amount of jobs, yellow is the planned addition by 2040 (Gemeente Delft & KuiperCompagnons, 2018)

to the municipality, quality improvement of the housing stock is the largest aim of the densification process. The housing challenge will function as catalyst for five other themes: creation of jobs, accessibility, quality of the living environment, sustainability, and facilities (Gemeente Delft & KuiperCompagnons, 2018).

The qualitative shortage of houses in Delft comes forth from a couple of target groups: the amount of one- and two-person household grows, the city of Delft is aging (so the amount of elderly grows), half of the knowledge-workers in Delft is not living in the city, and a large share of graduates decides to leave the city. Mid-priced rental and owner-occupied houses are to be added to the housing stock. The addition of jobs should be done well-balanced, for people of all educational backgrounds: jobs fitting graduates from University, HBO, MBO, as well as learn-work opportunities (Gemeente Delft & KuiperCompagnons, 2018).

The spatial challenge of the above-mentioned housing and job demand, however, is created by the lack of space to grow as a city. Delft already expanded to the municipal boundaries, creating a densification challenge, which in its turn asks for creative – or at least different – solutions. It is noticed that the city is – with the exception of the inner city – built up from residential areas, industrial areas, shopping areas, and sporting grounds. The solution should lay in mixing of programme: to add houses in working areas, add jobs in residential areas, and bring sports, culture and shops into the neighbourhoods (Gemeente Delft & KuiperCompagnons, 2018).

In the municipal visions, multiple locations within the city are appointed to add jobs and housing; the area seen to be able to realise the largest share of the challenge, is Schieoevers Noord. In this industrial area, the largest transformation can take place – from a relatively low-density working area, towards a lively higher-density district with a mixed programme (Gemeente Delft & KuiperCompagnons, 2018).

2.2. Industrial area Schieoevers Noord

The densification challenge of Delft created an urgency to think of transforming part of the industrial area Schieoevers: Schieoevers Noord, the half closest to the city centre. At the moment, Schieoevers – both the southern and the northern part – is a well-functioning industrial area; from that perspective, no urgency for transformation exists (Broekman, 2019). A development plan for the area has been created though, collaboratively by design firm Marco Broekman and the Municipality of Delft, which gives insight in why the area is developed.

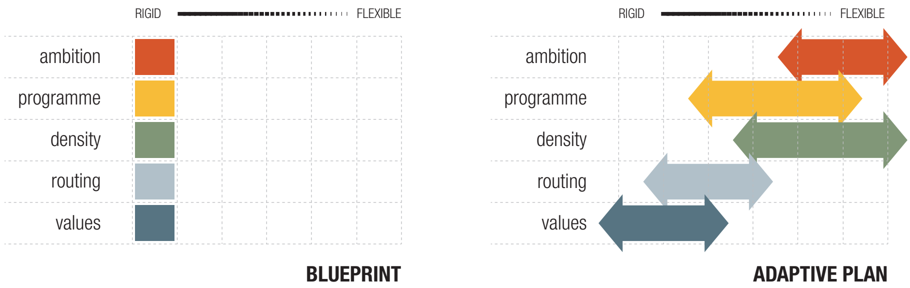


Figure 5: Difference between a “blueprint” and an adaptive plan, as used in the development plan for Schieoevers Noord (translated from (Broekman, 2018))

The addition of a new type of urban environment to the city is desired (lively, mixed and a high-density); space is needed for so-called “innovative making industry” – start-ups that have started their business in Delft should get a place to stay in the city, enabling connections between businesses alike; scarce space should be used more efficiently – one job in Schieoevers takes approximately 140 m^2 at the moment, while the new plans strive for 60 m^2 on average; the national aim is to not touch green rural areas, which makes expansion outside the municipal borders impossible; and, lastly, the city strives for connections between areas – Schieoevers Noord can become a connecting area between TU, city centre, heavy industry, and residential areas (Broekman, 2019).

For the development of Schieoevers Noord, the municipality has chosen an approach of organic area development, implicating that the development starts with initiative of parties from within the area and not by a strongly steering municipality. The municipality will also not buy any land, yet aims to collaborate with parties that have plans fitting the long-term vision of the city. The written development plan presents a direction for the area, yet no blueprint – the development plan is an adaptive framework (Figure 5) (Broekman, 2019).

The development plan has five central themes, which form the basis of the framework for the transformation of Schieoevers Noord:

- Lively and mixed-use urban area;
- Space for innovative making industry;
- Socially inclusive and culturally diverse;
- Healthy and sustainable environment;
- Good accessibility and new mobility.

The transformation will take place over multiple decennia; the adaptive character comes with a step-by-step development. Thereby, in essence, each step can also be the last step – and each (partial) development should lead to a liveable environment. One of the characteristics of the area, that enables this strategy, is the fact that the plots in the area (pieces of land with one owner) are relatively large – and thereby the amount of parties that collectively own the largest share of the surface area in Schieoevers Noord is relatively small. Therefore, the zoning plans address relatively large areas as well (Broekman, 2019). Figure 6 indicates the size of some of the largest plots within in the industrial area.

These ambitions have led to an open-ended development plan, yet an estimation is made of the amount of jobs and houses that could be present in Schieoevers on the long-term. The plan is split in a first (short-term) phase with developments until 2030, and a long-term vision. For 2030, it is estimated to have realised approximately 1,800 jobs and 4,200 houses in (parts of) Schieoevers Noord; on the long-term these numbers should expand to 5,500 jobs and 7,700 houses.

Figure 6: Indication of large-scale plots within the area of Schieoevers Noord

2.3. Organic area development

The city of Delft stated to approach the development of Schieoevers Noord as organic area development, but what does that actually mean? Area development in general, is defined as follows by De Zeeuw (2018): area development is the art of connecting functions, disciplines, parties, interests, and cash flows, in the face of development or transformation of an area. Area development could be market-driven (programmatic demand, such as housing demand), government-driven (urban renewal), or societally driven (residents' initiative). Each area development has at least one interest and a related party with resources for investment. Process of area development generally cover a long timespan; 10 years or more is no exception.

The Netherlands has a real tradition of planning and integral area development; however, over the past 10-15 years, the field has made through some large developments. Whereas the period from the mid-90s until 2008 can be characterised as flourishing, the economic crisis of 2008 had a large impact on the field of area development. The sector of area development and – maybe even stronger – the thinking and the debate on area development have been impacted. The direct impact of the economic crisis proceeds until the year 2014. In the years directly after the crisis, organic area development became the new standard: small-scale initiatives, and open-ended processes without blueprints. Organic area development is the cumulative effect of small-scale (re)developments. End-users have a more prominent role, municipalities facilitate (Buitelaar et al., 2012; Zeeuw, 2018). Table 1 shows the difference between the paradigm of integral development and the organic paradigm.

Municipalities can facilitate organic development, and create conditions for development in several ways, states De Zeeuw:

- communicative – by creating and communicating visions, municipalities can "seduce" parties to start spatial and/or social initiatives;
- organisational – by seeing organic area development as a process rather than a project, and thereby shift the focus to a more external focus: on initiating parties;
- financial and economic – thinking of overarching initiatives such as public space and infrastructure, strategies and financial plans could be initiated and created by the municipality;
- legal and planning – municipalities can choose to build in more flexibility in zoning plans.

As stated, organic area development was the most prominent paradigm in the years after the economic crisis, reducing risk, developing bottom-up and introducing much more flexibility in area development. Since 2014, when the economic situation improved, the necessity of organic development decreased. However, the organic paradigm has not been re-replaced by integral development as well. As Helleman (2018) describes, the sector is looking for a new paradigm: whereas integral area development can be seen as “area development 1.0”, and the organic paradigm as “area development 2.0”, the current period is used to find a paradigm 3.0. Urhahn (2015) also studies temporary area development strategies and how man copes with uncertainty in the time after the crisis, proposing a paradigm in which more or less control-oriented development strategies are dependent on the potential of, urgency of, and influence on developments. Different situations ask for different types of plans, including a higher or lower degree of flexibility.

Helleman (2018) describes the search to this paradigm 3.0 – with a recovering market, a growing housing demand and an important sustainability challenge. The organic – small, slow, bottom-up, spontaneous – approach will not provide the answer to the market demands and sustainability challenges. However, back to the classical, hierarchical and large-scale area developments, is not desired either, due to the complexity of current societal challenges and the risks that have to be taken. A shift is proposed, in which development is not a production chain, in which land is bought, a large volume is built, and then sold, but a collective process

Table 1: The contrast of integral area development and organic area development (Buitelaar et al., 2012)

	Integral area development	**Organic area (re)development**
Approach	In one go	Gradually
Scale of development	Large scale	Small scale
Process organisation	Project-based	Open-ended
Plan	Final image (or blueprint)	Strategic
Type of developer	Large professional developers	Small contractors/ developers, and private parties (collective private commissioning)
Role of municipality	Active and bearing risks	Facilitating
Development and maintenance	Sequential	Intertwined

– in which a concept is created collaboratively, commitment is organised, and the plan is executed as a community. The approach differs in the attitude towards time, scale, actors, and values. Concerning time, men should create a cyclic rather than linear approach, since the market is dynamic. Concerning scale, it is proposed to not see areas as a unity of function, yet as functioning unit – including a diversity of buildings, owners, and streams. Placing actors, the local community, central, increases the resilience of a development, yet asks for a more open attitude of governmental and developing parties. Placing values above profit creates more resilient cities, characterised by liveability, affordability and durability. As Helleman concludes his search for a new paradigm: there is no ready-made recipe for temporary area development – the new paradigm is at least contextually oriented, looking into the needs of local dynamics. It is important for parties to continuously switch between scales, timespans, interests and values, and to keep involved in a long-term processes.

The area development of Schieoevers Noord, although stated to be organic, actually fits in this new paradigm: taking the good aspects of organic development, yet having to cope with large market demands and sustainability challenges.

2.4. Energy transition ambitions

De Zeeuw (2018) states that energy provision within area development and the energy transition cannot be separated. With the Municipality of Delft setting high standards regarding the transition to renewable energy, and the area development in Schieoevers Noord generating both new energy demands as well as opportunities for the city – the challenge of the energy transition in Schieoevers, Delft, and the Metropolitan Region Rotterdam-The Hague is touched upon.

For the developments of Schieoevers Noord, an environmental impact assessment has been written, aiming to integrate the environmental interests in an early stage of the planning process (Lindeboom & Verhoeven, 2018). The assessment covers a variety of environmental topics; concerning energy, the following has been written. The plan prescribes hard and soft frameworks: the hard ones being the prevailing laws and regulations and policy in force – which the plan must meet, the minimum ambition level – the soft ones are desires and add on to the minimum ambition levels. The soft frameworks are guiding for the development since they support the development to reach higher ambition levels. For a “sustainable environment” the hard frame is stated to be national and local energy policy and regulations, as well as not hindering the municipal sustainability ambitions; the soft framework is stated as delivering a maximal contribution to the municipal sustainability ambitions.

The Municipality of Delft has many sustainability ambitions for the coming decades. Delft aims to be energy-neutral by 2050. An energy-neutral city is defined as follows by Delft:

> "Only energy generated from renewable sources (sun, wind, biomass, geothermal energy) will be used for room heating, cooling, lighting, and other processes (ICT, industrial processes, etcetera) of all buildings (houses, offices, business premises) – and for transport and mobility within the municipal area of Delft" (Leguijt, Hueting, & Wielders, 2011).

This definition does not imply that the entire energy consumption should be generated within the municipal area of Delft – but, it does imply that no fossil sources are used for the generation of the total energy demand. Thereby, the CO_2 emissions related to the defined sources of energy are minimised to zero (embodied energy in products and food produced elsewhere is not taken into account). As Delft does not own any rural areas, large-scale solar or wind parks are not realisable – so becoming "energy-neutral on the own terrain" would create a difficult task (Gemeente Delft & KuiperCompagnons, 2018).

Next to the aim of an energy-neutral city, several intermediary ambitions are added. In 2025, the first 5,000 houses should be connected to a local, open heat grid. In 2030, the energy use should be halved compared to 1990; the share of renewable energy in the total energy consumption should be 25%. In 2040, energy-neutral houses are the standard, also in the existing housing stock. The heat grid planned to transport heat from Rotterdam to The Hague via Delft should be in use by then and should be fed by sustainable waste heat and geothermal energy. This all together (also with other circularity/sustainability measures) should realise a CO_2 reduction of 50% by 2030, and a carbon-neutral city by 2050 (Gemeente Delft, 2017).

The Municipality of Delft has sustainability ambitions concerning other aspects than energy as well. As such, the city aims to be circular in 2050; the quality and quantity of green and blue infrastructures should be enhanced (leading to 30% more biodiversity in 2040); the mobility sector should be running on renewable energy only by 2040; Delft should be fully climate-adaptive in 2050 – the city should be able to cope with 99.5% of the climatic conditions (Gemeente Delft, 2017).

Concerning low-temperature heat, being the main scope of this thesis, Delft – and "the municipality" in general – has a large responsibility for the success of the national climate policy as well. As stated, the transition of low-temperature heat will mainly take place on a local and regional level. The Dutch Government, therefore, states that local governments should be able to make decisions concerning the local energy (heat) transition (Ministery of Economic Affairs, 2016). Policy concerning heat is made on a regional and local level and anchored in formal policy documents at the municipalities. In the coming years, two political tools are important for this heat transition: the Regional Energy Strategy (RES) and the municipal heat transition visions (Warmtevisie).

The national “Regional Energy Strategies” (RES) programme forms the interface between the Climate Agreement (national policy level) and the region (The Netherlands is divided into 31 RES-regions). A threefold function is given to the RES. Firstly, it is a product in which the region describes which energy-related objectives should be reached at which moment (concerning electricity and heat); secondly, it is an instrument to organise the spatial implementation of the objectives; and thirdly, the programme RES serves as a way to organise a long-term collaboration between all regional parties. The first version of the RES should be finished 12 months after the signature of the national Climate Agreement; the process is set up iteratively, with a bi-annual recalibration of the approach. This regular convergent adaptation cycle (plan-do-check-act) keeps the plans up to date, and increasingly creates certainty, which is desirable for the heat-transition plans of municipalities – and neighbourhoods on a smaller scale (Regionale-energiestrategie.nl, 2018).

In the same timespan, by 2021, each municipality should deliver a heat transition vision, according to the Climate Agreement. These plans should describe how different districts and neighbourhoods should be disconnected from the natural gas, which areas have the potential to be independent of natural gas by 2030, what the alternative for natural gas in these areas will be, and how the heat transition will be organised (Sociaal-Economische Raad, 2018).

Energy policy in Schieoevers Noord will be interrelated with the city vision on the heat transition, as well as the Regional Energy Strategy, at least to a certain extent. For the RES, Delft is part of Metropolitan Region Rotterdam-The Hague. The developments in Schieoevers Noord should not hinder the city to become energy-neutral in 2050 – as with new buildings and businesses, the energy demand will rise – and the developments can possibly offer opportunities to catalyse the transition of Delft.

3.

Approach and methodology

research design

methods

As introduced in Chapters 1 and 2, the research project addresses a tension between the fields of organic area development and planning for a transition towards sustainable energy supply. These two fields intersect in the case study of Schieoevers Noord, and in a theoretical exploration of adaptive planning. This chapter describes how the research is set up; how theory and practice come together, how the case study is used, and which methods are used to generate the desired input to be able to answer the main research question and sub-questions.

3.1. Research design

The aim of this study is to create an approach that enables planners at the Municipality of Delft to make decisions on the future energy strategy for Schieoevers Noord, while the end state of the area development trajectory is unknown: a framework for adaptive planning. As little knowledge as well as practical experience is available at the interface of planning for sustainable energy and organic area development, this study is of an exploratory nature – since exploratory research "*tends to tackle new problems on which little or no previous research has been done*" (Dudovskiy, n.d.). A great advantage of exploratory research is the flexibility and adaptability to change it offers, as well as the possibility to create a better understanding of the problem. While exploratory research does not necessarily lead to conclusive answers, the thesis aims for conclusions though.

To work toward conclusions, in an exploratory context – the study adopts a design-based research approach with extensive use of a case study. Design-based research is abundant in educational research practices, and is characterised by the bridging of theory and practice. *"Importantly, design-based research goes beyond merely designing and testing particular interventions. Interventions embody specific theoretical claims about teaching and learning, and reflect a commitment to understanding the relationships among theory, designed artefacts, and practice. At the same time, research on specific interventions can contribute to theories of learning and teaching."*, states the Design-Based Research Collective (Baumgartner et al., 2003, p. 6). An iterative process, moving between theory and practice is the resulting approach and the way of creating new knowledge. Related are explanations on "research through design", stating that *"new knowledge is created through an action-reflection approach"* (Frankel & Racine, 2010, p. 523).

The switching, or acts of action and reflection between theory and practice, are supported by executing research to a specific case. "*The case study is a research strategy involving in-depth investigation of single events or instances in context, using multiple sources of research evidence*" (Martin & Hanington, 2012, p. 28); case studies have proved to be the bridge needed between theories and real-life experience – to inform decision-making. A case study offers the opportunity to study a complex system in an inclusive way: "*case studies are inclusive, assuming that consideration of the whole, covering interrelationships, is more advantageous than a reductionist study of parts, and that this depth compensates for any shortcomings in breadth and the ability to generalize*" (Martin & Hanington, 2012, p. 28). A theoretical framework is based on the hypothesis of a need for knowledge on adaptive planning in the context of sustainable energy and organic area development. The theory is strengthened by reflecting it towards a case study, representing real-life uncertainties, interrelations and interdependencies. Furthermore, designing for a case study creates ideas in what knowledge or support is needed in practice. A notion that should be made, is that a single case is not enough to either support or reject an hypothesis – though it can be able to shed light on theory, state Martin and Hanington.

So, in short, the research approach is exploratory – studying the potential of adaptivity in the context of sustainable energy planning and organic area development; a design-based research approach is used – constantly reflecting between theory and practice; and a case study is used to introduce the "practice" and to be able to study a situation in which actual interrelations and uncertainties exist. The approach is globally structured by the "double diamond", a design process consisting of the four steps *discover*, *define*, *develop* , and *deliver* (Design Council, 2005), shown in Figure 7. These diamonds, representing a step of divergence followed by convergence, can roughly be divided in a stage of studying the problem, resulting in a problem definition of design brief, and a stage of developing solutions for the problem. In the research project, the first phase creates insight into the case study, theory on adaptivity, and the status quo on energy planning, resulting in a need for not-yet-existing approaches to be able to solve part of the case study's challenges. The second phase of creating solutions answers this need, resulting in an adaptive planning approach for the Municipality of Delft. This is written down in the thesis as follows (and as shown in Figure 8). Chapter 4 describes a theoretical discover phase, Chapter 5 defines which drivers of adaptivity lack in current approaches. Chapter 6 discovers the case study and defines the sources of energy fitting an adaptive approach. Chapter 7 describes the point where the diamonds come together: the design brief. Chapters 8 and 9 develop and deliver solutions corresponding to the design brief.

Figure 9 displays the research methods corresponding to the phases of the double diamond model, and corresponding to the specific research questions they aim to answer; the notion that these methods are not used subsequently, but iteratively and parallelly is illustrated by Figure 10. As displayed in Figure 9, the research methods are ordered on a line between theory and practice. Mainly in the second diamond, a sharp distinction between theory and practice is hard to make; the spatial designs and energy scenarios, based on key figures, are stated to be more theoretical; the practical insights – from stakeholders for example – are noted as “practice”.

3.2. Methods

A range of methods (see also Figure 9) has been used throughout the study; methods to be classified as qualitative or as more quantitative; ones that are highly transparent and replicable – as well as methods based on design and interpretation. This paragraph describes how the mix of methods answers the set of research questions, and explains how and why these methods are used.

SQ1 – “Which drivers and barriers for adaptive (spatial) planning and adaptive (energy transition/climate) policy-making do exist according to literature?” – is answered by the execution of a *systematic literature review*. SQ2 – Which drivers of adaptivity are present in current, academic approaches for energy planning? – is answered in two steps: a *literature review* was carried out to get insight in academic approaches to energy planning that have been developed and used over the past years, and a *content analysis* has shown which of the drivers defined in SQ1 are present in these existing energy planning approaches. SQ3 requires a more quantitative study of sustainable energy potentials for the case study area (SQ3: How do locally (or regionally) available sources of heat and cold fit the adaptive area development of Schieoevers Noord?), for which the method of *Energy Potential Mapping* will be taken as a basis. SQ4 – Which design guidelines for plot developments could be used by the Municipality of Delft, concerning the (local) energy balance of the plot, to establish adaptivity and energy-neutrality in the spatial and functional design of Schieoevers Noord? – is answered by a parallel process of *designing a calculation model*, and *designing a part of a neighbourhood* (functional, energetic, and spatial design). Answering SQ5 – What are the implications of these guidelines for existing spatial and functional design proposals for plot developments within Schieoevers Noord? – is done by *comparing* the calculation and design outcomes to an existing plan for the plot where the “Schiehallen” are situated.

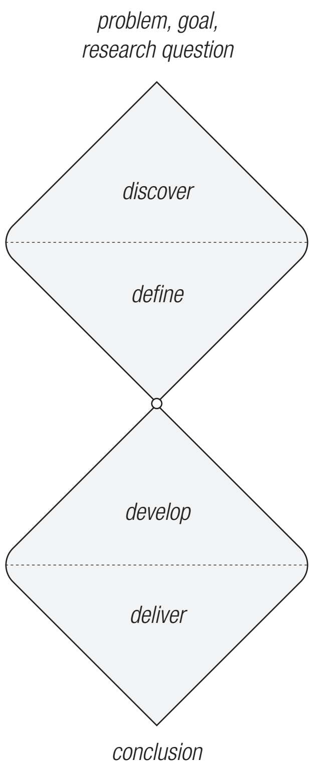
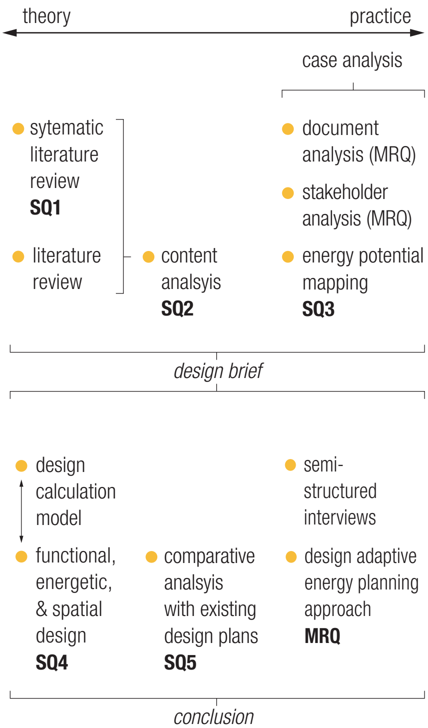


Figure 7: Design-based research: a research phase of problem exploration, resulting in a design brief, and a phase of problem solving

Figure 8: Reading guide: how the different chapters fit in the research process shown in Figure 7, and describe the outcomes of methods shown in Figure 9



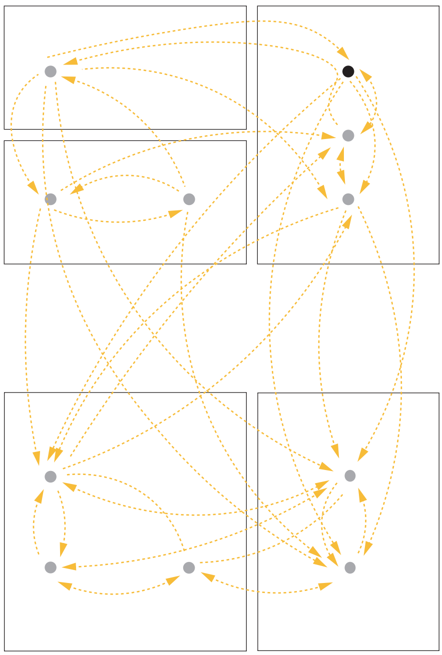


Figure 9: Overview of the research methods used per research phase, ordered from more theoretical to more practice-related

Figure 10: Schematic representation of the research steps: iterations are made, methods are not used step by step

The answer to the main research question – *How could an adaptive approach to energy planning enable the Municipality of Delft to guide the development of a future-proof energy supply (heat and cold supply) for Schieoevers Noord?* – is built up by the sub-questions, providing most of the ingredients. Some additional research methods are used, to retrieve additional information and insights on the specific case of Schieoevers Noord, Delft. These methods are a *document analysis* of the development plans and related documents, a *stakeholder analysis*, *semi-structured* interviews, and lastly, a *design for an adaptive energy planning approach*, suitable for the Municipality of Delft for the specific case of Schieoevers Noord.

All of the methods are described shortly below; in the case of methods that require a more extensive explanation (such as the systematic literature review), this is included in the related chapter.

Systematic literature review

A systematic literature review was carried out to create an overview of drivers and barriers for "adaptivity" in the context of (spatial) planning and (energy transition/climate) policy-making, as well as to define this concept. A systematic literature review is the preferred method, as it aims to minimise the bias of the author (Bryman, 2012). During literature search, it was concluded that literature, including the topic of planning for sustainable energy, related to organic area development and/or adaptive planning is not existing. Therefore, literature related to parts of the knowledge tension had to be used; a systematic review ensures the variety of perspectives in the studied literature – a literature review based on snowball sampling was expected to be more limited to one or a couple of perspectives, as the bias of the author is a steering force. So, a search query inserted in two search engines (Scopus and Web of Science), together with a predefined selection strategy (as described in Chapter 3) led to a selection of 21 articles that were included based on reading the full text.

The articles were analysed by a combination of open coding and axial coding (Bryman, 2012). Open coding was used, to cluster drivers and barriers in small groups in a first round of coding. A next round of (axial) coding connected related clusters, resulting in a set of 6 drivers. Due to the small amount of barriers found, no axial coding was applied there.

Literature review

A literature review is carried out to create an overview of – assessed to be – relevant academic methods and approaches designed for energy planning. This body of knowledge forms the basis for the research project: a starting-point on which to build further. The literature is retrieved in two ways:, based on the article "*Urban Energy Masterplanning – Approaches, Strategies, and Methods for the Energy Transition in Cities*" , which provides a clear overview of approaches and methods subsequently developed by Dutch academics since 2008 (Van den Dobbelsteen et al., 2018), and secondly, a search to academic energy planning methods for European cities and regions was carried out.

This type of literature review – narrative review – is of a more exploratory base than a systematic review; it is used to get insight in "what is already there" (Bryman, 2012). By the not-systematic way of finding literature, relevant energy planning methods can accidentally be left out. The articles are reviewed and written down in short methodological summaries; including the aim of the method, the relevant steps included in the approach, tools used in the approach, and when known – drawbacks are given as well.

Content analysis

Based on the outcomes of the systematic literature review, which defined six characteristics for adaptive processes, a content analysis is carried out. The literature gathered in the narrative review to energy planning methods is the content to be analysed. The content analysis would best be described as a qualitative content analysis as described by Bryman (2012). The analysis is based on a set of codes – being the six characteristics of adaptive processes. The codes have been predefined, yet the interpretation of the author is of great importance in the study: elements not exactly naming one of the characteristics, but implicitly mentioning them are incorporated as well.

The aim of the content analysis, in relation to the main research question, is to get insight in which knowledge is already present, and which characteristics of adaptivity are unknown or yet unapplied in the field of energy planning – helping to formulate a "design brief" and thereby helps scoping the second half of the research.

Document analysis

Several documents are published describing the case study: policy documents (concept development plan, and development plan), yet also advisory reports for the municipality (e.g. analysis of energy-related topics). These documents are analysed to get insight in the case study: what are the goals of the municipality, what are their ambitions, and how are they planning to realise these ambitions? The three elements important for the final energy demand and supply patterns – being spatial design factors (such as density and mixed-use), programme, and energy potentials – are subject of analysis. This is complemented by process related plans and ambitions – both elements from the defined set of drivers for adaptivity as well as other notions on organic and adaptive development are traced. Lastly, the document analysis can provide insights usable for the stakeholder analysis.

This document analysis is mainly carried out to understand the case study. The process of document analysis could also be named a qualitative content analysis – document are analysed on certain predefined themes, yet leaving room for the appearance of additional interesting themes while analysing.

Stakeholder analysis

A stakeholder analysis is carried out to get insight in both uncertainties and (responsibility for) decision-making; to get understanding of roles of different actors and potential influence they have on the unfolding of the organic development process in Schieoevers Noord. Here, information retrieved from the previously mentioned document analysis is incorporated, as well as parts of the semi-structure interviews and public letters to the municipality written by companies housed in the area. Furthermore, informal observations the author did – in the participation process organised during the development of the development plan – are incorporated, if considered valuable. The stakeholder analysis results in a power-interest grid of the involved stakeholders in the development process. The stakeholders that have the largest power and interests are studied more in-depth on their (identified) uncertainties, their positions, interests, and their mutual interdependencies. Thereby, the uncertainties that should be targeted by an adaptive process are discovered to a large extent.

Energy potential mapping

The method of Energy Potential Mapping is more extensively described as one of the energy planning methods that are reviewed in Chapter 5. The analysis of energy potentials, which is carried out for Schieoevers Noord is based on this method. However, for Schieoevers Noord, the future energy demand is unknown, so the energy potential analysis is mainly focused on potential sources; and the analysis is mainly focused on sources able to deliver (low-temperature) heat. Amongst others, the potentials of biomass, solar energy, geothermal energy, and waste-heat are analysed. Inspired by the energy planning method of REAP, the analysis is targeting different types of energy potentials, at the scale which they could serve (e.g. low-temperature waste heat is not efficiently transportable, and therefore studied on a smaller scale, than that geothermal energy potentials or biomass are). The method results in an overview of energy potentials for the area, complemented with an interpretation whether the sources would fit an adaptive development process or not.

Design of calculation model

To provide insight in ground rules for energy-neutral development fitting an adaptive planning paradigm, calculations are made on the relation between heat and cold demand and supply, in relation to spatial parameters (FMI, FSI) and functional programme. The base of these calculations is an Aquifer Thermal Energy Storage system, as will be explained. For such a system to function and provide a cluster or neighbourhood with sustainable heat and cold, a balance between heat and cold demand and supply should be created. This local heat balance forms the basis of the calculation model, which creates insight in the relation between mixing in the functional programme or building densities and the energy demand and supply patterns of building blocks and/or neighbourhoods. Based on the calculations, conclusions can be drawn and advice can be given, concerning the ambition level for low energy demands, concerning building density, and use of additional heat and/or cold sources.

Striving for adaptability (through transparency) of the calculation model, key figures are retrieved from official building norms for as far as possible; in all other cases, the author actively sought to key figures being as replicable or retrievable as possible. Since the developments will start in fall 2020 at the earliest, the norms that are used are the BENG norms (Bijna Energie-Neutrale Gebouwen, or Nearly Zero-Energy Buildings) – which will probably be used from summer 2020 onwards.

Spatial design

Designing of clusters of buildings as a method is done with a twofold reason: on the one hand to see which of the programmatic scenarios created by the calculation model are realistic from a developer's and an occupant's perspective (think of: making industry needs to be situated at the ground floor – to be accessible by truck) and which challenges arise from spatial design; on the other hand, it is used as an illustrative tool – to explore the diversity in possibilities created by ground rules based on local energy balances. The spatial design is illustrative and conceptual; many factors are excluded – yet it enables the author to iterate on the ground rules.

Comparative analysis

An analysis is made, in which existing ambitions and plans for plots in Schieoevers Noord are compared to the outcomes of the calculations and spatial design made within this research project. For the development of one of the plots – plot at which the "Schiehallen" (see cover image) are situated – the development plans are at a advanced stage; architectural design firm Mei architecten has made an architectural design proposal. This plan is reflected on, in the light of the triangle energy-space-function. Furthermore, the implications for other plots (with different supposed FMI and FSI) are studied – by comparing their input data, to the input data of the calculation model.

The execution of this comparative analysis, creates insight into the possible barriers for energy-neutral development and offers input to iterate on the framework. Thereby, the framework is adapted to the needs of the planning process for Schieoevers.

Semi-structured interviews

Five semi-structured interviews were carried out; two interviews were carried out with project members of the project team Schieoevers Noord at the Municipality of Delft (project manager and environmental strategist), one interview was held with two members of the board of "Bedrijvenkring Schieoevers", representing most of the enterprises housed at Schieoevers Noord, and one interview was held with a project developer. The fifth interview served as validation, and was held with another employee of the Municipality of Delft, without the scope of Schieoevers, but involved in several public-private partnerships concerning sustainability. A sixth interview has been initiated with the regional energy strategy (RES) representative of the Municipality of Delft, yet was not possible due to the limited working hours of the (potential) interviewee. The nature and goals of the interviews were quite different. The interviews carried out at the Municipality of Delft were quite similar – consisting of an exploratory part different per interviewee (focused on the status quo, steps made since the publishing of the development plan), a part with questions related to the definition of adaptivity, as well as the drivers of adaptivity, and a last part focused on the insights and possible implementation of this research. These two interviews are needed to design an adaptive energy planning approach for the Municipality of Delft. The third and fourth interview are mainly used to better understand the context, and are implemented in the stakeholder analysis. The last interview served as validation: the designed approach for adaptive energy planning has been reflected upon. All interview guides are included in *"Appendix A: Interview guides stakeholder interviews"* and *"Appendix B: Validation interview"*.

The goals of the set of interviews might differ, they all have an individual goal, and predefined knowledge to be gained. Therefore, semi-structured interviews were held, and not unstructured interviews. The semi-structured interview gives the structure needed to be sure to get the desired information, yet also provides the desired flexibility to pick up things the interviewee says and explore specific topics more in depth (Bryman, 2012). In the case of the municipality, the recurrence of some of the questions allows to compare the answers of the project manager and the environmental strategist. In the case of the other two interviews, the structure creates a certain control for the interviewer in the interview.

Design adaptive energy planning approach

The last "method" is one of synthesis and design; combining theory on adaptivity, literature on energy planning, case study analyses, interviews outcomes, results from calculations and spatial design, and all of the other methods described above into a morphological chart. The chart is a transparent and clear overview of all input, supporting the making of design choice. A design proposal is made for an adaptive approach to guide energy planning in Schieoevers Noord: in which the municipality gets the tools needed to handle the energy planning in a more adaptive way. This involves attention for all of the six characteristics of adaptivity, and a framework to shape ground rules for spatial and functional development with a local heat balance as foundation. A longitudinal design proposal is the outcome; one that does not finish after the first building rose.

4.

Uncertainty and adaptive strategies

uncertainty

complexity

adaptivity

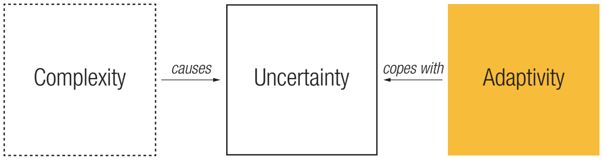


Figure 11: Main concepts of the theoretical framework – uncertainty, complexity, and adaptivity

Uncertainty is increasingly important in today's society; policymakers and also scientists providing decision support see and underpin the importance (W. E. Walker et al., 2003). However, the differences between uncertainties, their characteristics, and thereby the need for a range of strategical tools to cope with uncertainties, often lies outside our common sense. Wicked problems being the challenges of the century – of which a transition to renewable sources of energy is one – ask for a different attitude towards sometimes irreducible uncertainties. The development of new concepts as adaptive management comes with new attitudes towards uncertainty: no sole desire for the reduction of uncertainty is at stake, this stream practices acknowledgement of uncertainty and embraces it. Handling uncertainty is particularly important when it comes to long-term strategies (Zandvoort, van der Brugge, van der Vlist, & van den Brink, 2019).

The theoretical framework explores the concept of uncertainty: how can uncertainty be characterised, and which characteristics of uncertainty define the strategies to cope with that specific type of uncertainty? As stated in the introduction, this thesis hypothesises and studies the value of adaptive strategies to cope with uncertainty in the complex context of urban planning and directing an energy transition (Figure 11). To better understand this context, some ideas of complex systems theory are touched upon. Thirdly, and most importantly, the characteristics of an adaptive process are studied through a systematic literature review. An overview is created, defining the most important elements driving adaptivity in the context of planning and/or policymaking for urban development and/or the energy transition, as well as an exploration of the elements hindering adaptivity. This last part of the chapter answers the first sub-question (SQ1): *Which drivers and barriers for adaptive (spatial) planning and adaptive (energy transition/climate) policy-making do exist according to literature?*

4.1. Uncertainty

Uncertainty does not simply mean the absence of knowledge. Walker et al. (2003, p. 5) define uncertainty as: "*any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system*". Their definition is specifically applied in the context of uncertainty management in decision support. This paragraph describes a way to classify and thereby distinguish different uncertainties, it describes various sources of uncertainty, as well as strategies to deal with different types of uncertainty. Figure 12 shows the classification which is used for the thesis: the following paragraph explains the different columns step by step.

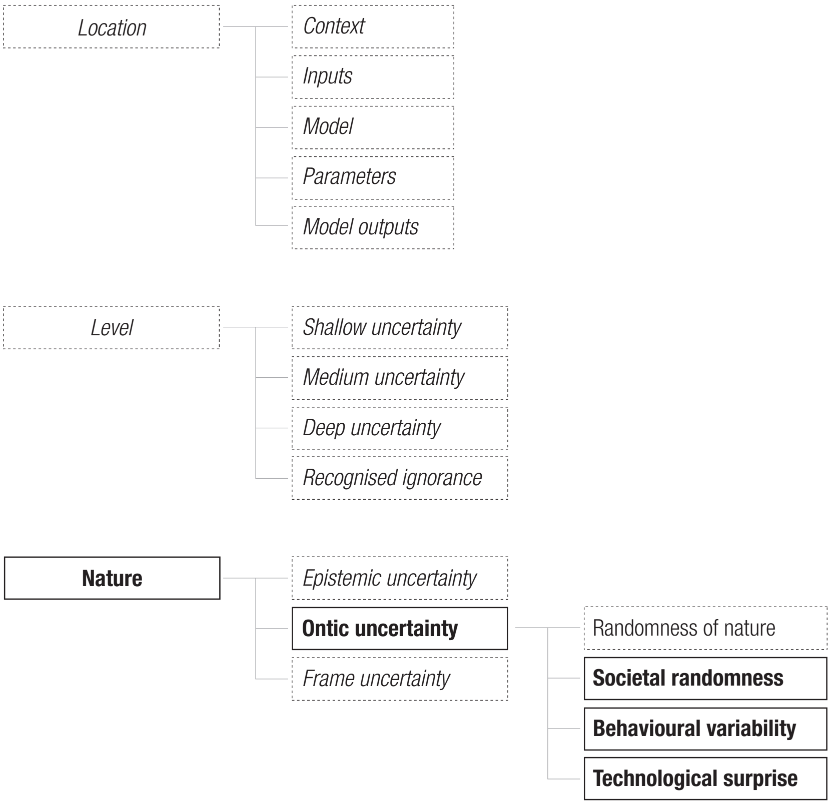


Figure 12: Classification of uncertainty – a three dimensional framework.
Dimensions (left), categories (middle) and causes of ontic uncertainty (right)

Classification of uncertainty

The presence of uncertainty in policy or planning processes is generally understood by decisionmakers. However, the need for a thorough understanding of the uncertainty at stake – its characteristics, magnitudes, and ways to deal with it – is not necessarily recognised.

Walker et al. (2003) distinguish three dimensions of uncertainty:

- "the *location* of uncertainty – where the uncertainty manifests itself within the model complex;

- the *level* of uncertainty – where the uncertainty manifests itself along the spectrum between deterministic knowledge and total ignorance;

- the *nature* of uncertainty – whether the uncertainty is due to the imperfection of our knowledge or is due to the inherent variability of the phenomena being described".

The *location* of uncertainty refers to what is actually uncertain (Zandvoort et al., 2019), where is the uncertainty located in the analysis framework of the system (W. E. Walker et al., 2003)? The dimension can be understood by the structure of a generic system model, in which the various sources of uncertainty can be pinpointed (W. E. Walker et al., 2003). The description of the model locations results from (the structure of) the system model. The aim is to pinpoint a location in a way that increases the understanding where in the model (or system) the uncertainty is generated (Figure 13). Walker et al identified five generic locations with respect to the modelling of a system: the context – or the determination of the system boundaries; model structure and model technical uncertainty – different interpretations of the dominant relationships within the systems, and the way this is technically modelled; inputs – external driving forces and system data; parameter uncertainty; and model outcome uncertainty.

The "severity" of the uncertainty is addressed by the *level* dimension; the gravity and possibility to quantitatively express the uncertainty. The level of uncertainty could be indicated on a scale from determinism to indeterminacy: from the ideal situation in which uncertainty can be described adequately in statistical terms (as mostly used in the natural sciences) to the situation in which we do not even know what we do not know (W. E. Walker et al., 2003) see also Figure 12. This spectrum is revised to a scale with four uncertainty levels, in which total ignorance is left out, based on reviews that altered the original scale (Kwakkel, Walker, & Marchau, 2010). The distinction of different levels aims to facilitate the choice for the right approach to cope with uncertainty. The last distinction of levels is as follows.

- Level 1 *shallow uncertainty* is the least uncertain: probabilities can be used to describe the likeliness of (uncertain) alternatives.
- Level 2 *medium uncertainty* is at stake when alternatives can be named and ranked in terms of likelihood. Decisionmakers or planners are able to point out whether alternatives are more, less or equally likely – but quantifying the difference is not desirable or possible.
- Level 3 *deep uncertainty* is characterised by the ability to enumerate alternatives, but the inability to rank these alternatives due to various reasons. Experts or decisionmakers might have other perspectives, or do not know for example.
- Level 4 *recognised ignorance* is the strongest form of uncertainty. Even when alternatives can not be pointed out, decisionmakers could or should keep open the possibilities of being wrong or of being surprised.

The *nature* of uncertainty is the key to strategically deal with uncertainty in decision making and planning. Literature describes either two or three different natures of uncertainty. Each of the read authors distinguish between epistemic uncertainty (also named uncertainty due to limited knowledge) and ontic uncertainty (or uncertainty due to variability) (Brugnach, Dewulf, Pahl-wostl, & Taillieu, 2008; Kwakkel et al., 2010; Rauws, 2017; Van Asselt & Rotmans, 2002; W. E. Walker et al., 2003; Zandvoort et al., 2019). A third nature of uncertainty which is addressed by Brugnach et al is frame uncertainty, or uncertainty due to ambiguity. Where Brugnach (2008) discussed the need of this third category in the context of natural resource management, Kwakkel et al. (2010) saw the need for this extra category to be generalised to a wider context, and explicitly added the category of ambiguity to the nature dimension in the revision of the original framework by Walker and Harremoes (2003).

Brugnach et al (2010) also describe uncertainty as a knowledge relationship between a decision maker (the knowing actor) and a socio-technical-environmental system (the object of knowledge). Corresponding with the distinction of uncertainty by its nature, three knowledge relations are identified: incomplete knowledge, unpredictability, and multiple knowledge frames. Each type of uncertainty is described in further detail in the next paragraph, in relation to the causes of uncertainty.

Sources of uncertainty

An overview of the distinctions of uncertainty, based on its nature and sources, is shown in Figure 12. The first named category of uncertainty was epistemic uncertainty, which is uncertainty resulting from the imperfection of our knowledge (also pointed out as the knowledge relationship "incomplete knowledge"). The incompleteness of knowledge ranges from a lack of (reliable) information to ignorance. Research or other empirical efforts might decrease the uncertainty. At the same time, an increase of available knowledge might also shed light on new and/or different uncertainties.

Ontic uncertainty (or unpredictability) is uncertainty due to inherent variability, as is the case in human and natural systems and concerning social, economic, and technological developments (W. E. Walker et al., 2003). Such complex systems are characterised by a variable behaviour; constantly learning and adapting to new conditions. Together with their

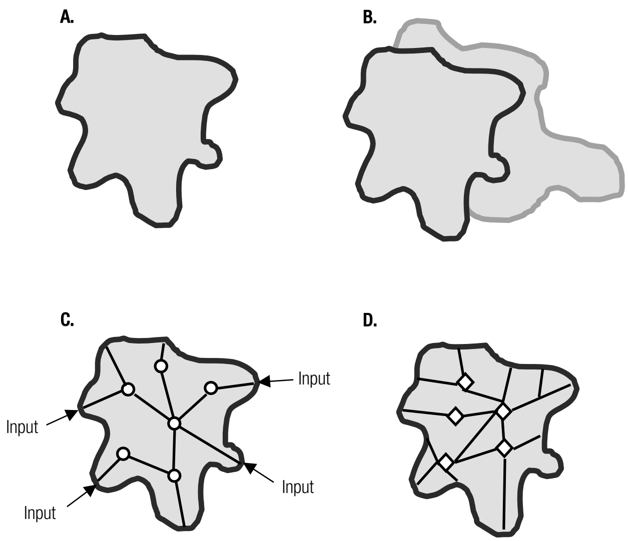


Figure 13: The location of uncertainty (Walker et al., 2003). A and B address context uncertainty: the step of defining the system boundary (A) might deliver ambiguity (B). C represents a model structure, consisting of the dominant relationships within the system, D shows how these dominant relationships are interpreted differently (compared to C) causing model structure uncertainty.

non-linear and sometimes chaotic behaviour, they become impossible to predict. This kind of uncertainty asks for acceptance of the unpredictability of the system, as a characteristic that will not change in the foreseeable future (Brugnach et al., 2008). Van Asselt and Rotmans (2002) distinguish between five sources of ontic uncertainty. The first four are also distinguished by Walker et al. (2003). Uncertainty is caused by either:

1. the inherent randomness of nature (e.g. the behaviour of clouds or ocean dynamics);
2. human behaviour (behavioural variability) – either "non-rational" behaviour, discrepancies between what people say and what they do, or deviations of "standard" behavioural patterns (e.g. consumption patterns);
3. social, economic and cultural dynamics (societal variability) – the non-linear, chaotic, and unpredictable nature of societal processes (e.g. the effectiveness of policy agreements – such as the Paris Climate Agreement, or institutional conditions for infrastructural changes in energy supply); and lastly
4. technological surprise: new developments or breakthroughs in technology or unexpected consequences of technology (e.g. renewable energy options).

Human behavioural variability is identified as a micro level scale uncertainty, whereas societal variability addresses macro-level behaviour.

The fifth cause of uncertainty according to Van Asselt and Rotmans (2002), is value diversity. A source of uncertainty coming forth from differences in people's mental maps, world views and norms and values – causing differences in perceptions and definitions of problems. However, multiple scholars (Brugnach et al., 2008; Kwakkel et al., 2010) suggested a third nature of uncertainty being frame uncertainty – a type of uncertainty being highly related to this fifth cause of ontic uncertainty by Van Asselt and Rotmans (2002).

Brugnach et al. (2008) elaborate on this specific nature of uncertainty. They define frame uncertainty or uncertainty due to ambiguity as: "uncertainty refers to the situation in which there is not a unique and complete understanding of the system to be managed". A frame is considered as "a representation of a valid view of a situation, reflecting a particular viewpoint". The involvement of multiple parties or actors in decision-making (or the management of a system) leads to a spectrum of opinions, experiences, expectations, values, and forms of knowledge.

Strategies to cope with uncertainty

Each of the three identified natures ask for a different strategy to deal with the uncertainty. Ontic uncertainty describes the unpredictability of a system, while frame uncertainty has to deal with different frames or views on the system or problem. The difference between frame uncertainty and epistemic uncertainty is best illustrated by its dimensions: whereas epistemic uncertainty could be described as ranging from complete knowledge, to complete ignorance – frame uncertainty could best be described as ranging from unanimous clarity to total confusion due to too many different yet valid frames. This asks for a fundamentally different coping strategy for each of the dimensions. As already stated shortly, epistemic uncertainty or uncertainty due to incomplete knowledge implies to be reducible or even eliminable by carrying out more research or collecting more or better data, and is thereby the most straight-forward from a perspective of coping with uncertainty.

For coping with frame uncertainty (dealing with multiple knowledge frames and/or ambiguity), a range of strategies is available as well. The problem lies either in conflicts between or multiplicity of frames of decisionmakers or stakeholders. This type of uncertainty may arise from different scientific backgrounds, different context-specific experiences, different general expert knowledge, differences in societal positions or ideological background, etcetera. As Brugnach et al. (2010) describe frame uncertainty as a difference in knowledge relationship between actor A and phenomenon X, and actor B and the same phenomenon X. Relevant strategies to address the uncertainty focus on the relationship between actors A and B, to address the differences between their frames. The following strategies could be used:

- “Persuasive communication” is based on the conviction of the other actor of the own’s frame of reference, by presenting it as attractive and worthwhile;
- A “dialogical learning” approach uses the power of an open dialogue to understand the frame of the other – mutual learning is central;
- Strategies based on a “negotiation approach” aim to reach an integrative agreement which is beneficial for all parties and makes sense from multiple perspectives or frames.
- Lastly, “oppositional modes of action” implies that actors impose their frame of reference upon others by force.

The *focus of this thesis will be on ontic uncertainty*, since energy planning for open-ended area development has to deal with *unpredictability* – a (physical) societal system is transforming to an unknown state; it is unknown what actions plot owners will take in the upcoming decennia. Literature on coping with this type of uncertainty is roughly dividable in two streams: either a strategy of control or a strategy that avoids control and focuses on adaptivity. The unpredictability which characterises ontic uncertainty implies that it is not possible to make predictions about a system or phenomenon, and that an increase of the amount of research which is done will not increase the predictability. A control strategy is based on the rationale that a system can be influenced by interventions that generate favourable conditions, which helps overcoming unpredictability. Control strategies are widely applied, mainly in natural resources management – however, they often include large-scale infrastructure, and thereby have to cope with large sunk costs and lack of flexibility. Scholars that emphasise on the effectivity of adaptive management, avoid control by creating the capacity to respond flexibly and effectively to changing and unknown situations, through learning and adaptation. Several strategies to respond in a good manner to unpredictable and uncontrollable systems, phenomena, and/or decisions are listed.

- The creation of "robust solutions": solutions that are useful under multiple plausible future scenarios;
- "diversification" of measures or solutions, in a way that part of the measures will be effective under each of the scenarios – allowing some of them to fail;
- to control damage – or deal with consequences and not with the phenomenon or system itself;
- the application of temporary adaptation strategies – taking measures that are feasible within the timeframe of an unfolding event;
- or lastly: improvise – so, no planning beforehand. Crucial for such a successful strategy are good monitoring, communication, and coordination capacity in crisis situations.

Brugnach et al. (2010) add to the previously described strategies, that at a higher abstraction level, a strategy to deal with uncertainty can also be the change of the nature of uncertainty. With this change in nature, a follow-up step consists of approaching the uncertainty with a strategy corresponding to its new nature. For example, an uncertain knowledge relationship based on incomplete knowledge or multiple knowledge frames, which is changed to unpredictability, means the acceptance that aspects of the problem or system can not be known, even not when more research is carried out, or discussions are held to explore different perspectives.

4.2. Complex systems theory in a nutshell

To be able to understand how a societal system, an urban environment, or an energy system – interwoven with the physical and social environment – changes, it is of importance to understand how a "complex system" is described in general; which features do they have, and (how) can they be steered?

Complex systems are open systems: systems that interact with their environment, and as a result constantly change and develop. They are built up of many diverse components (e.g. actors) and interactions between components (e.g. in networks of actors). The interactions between components are characterised as non-linear, meaning that small stimuli may cause large effects or no effects at all; in the same way large stimuli may cause either large, small, or no effects on the system. Complex systems contain many feedback loops: interactions between components can create either negative or positive feedbacks. Systems are prone to path dependency: influence of systems' history and previous paths on their future states. Systems contain multiple organisational levels; and thereby emergent properties – the ability of lower level interactions to change higher level organisational principles. Another characteristic of complex systems is the existence of multiple attractors: a preferred, stable, system state towards which systems are moving (Rotmans & Loorbach, 2009).

Cherp, Jewell, & Goldthau (2011) name as most important characteristics of complex systems, their interconnectedness (the large number of interacting elements), their unpredictability, non-linearity, path dependency, their openness – and thereby the unclear definition of system boundaries; and lastly adaptability and resilience. So, complex systems themselves, are able to adapt to restore resilience – in previously used terms: by adapting the system, it steers itself back towards an attractor, a state of stability.

A system which is able to maintain its functioning while undergoing stresses, shocks or any form of disturbances, is resilient. Adaptability, in this context, is the ability of system actors to influence resilience (B. Walker, Holling, Carpenter, & Kinzig, 2004) In the context of energy transitions or area development, this property of systems striving for resilience is not necessarily just positive. In the case of sustainable energy, it could be said that our current system is "locked-in" in a system of fossil energy sources (Kupers, Faber, & Idenburg, 2015) – a situation in which path dependency created a negative outcome. A tipping point is needed at which a system can flip towards a different state: transformability is needed here instead of adaptability – the capacity to create a fundamentally new system, when conditions create an untenable situation for the current system (B. Walker et al., 2004).

In the scope of this project, the current spatial system of Schieoevers Noord and energy system of the Netherlands are to be transformed. These systems in transition – the pathways towards new system states – should be resilient: the pathway of energy planning for organic area development should be able to cope with changing conditions, stresses, etcetera – requiring adaptability.

4.3. Systematic review of the concept adaptivity

As is motivated in *Chapter 4 Approach and Methods* as well, a systematic literature review to the concept of adaptivity was carried out. As uncertainty caused by complexity is hypothesised to benefit from adaptive strategies, it is of importance to know what that actually implicates: an adaptive strategy. The word adaptive (or adaptation, adaptability etcetera) is abundantly used – but was does it mean in the specific context of adaptive (spatial) planning and (energy transition/climate) policy-making? Both of these aspects aim for transition: change of the current system in to a more comfortable and sustainable one. What aspects should (always) be included in adaptive processes for area development and energy transition, and which should be overcome? Both the definition and those drivers an barriers are studied by means of a systematic literature review: a transparent review, aiming to create a broad view on the concept of adaptivity – not steered by the author's bias (Bryman, 2012).

The search for literature was carried out by using both Scopus and Web of Science as databases of reference; the two complement each other. As the context of the energy transition is a present-day topic of research; the literature search should result in a up-to-date set of research results. Literature published in the last ten years (2009-2019) was included, with an amount of minimally 5 citations or a publication date of 2017 or later. This last criteria could be used, as a lot is published in the context of (energy) transitions at the moment. Furthermore, some subject areas are directly excluded in Scopus and Web of Science. Both databases use their own structuring methods of subject areas, so different areas are selected. Only the real "outliers" as medicine, tourism, and mathematics are excluded.

Articles were included that describe either how adaptivity or adaptive approaches contribute to a transition or transformation process, or how adaptivity enables stakeholders to cope with complexity, long-term planning and/or the uncertainty or unpredictability that comes along with transition processes. The scope is adaptivity in a governance or planning process, not adaptivity in a purely technical system. Articles focusing on climate adaptation or strategies concerning consequences of climate change were excluded, just as articles in a context differently than either energy and/or sustainability transitions, or urban planning.

The keywords were defined based on three elements: adaptivity (being the main theoretical concept), the research context (energy/sustainability transition and urban transformation), and the main rationale to study adaptivity: the complexity and uncertainty inherently present in planning processes focused on the long-term. For each of these categories, relevant synonyms or search terms were collected, by help of explorative snowball literature search which was done to explore the research topic (e.g. by means of the key words, titles and abstracts of literature considered as accurately touching the research questions). The search terms used as inserted in Scopus are written down below; for the search in Web of Science the same query is used, but adapted to the search Boolean options of that search engine.

The search query that was used, is:

> TITLE-ABS-KEY ((adaptiv* OR adaptab* OR "adaptive capa*" OR flexibility OR robustness *OR "adaptive governan*"*[1] *OR "adaptive management" OR "adaptive spatial plan*" OR "adaptive plan*" OR "adaptive energy plan*"*))
>
> **AND**
>
> TITLE-ABS-KEY (("energy transition" OR "transformative change" OR "socio-technical change" OR "sustainable adaptive plan" OR "sustainability transition" OR "transition management" OR "urban transformation"))
>
> **AND**
>
> TITLE-ABS-KEY (("long-term plan*" OR ("long-term" W/5 change) OR ("long-term" W/5 transformation) OR uncertain* OR unpredictab* OR complexity OR "wicked problem" OR "complex problem" OR (unforesee* W/5 conditions)))

Based on the search query, year of publication, amount of citations, and subject areas, 77 records were found[2]. These were assessed on eligibility based on their title, abstract, and

---

[1] The author is aware that the terms in italic also meet the search term "adaptiv*" – yet at the moment of searching this was not noted. For the publication of this thesis is was chosed to display the used query – not a corrected version of it.

[2] The search for this query was done in March of 2019. Since then, new literature has been published. A last check upon the release of new literature withinw the scope of the query has been done in December of 2019. None of the papers published since March has been added to the results – as none of them did meet the selection criteria.

key words; on the presence of a clear link between adaptivity and (planning for) an energy transition or urban planning, and if this was not necessarily clear, whether it focused on a way of coping with complexity or uncertainty in a transition context. 28 articles were found to meet these criteria; articles focusing on enhancing resilience and adaptation to climate change (mostly in the area of water management), rather than focusing on change in the direction of a society based on renewable energy, were excluded. Furthermore, articles which were written in depth on a specific technology, or a specific fuel were excluded as well. The full-text of the resulting 28 papers was read and assessed with the same criteria in mind, leading to the exclusion of 7 more articles. These were either too much written from the climate adaptation perspective, or focused on bottom-up urbanism without any attention for adaptivity and/or energy transition. Furthermore, one article focused too much on flexibility in the context of energy security in developing countries, and one article had a too technical focus on creating flexibility by using power-to-X methods. The resulting 21 papers are included and analysed to answer SQ1 (Figure 14).

After collection of data, the articles are coded using a combination of open coding and axial coding. A first round of coding was done by open coding: "*the process of breaking down, examining, comparing, conceptualizing and categorizing data [...] this process of coding yields concepts, which are later to be grouped and turned into categories*"(Bryman, 2012, p. 569).

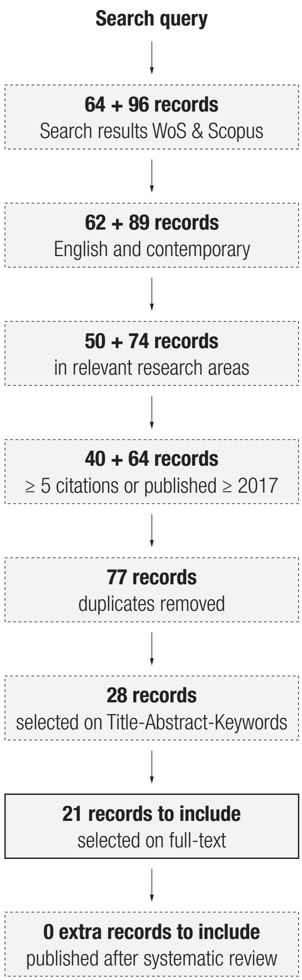


Figure 14: Overview of the selection process of records to include in the literature review

To be able to assess whether the different perspectives of literature (as will be explained in paragraph 3.4) would generate different sets of drivers and/or barriers, the open coding process was done with a basic distinction of three perspectives (Adaptive Management, Transition Management, and control-oriented planning). The outcomes showed that the three perspectives mostly overlapped with each other – describing many same concept by just choosing different words. A second round of coding could be classified as axial coding – "*a set of procedures whereby data are put back together in new ways after open coding, by making connections between categories*" (Bryman, 2012, p. 569). The codes assigned to pieces of text in the open coding process were clustered firstly; a process which was iterated when linking the small texts to the new categories. This process of axial coding resulted in a cluster of 6 characteristics or drivers/enablers of the concept adaptivity. Both the amount of barriers found, as well as the overlap between codes assigned in the open coding process, resulted in the choice to not apply a round of axial coding to the set of texts marked as barriers.

4.4. Results systematic review

The results of the systematic research are split over four themes: an insight in the abundance of different perspectives in the studied literature, definitions of adaptivity, drivers for or characteristics of an adaptive process, and barriers for adaptivity.

Perspectives from literature

Twenty-one papers have been included in this literature review, of which none presents research with the scope of sustainable energy planning suited for organic or adaptive area development and/or spatial design. This perspective seems to be newly shaped by the author. However, all of the reviewed papers are written from perspectives that together give insight in what the desired perspective on adaptive energy planning could entail. Some of the papers were entirely focused on adaptive planning, others just partly.

A couple of tendencies or clusters were spotted in the set of literature. Strategically, on how to cope with the management of complex systems, on how to design policies or cities, three tendencies were identified. Firstly, papers with roots in control-oriented strategies – researching how such planning strategies can open up to adaptive approaches; secondly, research on Transition Management (TM)– a perspective that admits the fact that societal systems cannot be controlled, but that aims to influence the direction and pace of societal change dynamics (Roorda et al., 2014; Rotmans & Loorbach, 2009); and thirdly, literature dedicated to Adaptive Management (AM) – a perspective which mainly focuses on maintaining system functions in the face of external change (Foxon, Reed, & Stringer, 2009). Next to these content-related distinction, it is seen that most of the literature focuses on (environmental) policy-making, some of them focus on urban planning, and a couple focus specifically on policy related to urban environments. Lastly, part of the papers specifically used complex systems theories, or highlights the research context being socio-ecological systems (mostly in the AM perspective) or socio-technical systems (mostly TM).

All of the perspectives, and all of the individual papers as well, have a focus which highlights certain elements of adaptivity. During the coding process however, no clear distinction between the drivers and barriers of each of the perspectives was found. Furthermore, there were no drivers found which solely originated from one perspective. For the remainder of this chapter, the distinction between the different perspectives is not explicitly mentioned.

Defining adaptivity

Not all of the papers give a definition for the word "adaptive" or any of the other forms of the verb "to adapt": 10 out of 21 define adaptive, adaptive planning, adaptation, or adaptability. The word "adaptive"– as a sole term – is defined as "*meaning that it can be adapted to changing (unforeseen) future conditions*" (W. E. Walker, Haasnoot, & Kwakkel, 2013, p. 956), "to cope with new system conditions" (Ferguson, Frantzeskaki, & Brown, 2013, p. 34), and "*to adapt over time to new circumstances and surprises*" (Hamarat, Kwakkel, & Pruyt, 2013, p. 408). So, in essence, it can be said that adaptive means "to be able to change when conditions change"; these conditions being either foreseen or unforeseen (W. E. Walker et al., 2013). When incorporating definitions from the related words, this definition can be extended. Adaptability, as most closely related term, is defined as the capacity of system actors to adapt the system (Peter & Swilling, 2014; Schilling, Wyss, & Binder, 2018); and the extent to which a process can be adapted (Schilling et al., 2018). Adaptation takes place either as response to changing external drivers (Campos et al., 2016; Foxon, Reed, & Stringer, 2009; Moore, Olsson, Nilsson, Rose, & Westley, 2018), and internal processes (Moore et al., 2018). Adaptation can either be a process of slow, incremental change (Schilling et al., 2018), or quick movement to adjust to rapidly changing conditions (Linnenluecke, Verreynne, Scheepers, & Venter, 2017). Adaptive management aims to maintain system functions or keep at the current pathway while coping with or responding to changing conditions (Foxon et al., 2009; Moore et al., 2018).

Combining all of the above, the following definition for the word “adaptivity” is created, and will be used throughout this thesis:

> “adaptivity is the characteristic of a system or pathway to adapt or be adapted by system actors, as a response to changing (unforeseen) future conditions”.

A term which is often used in the same context, is “robust” or “robustness”. However, there is a clear distinction to be made. Whereas adaptivity is a characteristic of a plan to be able to change, robustness means that a plan “*performs satisfactorily under a wide variety of futures*” (W. E. Walker et al., 2013, p. 956).

Characteristics of an adaptive process

After a first round of open coding and a second round of axial coding, the literature review resulted in six (clusters of) drivers for an adaptive process of systemic change; the preferred word choice of the author would be “characteristics” of an adaptive process. These characteristics are clusters of codes retrieved from multiple papers, mostly retrieved from multiple of the aforementioned perspectives as well. A step of interpretation is made by the author, to be able to translate the full set of codes to a comprehensible and workable set of characteristics. The six characteristics are listed first, more extensively described afterwards, and visualised in Figure 15.

An adaptive process should:

1. explore and embrace uncertainty;
2. connect long-term visions with short-term actions;
3. treat a process of systemic change as experiment;
4. focus on conditions for development;
5. spread responsibility for decision-making over the system;
6. integrate the diverse knowledge of those involved.

Prior to an in-depth underpinning per characteristic, the author wants to stress the following – in line with literature. To ensure the success of a transition or process of systematic change, adaptivity is a key element, yet the element of stability needs to be included as well to ensure progress. This is discussed by the concept of “resilience of sustainability transitions” involving the dimensions stability, adaptability, and progress (Schilling et al., 2018). A comparable balance is described by Cherp et al. (2011), using the terms of exploration and exploitation forming a trade-off.

The concept of "resilience of sustainability transitions" applies the definition and elements of resilience as described by Walker et al. (2004) to a transition process instead of a system; it is defined as "*the capacity of a system to absorb disturbance and adapt the sustainability transition process to still essentially retain its progress, goals, and pathway*" (Schilling et al., 2018, p. 5). Transition progress is the foundation of the concept – which is determined by the relation between transition drivers (innovation) and regime resistance. Stability defines the reaction to – internal and external – disturbance, whereas adaptability is established by the capacity of system actors to manage and adapt the system. Stability and adaptability can negatively affect each other: stability could hinder re-orientation of the transition process on the one hand, and as such, adaptability can decrease the commitment of system actors, in case of overly frequent adaptations and re-orientations interrupting stabilisation. A proper balance is needed to allow for a stable yet flexible transition process. The authors add the notion that the three dimensions should be in different states of balance per phase in a transition process: at the start – progress should have the highest priority, when accelerating – stabilising aspects should get attention, and further in the process (the longer it takes) adaptability is key – as system structures change over time (Schilling et al., 2018).

The trade-off between exploitation and exploration highlights the same balance: "*We argue that effective global energy governance requires striking a tenuous balance between the determination and efficiency needed to drive energy transitions with the flexibility and innovation necessary to deal with complexity and uncertainty*" (Cherp et al., 2011, p. 75). Exploitation refers to governance mechanisms supporting goal achievement, by so-called "hard coordination"; it increases stability, coherence, focus, and efficiency of a system. Exploration, on the other hand, makes use of softer forms of coordination; flexibility, diversity, experimentation, and innovation are central. Exploration enables a system to deal with uncertainty and nonlinearity. A balance between both forms of coordination is required according to the authors, to ensure progress and transformation, while also move along with the rapid changes expected in the context of energy systems.

1. Exploring and embracing uncertainty

The need for active exploration of uncertainties and the acceptance or embracing of uncertainty is referred to in twelve of the reviewed papers. Regarding the need to explore uncertainties, authors state the following. Walker et al. (2013) name the exploration of a wide variety of uncertainties as one of the key principles for the development of a sustainable

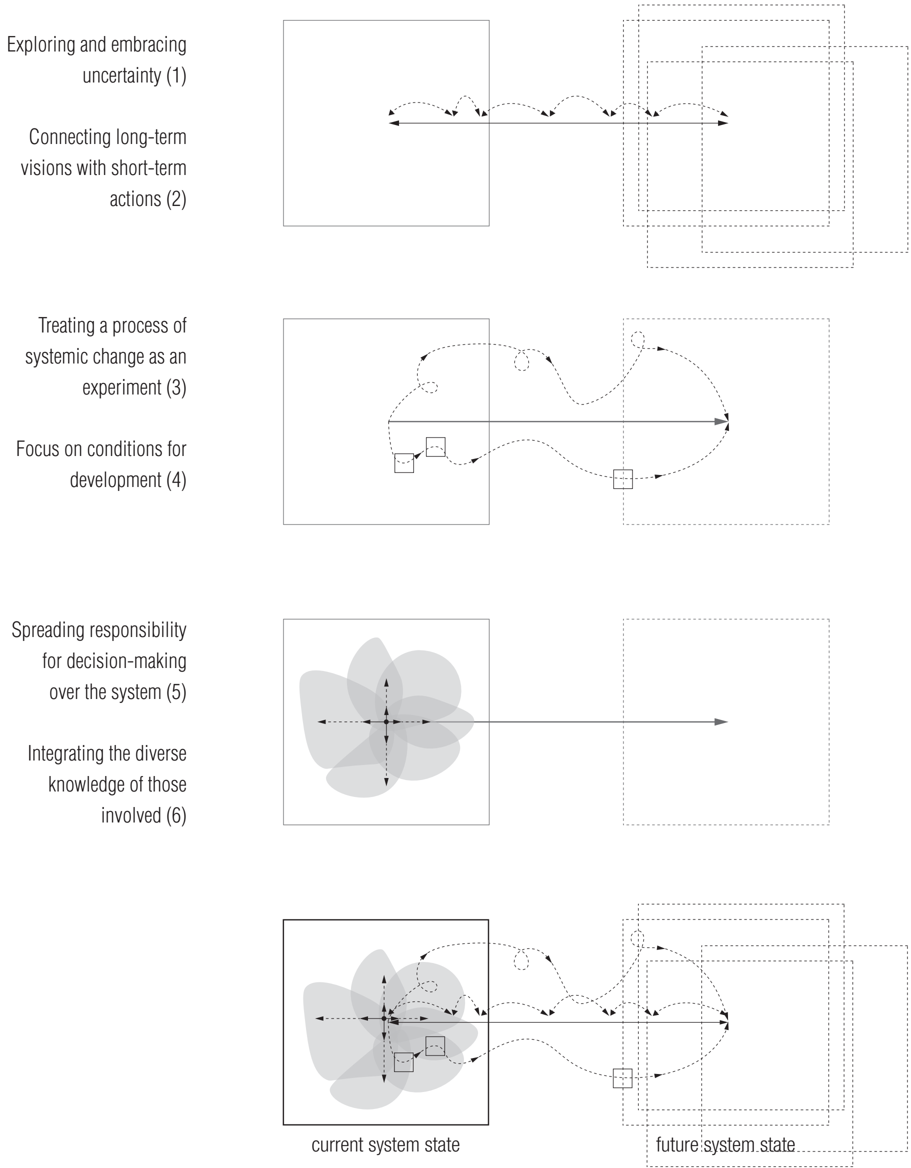


Figure 15: Factors collectively representing an adaptive policy-making process or (urban) planning process. The figure is to be read as: if a system transforms from a current state to a future state, where in this system change is the characterestic of adaptivity present? (1) explores uncertainties in future states, (2, 3 & 4) connect now and the future, (5 & 6) describe whom (actors) guide or impact the system change

adaptive plan; this exploration should take place in a dynamic way, over time. In the context of urban planning, it is advised to planners to ensure active and continuous exploration of likely alternative development trajectories in response to ongoing system dynamics (Rauws, 2017; Rauws & De Roo, 2016). The acceptance or embracing of uncertainty as a prerequisite for an adaptive process, is stated by many (Ferguson et al., 2013; Foxon et al., 2009; Rauws, 2017; Rauws & De Roo, 2016; Raynor, Doyon, & Beer, 2017; Voß & Bornemann, 2011; W. E. Walker et al., 2013). An adaptive paradigm should embrace uncertainty and complexity (Ferguson et al., 2013). With complexity being more widely acknowledged, this adaptive paradigm indeed emerged – a paradigm in which the limits to predictability are acknowledged (Foxon et al., 2009). Furthermore, it is stated that planners should accept inherently irreducible future uncertainties and shift their focus to reducing uncertainty about the prospected performance of their policies and/or plans (W. E. Walker et al., 2013). In the context of urban development, Rauws and De Roo (2016, p. 1056) state the following: "*non-linear development trajectories challenge planners and other stakeholders to embrace uncertainty as a core component of urban development*". Additionally, the acceptance of uncertainty should come with flexible and adjustable objectives at a system-level – enabling a system to better respond to changes from within the system or from the outside (Foxon et al., 2009). During a period of change, a system's structure changes, so the set objectives should change as well – complexity "is at odds with the formulation of specific objectives" (Wittmayer & Loorbach, 2016, p. 18).

Several authors stress the usability of strategic tools to accept or explore uncertainties: narratives, scenarios, and dilemma thinking could help. In the context of decision-support, uncertainties are often tried to capture in models. Narratives could help explore uncertainties that are difficult to describe by quantitative models, and can thereby help analyse a broader spectrum of future uncertainties (Li & Pye, 2018). Linnenluecke et al. (2017) describe scenario building as a tool for expanding knowledge about future change, and involves identifying uncertain forces. Foxon et al. (2009, p. 15) also introduce the usage of scenario development: "*scenario development is increasingly being used to help decision-makers better understand, anticipate and respond to the sorts of dynamic and uncertain change that are likely to happen in future*". Scenarios are described as future images presenting situations for which planners need to prepare. Specifically addressing unpredictability could be done by the use of "surprise scenarios" – scenarios that seem highly unlikely, but that would have a significant impact if they would occur. Lastly, Sharpe, Hodgson, Leicester, Lyon, and Fazey (2016), underwrite the use of scenarios, and add the value of dilemma thinking as a tool to explore the problem and identify critical unknowns: a method in which choices are viewed as two competing sets of values which both must be respected.

These tools are mainly used for identifying uncertainties, rather than supporting the acceptance of these uncertainties. However, the author would dare to state that acceptance and understanding of uncertainty are two reciprocal concepts; in line with Foxon et al. (2009) stating that understanding of uncertainty is related to the ability to anticipate and react to uncertainty.

2. Connecting long-term visions with short-term actions

Inclusion of the factor time in planning – together with a feedback mechanism – allows for adaptive plans. The need for the factor time is described by Walker et al. (2013 p. 963): "*an endpoint in the future is not only determined by what we have experienced in the past and envision for the future, but also by what we will experience on our way to the future [...], how we respond to changes over time, and how our vision for the future changes over time [...]. Considering time in the development of a plan, results in a plan that can adapt over time as conditions change.*"

The most mentioned aspect related to the factor of time, is the creation of a long term vision, and the connection of this vision with concrete short-term actions. Literature mentions the need to connect short-term objectives and long-term goals (Campos et al., 2016); to commit to short term-actions yet keeping options for the future open (W. E. Walker et al., 2013); to combine inspiring visioning with a pragmatic development approach in case of (unplanned) opportunities that arise (Rauws & De Roo, 2016); and to use long-term thinking (>25 years) as a framework to shape short-term policy (Wittmayer & Loorbach, 2016).

Wide stakeholder involvement, or co-creation, in the process of long-term goal formulation and planning, can facilitate a "*free flow of innovative ideas*" (Cherp et al., 2011, p. 80), or visioning – the imagination of possible futures can stimulate pioneering actions to achieve the future vision (Sharpe et al., 2016). These innovative ideas or pioneering actions are a result of the distance created between the future vision and the current concerns and interests of stakeholders, enabling to bundle knowledge and agree upon a collective movement in a positive direction. A strategic tool supporting the process of translating collective future visions into short-term action, is the "transition image": a translation of generic guiding principles to concrete settings, subsectors or themes (Rotmans & Loorbach, 2009). These images, creating consensus among actors about what sustainability means for a particular topic, inspire and mobilise actors to take action. A transition vision should involve multiple transition images, together embracing multiple pathways while also being adjustable in case of new insights.

The connection of the short-term and long-term should be accompanied by a framework to guide future actions (W. E. Walker et al., 2013) consisting of for example monitoring systems, triggers and contingency actions. (Hamarat et al. (2013) plead for taking only urgent and non-regret actions, while postponing all others to a later state. When choosing for such a strategy, a framework with predefined responses that should be given at the reach of trigger points, or certain moments at which particular decisions or actions should be taken, is needed to complement basic policies. Walker et al. (2013) propose to build flexibility in policies by sequencing actions over time, yet leaving options open to deal with multiple (plausible) future conditions. Strategic tools to bridge the short-term and long-term, are backcasting and forecasting, complemented by reflection on future developments to be able to adapt the pathway (Wittmayer & Loorbach, 2016). Forecasting implies the understanding of current trends, the variables steering those trends, and how they can create future situations which ask for a response. Backcasting is built on a shared vision of a (sustainable) future state, whereafter strategic milestones are set back to the present.

3. Treating a process of systemic change as an experiment

The role of experimentation and learning – as well as the iterative character of a process, including mechanisms for monitoring, evaluation and evolution – is the characteristic of an adaptive process which is most abundant in literature.

The concept of adaptive policies is retraceable to 1927, to the proposal of Dewey to treat policies as experiments: as working hypotheses rather than programs to rigidly execute. His way of thinking aimed to promote continual learning and adaptation in response to experience over time (Dewey, 1927). The notion to think of policy as of experiments is supported by many (Ferguson et al., 2013; Hamarat et al., 2013; Raynor et al., 2017; Rotmans & Loorbach, 2009; Voß & Bornemann, 2011; W. E. Walker et al., 2013; Westley, Olsson, Folke, Homer-Dixon, et al., 2011; Wittmayer & Loorbach, 2016). Not explicitly using the word "experimentation", other authors emphasize the need for "learning by doing" (Boodoo, Mersmann, & Olsen, 2018; Campos et al., 2016; Cherp et al., 2011; Rauws & De Roo, 2016).

Adaptive management is said to adopt a science-like approach to problem solving: designing, testing, and reformulating hypothesis (Voß & Bornemann, 2011). Foxon et al. (2009) add that AM designs interventions to test hypotheses on the functioning of a complex system, Voß and Bornemann (2011) emphasize that experiments are supposed to support knowledge acquisition and learning about system's structures. Experimentation is about the definition of a societal challenge and the ideation of ways to address it in a multi-actor setting: actors learn while engaged in action. (Wittmayer & Loorbach, 2016) .

Learning by doing manifests it self among others by the need of constant revisions of goals, rules, and directions of future development (Foxon et al., 2009). As Rotmans and Loorbach (2009, p. 189) state "*We have formulated rules for managing societal change, but we realize that once we apply these rules in a process context, they need to be adjusted because the conditions and dynamics (content) will change as a result of the application of these rules.*". An iterative or multi-stage decision-making process allows for a constant revision of assumptions, when new uncertainties are revealed (Li & Pye, 2018). Adaptive planning or management is per definition an iterative – cyclic – process (Campos et al., 2016; Foxon et al., 2009; Hamarat et al., 2013)

An important factor within an experimental process, or a process of learning by doing, is monitoring and evaluating; such as Walker et al. (2013, p. 955) state "*continuously monitor the world and take actions if necessary*". A strategy of monitoring and adapting is preferred for strategic long-term planning, over a strategy of predicting and acting. Reflexivity is preferred over determinism; which reflects the notion that sustainability transitions specifically, and complex systems generally can be directed to only a limited degree (Boodoo et al., 2018; Rauws, 2017; Rotmans & Loorbach, 2009; Voß & Bornemann, 2011). Monitoring of developments over time and the specification of actions which should be taken when certain trigger values (or tipping points) are reached, should complement a basic policy to increase its flexibility and adaptivity (Hamarat et al., 2013; W. E. Walker et al., 2013). In the learning process of transitions, continuous monitoring is an important aspect; a distinction is made between monitoring the transition itself (the process of change or development) and monitoring transition management (the process of steering or directing change).

A way to support experimentation and learning in specific processes, is the creation of "policy laboratories", "Change Labs", or "Urban Transition Labs" (Westley, Olsson, Folke, Homer-Dixon, et al., 2011; Wittmayer & Loorbach, 2016). These change laboratories offer a place to explore wicked problems in a cross-sector and cross-disciplinary decision-making setting. Specifically, the Urban Transition Lab is coupled to a physical location in a city – where multiple domains interact automatically. "It is a hybrid, flexible and transdisciplinary platform that provides space and time for learning, reflection and development of alternative solutions that are not self-evident", state Wittmayer and Loorbach, (2016, p. 21).

4. Focus on conditions for development

The fourth driver for or characteristic of an adaptive process – emphasize on conditions for development – originates from two different perspectives found in literature. Literature originating from urbanism studies as well as from complexity science, was fruitful for this characteristic. It is stated that in social innovation contexts, setting the conditions works better than setting down rules (Westley, Olsson, Folke, Homer-dixon, et al., 2011); and that "*While the strategic spatial planning repertoire is mainly oriented at fostering desired change given certain conditions, the adaptive planning approach targets exactly these conditions as the object of intervention.*", states (Rauws, 2017). A shift from the content and process towards conditions for development is needed; these conditions are end-state independent. The type of conditions for urban area development that can be influenced by urban planners, are distinguished in two categories by Rauws: conditions related to spatio-functional configuration and conditions related to capacity building of local actor coalitions. The conditions that are defined for the guidance of spatio-functional transformations, are about: (1) "*securing the quality of life under a variety of potential development trajectories*", (2) "*generating context-sensitive flexibility in the pace and direction of development*" and thereby aiming for more incremental development, and (3) "*stimulating the emergence of societally desired development trajectories*" (Rauws, 2017, pp. 37–38). The operationalisation of these conditions can be facilitated by both clear and ambiguous formulations and explanations of the guidelines, and by choosing the right level of generalisation: conditions that apply to a city can be more generic, than conditions applying to a street for example. The second type of conditions concerns the capacity building of local actor coalitions: "*The challenge for planners is to facilitate local coalitions in developing their initiatives and as such trigger the self-innovating and self-stabilizing capacity of urban systems, without fostering socio-spatial segregation.*" (Rauws, 2017, p. 40). These actor targeting conditions include measures that foster information exchange between actors, and that increase the connectivity between actors (Rauws & De Roo, 2016). The authors believe that governments should play an active role in empowering local actors. The previously mentioned "Change Labs" can be of value in empowering local actors, as it creates conditions for social learning, to share knowledge and integrate different perspectives, which in turn enhances local innovative capacity (Westley, Olsson, Folke, Homer-dixon, et al., 2011).

The empowerment of local coalitions, can be seen as a parallel to the need for creation of space for niches in transition contexts, and the need to focus on frontrunners. In terms used to describe the dynamics of complex systems, a niche is a new – small – structure in a system which deviates from the "regime" (simply said: the structure, culture, and practices of a societal system) and which might build up a new regime. Frontrunners are the "agents" in a system that can create new structures – they can do so if and because they are not directly dependent on the regime. Empowering these niches and frontrunners (stimulating innovation), by e.g. knowledge, finances, exemptions of rules and laws, space for experimenting, and developing coalitions and networks, is needed to create a regime shift. Such a shift of radical change should be built up in incremental steps – allowing the system to adjust to new conditions and build up new structures: emergence. It can be directed by decision-makers by setting out a broad direction for adaptive change, and by letting details emerge over time (Linnenluecke et al., 2017).

5. Spreading responsibility for decision-making over the system

After four characteristics pointing out "how" to organise an adaptive process, this one focuses on the subject of these actions: who is responsible for decision-making in adaptive processes. In the context of adaptive governance or policy-making, part of the studied set of literature refers to the need to decentralise decision-making: polycentric and multi-level governance seem most successful in uncertain, long-term, complex contexts. So, responsibility for decision-making is to be spread over the system both horizontally and vertically.

Adaptive management for transitions should be "plurifocal, multi-scale, multilevel, and adaptive" (Peter & Swilling, 2014). Westley et al. (2011) add that all complex systems that are highly adaptive share (among others) the characteristic that the power of decision-making and problem solving is not centralised but distributed over the system, acknowledged by Voß and Bornemann (2011). This distribution could be explained by the notion that "*transitions per definition cross multiple domains and scales*" (Rotmans & Loorbach, 2009, p. 190).

As described before: to steer a change process, a certain balance between stability and adaptability – or exploitation and exploration needs to be sought. This balance is hard to find within a single organ; it asks for a polycentric governance system. Each of the links in the governance system fosters different system properties; different organs are complementary (Cherp et al., 2011). Furthermore, it is acknowledge that both bottom-up and top-down processes are individually not effective enough in the context of short and long-term sustainability challenges. Foxon et al. (2009) therefore aim to create polycentric and multi-level governance structures that are adequate in the face of uncertainty; diversity in systems is created as means of risk-management. A note the author wants to make; is the potential reduction of ontological uncertainty by the spread of responsibilities in decision-making, potentially introduces a new uncertainty: frame uncertainty. Since an increase in governing parties exists, the presence of unique frames increases as well.

6. Integrating the diverse knowledge of those involved

Multiple of the aforementioned characteristics are related to knowledge creation and integration: an important characteristic therefore is stated to be the active integration of the diverse knowledge of those involved. Those involved is a broad term: they are those related to a process – spread over scales, sectors, domains, disciplines, professional or personal involvement, scientists or lay men. As (Rotmans and Loorbach (2009) stated, transitions per definition cross multiple domains and scales. Participation and actor involvement are crucial to make use of diverse knowledge available in all of the domains and scales.

The exchange of diverse knowledge contributes to an adaptive process in multiple ways. Firstly, participatory processes would lead to higher quality decisions and an increase of anticipation, as more complete information is available within the decision-making process. Integrating a diversity of knowledge – scientific, professional, but also local (lay) knowledge – supports the creation of a more comprehensive overview or a shared understanding of problems within a complex systems context. Interdisciplinarity is supportive in case of uncertainty – it creates robustness – as it is based on multiple epistemological and ethical foundations (Campos et al., 2016; Foxon et al., 2009; Li & Pye, 2018; Peter & Swilling, 2014; Voß & Bornemann, 2011). Tools enabling participants to collectively create a common language, will enable more effective collaboration between participants with different ideologies, values – or backgrounds and knowledge (Sharpe et al., 2016).

Secondly, complexity of energy challenges asks for wide actor involvement; maintaining open flows of knowledge is crucial. The facilitation of open flows of knowledge creates flexibility, and makes a system ready to change as response to both rapidly and slowly changing conditions (Cherp et al., 2011). Schilling et al. (2018) point out that the amount of adaptive capacity in a system is – among others – dependent of the amount of institutionalised and informal exchange between actors.

Lastly, Cherp et al. (2011) insist on the following: non-mainstream system actors are likely to be a source of innovation; they are needed to counteract path dependency of mainstream actors. Westley et al. (2011, p. 770) add that experimentation and innovation "*requires enabling those closest to the problem to shape and define solutions*". Enabling them, closest to the problem, can be facilitated by the aforementioned Change Labs or Urban Transition Labs, creating a point of interaction (Westley, Olsson, Folke, Homer-dixon, et al., 2011; Wittmayer & Loorbach, 2016). An Urban Transition Lab is build around a certain location in a city, there were multiple transitions and domains overlap: a spot for multi-domain interaction. Integral perspectives on future visions are shaped – as the specificity of the location forces people to do so, since the complex dynamics between domains is visible.

Barriers for adaptivity

In the set of 21 reviewed research papers, barriers for adaptivity are much less abundant than drivers. However, the barriers that are named, are discussed here shortly. They are mostly related to – or the exact opposite of – one of the described drivers.

Multiple times, the disbalance between adaptability and stability is mentioned: the aforementioned balance between exploration and exploitation should really be a balance. Too much "exploitation" causes rigidity, a narrow scope, a short-term focus, and a lack of inclusiveness; too much exploration could lead to low levels of commitment, weak long-term coherence, and low efficiency (Cherp et al., 2011). Too much stability creates problematic path dependencies – or pathway lock-ins, making it very hard to adapt a system (Linnenluecke et al., 2017; Rauws & De Roo, 2016; Schilling et al., 2018).

Another recurring theme is the creation of new uncertainties by adaptive strategies. For example, decision-makers might feel uncomfortable committing themselves to and spending resources of processes with an unknown outcome (Foxon et al., 2009). The other way around is a barrier as well: when (large) investments are already done to pursue a certain pathway, the threshold to change the pathway is large (Schilling et al., 2018). Another uncertainty, or maybe complexity, which is introduced by an adaptive process, is the amount of actors that is involved (e.g. for the diversity of their knowledge): this large range of actors makes coordination complex (Linnenluecke et al., 2017).

Barriers related to power issues are created in situations where social learning is of importance, but the design of the social learning process did not incorporate conflict, power, and tactics well enough. These processes are at risk of domination and strategies in which (a few) powerful place strengthening of their own interests and positions above the mutual learning process (Voß & Bornemann, 2011).

Lastly, a short notion that is made is the following: adaptation is largely seen as reactive, however adaptive strategies more and more ask for proactiveness (Linnenluecke et al., 2017).

4.5. Conclusion

The theoretical framework (Figure 16) firstly sought to understand the need for adaptive planning approaches – found in ontic uncertainty – a category of uncertainty coming forth from inherent variability present in human and natural systems. This type of uncertainty closely relates to complexity: unpredictability is caused by among others the non-linearity of complex systems. Literature describes two strategies to cope with this ontic uncertainty: a strategy that focuses on control, and a strategy that avoids control and focuses on adaptivity. Understanding the need for adaptive strategies, the remainder on the chapter aimed to answer the first sub-question (SQ1): "*Which drivers and barriers for adaptive (spatial) planning and adaptive (energy transition/climate) policy-making do exist according to literature?*".

A literature review was carried out to define the concept "adaptivity" as well as to create an overview of drivers and barriers for adaptive processes. Literature sheds light on the concept from many perspectives – of which none includes all of the aspects that form the scope of this graduation study: sustainable energy planning approaches suited for organic or adaptive area development and/or spatial design. Nevertheless, all of the presented perspectives partly overlap the scope – which enabled the creation of the following definition: "*adaptivity is the characteristic of a system or pathway to adapt or be adapted by system actors, as a response to changing (unforeseen) future conditions*".

Six drivers for adaptivity – or preferably named as characteristics of an adaptive process – were found, being:

1. explore and embrace uncertainty;
2. connect long-term visions with short-term actions;
3. treat a process of systemic change as experiment;
4. focus on conditions for development;
5. spread responsibility for decision-making over the system;
6. integrate the diverse knowledge of those involved.

For an adaptive process to be successful, it is important to find a certain balance between adaptivity and stability – to make sure the process progresses. In contrast to the abundance of drivers, barriers for adaptivity were much more limitedly available. The found barriers mostly address the same topics as the drivers: adaptivity reducing uncertainty, can cause new uncertainty for example. Lastly, a call for adaptive approaches to be proactive rather than reactive is made; a too reactive attitude forms a barrier.

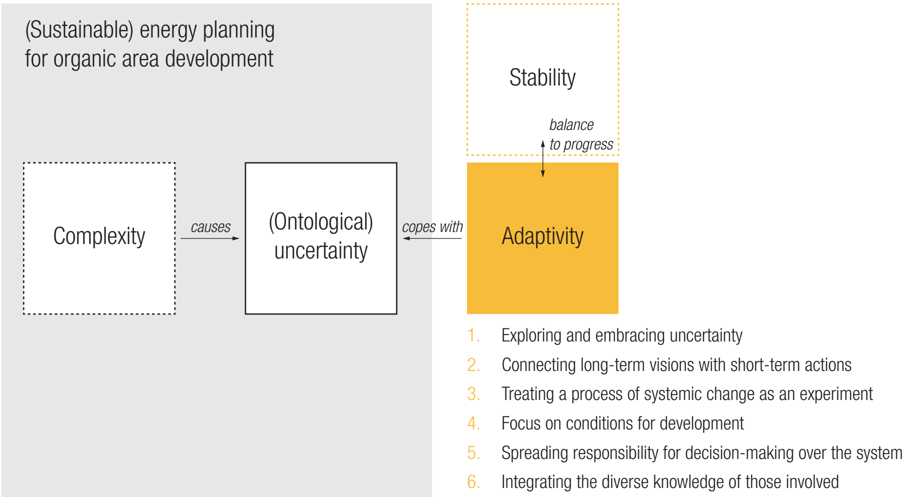


Figure 16: How adaptive strategies cope with ontic uncertainty, caused by the complexity inherently available in the challenge of (sustainable) energy planning for organic area development

Ingredients for design brief

- Adaptive strategies could be used to cope with ontic uncertainties, a type of uncertainty closely related to complexity. Ontic uncertainty could also be seen as "unpredictability".
- For this study, adaptivity is defined as "*the characteristic of a system or pathway to adapt or be adapted by system actors, as a response to changing (unforeseen) future conditions*"
- Six characteristics of adaptivity have been defined, being: (1) explore and embrace uncertainty; (2) connect long-term visions with short-term actions; (3) treat a process of systemic change as experiment; (4) focus on conditions for development; (5) spread responsibility for decision-making over the system; (6) integrate the diverse knowledge of those involved.

5.
Adaptivity in energy planning

REAP

Energy Potential Mapping

Energy Master Planning

Swarm Planning

SREX

STEEP

Many cities have the ambition to become carbon neutral, energy-neutral, or even more ambitious. However, many cities and countries lag behind in their transitions to sustainable energy systems. Causes that are suggested is the lack of understanding within the network of cities' stakeholders to "gain and maintain control over the complex process of the energy transition" (Van den Dobbelsteen et al., 2018b, pp. 635). Another cause might be the lack of appropriate methods, approaches, and strategies to guide the energy transition.

This thesis aims to explore the added value of adaptive approaches to energy planning, helping cities in this complex process, which is – as stated – hard to control. Over the past decade, many (urban) energy planning methods have been developed – building on their precedents and validated by case studies all over the world. This chapter describes six methods or approaches applied in the context of planning for a sustainable energy transition in European cities and regions. Furthermore, each of the approaches is compared to the theoretical framework for adaptive processes as presented in Chapter 4, to be able to anwer the second sub-question (SQ2): "*Which drivers of adaptivity are present in current, academic approaches for energy planning?*". How could be built further on that?

5.1. Review approach

As described in Chapter 4, a narrative review was carried out to create an overview of academic methods and approaches designed for energy planning. This overview is used to study which characteristics of adaptive processes are present in previously developed approaches. To scope the literature search, the application of the approaches is limited to European cities and regions, and only methods developed in academics are used.

The literature is retrieved in two ways: firstly, based on the article "*Urban Energy Masterplanning – Approaches, Strategies, and Methods for the Energy Transition in Cities*" , which provides a clear overview of approaches and methods subsequently developed in Dutch academics since 2008 (Van den Dobbelsteen, et al., 2018b), and secondly, a search to academic energy planning methods for European cities and regions was carried out. Together, this resulted in six approaches that are studied. The first four are retrieved from the mentioned article, the additional literature search added the last two.

The six approaches are:

- Rotterdam Energy Approach and Planning (REAP) – 2009;
- Energy Potential Mapping (EPM) – 2007-2013;
- Energy Master Planning (and the City-zen approach) – 2014-2018;
- Swarm planning – 2012;
- Synergy between Regional Planning and Exergy (SREX) – 2010;
- Systems Thinking for Efficient Energy Planning (STEEP) – 2013-2015.

The method applied to investigate the presence of characteristics for adaptive processes, could best be named as a (qualitative) content analysis – as explained in Chapter 4. The literature on the six approaches is analysed in NVivo software, using a compact code tree consisting of six codes; one for each of the characteristics for adaptive processes. Each of the energy planning approaches is studied individually. As described in Chapter 3, the Theoretical Framework, each of the characteristics represent the authors interpretation of a set of interrelated codes. Therefore, the coding carried out for this content analysis included a step of interpretation as well – elements not exactly naming one of the characteristics, but implicitly mentioning them are incorporated as well.

The six characteristics of adaptive processes were (Figure 17):

1. explore and embrace uncertainty;
2. connect long-term visions with short-term actions;
3. treat a process of systemic change as experiment;
4. focus on conditions for development;
5. spread responsibility for decision-making over the system;
6. integrate the diverse knowledge of those involved.

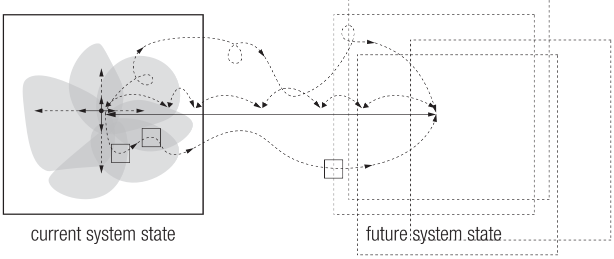


Figure 17: Characteristics of adaptivity (summarised)

5.2. Rotterdam Energy Approach and Planning

The Rotterdam Energy Approach and Planning (Tillie et al., 2009) builds on the New Stepped Strategy (NSS), by linking urban planning to CO_2 reduction and energy goals. The New Stepped Strategy in its turn, roots from the "Trias Energetica", a three-stepped strategy for sustainable energy used since the late 1980s: 1. reduce the demand, 2. use renewable resources, 3. solve the resuming demand efficiently and clean. (Duijvestein, 1993; Lysen, 1996; Entrop & Brouwers, 2010). Andy van den Dobbelsteen (2008) concludes that after twenty years, these three-stepped strategies did not bring the built environment to the desired level of sustainability. Step 2 was most dissatisfying – which could be explained by the high costs that came with sustainable energy, while the demand of energy was not maximally reduced. Resultingly, most effort was put into step 3, that still included fossil fuels. The New Stepped Strategy was introduced to catalyse the shift to renewables, a refreshed "Trias". The new steps proposed are: 1. Reduce the demand, 2. Reuse waste flows, and 3. Produce from renewable sources and let waste be food; leaving out fossils completely.

The Rotterdam Energy Approach and Planning (REAP) translates the New Stepped Strategy to the scale of urban planning. The NSS – when applied to an individual building – will create a more sustainable building. However, a certain amount of energy still needs to be generated in a renewable way. As stated before, investment costs are high though. Perceiving cities as systems comprised of different functions that create a different pattern in energy use – the remaining heat demand of buildings might be solved by upscaling the reuse of energetic waste streams from a building level to the level of the neighbourhood, district or city, instead of solving the remaining demand by renewable energy. At the moment of publishing, no other approach used this potential of exergetic quality of waste streams on the scale of a city.

Figure 18 shows a schematic overview of the application of the three steps of the New Stepped Strategy on the scale of building, neighbourhood/cluster, district, and city. As stated, the novelty of the NSS was the introduction of the step "reuse waste flows"; the novelty of REAP is the introduction of upscaling the reuse of waste flows – step by step from building to city. Scaling from building to neighbourhood, energy could be exchanged between functions, cascaded, or excess heat and cold could be stored. Some examples illustrate these utilisations of waste flows. Modern offices, for example, require cooling at outdoor temperatures of 12°C or higher, because of the high internal loads – while other functions still need heating under these conditions. Supermarkets also have a year-round cooling demand, and thereby excess of heat. A cascading scheme could degrade step by step from the industry, where high-temperature process heat is needed, but also the passive solar energy capture of greenhouses

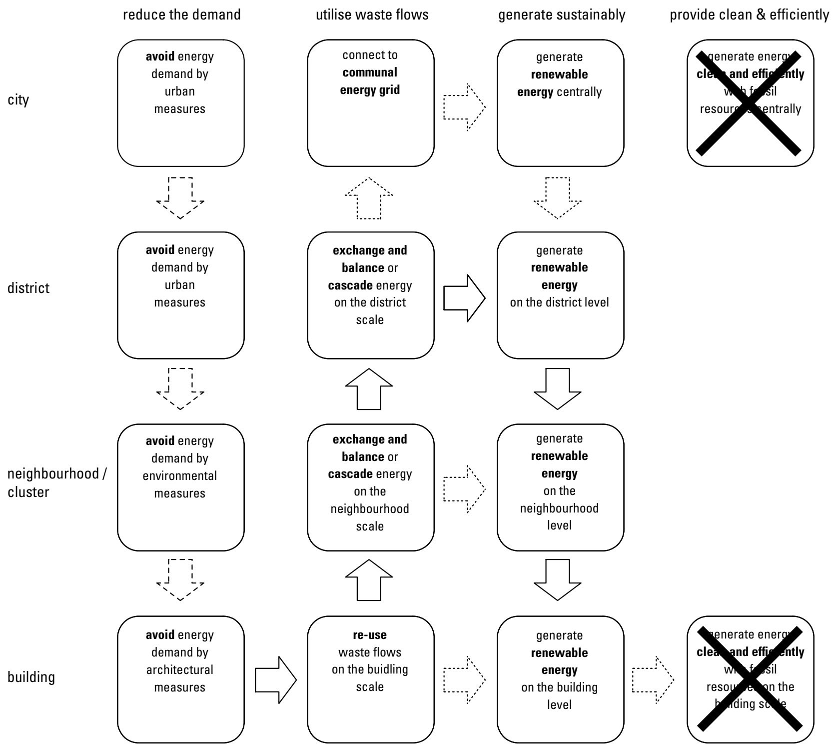


Figure 18: Overview of the Rotterdam Energy Approach and Planning (Tillie et al., 2009)

could be reused – otherwise the energy is just slowly lost to the environment. Heat and cold storage is a good alternative to heat exchange, but with a delay; so when it could not be exchanged directly. An energetic implant could be an addition at neighbourhood level: the addition of a function to complete missing links in the energy supply (Tillie et al., 2009).

Upscaling to the city or region, a communal energy grid is the way to reuse and distribute energy. Generally, a temperature between 70 and 90°C is provided. This serves well for old and poorly insulated buildings, heated by heating systems based on these temperatures. However, a problem exists for newer and much better insulated buildings – which would be served better with medium (50°C) or even low (30°C) temperatures. It is a waste of energy to couple these buildings to the communal heating network. Once these buildings are connected to the city heating system, exchanging, cascading and storing waste energy is not needed anymore (Tillie et al., 2009). A problem which arises is the release of local waste heat into the environment, instead of useful extraction and reuse. As a consequence, cities get warmer: urban heat islands will be created (Van den Dobbelsteen, et al., 2018b). This is an important argument for the REAP methodology to scale up reuse of waste streams from the smallest scale, to bigger scales.

Lastly, Tillie et al. (2009) state that the application of REAP for the creation of the most energy efficient system results in hybrid buildings and urban configurations, creating a different method of urban planning. Strategically combining complementary urban programmes in terms of energy exchange, as well as relations of density and distance with energy storage capacity will create a new set of design principles for urban planners and architects.

Elements of adaptivity in REAP

The two elements of adaptivity most clearly coming forth in the REAP documentation, are the spread of responsibility for decision-making over the system, and the integration of the diverse knowledge of those involved. The approach does not directly mention either of them: the “whom” is not named. However, the strategy reaching over multiple city scales – from building, to cluster, district, and city scale – interaction between the scales is inevitable. From an energy planning point of view, the collaboration between the scales is stated to be crucial (Tillie et al., 2009); implicating the necessity of a spread of decision-making as well. Knowledge integration mostly comes forth from the notion that energetic planning would lead to a new set of design principles for urban planners and architects. Furthermore, in the test case for the REAP – being Rottterdam South – the integration between energy measures and social integration, as well as food production is named. Naming all these disciplines, would logically lead to an integration of knowledge of both energy experts, and experts in all the other fields.

5.3. Energy Potential Mapping

The method of Energy Potential Mapping (EPM) is developed to fill in the knowledge gap of precise and accurate data of the energy potentials of an area – which is knowledge that is required to be able to make a transition to a society powered by renewables (Broersma, et al., 2013). The data which is required, involves the physical availability of renewable and residual resources, the proximity of the resources, their synchronisation with demand, and the exergetic quality of the sources (Van den Dobbelsteen, et al., 2018b). The individual mapping of these data has been done before, however, combining these data without giving up spatial data has not been done often before.

In Figure 19, which schematically represents the methodology of EPM, a distinction is visible between sinks and sources. Sinks on the left are the input data which is needed to define the demand – which mainly consists of energy consumption data. The sources originate from the sun, wind, water, soil, biomass, or the built environment. For each of the available sources, the theoretical potential for the specific location circumstances is calculated. Which is needed further, is insight in the conversion techniques of the present – which convert the sources into the useful and/or desired forms of energy. Furthermore, the yield has to be determined, by quantifying and allocating limitations of each source (e.g. a limitation such as “avoiding single land use” has an impact on the potential of solar energy – disabling the option of solar fields). The outcome of this process is a set of maps, each displaying a different energy potential (Broersma, et al., 2013).

Thermal energy (mainly low-temperature heat) is a different challenge than for example electricity within the EPM studies, as transporting heat and cold over large distances is often uneconomical when going beyond the regional scale. Therefore, Heat Mapping is developed as a particular form of Energy Potential Mapping, having the purpose to show the net energetic (or preferably exergetic) balance of an area by geographically showing all thermal sources, sinks and the infrastructures (Stremke & Van den Dobbelsteen, 2013). Whereas the outcomes of Energy Potential Mapping are presented in two dimensional maps, Heat Mapping can make use of the focus on one type of energy, and visualise the data with an extra dimension representing the cumulative amount of energy.

The methodology of Energy Potential Mapping is originally developed to support public institutions in their process in the energy transition. One of the strengths of the method is the presentation of data in a way which is comprehensible for audiences without an highly technical background as well (Van den Dobbelsteen, et al., 2018b). Energy Potential Mapping has been useful over the past years on the scales of the country, region, city, district and

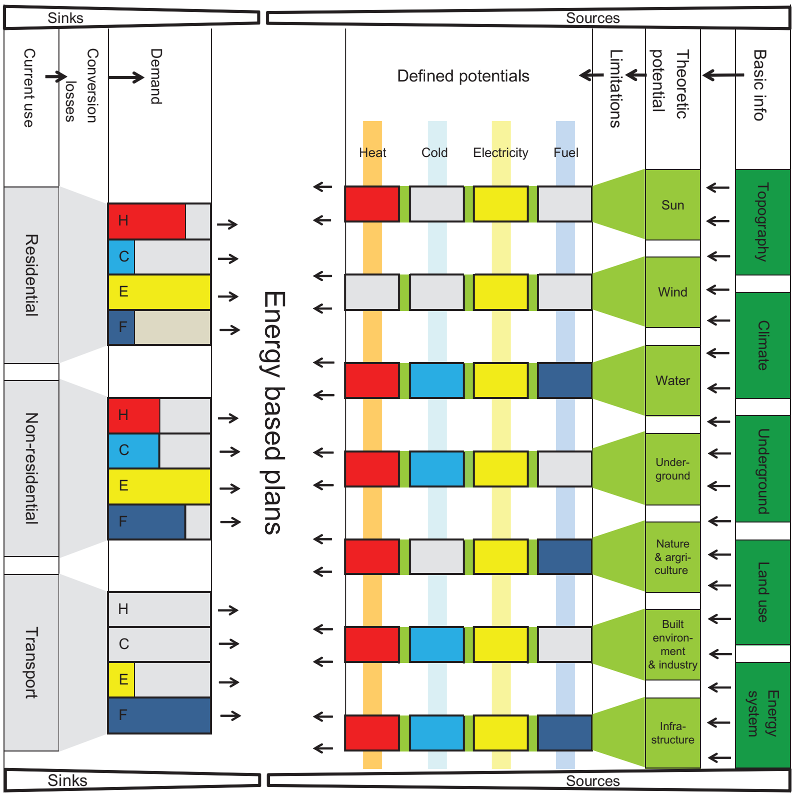


Figure 19: Energy Potential Mapping (Broersma, et al., 2013)

neighbourhood. By giving insight in the spatial distribution of energy in a specific region, it is stimulated to firstly apply local energy opportunities before importing energy from somewhere else. Local potentials in energy supply can be steering in the patterns of urban design (Van den Dobbelsteen, et al., 2011). At least, the accessibility and comprehensibility of a region's energy potentials will enable planners to make more informed decisions of infrastructure and technological investments. The main limiting factor in both EPM and Heat Mapping, is the availability of (comprehensive) data on energy demand and production. The smaller the scale, the harder to retrieve the desired data. Furthermore, the fluctuations of energy demand and production over time are not yet incorporated in the methodology (Stremke & Van den Dobbelsteen, 2013).

Elements of adaptivity in Energy Potential Mapping

On the one hand, the methodology of Energy Potential Mapping could be seen as essential for each energy planning process: the creation of an overview of sources and sinks is data which is essential to know for decision-makers and planners. As in REAP, energy is connected to spatial parameters – as described in the introduction, due to the low energy density of renewable sources, this connection will be inevitable in each developed sustainable energy planning approach.

A specific characteristic of adaptivity is addressed by the way Energy Potential Mapping deals with the abundance of energetic data. Firstly, in the case of heat mapping, all of the data is expressed by the same unit – in amounts of energy (GJ), or amounts of energy per surface area per year (GJ/(ha∗yr) – making the potentials and demands of different sources and sinks directly comparable (Van den Dobbelsteen et al., 2011). Furthermore, the entire method focuses on clear data visualisation, designed to be understandable for a non-specialist audience as well. By making data accessible and understandable for all stakeholders – e.g. for policy makers, urban and regional planners, entrepreneurs – the information can be applied in (local) plans (Broersma et al., 2013; Van den Dobbelsteen, et al., 2018b).

5.4. Energy Master Planning

The Energy Master Planning approach (EMP) aims to support cities with the creation of a sound plan which helps them achieving their goals for the energy transition. Such a plan should give directions, guidelines, proposals of energy interventions, and horizons to its goals. Based on the New Stepped Strategy, REAP, and Energy Potential Mapping, Energy

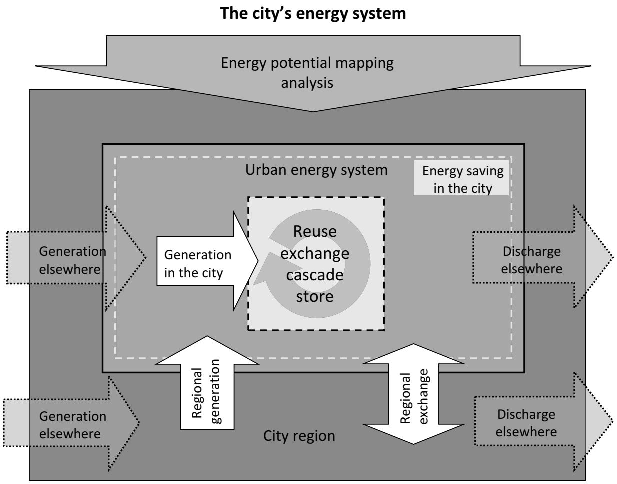


Figure 20: Schematic framework of the Energy Master Plan for self-sufficient cities (Van den Dobbelsteen et al., 2018)

Master Planning provides an incremental approach for urban energy transitions; executing an integrated design from scratch is impossible while handling existing cities (Van den Dobbelsteen, et al., 2014; Van den Dobbelsteen, et al., 2018b).

Understanding the current energy system – its demand and supply patterns – is the foundation for the creation of an Energy Master Plan (Figure 20); the aforementioned method of Energy Potential mapping could provide this understanding. Afterwards, the three steps of the New Stepped Strategy come together in a plan for the city as a whole, integrating the different scales of a city at which interventions can be planned.

The first step is the reduction of the energy demand by for example energy friendly retrofitting measures – both reducing the quantitative and the qualitative energy demand. After retrofit, low-temperature heat might be sufficient to meet the demands. The second step is again the creation of energetic synergies – by exchange, cascading or intermediate energy storage – first within the city, next, also regional exchange is explored. The third step is the generation of the remaining demand by renewables; local production within the city is preferred – proximity is desired to prevent the need for uneconomic heat and

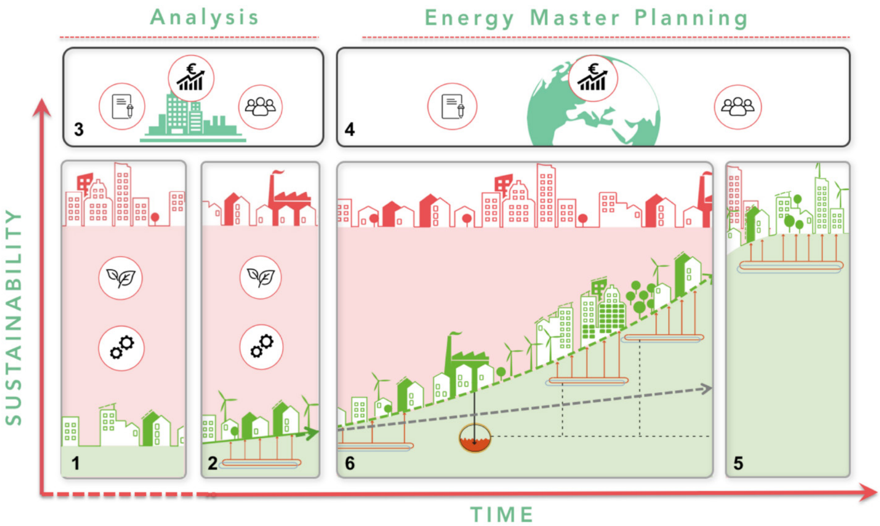


Figure 21: Six steps of the City-zen approach (Van den Dobbelsteen et al., 2018)

cold infrastructure. However, renewable energy production requires more space than fossil energy – while cities have an high density in demand and little space (Van den Dobbelsteen et al., 2014; Van den Dobbelsteen, et al., 2018b).

Energy Master Planning is further developed in the European FP7 Project "City-zen" (Broersma & Van den Dobbelsteen, 2018; Van den Dobbelsteen, et al., 2018a; Van den Dobbelsteen, et al., 2018b). The City-zen project is focused on creating a method, tools and solutions for urban energy transitions, targeting two main partner cities (Amsterdam and Grenoble) and a set of cities that are no partner but aim to become carbon neural on the short-term.

The "Energy Master Plan" is the output of a process of planning for self-sufficiency in cities, the City-zen project developed a stepped approach to create such masterplans. Whereas an Energy Master Plan is mainly technical-spatial oriented, the City-zen approach also addresses non-technical factors related to the energy transition. These factors – such as the political, legal, social, and economic climate – provide insight in barriers and opportunities for the implementation of energy measures and systems.

A six-step approach is created (Figure 21):

1. Energy analysis (present circumstances, current energy demands etc.);
2. Current planning and trends (the near future plan already started);
3. Societal and stakeholder analysis (political, legal, social, economic);
4. Scenarios for the future (external variables that will influence the future state of cities);
5. Sustainable city vision with goals and principles (broke down to the share of city districts and neighbourhoods as well, and including main locations for planned measures);
6. The Roadmap, with energy strategies and actions.

Although the large share of technocracy in the approach, stakeholders and non-technical planning factors are incorporated. In several studies, design charettes were an important tool of strategy making; a design charette is a time-limited, multi-party design event organised to generate a collaborative produced plan for a sustainable community. The City-zen project developed the principle of the design charette to a Roadshow: a five-day event in which expert and lay-knowledge is brokered, and sustainable city visions are created together with concrete design principles enabling the city to make steps towards the vision. These Roadshows are held in the cities that were involved in the City-zen project yet not as partner city. Next to helping these cities, with a process of energy visioning and planning, the Roadshows function as test cases for the developed six-step methodology (Broersma & Van den Dobbelsteen, 2018; Van den Dobbelsteen, et al., 2018a; Van den Dobbelsteen, et al., 2018b).

Elements of adaptivity in Energy Master Planning

The Energy Master Plan, and mainly the extended study within the City-zen project contains a lot of elements fitting an adaptive process; demonstrated among others by the notion that transitioning existing urban areas by an integrated design is impossible – a stepped approach is needed. The adaptivity characteristics related to the connection of long-term visions with short-term actions and goals and the knowledge integration of stakeholders, are strongly interwoven in the approach. The exploration of uncertainties, as well as the experimental approach, and the focus on conditions rather that content, are directly or indirectly mentioned as well.

Concerning the exploration of uncertainties – these are not mentioned directly, but the mapping of barriers for implementing energy measures and systems is mentioned. Laying the societal and stakeholder analysis of step 3 next to the energy analysis of step 1 gives insight in both the opportunities and barriers for energy measures and systems. By generating this insight, creates room to think of (non-technical) actions to remove the barriers upfront (Van den Dobbelsteen, et al., 2018b). The characteristic to treat change process as experiments, can be seen in the way the method is tested and refined in the cities where Roadshows take place (Van den Dobbelsteen, et al., 2018a). Concerning conditions for development, the need for incremental steps is highlighted (Van den Dobbelsteen et al., 2014; Van den Dobbelsteen, et al., 2018b), as well as the need for an Energy Master Plan to give directions and guidelines (Van den Dobbelsteen, et al., 2018b).

The connection of long-term visions with short-term actions is a central element in the City-zen project: long-term inspiring and tempting sustainable visions for the city are translated back into interventions: the urban energy transition roadmap (Broersma & Van den Dobbelsteen, 2018), an elaborate process of back casting.

The Roadshow, as a strategic tool, can stimulate the process of visioning. As described in Chapter 3, "*co-creation in the process of long-term goal formulation and planning, can facilitate a free flow of innovative ideas*". The Roadshow explicitly is not intended to be a substitute for the usual process of socially-engaged urban planning – yet it is a challenge; an opportunity to play and imagine, to get inspired and generate different ideas towards sustainable futures. By this process, participants of the Roadshow – who are stakeholders in city planning anyway – are empowered to be bolder in their plans (Van den Dobbelsteen, et al., 2018a). The Roadshow event results in a sustainable city vision, illustrated by both spatial intervention proposals, as well as ideas for energy measures: the focus lays on how to work towards a vision with real solutions (Van den Dobbelsteen, et al., 2018b).

The integration of local and lay knowledge with a group of spatial and energy experts is central within the Roadshows as well. A range of activities is organised, to enable local stakeholders to participate in a way they feel comfortable with: field visits, stakeholder interviews, design work-shops, serious gaming, mini-masterclasses and seminars facilitate interaction and knowledge exchange (Van den Dobbelsteen, et al., 2018a). When it comes to the selection of participants, it is important to create a diverse group: "*A combination of scientists, local experts, and stakeholders, decision makers and knowledge brokers, designers and technical experts, all contribute to the dynamic of the event.*" (Van den Dobbelsteen, et al., 2018b, p. 653). It is added, that the identification, reach and gain of trust of the city inhabitants and decision-makers has been key to the success of the Roadshow.

5.5. Swarm planning

With the development of the Swarm planning methodology, Roggema (2014) aimed to create a way to incorporate wicked problems in spatial planning. The method "*does not aim to define a blueprint for the future, but envisages a plan that is adjustable if, turbulent, circumstances require so*" (Roggema, n.d.).

Roggema highlights the increase of future uncertainty which is increased by long-term changes society faces: climate change and the provision of sustainable energy are impactful examples of these long-term changes. Building houses and generating urban patterns are processes with a similar timespan: 100 years and more. So, Roggema states, in theory it should be easy to integrate long-term changes and developments with spatial planning. Nevertheless, spatial planning often places its horizon at the end of a timespan of about 10 years, creating a short-term focus in which predictions about long-term changes should be incorporated (Roggema, 2014). The political timeframe – timespan in which policy pathways change and decision are made – is even shorter (see Figure 22).

Next to this difference in time span, spatial planning is mostly used to decision-making for well-described problems – while climate change and energy systems planning can be defined as wicked problems – Roggema builds on the theory of Rittel and Webber (1973), who define wicked problems as follows.

- They have no definite formulation.
- They have no stopping rules.
- Their solutions are not true or false, however, better or worse.
- There is no immediate and ultimate test of a solution.
- Every solution is a "one-shot operation"; since there is no opportunity to learn by trial and error, every attempt counts significantly.
- They do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
- Every wicked problem is essentially unique.
- Every wicked problem can be considered as a symptom of another (wicked) problem.
- The causes of wicked problems can be explained in numerous ways; the choice of explanation determines the nature of the problem's resolution.
- With wicked problems, the planner has no right to be wrong.

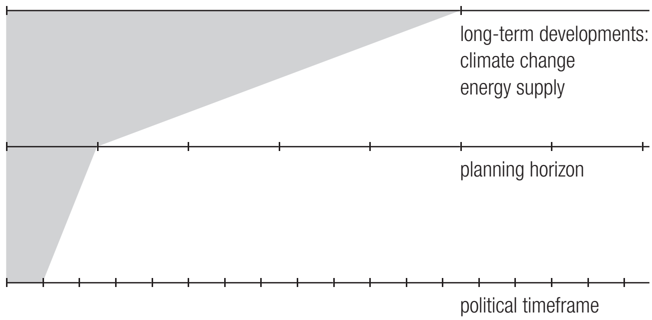


Figure 22: Differences in time horizon for climate and energy-related developments, spatial planning, and politics (adapted from Roggema, 2014)

So, Roggema aimed for a new planning paradigm, able to deal with these wicked problems – a paradigm which is more flexible than current planning systems. He proposed the approach of "swarm planning", which appoints spatial planning the responsibility to create essential impulses to influence the complex system of space, energy supply and climate change – comparable to a swarm of birds constantly anticipating and adapting due to external forces. So, a shift is made from a planning paradigm focusing on the entire (final) image, to a planning paradigm focusing on design interventions which enforce a region to reshape itself. "No blueprint design, but acupuncture planning" (Roggema, 2009, pp. 336).

For the creation of the Swarm Planning methodology, Roggema builds on complexity theory. As he states, socio-economic systems as cities and landscapes, have a dual complexity: the city as a whole is a complex adaptive system as is each of its parts (Stremke & Van den Dobbelsteen, 2013). Adaptation of (or within) systems is an internal process of self-organisation, the tendency to move towards or to restore order instead of disorder. The state of equilibrium is called attractor – self-organisation or adaptation is done to remain with the current attractor; moving to a new attractor (alternative state) is only forced by shocks driving a system out of its current state. A fitness landscape could be visualised as in Figure 23a – consisting of valleys (less favourable) and mountaintops (favourable) positions. A complex system moves through this landscape, through valleys in the direction of the attractor – the position where the adaptive capacity is the highest. Figure 23b shows the path of a complex system, reaching the attractor by increasing order. However, building order after reaching the attractor causes a decrease in adaptive capacity, by which the system becomes unstable and starts looking for an new attractor. At point E, two options are possible for the complex system – dying away or self-organising. This point E is called the tipping point (Stremke & Van den Dobbelsteen, 2013).

At the scale of a whole complex system, an intervention is able to start "the swarm to behave". Currently, we deal with tipping points in a descriptive manner: they are identified after they occurred, or the patterns announcing tipping points are identified. A prescriptive approach – planning tipping points is not (yet) happening. But in the case of climate change, the system (preferable) should be anticipating, and interventions are needed to allow the system to "flip" (move towards another attractor). The main difficulty is the identification of the location to intervene, as well as the type of intervention and the handling actor.

The approach of thinking in points able to enforce change (the tipping points), is significantly different from spatial planning in practice. Comprehensive developments, planned in great detail and for entire areas, are generally sought. An aversion against tipping points and any surprise exists, many countries operate with a political culture avoiding risk and uncertainty (or "uncontrollabilities"). However, this political and planning rationale, does not produce the spatial interventions required to deal with wickedness, says Roggema (Stremke & Van den Dobbelsteen, 2013).

Roggema's design methodology for fossil-free regions consists of three steps: potential mapping, conceptual design, and swarm planning. With Energy Potential Mapping, again, the characteristics of the area are studied; climatic, physical, natural, and technical features which form a basis for the energy analysis and development proposals. In the phase of conceptual design, decisions are made on the topic of energy drivers: will exergy principles direct spatial planning, will functions follow the potentials from step 1, and will climate adaptation be integrated in energy planning? Step 3 aims for realisation, by either a "business as usual model" with a low innovation pace, a strategy focused on transition, or the Swarm Planning strategy aiming to create breakthroughs and accelerating developments (Roggema, 2014).

The last step of this process of sustainable spatial design – swarm planning – asks for further explanation. Besides the foundation of complexity theory, swarm planning is based on a layer approach. The layer approach defines different time rhythms which represent the pace of change of different urban systems. Time rhythm as a basis for the planning framework is helpful in integrating long-term changes in the urban environment. The five layers that Roggema (2014) proposes (also shown in Figure 24) are:

1. *Networks* – they are adjustable, but remain steady over longer periods. Spatial elements as road, water, and ecology are part of this layer.

2. *Focal points* – determined by network linkages; they can change, but can also stay the same over a longer period. The most significant nodes, where different and intense networks cross belong to this layer.

3. *Unplanned space* – is highly dynamic. The space around focal points does not have a specific function appointed. Unplanned space gives room to processes of self-organisation; in case of unprecedented events. This layer impacts urban planning concerning density – free space surrounding urban entities may result in a lower overall density, but create higher adaptive capacity.

4. *Natural resources* – the underground determines locations for natural resources, such as food, water, energy and nature. The layer is robust; the locations are long-lasting, steady and will only change due to rigorous changes in circumstances. To decrease vulnerability of the system, safeguarding these spatial elements is inevitable.

5. *Emergent occupation patterns* – these patterns are characterised by a "slow pace dynamic" – they change over time and adjust to changing circumstances.

The first two layers identify the point of intervention, layer three defines the freedom to emerge, and the last two layers allow for the individual components to self-organise.

The framework can be applied in spatial planning in different ways. Two ways Roggema (2014) points out are as follows. The time and scale dimension of the layers could be guiding, starting from long-term changes occurring at large scales, step-by-step planning towards the smallest scale and most dynamic layer of unplanned space; being the way which lays closest to the current planning paradigm. A second option is based on the dual complexity of the urban system: first elements are identified that could influence the whole system – which is most likely to occur in the most intense nodes (focal points) in the network. Then, unplanned space should be designed around these nodes. The outcomes of this step form the basis of changes in layers four and five.

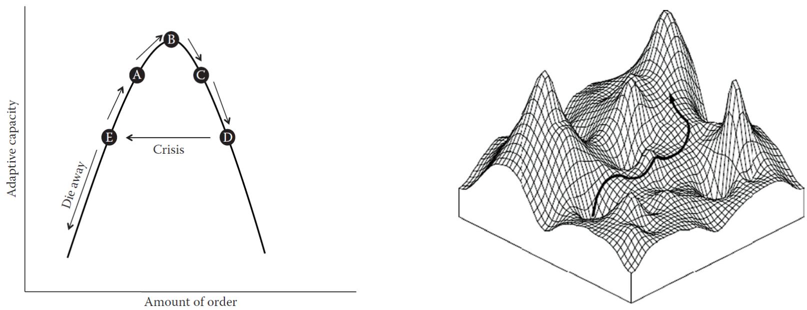


Figure 23: (a) Typical pathway of a complex system towards an attractor, becoming unstable, and becoming in need for a new attractor (or die away); (b) movement of a complex system through a fitness landscape (Stremke & Van den Dobbelsteen, 2013)

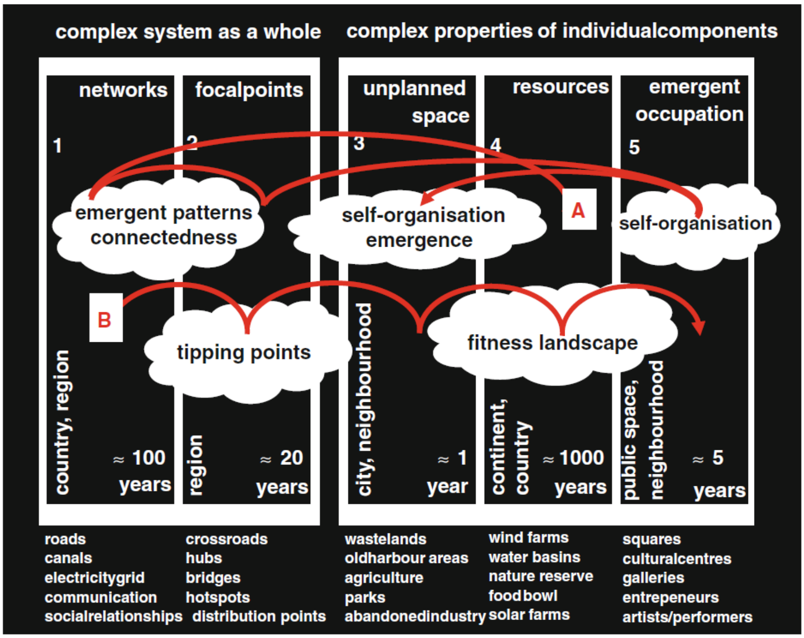


Figure 24: Swarm Planning framework (Roggema, 2014)

To conclude the thoughts of Roggema, the identification of starting-points of realisation is needed instead of creating blueprints for the future – as fossil-free regions cannot be realised on a short-term, and planning systems tend to focus on periods of about ten years. Flexible long-term oriented planning (by means of Swarm Planning) allows future dynamics to influence and change development pathways – and thereby overcomes path dependency. Analysis of different network types makes it possible to distinguish nodes with strong and multiple connections – these points and their zones are the places of "emergence": places with the highest probability for the realisation of energy-conscious interventions (Roggema, 2014).

Elements of adaptivity in Swarm Planning

Roggema stresses, with the development of Swarm Planning, the need to incorporate or accept uncertainties in spatial planning, to connect the long-term and short-term, and to create conditions for spatial development – by acupuncturing interventions.

The exploration and embracing of uncertainties is not directly included as a step in the methodology of Swarm Planning. The need for spatial planning to react to and adapt itself to uncertainties coming with complex challenges as sustainable energy supply and climate adaptation is stressed though. Exploration of uncertainty due to complexity is not one of the steps, but the understanding of complex systems theory is the base of the approach.

The framework bridges the long-term energy supply and climate adaptation visions with the short-term, by its layer-approach. The notion that parts of landscapes and cities change at different paces, was the incentive to introduce different layers for planning – each characterised by its pace of change (for example, think of the differences in change between a tree – which slowly grows – and a terrace – built up or broke down dependent of the weather). Fast changes mostly happen at a smaller scale, larger spatial scales often come with slower changes. When planners work with this layered approach, they still got the freedom *how* to connect the layers corresponding to the long-term with interventions at layers connecting to the short-term. As described, planners can either start planning at the layers with the slowest changing elements and work towards the more changeable layers, or start at the layers most suitable to execute strategic interventions and work from there (Roggema, 2014)

Spatial interventions planned by Swarm Planning, mainly when started planning at the layer of Focal Points, is based on the property of emergence – the way complex systems set up new system structures. In previous theory, the aforementioned tipping point – the point at which a system starts moving in the direction of a new attractor – is identified after its occurrence, and patterns are identified that announce tipping points. Swarm Planning, however, aims to strategically plan tipping points. Whereas a system normally shifts towards other states due to "crises", in the case of climate change anticipation is preferred. Thereby, interventions in the self-organisation process of a complex system is needed. The difficulty is to find the right location and type of intervention, and the actor to intervene. Studying the system by network theory, and planning the intervention based on the local context is proposed. So, Swarm Planning both steers a process of change om the level of the entire system, by active design interventions, and on the level of individual system elements, the process is left open – self-organisation of the system is the way to change. This combination of intervening and self-organisation fits the adaptive characteristic of the creation of conditions to develop: actively stimulating emergence.

5.6. Synergy between Regional Planning and Exergy

The development of the "five-step approach" was motivated by the need of the transition to renewables to further advance long-term thinking in regional planning and design. Each proposal for a long-term development of a large (territorial) system has to cope with critical uncertainties beyond the control of planners and designers – the far-future is unpredictable. The "five-step approach" is developed building on the strengths of both the field of spatial planning and landscape architecture; spatial planners embrace scenario thinking, but have difficulties giving shape to a desired future – whereas landscape architects are skilled to design desirable futures, but not to incorporate uncertainties (Stremke, et al., 2012).

A methodology had to be created to compose imaginative, yet realistic long-term visions for desirable futures. In order to compose these imaginative yet realistic long-term visions, Stremke et al. (2011) state that current projected trends, critical uncertainties, and intended change must be integrated in the design process. For each of these three variables, a step is included in the approach – being "step 2. near future developments", "step 3. possible far-futures", and "step. 4. integrated visions" (Figure 25).

The total methodological framework is organised around a set of five questions – each representing a step in the design process. The series of five questions, at least should be passed twice – in the first cycle the context and scope of the study is defined, in the second cycle a vision is created and spatial interventions are defined. So, a five-step method is created, however, it is stressed that the process should be iterative as well – returning to a previous

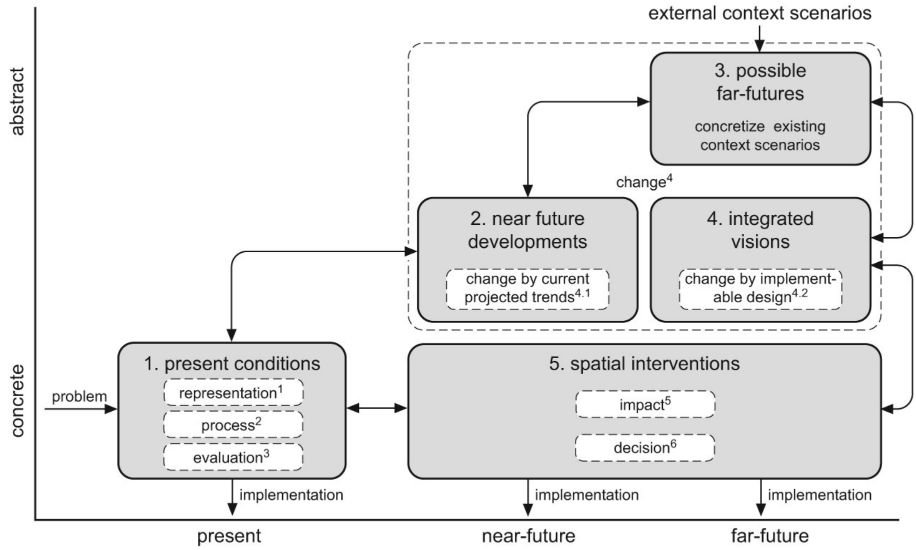


Figure 25: Methodological framework of the five-step approach (Stremke, van Kann, & Koh, 2012)

question might be needed to be able to go through the entire process (Van den Dobbelsteen et al., 2011). Each of the five questions can be further specified to meet the specific objectives of the study where the approach is applied (Stremke & Van den Dobbelsteen, 2013). The five questions are as follows.

1. How does the present region function and how can it be evaluated in comparison with other regions?
2. How will the region change in the near future?
3. What kind of possible long-term developments (at which locations) are expected in the study region?
4. How to turn a possible future into a desired future?
5. Which possible intervention should be implemented?

The use of this "five-step approach" does not necessarily lead to a single spatial master plan or design, alternative proposals are preferred. A growing consensus is reached about the ability of exploring a range of possible futures by means of scenarios. For many countries and regions, socio-economic scenario studies are available, which can and should be used in long-term spatial planning (Stremke & Van den Dobbelsteen, 2013). Flexibility, avoiding of closing of future options, and the integration of uncertainty in the process are key. The method should result in a set of explicit spatial visions and a list of innovative and robust interventions (Stremke et al., 2012).

Elements of adaptivity in SREX

Overall, the five-step approach, or the approach developed as "Synergy between Regional Planning and Exergy" is aiming for and adaptive process; one of the requirements for their approach-design was stated as it must "*Help develop alternative proposals rather than a single master plan*" and it must "*Avoid closing of future options*" (Stremke et al., 2012, p. 313). The characteristics of adaptivity that are specifically addressed by this method, are the exploration and embracing of uncertainties, the connection of long-term visions with short-term actions, and the incorporation of experimental elements. It is not a key component of the method, yet participation, and thereby knowledge integration of the involved stakeholders is included as well.

So-called critical uncertainties – uncertainties which probability of occurrence is hard to estimate – should be integrated in spatial and energetic design processes. As a way of coping with these critical uncertainties, the authors propose to identify robust interventions: interventions that are not too much dependent on the identified critical uncertainties. Uncertainties are identified by possible far-future scenario studies (Broersma, et al., 2011; Stremke & Van den Dobbelsteen, 2013).

Scenarios are more widely applied in the five-step approach. Three types of scenario studies that are carried out, are predictive scenarios (probable futures – included in step 2), explorative scenarios (possible futures – included in step 3), and normative scenarios (desired futures – included in step 4). Step 4 of the approach exactly targets the gap between a long-term vision and short-term actions, by posing the question "How to tun a possible future into a desired future?". The answer should not involve one ideal pathway towards the desired future, but a multiple possible pathways. The next and last question – "Which possible intervention should be implemented?" – makes the pathway towards the future tangible. To both identify a wide range of possible interventions and to create a sense of realism, these last two steps are suggested to be carried out in a trans-disciplinary set-up: in workshops or design-charettes for example – bridging the knowledge of experts, decision-makers, and other stakeholders (Stremke et al., 2012).

The process is not necessarily built up as an experiment, yet the importance of iterations is stressed. The method consists out of five steps, but these steps are intended to at least go through for two times. The first cycle aims to define the context and scope of the study. For this cycle, participation and knowledge integration of stakeholders as well as decision-makers is valuable. The second cycle aims to develop the actual visions; a process for which it might be needed to go back and forth through the steps (Stremke et al., 2012).

5.7. Systems Thinking for Efficient Energy Planning

Like Roggema's Swarm Planning, the Systems Thinking for Efficient Energy Planning project addresses the challenge of greenhouse gas emissions at city and district scale from a perspective of (super) wicked problems – as defined by Rittel and Webber (1973), and Levin et al. (2007). The methodology is based on systems thinking, which is grounded on the principle that a problem can only be fully understood when one understands the parts in relation to the whole ("STEEP: Systems Thinking for Efficient Energy Planning," n.d.). Therefore, the STEEP methodology aims to support energy planning in urban (re)development by means of problem structuring methods (PSM); understanding and structuring (super) wicked problems to be able to work on solutions. The STEEP project (which ran from 2013 to 2015) applied a PSM to support the development of an energy master plan for three city districts in Bristol (UK), San Sebastian (Spain), and Florence (Italy) – having the dual goal to increase both sustainability and economic development. The method turned out to be able to reduce the wickedness of the problem, and to enable local authorities to set and reach realistic goals (Freeman & Yearworth, 2017).

Problem structuring methods are defined by Yearworth (2016, p. 39) as:

1. "Methods, not mathematical, but structured and rigorous and based on qualitative, diagrammatic modelling;
2. Allow for a range of distinctive views to be expressed/explored/accommodated and allow for multiple and conflicting objectives;
3. Encourage active participation of stakeholders in the modelling process, through facilitated workshops and cognitive accessibility;
4. Can facilitate negotiating a joint agenda and ownership of implications of action;
5. Significant uncertainty is expected and tolerated;
6. Operate iteratively;
7. Aim is for exploration, learning, and commitment from stakeholders."

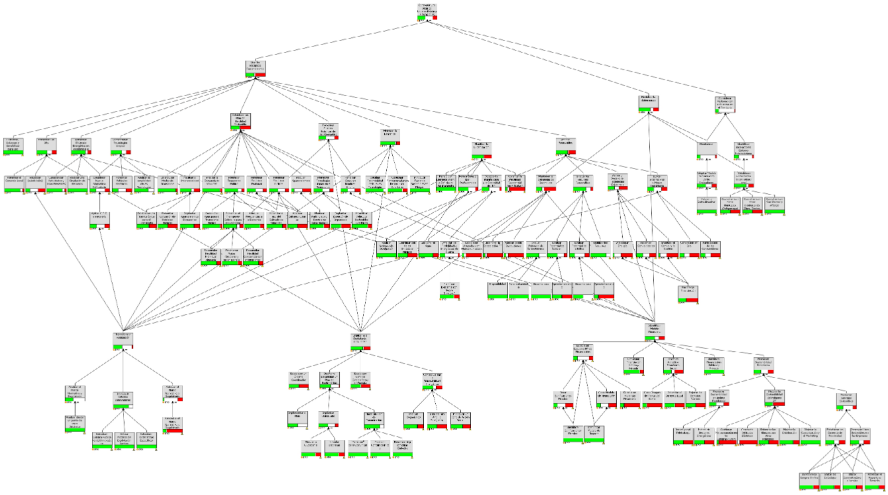


Figure 26: Model from the STEEP project – for the case of San Sebastián (University of Bristol, 2015)

The STEEP methodology consisted of three main elements: 1. Soft Systems Methodology's of defining a root definition (= a concise description of the core purpose of a relevant system); 2. Approaches related to group model-building – aiming to build a systems model by working with a group of experts/stakeholders rather than a consultant; and 3. The use of Hierarchical Process Modelling (including action planning). The third element of the methodology – Hierarchical Process Modelling (HPM) – turned out to be the most appropriate method, and will be discussed in further detail (Figure 26).

Hierarchical Process Modelling "allows complex problems to be broken down into smaller processes, which leads to identification of suitable and practical actions" (Freeman & Yearworth, 2017, pp. 54). The methodology of HPM starts with the agreement of all stakeholders on top-level of the transformational process – compared to the root definition in Soft Systems Methodologies: it is the purpose of the system which is modelled. The next step is modelling, which is conducted in group model building sessions. A facilitator leads the participants to a "language game" of answering 'How?' questions – to decompose the top-level into smaller steps of how the transformation could be achieved, while also building shared understanding. During the process, steps back up in the hierarchy to the "why" could be made to better understand this. Next to the "How?" questions which are clarifying the transformation, they also aim to define the system's boundaries. An important rule in the "language game" – is the aim that each answer is giving in the form of a process description (active verbs, a sense of doing). When the participants have sufficient understanding of the system, a round of assessing the performance is done with indicators of good or bad performance (green and red) and of uncertainty (white) – also called the "Italian flag" notation (Figure 27) (University of Bristol, 2015).

Next to the creation of understanding, HPM can also be used to help action planning. The workshop groups could debate and decide upon possible ways to address the sub-process indicated as poorly performing, or which additional actions could fill up "unknowns" (Freeman & Yearworth, 2017).

The implementation of the STEEP approach asks for engagement with stakeholders in each city district which is studied. The modelling process (for each district) is an iterative process, based on feedback and discussions, rather than a method of strategic planning. The ongoing modelling process creates a learning system on the one hand, enabling the stakeholders to gain more knowledge and insight in the problem, as well as it creates a base for creating concrete actions – by the identification of areas for improvement and uncertainties.

Elements of adaptivity in STEEP

In the approach used in the project Systems Thinking for Efficient Energy Planning contains several of the characteristics for an adaptive process; attention is paid to the exploration of uncertainties, and to the connection of visions with concrete (prioritised) actions, in a process which is iterative and prioritises participation and knowledge integration of system actors. However, in general problem structuring methods are not used to react adaptive towards a complex problem (as urban energy planning), or to solve a problem – they are used to reduce uncertainty and to "tame" a problem (Freeman & Yearworth, 2017).

The "Italian flag" is used as a qualitative measure to indicate processes within the system which are either performing well (green), performing badly (red), or contain a high level of uncertainty (white). Hierarchical Process Modelling supports participants to find consensus in prioritisation of actions in situations of uncertainty; in case of a red flag actions should be "fixes" or interventions, whereas white flags ask for "finding out more". A distinction is made between ontic and epistemic uncertainty – the white flags representing epistemic uncertainty. Ontic uncertainty is part of the system, whereas epistemic uncertainty comes from lack of knowledge of the system (University of Bristol, 2015).

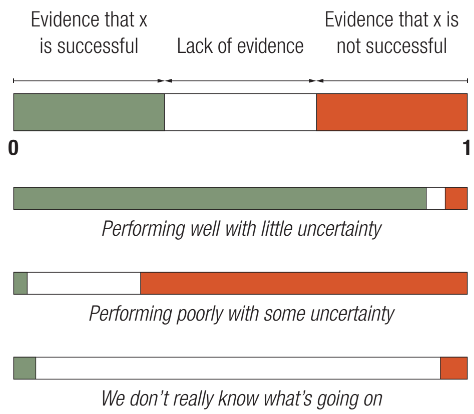


Figure 27: The "Italian flag" indicators of performance and uncertainty (adapted from Bristol City Council, 2014)

The project describes the "*need for a modelling approach that is "sufficiently transparent or familiar that participants can 'read' the model without real-time coaching'*"" – an approach which enables easy collaboration. The entire process is built around participants collaboratively determining the structure of their particular transformational system, and determining the actions to be taken to improve the system (University of Bristol, 2015). One of the lessons learnt from the project, has to do with the variety of interventions included in the model – coming from the diversity of perspectives – ranging from implementable interventions to planning process interventions. Therefore, the stakeholder analysis carried out in the initiation phase of the project, turns out to be critical. In practice, the incorporation of large energy companies and developers (with a large responsibility in the final decision-making) were hard to include in the project (Bristol City Council, 2014).

At the start of modelling, an objective or transformational statement is created, guiding the further modelling process towards interventions. Concerning the bridging of the overall sustainable city vision with concrete actions – or interventions – an important lesson learnt from the project, is the fact that early decisions in the process have high influence in the final prioritising of interventions. Lastly, a note which is made, is that the problem structuring steps are part of an iterative process, in which also the general objective can be adapted while modelling. This iterative character is inherently connected to a systems thinking approach – as continual review is created by switching from the perspective of the whole to the perspective of a part and vice versa (Bristol City Council, 2014).

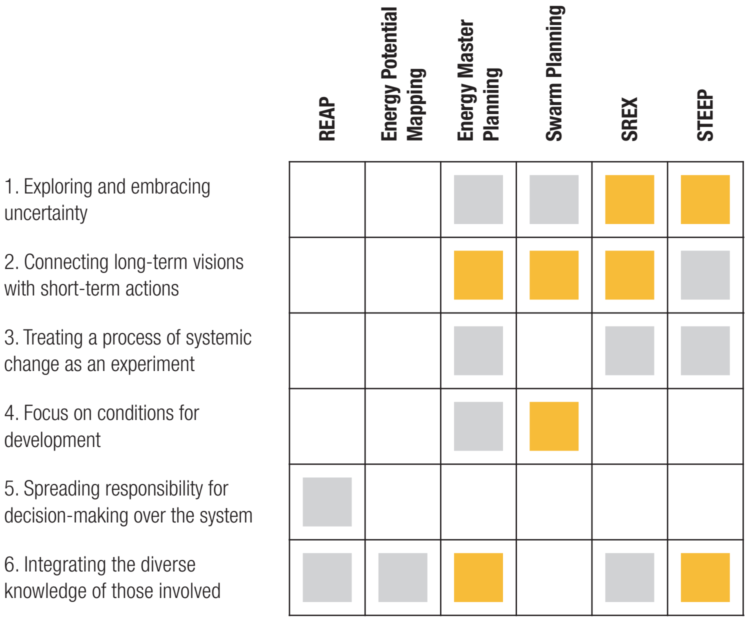


Figure 28: Presence of characteristics of adaptivity in the studied energy planning methods and approaches. **Yellow** indicates the presence of explicit steps or measures, **grey** indicates the mentioning of the characteristic, or the presence of indirect measures.

5.8. Conclusion

This chapter analysed existing energy planning approaches and methods on the presence of characteristics of adaptive processes, answering SQ2: "*Which drivers of adaptivity are present in current, academic approaches for energy planning?*".

To answer this question, six academic approaches or methods are studied which are concerned with planning of urban or regional energy transitions. As a second step, the approaches are analysed on the presence of the six characteristics of adaptive processes.

It could be concluded that all of the characteristics are present, at least mentioned or present indirectly, in one or more of the approaches (Figure 28). However, decision-making in general, and thereby the factor of spreading responsibility for decision-making over the system is not represented.

REAP and EPM are mainly technically-spatially oriented: mainly focused on finding a solution for a specific energetical design challenge or on analysing data to create an overview of potentials. In these two approaches, little adaptivity is included. The other four approaches include more of the characteristics for adaptive processes, and have a more wide perspective on (urban) energy transitions – including perspectives of society and complexity. Overall, a lot of attention is paid to the connection of long-term visions and short-term goals, as well as to the aspect of integration diverse knowledge of stakeholders.

Aspects that are missed out in (most of) the approaches, are explicit exploration of ontological uncertainty or unpredictability. Attention is paid to uncertainty in the shape of "possible scenarios", whereas studying unpredictability would also include room for scenarios man cannot imagine. Furthermore, the element of experimentation – learning and iteration – is mentioned multiple times, however the planning processes are not explicitly designed to be iterated while the plans have started to be carried out. Lastly, conditions for development are subordinate to planning the actual energy and/or spatial system in the studied approaches.

Ingredients for design brief

- The characteristics of adaptivity "(2) connect long-term visions with short-term actions" and "(6) integrate the diverse knowledge of those involved" are most clearly integrated in current approaches
- The characteristics that need more attention, are "(1) explore and embrace uncertainty", "(3) treat a process of systemic change as experiment", and "(4) focus on conditions for development"

6. Analysis of Schieoevers Noord

spatial analysis

document analysis

stakeholder analysis

sustainable energy potential analysis

This chapter contains a range of case study analyses: a spatial exploration of the case study area and its position within the larger spatial context; studies into the development plan for Schieoevers Noord, (environmental) policy, and spatial, programmatic and energy-related ambitions; into the stakeholders, their roles, positions, but also their interdependencies and uncertainties. Lastly, an analysis to the energy potentials of the area is carried out, and it is thought of which of the potentials would best fit an adaptive development strategy. Thereby, the last paragraph aims to answer the third sub-question of this thesis (SQ3): "*How do locally (or regionally) available sources of heat and cold fit the adaptive area development of Schieoevers Noord?*"

6.1. Spatial analysis

As written in the development plan, Schieoevers Noord has large potentials for development because of – among others – its strategic location. The position of Schieoevers Noord has been described as strategic at multiple scales: at the regional scale, within the city of Delft, and as connector between its adjacent districts.

This spatial analysis explores the area of Schieoevers Noord on the three aforementioned scales: as part of the region (Metropolitan Region Rotterdam-The Hague), as part of the city of Delft, and in relation to its adjacent neighbourhoods. Then, it is zoomed in to the scale of the location, and how the 75 hectares are subdivided in smaller areas (Figure 29). Lastly, it is looked into the level of plots and the usage of their area: which buildings are occupied by what (type of) companies, which buildings are monumental or should be preserved for another reason.

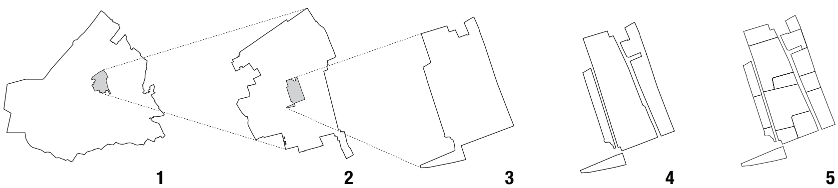


Figure 29: The different scale levels at which the area of Schieoevers Noord is analysed; (1) *regional level*, (2) *city level* - Delft, (3) *district level* - Schieoevers Noord, (4) *neighbourhood level* - spatial entity, (5) *plot level*

Schieoevers Noord within the Metropolitan Region Rotterdam-The Hague

Figure 30 shows a cut-out of the province of South-Holland: 23 municipalities that collaborate under the name "Metropolitan Region Rotterdam-The Hague" (MRDH). The area houses 2.3 million residents and has 1.2 million jobs to offer. In the national programme "Regional Energy Strategies" the same municipalities collaborate to set-up strategies for the sustainable supply of electricity and heat. The Municipality of Delft is part of this regional collaboration.

The map shows the city centres of the two largest cities within the region: Rotterdam (bottom-right) and The Hague (top-left). The city of Delft is situated on multiple infrastructural axes between Rotterdam and The Hague, and so does Schieoevers Noord. The railway as well as an important regional shipping route (the Schie) crosses the area of Schieoevers. The accessibility of the area by public transport offers a strong starting-point for densification of the area.

As Broekman (2019) describes, the area of Schieoevers Noord is also strategically positioned on the "knowledge axis" running from Rotterdam, via Delft and The Hague to Leiden. This axes is developing itself to a strong economic zone, in which a multiplicity of working areas (industrial areas) are currently transforming to mixed-use living-working areas.

Figure 30: The Metropolitan Region Rotterdam-The Hague; Schieoevers Noord is located strategically on the axis between Rotterdam and The Hague

The position of Schieoevers Noord within the city of Delft

The area marked as "Schieoevers Noord" has a remarkable shape – not directly corresponding with neighbourhoods. In an interview with the project manager of the project team for Schieoevers Noord at the Municipality of Delft, the constitution of the plan area was explained to the author.

Shown in Figure 31, an area was defined which – with the exemption of a hand full of houses – houses business and industry only. Roughly, the part of the area which is located north of the Kruithuisweg (east-west oriented road crossing the area at station Delft Campus) is included in the development plans of Schieoevers Noord, the part south is not.

Within the municipality, it has been discussed whether the railway should or should not be the left border of the developing area. It was to concluded to add the part located west of the railway to the development plan, since its function connects the area more to the rest of Schieoevers Noord, than that it does connect to the adjacent residential neighbourhoods.

Because of the planned developments at station Delft Campus (formerly Delft Zuid) and the planned realisation of residential tower The Leo, the area south-west of station Campus is included in the development plan as well.

Figure 31: The origin of the composition of Schieoevers Noord – the Northern part of the area housing business and industry, with the addition of the *Tanthofdreef*

Barriers and borders: a division of the area of Schieoevers Noord

Considering the city of Delft as a whole, it is striking that most of the infrastructure is oriented north-south, with the exception of the Kruithuisweg/N470 (Figure 35). The development of Schieoevers Noord could potentially play a role in the creation of more east-west connection within the city.

When zooming in to the 75 hectares of surface area of Schieoevers Noord, it can be seen that the area (physically) is crossed by several of these infrastructural axes – or in the case of this of spatial development – barriers: the canal Schie, the railway, and the Kruithuisweg (Figure 32 & Figure 35).

These infrastructural barriers divide Schieoevers Noord into four spatial entities (Figure 33). They are mostly named after the road that crosses or neighbours the entity. Spatial entity I is positioned along the *Tanthofdreef*, entity II along the *Vulcanusweg*, entity III is crossed by the *Schieweg*, and entity IV is located at the *Rotterdamseweg*.

One scale smaller, the area is divided in fifteen "subareas" (Figure 34) – in the remainder of this thesis also referred to as the level of the "plot". The division in plots is made by Broekman (2019) – based on their geographical location, owner and/or function. The owners and functions of the fifteen plots are discussed in more detail on page 101.

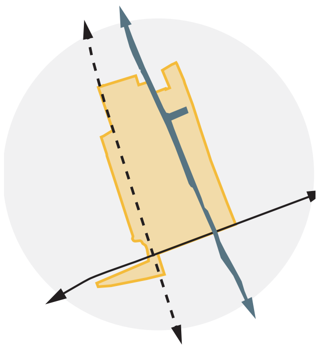


Figure 32: Physical barriers in SON

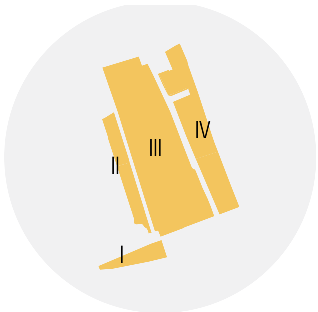


Figure 33: Four spatial entities

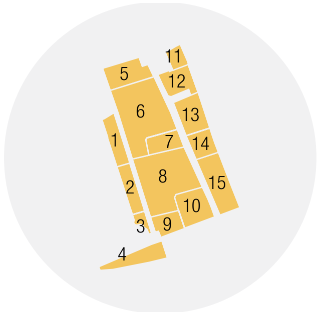


Figure 34: The area is divided in 15 subareas or "plots"

Figure 35: Schieoevers Noord in relation to the main infrastructural axes within the city of Delft. The *Kruithuisweg*, railway and Schie cross the area of SON and divide it.

The area of Schieoevers Noord and its neighbours

Schieoevers Noord is positioned in the middle of a diversity of districts (Figure 36): residential district Voorhof at the east side, residential district Tanthof-Oost at the south-east side. Whereas Voorhof-Oost houses a lot of residential high-rise buildings, Tanthof-Oost is characterised by low-rise. At the south side of Schieoevers Noord, the southern part of industrial area Schieoevers is housed: Schieoevers-Zuid. The TU campus and business/research area Technopolis are located at the west side. With some mixed residential and university buildings in between, the inner-city is located at a small distance to the north.

Broekman (2019) expresses several opportunities that the area development of Schieoevers Noord offers. The area as a whole can create a more soft and gradual transition between the surrounding residential areas and the "working" areas. The development of the area can also improve the infrastructural connections between the different surrounding areas, mainly for slow traffic (pedestrians and cyclists).

Characterising for Delft – for many other cities as well – is that most areas are rather monofunctional: either working, or living, as will be further explained on the next page.

Figure 36: Schieoevers Noord and its surrounding districts: between the inner city, residential areas, TU campus, and industry

Function-mixes and densities in Delft

As stated on the previous page and shown in Figure 37, the area of Schieoevers Noord is near 100% non-residential. Most areas in Delft are either used for working or for living, the level of mixing is mainly high in the city centre, and otherwise limited to a single block. For densification, the mixing functions is seen as a promising strategy.

Figure 38 and Figure 39 show the average building density of the city, respectively per neighbourhood and per block. Here, it can be seen that the city centre is dense, the west of Delft has a lot of high-rise buildings, with large in-between spaces, and the area of Schieoevers Noord has a low density (except for the part of the Tanthofdreef).

MXI building block level

- 0,00 - 0,10 (non-residential)
- 0,10 - 0,20
- 0,20 - 0,30
- 0,30 - 0,40
- 0,40 - 0,50
- 0,50 - 0,60
- 0,60 - 0,70
- 0,70 - 0,80
- 0,80 - 0,90
- 0,90 - 1,00 (residential)

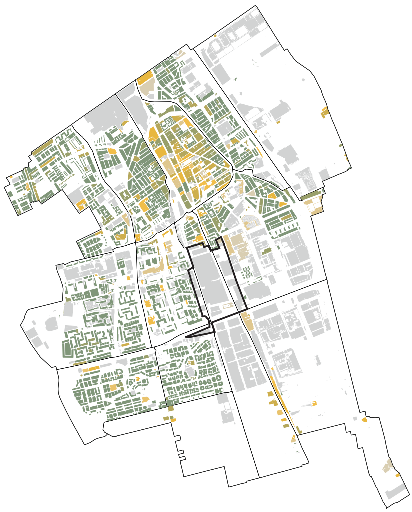
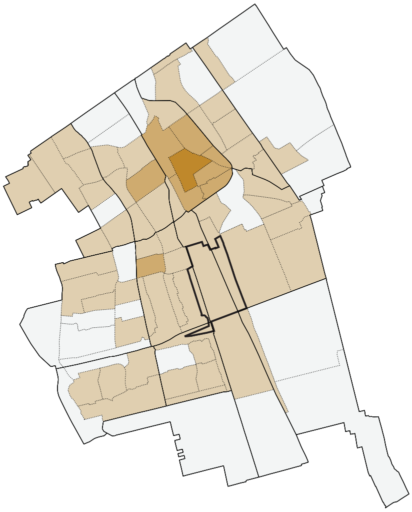


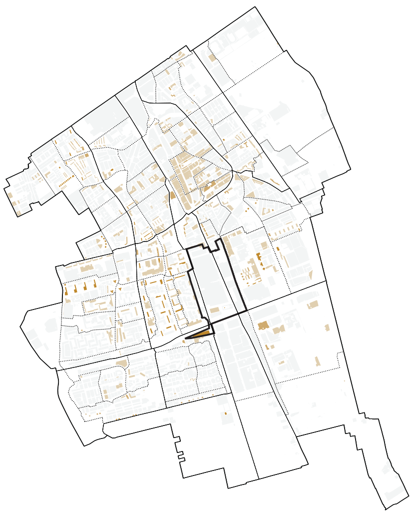
Figure 37: The Mixed-use Index in the city of Delft; the area of Schieoevers Noord is near 100% non-residential.



FSI per neighbourhood

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0

Figure 38: Building density per neighbourhood expressed as FSI (Floor Space Index - ratio between floor space area and surface area)



FSI per building block

- 0.0 - 2.0
- 2.0 - 4.0
- 4.0 - 6.0
- > 6.0

Figure 39: Building density per building block expressed as FSI (Floor Space Index - ratio between floor space area and surface area)

1. (Vulcanusweg) Variety of small and medium enterprises, child care centre, mosque situated between the railway and the residential area of Voorhof

2. (Vulcanusweg) Gas station, Stichting Perspectief (social assistence), medium-sized construction company, and for the next 5 to 10 years a spot for tiny-houses

3. Currently undeveloped, green area situated next to station Delft Campus, owned by the Municipality of Delft

4. The strip at the Tanthofdreef is used by larger companies than located along the Vulcanusweg, mainly technically oriented companies. The building at the corner of the railway station will be demolished and replaced by residential tower "The Leo"

5. Construction markets, kitchen and bathroom vendors, furniture stores; an indoor children's playground and a gym

6. Prysmian, multinational company producing cables, the headquarters are situated in Milan

7. Transport company Zwatra, construction market Praxis, car dealer Peugeot

8. Schiehallen – former cable factory complex, now used as business spaces, as storage facility, and a.o. by a boulder hall and beer brewery. Recycling company Suez is housed at the same plot

9. Festo, company in industrial automation

10. National monument "Het Kruithuis", housing a scouts centre, a small student association, and a home

11. Royal Delft – 17th century ceramics factory (monument, still in use) and museum, and Octatube, an engineering firm with own production facilities

12. Currently unused land, to be developed to a small-scale residential neighbourhood. Part of the plot is owned by Octatube and reserved for their growth

13. EPS producer Hordijk and caravan and camper seller Duijndam

14. Lijm & Cultuur, municipal monument, used as event venue, also housing company improve, offering technical event support

15. Mixture of entreprises: concrete supplier, building materials, kitchen vendor, glass supplier, and student rowing association Proteus-Eretes

- Building
- Monumental building (part)
- Building (parts) to be preserved
- Plot developed before 2030
- Station Delft Campus

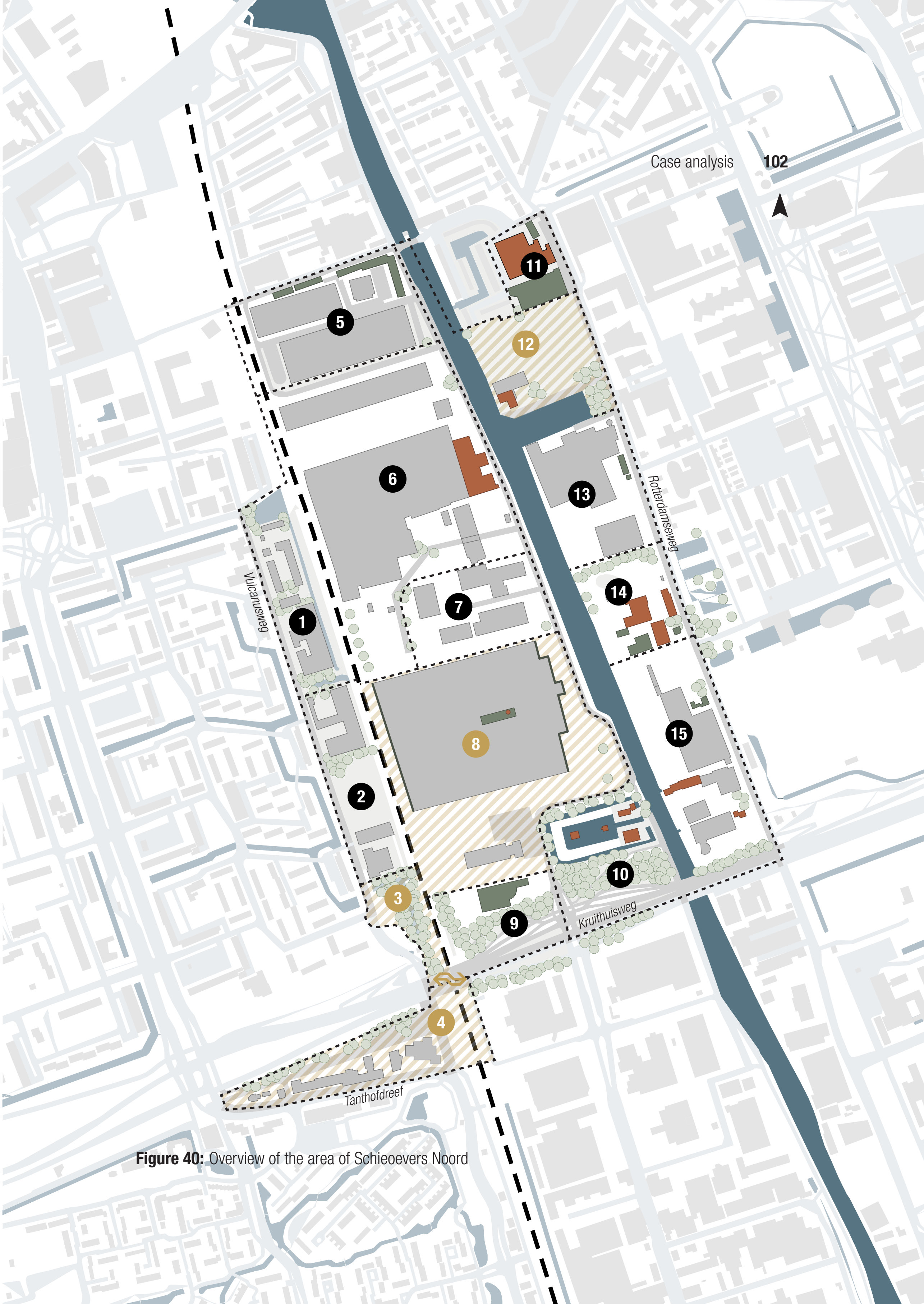
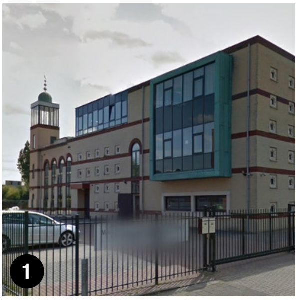
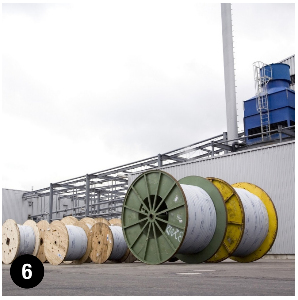


Figure 40: Overview of the area of Schieoevers Noord





imagery retrieved from

Google Maps

dijksmankruiper.nl

vastgoedjournaal.nl

duurzaamgebouwd.nl

kondorwessels.nl

caparol.nl

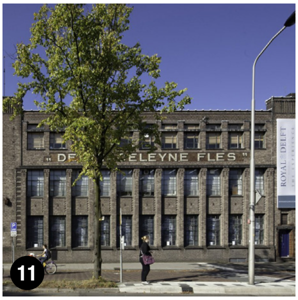
absolutefacts.com

akoestiekopwerk.nl

Julio César Mesa (Flickr.com)

hordijk.nl

reindustrialheritage.eu



1. Mosque Al Ansaar
2. Business space and lot for tiny houses
3. Green space next to Delft Campus station
4. To be demolished building at Tanthofdreef
5. Gamma
6. Prysmian
7. Praxis
8. Interior Schiehallen
9. Festo
10. Kruithuis
11. (left) Royal Delft ceramics factory (right) Octatube
12. Nieuwe Haven, unused, to be developed land
13. Hordijk
14. Lijm & Cultuur, the large even hall
15. Concrete supplier, rowing association

Buildings and use of Schieoevers Noord

The previous four pages have shown the area of Schieoevers Noord in further detail: the buildings, their users, and their architecture. It has shown which buildings are monumental, and which have to be preserved due to either their characteristic appearance (e.g. the Schiehallen) or their function: companies fitting the future visions are included in these visions (e.g. Octatube, Festo), as well as buildings which already have a residential function.

The next paragraph, describing the development plan for Schieoevers Noord as well as other vision document, explains the development path in further detail. Figure 40, though, highlighted four plots which will be developed until 2030, and for which advanced plans are made at the moment, or realisation has started (marked with a yellow stripe in the map). The plans for these four plots are shown on the page at the right (Figure 41).

At plot 3, the railway station (Delft Campus) will get a new canopy, and the square will be updated with renewed infrastructure for pedestrians and cyclists. At plot 4 residential tower The Leo will be built, targeting mainly young professionals as residents. Plot 8 – a twelve hectare large piece of land – will transform into the dense mixed-use area called "Kabeldistrict", maintaining elements of the Schiehallen. At plot 12 the Nieuwe Haven will transform to low(er)-density residential neighbourhood "Delfts Schiekwartier".

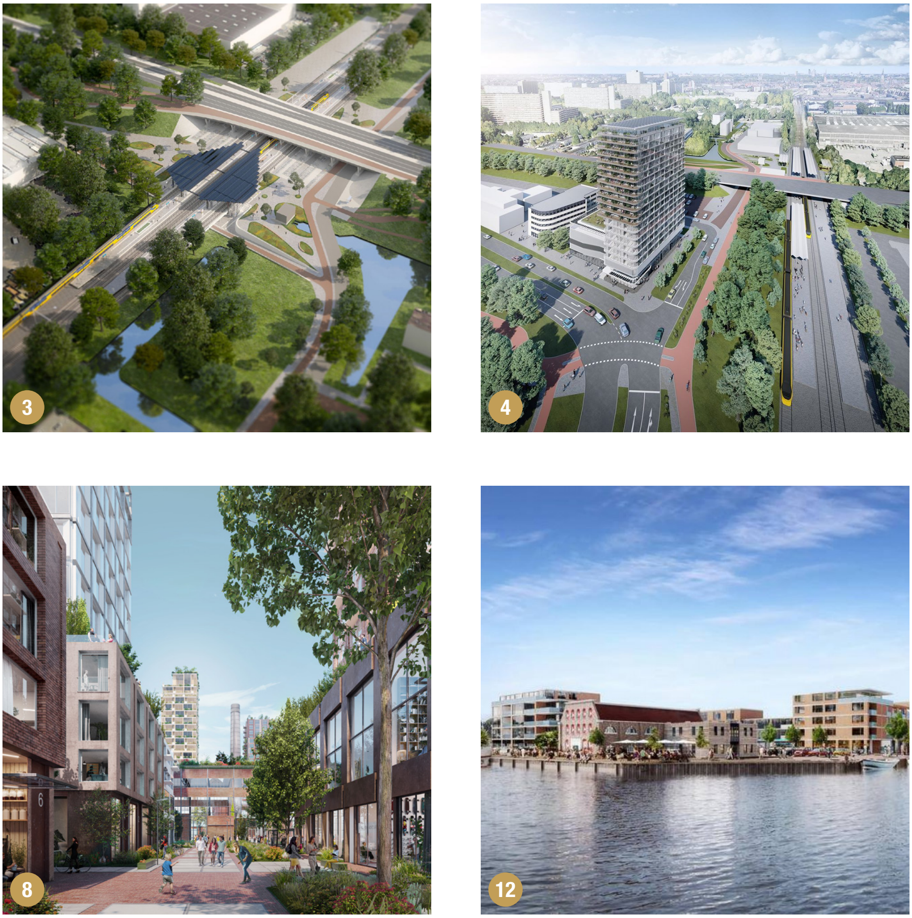


Figure 41: Impressions of the developments that are planned for the phase until 2030; the transformation of station Delft Campus (3), the realisation of residential tower The Leo at the Tanthofdreef (4), the transformation of the Kabeldistrict (8), and the realisation of a residential area at the Nieuwe Haven (12)

6.2. The development plan for Schieoevers Noord

The vision, ambitions and considerations that form the base for the area development of Schieoevers Noord are written down in several policy documents. Furthermore, some consultancy reports on the topic of energy and sustainability were provided by the Municipality of Delft to the author. This paragraph presents the elements of the different documents which are most relevant for this thesis. Documents that were assessed, are:

- the *development plan* (concept version and final version), written by Marco Broekman (office for urban design, research and (landscape) architecture) in collaboration with the Municipality of Delft (Broekman, 2018, 2019);
- the *environmental impact assessment*, written by engineering and consultancy firm Antea Group (Lindeboom & Verhoeven, 2018);
- a *sustainability analysis* "Duurzaam Schieoevers" by consultant Metabolic (Blok, Streefland, & Haisma, 2018); and
- the *energy vision* for Schieoevers Noord by consultant Merosch (Vlot & Van de Griendt, 2019).

Chapter 2 already described the rationale to develop the area of Schieoevers Noord: a response to the urgency for the creation of jobs and houses within the city of Delft. This paragraph gives a more in-depth overview of the vision, approach, ambitions and design guidelines for plot developments, as presented in the above-mentioned documents. At certain topics, documents present contradictory visions, ambitions, or strategies; the author will mention this in *italic*.

Vision for Schieoevers Noord

The creation of a municipal vision for the development of Schieoevers Noord has been a process in which previous visions have been delivered in 2006 and 2010. The current vision, or the "concept development plan" has been created in 2017/2018. From October 2018 until May 2019 a participation trajectory has run, with a final development plan as a result in June 2019.

As stated in Chapter 2, the development plan is built around five central themes. Based on these five themes, the vision on the future of the case study area Schieoevers Noord is explored; the five themes being

- a lively mixed-use urban area;
- space for innovative "making industry";
- socially inclusive and culturally diverse;
- a healthy and sustainable environment;
- good connections and new mobility.

The municipality describes the opportunity that is offered by the strategic location of Schieoevers Noord (as has been shown in Paragraph 6.1): the area links the historical inner city, TU Delft campus, south-western residential areas, and rural area Midden-Delfland, and is located close to two train stations and exit roads. Thereby, the area has the potential to transform from an extensively used industrial area to a more intensely used mixed-use area. The ambition is to realise an equal amount of jobs and houses, to create a "16-hour dynamic" – liveliness in the area for 16 hours per day. The development plan of Marco Broekman introduces the "Schie-unit": each house (average $90m^2$) relates to one work spot (average $60m^2$). Next to (modern forms of) housing and working, the area should offer opportunities for sports, culture, and education. Quantitatively, the municipality aims for the realisation of a total number of 4156 houses and 1831 jobs in Schieoevers Noord by the year 2030; on the longer term, this number should approach 7726 houses and 5481 jobs (Broekman, 2018, 2019). *The author wants to stress that these numbers do not correspond with the aim to realise an equal amount of jobs and houses.*

The city of Delft has the ambition to develop from a knowledge city to the "*capital city of technology and innovation*". Next to that, the city aims to be a city where all Delft citizens have opportunities and chances, in particular concerning the economy and employment. Therefore, the work and economy-related vision for Schieoevers Noord both involves opportunities for innovative making industry to grow and the creation of jobs at all educational levels. Thereby, the development plan aims to create space for existing and new companies. Specifically concerning the making-industry, the focus lays on technology-driven making industry – the potential to develop, prototype and produce ideas being thought of at the TU Delft. Different types of making industry come with the need (and legislation) to be housed in different environmental classes – with a specific distance that should be left open between the industry and other buildings functions. The sector of the making industry, and the different perspectives on this industry within the plan, is discussed in Box 2 on page 126.

The vision concerning a socially inclusive and culturally diverse area is explicated in the vision to realise a range of social and cultural facilities that attract different user groups. The need and wish exist to house education (school for VMBO and MBO), a culture stage, a swimming pool, and a festival terrain, but also the more common district facilities as primary education, playgrounds, sports facilities, green, and a healthcare centre are included in the long-term vision. As described above, jobs for all educational levels should be housed. Regarding housing, a mix is envisioned consisting of social housing (15%), student housing (15%), mid-priced rental housing (20%), and high-priced rental and owner-occupied homes (50%), aiming to attract a mixed user group (Broekman, 2019).

Aiming for a healthy and sustainable living environment covers a wide range of visions and ambitions: think of the realisation of green, sports facilities, contributing to biodiversity and climate adaptation, but also a contribution to the energy transition and a circular economy, and awareness and consciousness regarding noise, air quality and safety. The aspect of sustainable energy is covered more in-depth later in this section (Broekman, 2019).

Lastly, the element of mobility focuses on pedestrians, cyclists, and the use of public transport; the redevelopment of the railway station Delft campus fits this vision. The parking norms are much lower than usual – as a measure to reduce unnecessary traffic. The connection with other areas in Delft is a priority, currently, the area mainly lacks east-west connections – one of the ambitions is to construct a new bridge crossing the Schie between the two existing bridges (Kruithuisbrug and Abtswoudsebrug). The last starting-point is the development of mobility hubs (Mobility as a Service) as a future-proof mobility concept, catalysed by the renewable of station Delft campus.

Framework map and design guidelines

The area development process is mainly guided by the framework constructed by the development plan and the environmental impact assessment. The – for this thesis relevant aspects – of the environmental impact assessment are described under “Energy visions and ambitions”. The development plan offers two main instruments for guiding the different stages of development: a framework map (*Dutch*: raamwerkkaart) and a set of spatial design guidelines (*Dutch*: spelregels). These two instruments are described below.

Framework map

The adaptive long-term development leaves room for adaptations during the process of developing; the framework map offers a basis for the long-term process. The map as shown in Figure 42 visualises the desired spatial plan for the area as a whole; the map is intended to be used as an underlay for the spatial structure. The framework of green, water and public spaces forms the base of the area development. The white areas are the buildable parts of the different plots, which are not filled in. The most important elements of the spatial framework are described below. All is retrieved from (Broekman, 2019).

- The element firstly striking the eye, is the large green area along the Schie. The road – Schieweg – currently running parallel to the Schie is intended to be flipped to the other side of the plots, so that it will run parallel to the railway. That creates room for a high quality green area along the water: the Schiepark. Moreover, the railway and road being both longitudinal sound sources are thereby clustered, offering the potential to organise the space in zones with more noise and more quiet zones.

- In between the new Schiepark and the new road along the railway, building blocks will be realised, connected in their heart with the so-called "Hartlijn". This Hartlijn is a sequence of squares connected by a 20-meters wide street. This line strategically functions as an attractor for commercial and societal functions; the square are natural switching points – were later developments can "plug in".

- Since the identity of the area is to partly derived form the Schie, multiple sightlines are introduced, offering users and residents the sight and orientation towards the Schie. This same Schie is a barrier between east

and west. A new bridge over the Schie and a new tunnel at station Delft will create new routings for slow-paced traffic (pedestrians and cyclists) between east and west of the Schie. With an intended increase of users in the area, and an expected in-crease in passers-by due to the renewable of station Delft campus, these extra connections will be necessary to facilitate all people movement.

- In dark grey and brown, a series of buildings is indicated which are foreseen to be preserved on the long-term. Other buildings could also be preserved, since the adaptive character of the development. The indicated buildings have a monumental status, or are (partly) of cultural historic value – the latter should be assessed for each plot development. For example in the case of the Schiehallen; the scale and length together with the distinct structure are most important for the industrial character. Furthermore, buildings with a function fitting the development plan are preserved as well (companies as Festo and Octatube), just as the few homes that are present.

Design guidelines

For the actual development, more guidance is needed than the framework map only – since it does not indicate anything about the infill of building plots. Since the ambition is to realise a high density, in which functions are mixed, attention is needed to guarantee a qualitative living environment. Within the development plan, guidelines are presented concerning the mixing of functions, for building in high densities, for the preservation of the human scale, and for public space, which are shortly discussed here (Broekman, 2019).

- Concerning the mix of functions, guidelines intend to stimulate exchange and interaction between functions and people, to organise ways of smart and double usage of space, and overcome or limit nuisance as a result of function mixture. On the scale of the entire development, the guideline that is applied, is a distinction between zones for noise, vivacity, and quietness (*Dutch*: ruis, rumoer en rust). With the noisy zone at the side of the railway offering space for making, the quiet zone,

◄ **Figure 42:** Framework map for the development of Schieoevers Noord (Broekman, 2019) oriented at the green side offers space for living, with a vivid zone used for urban facilities in between.

- Guidelines for building high densities, should take certain aspects into account: the amount of sunlight in public spaces, daylight entry in houses, limitation of wind hinder, preventing heat stress, avoiding water nuisance, and stimulating the encounter and movement of people. The following guidelines should support the above. Highrise (ca. 90m) is concentrated around station Delft Campus; the building heights decrease gradually in the direction of the city centre until around 30m, important sightlines are maintains (sight on the church from the Schie, and the newly created sightlines perpendicular to the Schie), at the east side of the Schie, buildings should be distinct volumes with a height of maximum 25m. Furthermore, building plinths are 8m high, the building is split in a lower part with a maximum height of 15 meters, and a upper part which incidentally is high-rise, the building line (*Dutch*: rooilijn) is followed, and building blocks are fordable.

- Concerning the human scale, attention is needed to create an attractive city on the eye level, which asks for guidelines on the level of the district, cluster, and building. Guidelines focus on the creation of pedestrian streets, smart use of surfaces (green roofs, collective gardens), the liveliness of the plinth, and the stimulation of encounters with neighbours.

- For the layout of public space, four types of public space are created as indication: working streets, living streets, sightlines, and parks (green spaces). For each spatial entity, a proposal is done for the use of these four typologies for public space.

The environmental impact assessment adds multiple guidelines – related to environmental themes. These guidelines have a dual goal: on the one hand reaching the ambitions that are set for the transformation, and on the other hand guaranteeing an acceptable quality of the living environment (Lindeboom & Verhoeven, 2018). Compared to the development plan, the guidelines in the environmental impact assessment are more specific and numerical. The guidelines that are concerned with the energy strategy are discussed more detailed in the paragraph on the energy vision and ambitions.

Development strategy

As is shown an explained in Paragraph 6.1, the area of Schieoevers Noord is divided in several sub-areas, also indicated as plots, which will be developed step-wise. The order of development is unpredictable, the extent to which plots will transform will vary as well, and the framework map could be programmatically filled in in multiple ways. Therefore, it is stated, that each plot should be developed in a way that that step could be the end phase of the area development.

To keep an overview on the development, the long-term is cut in two parts: a phase before 2030 and a phase after 2040. Three areas area allowed to be developed: the “Nieuwe Haven”, the “Kabeldistrict” and the station environment of Delft Campus. Owners of these three locations have initiated developments, which is facilitated by among others the creation of a new zoning plan. For the other areas it is not allowed to start developments in the period up until 2030. For existing buildings, it might be possible to develop their building, yet within the current zoning plan, and thereby not if different building functions are intended to be added.

Within this long-term process of area development, the Municipality of Delft takes a range of roles, which are summarised per topic in Table 2. Concerning certain topics, the municipality takes or plans to take an active or even proactive role, for other topics, a facilitating role fits better. Overall considered, the municipality assigns itself a facilitating role: focused on facilitating and making initiatives of third parties possible, by making adequate frameworks and enabling new building functions in zoning plans. As a result the third parties can start (risk-bearing) land and property development.

Specifically of interest for this thesis, is the position the Municipality of Delft will take concerning the energy strategy and energy provision of the area. *Striking is the following, according to the author.* As will be explained in the next paragraph, different scenarios exist for the energy supply – of which the connection to a heat grid, or the use of heat pumps using heat and cold from the subsurface are two. *However, whereas the realisation of a heat grid would be seen as a district facility, the use of energy from the shallow sub surface could be seen as a plot development, since the scale is much smaller. In the first case, the municipality would take an executive hinders an adequate choice for a position to take concerning the energy provision of the area.*

Table 2: Roles the Municipality of Delft takes up in the area development (Broekman, 2019)

Topic	Role
Spatial planning	Stimulator
Plot development	Facilitator
Structure of the plan	Director with framework-setting policy
District facilities (*Dutch*: bovenwijkse voorzieningen)	Executor
Collective costs	Process manager
Established companies	Roles differ: dependent on the course of the company
Alternatives (for companies to relocate)	Facilitator

Energy ambitions and visions

The development plan for Schieoevers Noord describes ambitions regarding the energy provision of the area in development, supported by three other documents: the environmental impact assessment, the exploration of "Duurzaam Schieoevers" by Metabolic, and the energy vision for Schieoevers Noord by Merosch. This paragraph firstly describes the ambitions, and then explores the vision – how could the ambitions be reached?

The development plan for Schieoevers Noord describes three main energy demanders: buildings, business/industrial processes, and mobility. Since the thesis mainly focuses on the built environment, this paragraph does so as well. Buildings require energy for heating, cooling, ventilation, lighting, and tap water. The development plan describes the following ambitions for the energy provision of the built environment:

- energy-neutral development for the building-related energy demand;
- sufficient comfort, with attention for cooling besides heating;
- not using air-conditioning systems, or systems alike for cooling, due to their noise production and high energy consumption (Broekman, 2019).

As described in Chapter 2, the environmental impact assessment adds on the development plan. The Municipality of Delft as a whole aims to be energy-neutral; Schieoevers Noord becoming energy-neutral is no hard requirement. It could be stated that "*not hindering the Municipality of Delft in the road to being an energy-neutral city*" would be complying. The environmental impact assessment describes two hard requirements of frameworks and a soft one – which could be stated to be an ambition. These are:

- (*Hard framework*) to meet the prevailing laws and regulations and the current national and local energy policy;
- (*Hard framework*) to not hinder the municipal sustainability objectives;
- (*Soft framework*) to put maximum effort in contributions to the municipal sustainability objectives (Lindeboom & Verhoeven, 2018).

Later in the document, the environmental impact assessment states several standpoints: that Schieoevers Noord should become energy-neutral and that the subsurface should be optimally used for the energy provision. *More detailed guidelines limit the energy-neutrality again to the building-related energy demand only.* Furthermore, the document pleads for a free choice of a sustainable energy system for parties, as long as their choices do not hinder possibilities in the surrounded area. It also states that, if for the greater good, the municipality can oblige developments to connect to a certain system (think of a heat grid) objectives (Lindeboom & Verhoeven, 2018).

Lastly, Lindeboom and Verhoeven (2018) state that it is hard to make concrete statements on the topic of energy, when detailed plans are absent (or non-existing). The environmental impact assessment proposes two policy alternatives concerning energy: either an neutral energy balance per development as prerequisite or making a choice for an energy carrier for the energy transition. The last one – choosing a carrier – is assessed to be the best alternative of the two.

So, how should Schieoevers Noord live up to these ambitions? The explorative study "Duurzaam Schieoevers" has been written prior to the publication of the development plan and has functioned as input for the vision as presented in the development plan. This exploration into among others a sustainable energy provision highlights several opportunities for the area: the underground is suitable for the application of ATES systems (Dutch: WKO or warmte-koudeopslag); the TU Delft has plans to construct a geothermal well, plans exist to transport waste heat from the port of Rotterdam to The Hague, via Delft, and waste heat is available within the area of Schieoevers Noord (a.o. at Hordijk). Furthermore, two profiles are created for the plots within Schieoevers Noord: plots that are connected to a heat grid, and plots that are heated by other sources (mainly ATES systems in combination with reduction of the demand and high quality insulation measures) (Blok et al., 2018).

The energy vision for Schieoevers Noord written by Merosch describes three energy concepts – which correspond to the three paths that are published in the development plan. These are closely related to the two profiles that Metabolic created as well. A first variant is based on the use of ATES systems only, a second variant makes use of a return pipe from a heat grid fed by the above-mentioned geothermal sources of the TU Delft (which still has to be constructed), the third variant is a hybrid one – using the return pipe from the geothermal energy to increase the efficiency of ATES systems and to regenerate the wells (Vlot & Griendt, 2019).

The development plan specifies the application of the three concepts for several plots/spatial entities within Schieoevers Noord. In the area of the Schieweg (e.g. Kabeldistrict), the application of the hybrid variant is stated to be most likely. In the areas of the Tanthofdreef and station Delft Campus, ATES systems are most likely, since the expected distance from a heat grid is too large. The Nieuwe Haven can use ATES systems, or make use of aquathermal energy. For the areas of the Rotterdamseweg and the Vulcanusweg, a decision will be made on the longer term, concerning which solution fits best (Broekman, 2019). Deviating from the above is possible in case it is discussed with the municipality, in case it leads to energy-neutrality, and in case the opportunities for other parties and/or future developments are not (significantly) hindered.

Paragraph 6.4 will study in further detail which sources of energy are available in the region, which offer potential for Schieoevers Noord, and which fit the adaptive development trajectory.

Box 1. "Adaptive" and "organic": definitions by the Municipality of Delft

During the two interviews that were held at the Municipality of Delft, it was asked to both of the interviewees (environmental consultant and project manager) how they would define adaptive or organic development – and whether organic and adaptive have the same meaning for them.

The project manager stated the following: *adaptive means that we [the municipality] are prepared for change, organic implicates that something is coming from stakeholders.* Though, he states, the Municipality of Delft has decided more on the direction of the development than in a purely organic process. The adaptivity or organicity in the process is mostly coming forth from the choice to not buy land on a large scale and resell it gradually, to not decide on the pace of the developments, and to not decide which building function will be located where and how. The role of the municipality is not traditional. The tendency to choose for organic development processes as a municipality, and to shift from blueprint planning to organic developing is purely to avoid risks – rooting from the economic crisis. If initiatives arise from the market, municipalities will facilitate these.

The environmental consultant states that the adaptivity in the process comes from the role the municipality takes in the development: *the municipality determines the framework within which developments can take place – the exact developments are open for developing parties.* He sees organic and adaptive as two close terms, hard to differentiate. The organic part of the development, again, is the role the municipality takes: they do not plan to buy out companies (except for the sand trader – since that stands developments in the way) – it is up to private parties to buy out companies to be able to develop the land.

Both confirm that the adaptivity manifests itself mainly on the scale level of the plot, so this level could be stated to be the "*grain size of adaptivity*". Adaptivity on a smaller level (cluster or building) could be desired to be more future-proof, yet that is not what is meant with an adaptive development plan.

Figure 43: Power-interest grid for the major stakeholdersin the area development of Schieoevers Noord

6.3. Stakeholder analysis

The area development process that has been initiated in Schieoevers Noord is a process which involves different stakeholders and stakeholder groups with conflicting interests and varying positions of power. The choice for an adaptive area development in which the municipality takes up a rather facilitating approach, instead of a more integrated approach with a stronger steering municipality, largely comes from interdependencies existing between the municipality and the landowners and current users of the area.

This paragraph describes a stakeholder analysis, mainly focused on the area development process as a whole – slightly touching the specific case of energy planning. Firstly, all relevant stakeholder groups are shortly discussed based on the power-interest grid shown in Figure 43. The three stakeholder groups in the quadrant with the largest power and interest are identified as the key players in the area development: the Municipality of Delft, the established companies (mostly united in the Bedrijvenkring Schieoevers), and project developers. These three stakeholder groups are more intensively discussed afterwards.

Range of stakeholders

The concept development plan for Schieoevers Noord (Broekman[1], 2018) presents a force field of stakeholders involved in the area development. The first eight stakeholders as presented in Figure 43 are mentioned in this force field by Broekman, yet the force field does not make any distinction in power, interest, size of the stakeholder group, etcetera. Stakeholder group 9 is added by the author following the rationale that a future target group is of influence for an area development that intends to attract many new people to an area; 10 and 11 are added since they are relevant for developments concerning the energy system.

The stakeholders were ordered in the power-interest grid, partly based on insights gained by attendance of participatory events by the Municipality of Delft, partly by stakeholder interviews, and partly by the sensitivity of the author for the case and its forcefield, which has been created over the course of the study. The list below shortly discusses all of the involved stakeholder groups and their position in Figure 43.

---

1 Marco Broekman (urban design, research and (landscape) architecture) is not included as a stakeholder in the power-interest grid. The firm created the development plan, commissioned by the Municipality of Delft. They do not have interest nor power by themselves, as they operate on behalf of the municipality: power is shaped by their role of advisor. The same counts for all advisory parties that are commissioned by the Municipality of Delft.

1. Since the densification challenge the city of Delft faces – the urgency to add about 15,000 houses and 10,000 jobs by the year 2040 – the *Municipality of Delft* has a large interest in the development of Schieoevers Noord, as means to provide an answer to the densification challenge. The main source of power for the Municipality of Delft is the zoning plan (*Dutch*: bestemmingsplan). The current zoning plan mostly allocated a business function to Schieoevers Noord; developers aiming to transform a plot in a way that other functions are included, need a new zoning plan.

2. The *established companies* are divided in two: (a) the companies located at both sides of the Schie, of which most are united in the Bedrijvenkring Schieoevers, and (b) the companies at the Vulcanusweg/Tanthofdreef united in different business associations. The whole stakeholder group has large interests in the ongoing developments: the continuation of their business operations is dependent on the developments. Meanwhile, except for the plots that will be developed in the upcoming 10 years, the land is owned by this stakeholder group – so it can only be developed when parties sell their property.

3. For *project developers*, the scale of the plots together with the urgency to create residential real estate is favourable. The most important means of power for developers are the financial means to invest in land and construction. The project developers are not keen on additional costs related to design guidelines for energy-neutrality; this is a threat for the return on investment for the project they develop.

4. The *province of South-Holland* is responsible for shipping routes, and since the canal Schie – which is part of the regional shipping route – crosses the area, the province is a stakeholder. The plans in Schieoevers Noord should not be disadvantageous for the shipping routes or sightlines. Furthermore, the province is responsible for the bridges and thereby involved due to the planned gelatine bridge. Furthermore, the shortage of housing is a general problem in a large part of South-Holland. Since the development of Schieoevers Noord is not that large within the province, it is estimated that the power of the province is larger than their interest. The province will benefit from the developments, yet is not actively at the foreground.

5. The *TU Delft* is expected to have a bit more interest in the developments in Schieoevers Noord, yes slightly less power than the province. Since the area neighbours the TU campus, as well as offers potential to house scaled-up companies, started at the TU Delft, the TU will benefit from the area development. Concerning energy, the TU Delft and its potential geothermal well offers chances for sustainable energy supply for parts of Schieoevers Noord. The TU Delft does seem to not be actively involved in the planning process, yet is a powerful party within the city of Delft.

6. *Current residents* have large interests in the area development – since it affects their living environment. The number of current residents is rather low, which creates limited power for this group. Yet, the power they do have as a small groups should not be underestimated.

7. Comparable to the position of residents is the position of *sports associations* in the area. They have large interests since it concerns their accommodation. Mainly water sports are housed in Schieoevers Noord, which also creates an interest concerning plans for additional water movements. Their power is rather low, except for ownership of land.

8. *Cultural institutions* were mentioned by Broekman (2018), as being part of the stakeholder force field. The author mainly thought of the mosque and Royal Delft belonging to this category. The mosque will have somewhat more power than sports associations since it fulfils public needs. Royal Delft has even more power since it represents important cultural heritage for the city of Delft.

9. Since a large share of the developing plots will be transformed into newly built neighbourhoods, the interests of *future residents and entrepreneurs* are important to take into account on the long term. The future inhabitants of the Nieuwe Haven or Kabeldistrict, for example, will benefit from developments and neighbouring plots – since that will decrease nuisance of the industry and possibly enlarges the amenities in the area. The power is relatively large for a not-yet-existing stakeholder group – because if they do not come into existence, the plan will fail. This risk mainly exists for the future entrepreneurs in the making industry, state both the project developer of the Kabeldistrict, as the project manager for Schieoevers Noord at the Municipality of Delft.

10. Stakeholder in the development of a new energy system is the current *network operator*: the one responsible for foreseeing the area of energy; Stedin, in the case of Schieoevers Noord. The area development can be a catalyst for Stedin to move forward in the energy transition; meanwhile, Stedin can be an important partner in realising sustainable solutions in Schieoevers Noord. At the moment, conversations are already going on, concerning the exchange of heat, cold, and electricity between existing companies in Schieoevers Noord.

11. Lastly, Gasunie is appointed to develop the "Leiding door het Midden" – part of a larger regional heat grid, transporting waste heat from the Rotterdam harbour area towards The Hague, via Delft – as will be described in Paragraph 6.4. A connection to this heat grid could either be a primary source of heat for Schieoevers, or a secure back-up system. The success of the "Leiding door het Midden" is not dependent on a connection by Schieoevers, is the expectation of the author.

Triangle of main stakeholders

As stated, the main stakeholders in this area development are the Municipality of Delft, the established companies, and project developers. Only when all three parties are "on board" this area development process is expected to be a success. Representatives of these three stakeholder groups have been interviewed; on behalf of the Municipality of Delft, the author has spoken to Stijn van Liefland (abbreviated as SvL), environmental consultant (a.o. energy) within the project-team Schieoevers Noord, on behalf of the municipality, Derk van Schoten (DvS), project manager of the project-team Schieoevers Noord, has been interviewed as well. On behalf of the established companies, Nils Eekhout (NE) and Jaap Langhout (JL) have been interviewed – both board members of Bedrijvenkring Schieoevers. Lastly, project developer Thomas Piekhaar (TP), on behalf of Kondor Wessels Vastgoed, has been interviewed.

This series of interviews that were held, had plural objectives: some more explorative (which will be used in this chapter), some more in-depth objectives, that are used in Chapter 8 and Chapter 9. The more explorative goals were to gain understanding of the context of the energy planning process, to understand the roles and positions of the stakeholder groups, getting insight in their view on the energy provision of Schieoevers Noord, getting to know their view and/or definition on the organic or adaptive area development, and learning about their uncertainties within the process.

This paragraph discusses the main insights from these conversations: the different perspectives on and positions in the area development, the uncertainties that the parties experience in the development process, the interdependencies between them and the other stakeholders, and other differences and/or commonalities.

In the unfolding of the area development process, the *positions* of the three stakeholder groups are and will be diverse and complementary – they are described above. Their interests conflict at certain aspects and overlap at other aspects. Among the group of established companies, much resistance exists (or existed) against the development plans; which can be concluded by a large number of letters to the municipality. Important to note is that both the municipality and the project developer which was interviewed understand the interests of the companies, and their resistance.

A difference between the stakeholder groups is the perception of the *long-term and short-term.* For the Municipality of Delft – the phase until 2030 could be marked as short-term, whereas DvS states that companies do mostly not look further ahead than 10 or maybe even five years. This was confirmed by NE (on behalf of BKS) – he mentions that a entreprises mostly have a horizon of 3 to 5 years – and in case it possesses expensive machinery the horizon might be stretchep up to 20 years. For TP as project developer within Schieoevers Noord, the year 2030 is about the target to finish the Kabeldistrict – the dot on their horizon, and as such it can be seen as long-term for this stakeholder group as well.

The *involvement* in the area development process differs for project developers compared to the Municipality of Delft and BKS/companies. The developing parties are committed to single plot developments; as such their horizon is inevitably shorter than a full area development. The established companies as main occupants of the area are involved in the process for as long as they are able to and willing to continue their business. The involvement of the municipality also covers a horizon of multiple decades.

During all of the interviews, the presence of *uncertainties* in the area development process has been raised. The uncertainties that were mentioned are all different – dependending on the position and interest of the stakeholder group. SvL was the stakeholder most concerned with the topic of energy, the uncertainties he describes are very different than the one the others mention. SvL names the following: whether the planned geothermal well of the TU Delft will proceed (explained in further detail in Paragraph 6.4), whether the thermal energy of this source will be cascaded towards Voorhof (see Paragraph 6.4 as well), how the energy prices will develop, as well as the prices for drilling in the subsurface (to construct ATES or BTES systems), and how the building market and its prices will develop as a whole

– impacting the bigger financial picture and thereby the budget for sustainable energy measures. The author added the uncertainty of not knowing the presence of all future building functions, which was confirmed by SvL, who added hereto the unknown phasing or term at which building fucntions will change.

Colleague DvS, project manager of the project team Schieoevers Noord, names the mix of the type of working and housing that the Municipality of Delft has envisioned as largest aspect which "*has to prove itself*". The development plan anticipated on the possible problems arising by the mix through the creation of several spatial and organisational concepts. If, on the longer term, companies are keen to set up their business in Schieoevers Noord, the mix has proven itself. The author noticed that DvS did not use the word "uncertainty" while answering a question on the existence of uncertainties in the project and how he copes with them. TP, on behalf of a project developer, names the same uncertainty – or risk – the mixing of living and working. The making industry is that broad, that it is hard to predict who exactly will work in the area, and therefore it is unknown for who is developed. Furthermore, a new financial crisis would be a large risk for developing parties. The impact of the open-ended development process on the developments in the Kabeldistrict is mainly seen as the conflict of interest between the developer and surrounding companies.

Bedrijvenkring Schieoevers has related *uncertainties*, as NE and JL explained. With the start of the process, a lot of anxienty and unrest among companies in the area arose concerning the continuation of their business. The future proximity of a residential function is perceived as a thread for continuation and growth – since many industrial parties produce noise, smell, transport movements and/or other types of (potential nuisance). NE mentions that the certainty which is created for the established companies by the mark of the year 2030 was initiated by the BKS.

Concerning the involvement of not-transforming plots in the energy vision for the area development of Schieoevers Noord, the opinions differ. Within the municipality, the plots that do not develop are not included in the sustainability/energy vision of Schieoevers Noord; that is a different project, lead by a different person. Summarising what is and what is not included into the area development: all developments for which the zoning plan has to be adapted are included in the area development, developments for which that is not needed – retrofitting for example – is not a part of the area development. The BKS would rather see that the challenge of the energy transition is approach in a more integral manner – current companies and developing plots all together; and if that is done under the label of area development or not, does not matter for them.

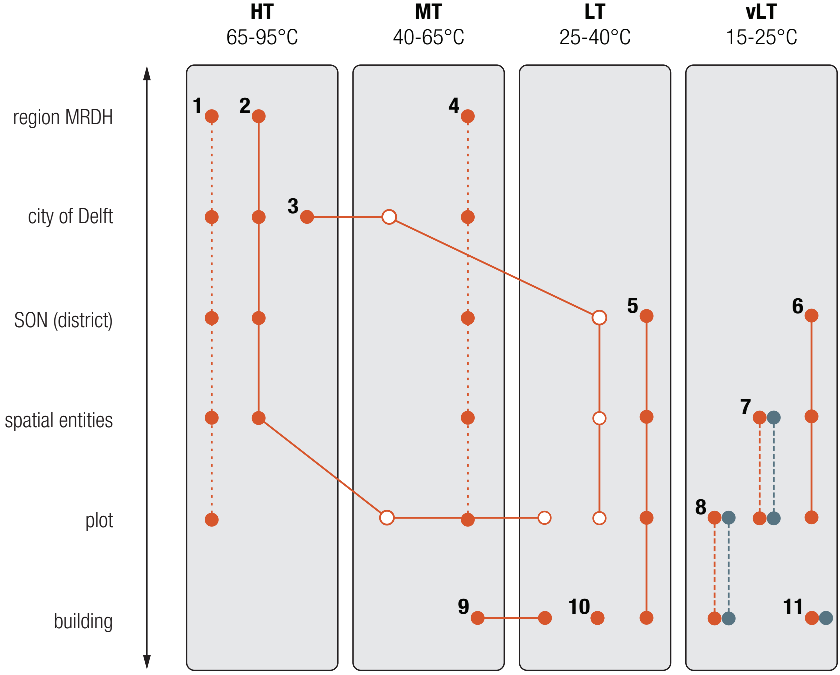
Box 2. The making industry: perceptions on the definition of this sector

The different stakeholder interviews, created the perception with the author, that the so-called "making industry" – one of the main target groups for Schieoevers Noord according to the municipality, project developer Kondor Wessels, and de BKS – is a sector without a clear definition. At the moment though, the three parties seem to be on the same page.

The *Municipality of Delft* was not asked for a definition, yet several statements are collected. In the development plan, the aim is expressed to house "knowledge-intensive making industry" who shape the "industrial revolution 4.0", as well as start-ups and scale-ups that look for a venue in Delft and cannot find it at the moment (Broekman, 2019, p.16). Schieoevers-Zuid will focus on heavier and water-bound industry. In the interview with DvS, it became clear that relative heavy infrastructure (with environmental classes 3.1, 3.2 and 4.1) should also get or keep its place in Schieoevers Noord – industry aiming for large overhead doors, buildings enabling trucks to drive in. It should be proven whether this type of industry could be mixed with residential buildings in practice, a large uncertainty according to DvS.

Bedrijvenkring Schieoevers (NE & JL) sketches a range of industry which could be collected under the name "making industry" – ranging from car revision to prototyping. Making industry is described as companies were people make things with their hands; specifically not including "creative industry". Characteristic for this industry is the (chance of) nuisance it creates, the need for transport movements, and the fact that the environment among others offers jobs to people who might be "less communicable" or mostly practically educated. At the moment, BKS has the perception that they are on the same page as the municipality – however, they foresee a risk when the mix of industry and living does not work out as intended; at such a moment – they expect – definitions will fade, and creative industry (creating less nuisance) might be included in the category of making industry as well.

Project developer Kondor Wessel, creates space for the making industry in the development of the Kabeldistrict. TP describes the type of making industry that he has in mind as follows. Making industry comprises companies that have created an innovation somewhere in an office, which they are able to produce in a making hall 200 meters away. After interrogation, TP stressed that this making does not address prototyping, but products that can go straight up to the market. The aim is to focus on the production of innovative products though.


HT
65-95°C
MT
40-65°C
LT
25-40°C
vLT
15-25°C
region MRDH
city of Delft
SON (district)
spatial entities
plot
building
1
2
3
4
5
6
7
8
9
10
11

6.4. Sustainable energy potential analysis

Energy Potential Mapping, one of the methods used for sustainable energy planning as described in Paragraph 5.3, aims to match (local) energy demands and energy potentials; not only based on quantity, yet also on quality, location and temporality. The energy demand pattern of the area of Schieoevers Noord is about to change in the upcoming decades as a consequence of the intended area development; the final energy demand pattern is unknown. That pattern depends on the amount of plots that are developed, what is developed on these plots, and it depends on the continuation and/or improvement of existing industrial processes and other activities.

Independent of the exact future activities, densification of an area with a large share of housing in the added square meters will lead to an (increased) demand for room heating as well as hot tap water. Office spaces and several public functions, on the other hand, will have a significant cooling demand. Both for heating and cooling the quantity is unknown; the qualitative heating demand will largely be fulfilled by low-temperature heating sources, yet for the sector of the making industry a high(er) temperature heat demand might exist dependent on the specific business, intended for industrial processes.

A variety of sources and infrastructures can foresee The Netherlands, and Schieoevers Noord in particular, with “low-temperature heat” (heat with a temperature up to 100°C). These solutions can be clustered by energy carrier: the use of green gas or warm water as a transporter for energy, or all-electric variants based on the use of electric heat pumps.

Figure 44: (left page) Overview of sustainable heat potentials for Schieoevers Noord

1. Biogas
2. Industrial waste heat (cascading)
3. Geothermal energy (cascading)
4. Biomass
5. Low-temperature waste heat
6. Very-low-temperature waste heat
7. Aquathermal energy (H+C)
8. Aquifer Thermal Energy Storage (H+C)
9. Solar thermal energy
10. Asphalt collectors
11. Borehole Thermal Energy Storage (H+C)

This section discusses a variety of heat sources, accompanied by their prerequisites and implications (think of need for insulation or the construction of new infrastructure). Next to the demand for heat, the phenomenon of global warming and the existence of urban heat islands (and an increase of the application of thermal insulation), ask for cooling solutions – without increasing the use of air-conditioning systems that use a lot of electricity and further heat the environment.

Next to the classification by energy carrier, sustainable heat sources below 100°C could be categorised as High, Mid, Low or very-Low-temperature heat sources (respectively 60-95°C, 40-65°C, 25-40°C, and 15-25°C). This indication of "High-temperature heat" should not be confused with the temperature indication for the transition path High-temperature heat, since this transition path addresses temperatures above 100-120°C.

An overview of the energy potential analysis is visualised by a grid setting out sources of these different temperature groups against the scales of the built environment at which they can be generated and/or distributed (Figure 44). Differences in line types indicate the energy carrier (small dash – gas, larger dash – electricity, continuous line – hot water); a filled circle indicates the energy potential, an open circle indicates cascading of an energy source to a lower yet still functional temperature.

Current demands and future plans

At the moment, the main source of heat used in Delft is natural gas. A couple of heat grids exist within Delft – within the residential district Voorhof and at the TU campus for example. However, at least the water running through these two examples is heated by natural gas as well. In recently developed areas, such as the area called "Spoorzone", both Aquifer Thermal Energy Storage systems, as well as Borehole Thermal Energy Storage systems are used for heating (Jonge, 2017).

Expressed in numbers, based on the data displayed in Figure 45 and Figure 46, the area of Schieoevers Noord has a yearly use of natural gas of about 170,000 GJ, which is rather low compared to for example the inner-city of Delft using over 1,200,000 GJ. The area of Schieoevers Noord houses little residential buildings; the gas is used either for room heating of business spaces and/or production halls or as high-temperature heat for the use of production processes. The consumption of hot tap water, is estimated to be low in the area – since the amount of houses is low, and no other functions specifically asking for hot tap water are located in Schieoevers Noord.

Note: the following figures displaying energy consumption and potentials are all made by the author, data is retrieved from PDOK, rvo.nl, and Google Maps

Annual consumption of natural gas by houses (m³)

- 0
- 0 - 500,000
- 500,000 - 1,000,000
- 1,000,000 - 1,500,000
- 1,500,000 - 1,517,000

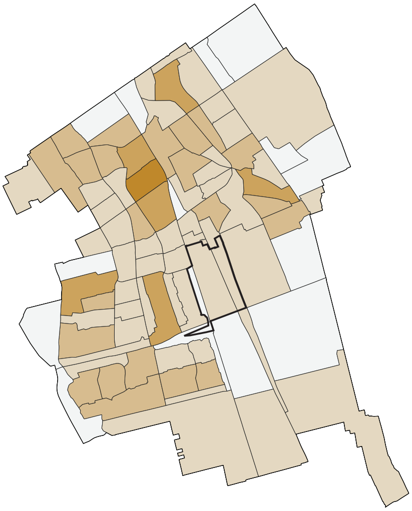


Figure 45: Annual consumption of natural gas by houses (total per neighbourhood)

Annual consumption of natural gas by companies (m³)

- 0
- 0 - 2,000,000
- 2,000,000 - 4,000,000
- 4,000,000 - 6,000,000
- 6,000,000 - 8,000,000
- 8,000,000 - 10,000,000
- 10,000,000 - 10,735,000

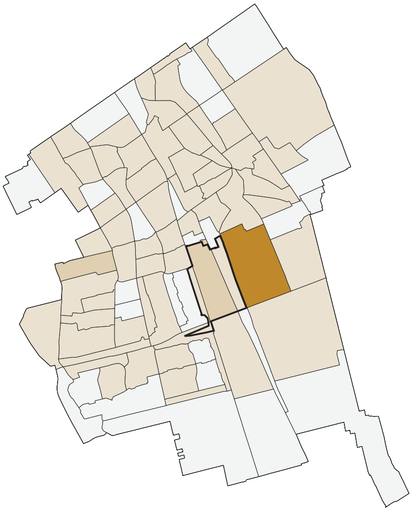


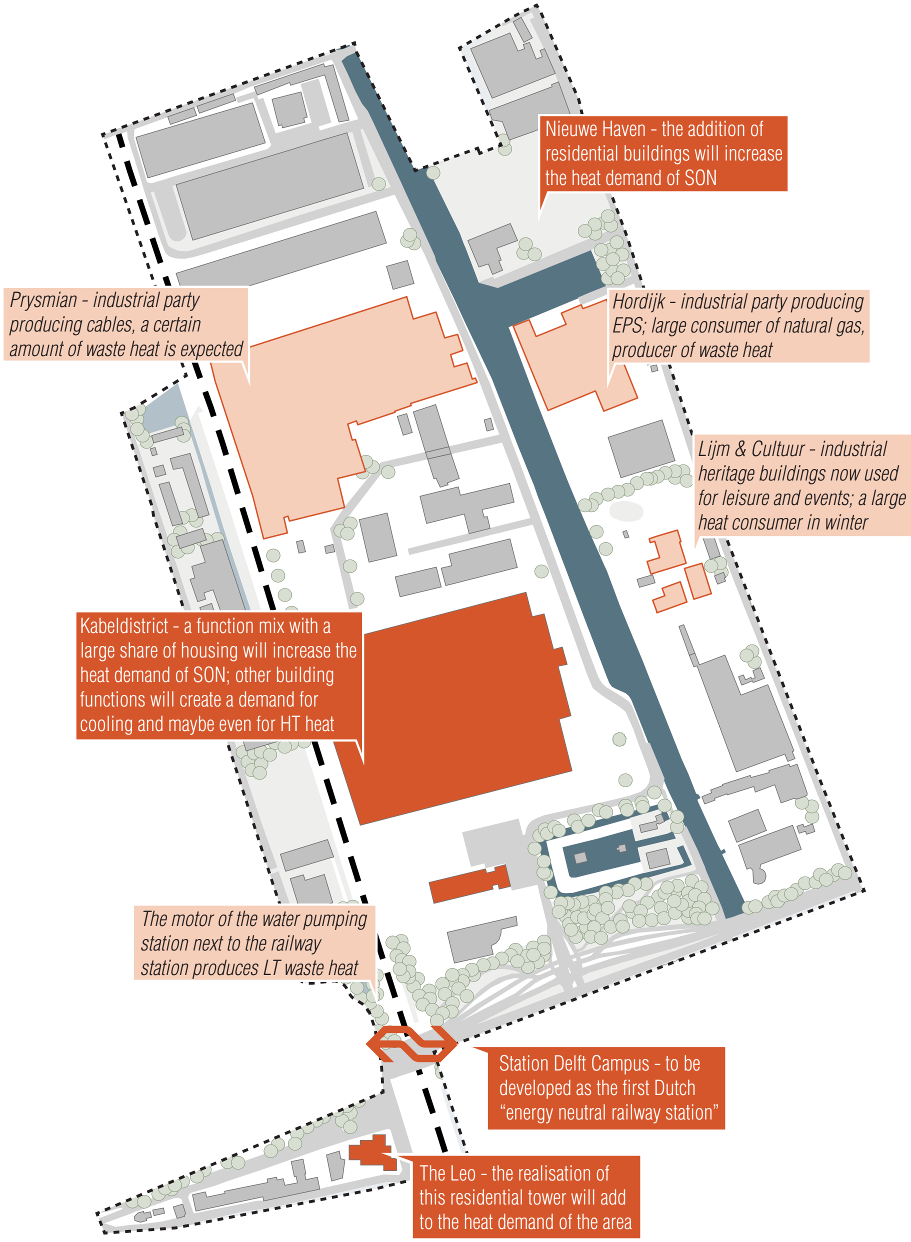
Figure 46: Annual consumption of natural gas by companies (total per neighbourhood)

As stated, the energy demand at a certain point in time is hard to predict for Schieoevers Noord, because of the unpredictability of the area development. Figure 47 (right page), shows the energy demands and potentials of some large existing parties in the area – which will not be developing until 2030 (light orange). Next to that, the figure shows the knowledge that is present on the developments that are planned for the phase until 2030 (orange).

Starting with the existing parties: companies Prysmian and Hordijk are potential suppliers of waste heat. Prysmian produces cables, a process requiring motorised machinery producing an unknown amount of excess heat. Hordijk produces EPS (expanded polystyrene, *Dutch*: "piepschuim"), a process requiring high-temperature heat, and thereby more certainly a potential supplier of low-temperature waste heat – again with an unknown quantity. Furthermore, a water pumping station (*Dutch*: gemaal) is located close to railway station Delft Campus, and is identified as potential source of waste heat in the report describing the environmental impact assessment (Lindeboom & Verhoeven, 2018). On the contrary, the venue of Lijm & Cultuur is a large user of low-temperature heat, since the old industrial halls require a large amount of heat to become comfortable for a gathering or event in the colder seasons.

Concerning the (near) future plans for Schieoevers Noord, it could be said with certainty, that densification almost will lead to an increase in energy demand. Since the plots that will be redeveloped are either un-used or the building density is (much) lower than foreseen in the development plans. With the desire to add many houses to the area, mainly the demand for low-temperature heat (for room heating) and mid-temperature heat (hot tap water) will increase significantly. This is the case for the developments in the Nieuwe Haven, in the Kabeldistrict, as well as for residential tower The Leo at the Tanthofdreef. Then lastly, the railway station will be developed energy-neutrally. The planned canopy of the railway station will be covered by solar panels, but what if that would be changed to PVT panels? There might be an opportunity to create an energy positive railway station by generating additional thermal energy for the neighbourhood.

Figure 47: Energy potentials and demands for Schieoevers Noord, with the knowledge of today ►


Nieuwe Haven - the addition of residential buildings will increase the heat demand of SON
Prysmian - industrial party producing cables, a certain amount of waste heat is expected
Hordijk - industrial party producing EPS; large consumer of natural gas, producer of waste heat
Lijm & Cultuur - industrial heritage buildings now used for leisure and events; a large heat consumer in winter
Kabeldistrict - a function mix with a large share of housing will increase the heat demand of SON; other building functions will create a demand for cooling and maybe even for HT heat
The motor of the water pumping station next to the railway station produces LT waste heat
Station Delft Campus - to be developed as the first Dutch "energy neutral railway station"
The Leo - the realisation of this residential tower will add to the heat demand of the area

Heating with biogas and woody biomass

A carrier of energy which might be able to provide both industry and residential areas with thermal energy, is biomass: a term covering all material coming from recently grown plants and organisms. Examples are food, wood, agricultural products, algae, animal fat, and all sorts of organic waste. Biomass can be converted to all desired energy carriers: liquid fuels, gasses, solid fuel (pellets), and electricity. Whether biomass can be named "sustainable" depends on many factors: among others whether the resources are renewable (they grow as fast or faster than they are used), and whether the production does not harm biodiversity and food production (Ros & Prins, 2014).

For the heat supply of the built environment in general, most promising are the use of wood pellets for the heating of individual buildings or small clusters of buildings with MT (mid-temperature) heat, and the use of biogas for heating with HT heat.

Figure 48 and Figure 49 show the potential for biogas and biomass in the region. The potential of the city of Delft is low for woody biomass, and zero for biogas. The neighbouring municipality of Midden-Delfland has a higher potential for heating by biogas (83 GJ/(ha*yr)), which still is rather low compared to the energy consumption of Schieoevers Noord. Only by importing biomass or biogas from elsewhere, this type of energy could become a serious potential for the area of Schieoevers Noord.

When qualitatively comparing the features of biomass and biogas, to the needs for the area of Schieoevers, it could be stated that for new built buildings, the temperature of heat that both biogas and woody biomass can provide is higher than needed. Buildings complying to contemporary building norms can be heated with low(er) temperature heat. For existing buildings, think of monuments that might not be able to reach insulation standards that are required for low-temperature heating systems, biomass might be a solution. Furthermore, production processes (e.g. the EPS production by Hordijk) might need biogas as replacement for natural gas, to be able to continue their business.

As is stated by multiple sources in literature, what the author wants to emphasise, is that biogas might be effective for low-density areas, where the potential to digest biomass is high. In here, the construction of collective systems will not be feasible; individual systems will probably be used. For example, areas with a relatively large livestock or agricultural sector will have a large spread of buildings, and a high amount of digestible bio-materials, and thereby might benefit from the creation and use of biogas. In these areas, the current gas infrastructure can be kept intact and fed by biogas (Sijmons, 2017).

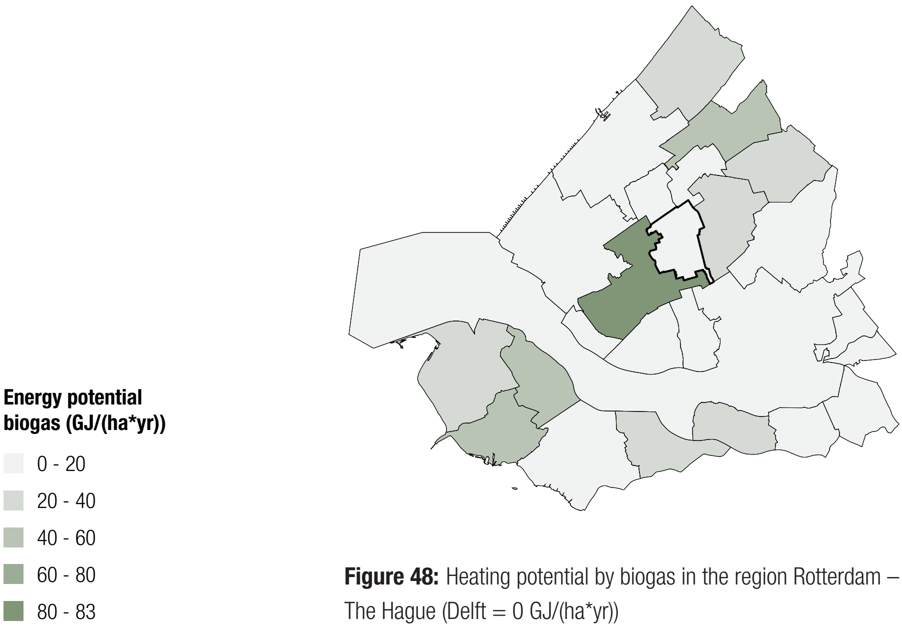


Figure 48: Heating potential by biogas in the region Rotterdam – The Hague (Delft = 0 GJ/(ha*yr))

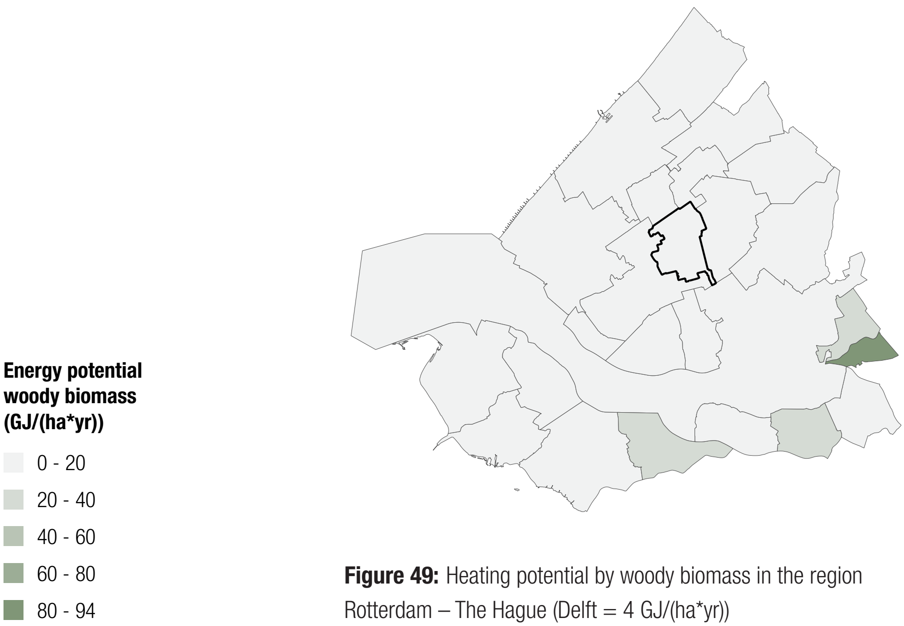


Figure 49: Heating potential by woody biomass in the region Rotterdam – The Hague (Delft = 4 GJ/(ha*yr))

Heating with hot water

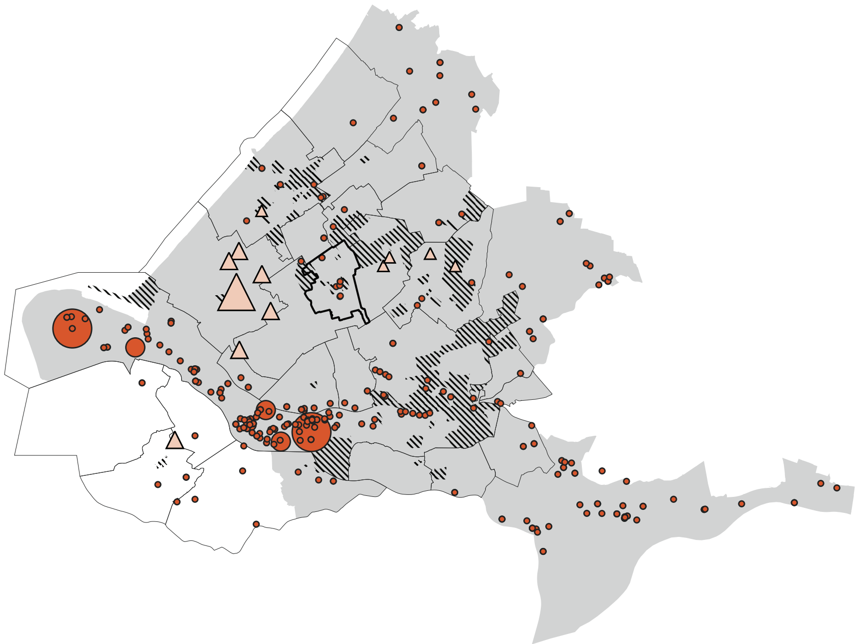
Next to biomass and biogas, one of the solution paths in the transition to a sustainable low-temperature heat system is the application of heat grids: a solution path with possibilities ranging from small-scale collective heat grids to regional heat grids. Heat grids transport and distribute heat to the built environment using hot water as energy carrier.

The heat grids of the past – closed heat grids fed with energy supplied by one heat supplier – will change over time to open heat grids, provided by heat by multiple suppliers, states the PBL (Hoogervorst, 2017). This change is needed to make full use of waste heat potentials: when multiple suppliers together feed a grid, smaller suppliers, or suppliers with a fluctuating supply pattern can become part of the chain, together forming a robust system. The temperature of heat grids is expected to lower in the future as well since the future heat supply is expected to have a lower temperature. The PBL sees two parallel developments in the rise of heat grids: local initiatives focused on small grids and renewable sources (geothermal energy, ATES, biomass), and large-scale initiatives for new regional networks to employ (industrial) waste heat and deliver heat to consumers without the proximity of heat sources.

Heat roundabout South-Holland

Within the province of South-Holland, concrete plans exist to create a large-scale heat grid: the "heat roundabout" (Dutch: warmterotonde). This grid should connect industrial waste heat from the Rotterdam harbours to residential areas and greenhouse areas in the region (Rotterdam – Delft – The Hague – Leiden and the Westland area). The intention is to create a back-bone through the area, which is able to connect heat demanders and suppliers with HT heat. The Rotterdam harbours would produce enough waste heat to supply 500,000 households and a substantial part of the regional greenhouse sector with heat (Port of Rotterdam, 2019). It is expected that after the improvement of industrial processes to more sustainable processes, enough waste heat will still be available in the future to foresee the region of thermal energy. Furthermore, over time, more sources of renewable heat will become available which can be coupled to the regional heat grid. The heat roundabout thereby should offer a future-proof heat supply to the region.

Figure 50 shows the current availability of sources of industrial waste heat (HT) and existing geothermal wells (HT/MT). Most of the current geothermal wells are realised by horticulturists, or horticultural collectives. Yet, the region has a relatively favourable



Study area integrated heat grid

Current heat grids in RES region

Existing geothermal sources (MW)

- 7,0 - 10,0
- 10,0 - 20,0
- 20,0 - 30,0
- 30,0 - 35,0

Industrial waste heat (TJ/yr)

- 0 - 10000
- 10000 - 20000
- 20000 - 30000
- 30000 - 40000
- 40000 - 50000
- 50000 - 60000

Figure 50: Potential sources of HT/MT to feed a regional heat grid in the area Rotterdam - The Hague

potential for the generation of geothermal energy. Figure 50 also shows the presence of current heat grids in the region, which are partly fed by natural gas at the moment. Part of these could potentially be connected to the regional heat grid.

The “Leiding door het Midden”, the part of the planned heat grid connecting The Hague (via Delft) to the heat sources of Rotterdam, offers potential for the city of Delft and for Schieoevers as well. Figure 51 shows a bigger picture of parts of the heat roundabout and the Leiding door het Midden – Figure 52 zooms in to the city of Delft. The Leiding door het Midden is planned to be operational in 2023. The designed grid will transport water of maximally 110-130°C – with a return temperature of about 50°C lower than the supply temperature. The heat will be transported over quite a distance (circa 35 km between the Rotterdam harbours and the city centre of The Hague); the heat loss is expected to be limited to 0.5°C per 10 kilometres. To make the grid suitable for the transportation of geothermal energy and other (lower temperature) sources of heat, the temperature of the back-bone should be lowered (Gasunie, 2020).

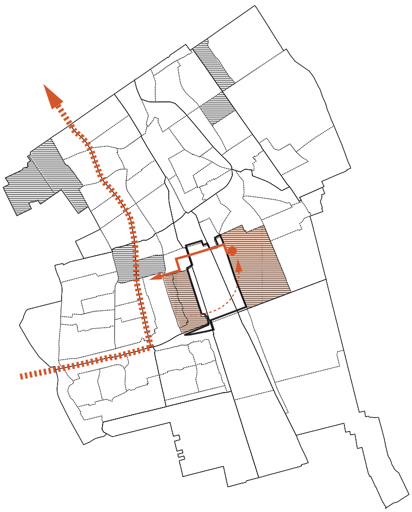
Geothermal energy TU Delft

Figure 52 shows another potential for the city of Delft: geothermal energy. The TU Delft has elaborate plans to construct a geothermal well at the TU campus. Initially, this source will be used to heat the university buildings. Next to a heat source for the campus, the well will also function as Living Lab – to make further developments in the generation and use of geothermal energy. A second phase for which is strived, to make use of the exergetic quality of the water running through the return pipe: the district of Voorhof is intended to be connected to the return pipe which could still deliver a temperature of about 55°C (Blom & Dobbelsteen, 2019). The district of Voorhof is already partly heated by a heat grid fed by natural gas; connecting this district to a the geothermal source should therefore – after retrofitting (insulating) – be feasible and relatively easy.

In an interview at the Municipality of Delft as well as in the development plan for Schieoevers Noord (Broekman, 2019) the suggestion is made that the return pipes from Voorhof (with a maximum temperature of 40°C) could be used to heat well-insulated new-built buildings in Schieoevers Noord. Since a the efficiency of a geothermal well increases with the temperature difference between the well and return water (Blom & Dobbelsteen, 2019), this might be valuable for all parties. Planning-wise, the geothermal well and the cascade net towards Voorhof in a second phase, will run behind the first developments in Schieoevers Noord.

- Main grid - *existing*
- Distribution grid - *existing*
- Main grid - *in preparation*
- *“Leiding door het midden”*

Figure 51: Heat grids in the region of Rotterdam – The Hague; existing grids and grids in preparation



- *“Leiding door het midden”*
- Geothermal source - *planned*
- Cascade net - *planned*
- Heat grids - *existing*

Figure 52: Heat grids in the city of Delft; existing grids and grids in preparation

Re-use of low-temperature waste heat

Next to sources of HT and MT (waste) heat that could be transported by a regional heat grid, a lot of low-temperature sources of waste heat are present on a regional scale as well. However, the efficiency of transporting sources of low-temperature heat is rather low. These sources could mainly be reused on a local scale – transported over smaller distances through local LT heat grids. Sources of this LT waste heat are supermarkets, data centres, and wastewater treatment plants – as well as swimming pools, ice skating rinks, crematoria, and more. The sources of low-temperature and very-low-temperature waste heat that are available in Delft are displayed in Figure 53, together with the existing (local) heat grids. The sources of low-temperature waste heat that are located within Schieoevers Noord, are Prysmian, Hordijk, and the water pumping station next to the railway station, as discussed on page 131.

Next to the displayed functions, which will produce waste heat mostly independent of the season, seasonal sources of waste heat can be identified: think of offices, schools, or sports facilities – spaces that need to be actively cooled during a part of the year, when residential areas – for example – still have a heating demand. These building functions demand heat from a grid for a part of the year and can supply for a part of the year as well.

Using low-temperature heat sources has an important prerequisite to be successful: buildings have to be well insulated and should be foreseen of heat transfer systems suitable for low-temperature heat, to be able to create the same level of thermal comfort as human are used to (heating by natural gas, HT heat, and radiators). There will be areas where buildings cannot be retrofitted in a way that LT heat is applicable; here MT or HT should still be supplied – think of monuments that are not allowed to be adapted.

Furthermore, an additional need for energy will always exist for upgrading (v)LT heat sources to the desired temperature level for hot tap water. Hot tap water should be delivered to the tap with a temperature of 60°C because of legionella prevention. In the future, this norm will possibly be lowered to a supply temperature of 50°C. At the moment, buildings that are heated with temperatures below 60°C, need additional post-heating, for example by individual systems as booster heat pumps or electric boilers (currently, gas boilers are used as well). Dependent on the temperature of the LT heat grid, the upgrading of the water temperature causes peak loads in the electricity grid (Posad Spatial Strategies et al., 2018).

Figure 53: Potential sources of LT/vLT to feed a local heat grid in the city of Delft

Heating with electricity

Next to energy in the form of biomass and biogas, or renewable/waste heat that can be transported by hot water, a third option is the use of so-called "all-electric" variants. Whereas heat grids are a collective solution, the electric variant is targeting individual buildings or clusters by making use of heat pumps in combination with the thermal energy potential of the subsurface, of the air, or – if available – surface water. Since this variant is based on the use of very-low-temperature heat, thermal insulation of the building envelope is of high importance. According to Sijmons (2017), this variant – a combination of electric heat pumps and energy reduction measures – has a more favourable carbon footprint than all sorts of district heating (fed by waste heat from power plants or waste incinerators, by geothermal heat, biomass, or natural gas). An aspect which should not be forgotten, is the need for renewably generated electricity, to make this solution path for the heat demand of the built environment indeed a sustainable solution.

This decentral solution by use of heat pumps can be combined with the use of thermal energy storage in the subsurface: Aquifer Thermal Energy Storage (ATES). This principle is explained in detail on page 172. In short, a heat pump can "move" heat in the counter-natural direction: for example, it can extract heat from groundwater with a temperature of 16°C to heat a room from 20 to 21°C. Groundwater in the subsurface can be a stable source of heat and/or cold water for a heat pump system.

The heat and cold potential for ATES systems differs among others on the composition of the underground. In the region of Delft, the potential for Aquifer Thermal Energy Storage is much larger than in for example eastern parts of The Netherlands. The potential for Delft is shown in Figure 54 and Figure 55. The potential for heat and cold is equal since the temperature of the underground should be in balance – on the long term – to be a renewable source of heat and cold. This also implicates that if, annually (on the longer term) the heat and cold demand should be equal. If a disbalance exists, one of the wells should be regenerated by another energy source (either a heat source or a cold source).

As already mentioned shortly, an ATES system offers a large cooling potential as well, which is a large advantage of this system; offering an alternative for electricity-guzzling air-conditioning systems. An important advantage since the cooling demand for buildings is expected to only rise further in the upcoming years, due to climate change and heat stress in cities (together with the increase of insulation).

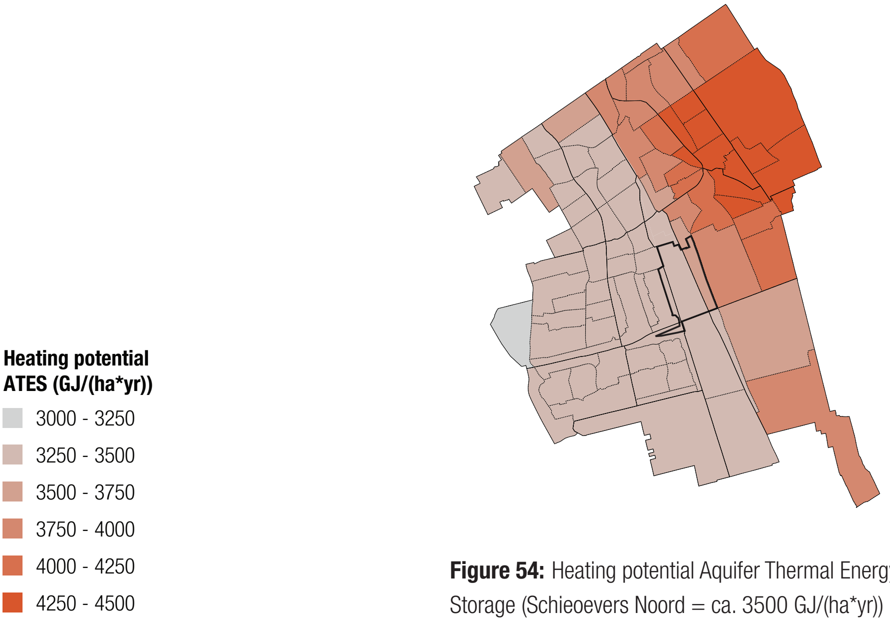


Figure 54: Heating potential Aquifer Thermal Energy Storage (Schieoevers Noord = ca. 3500 GJ/(ha*yr))

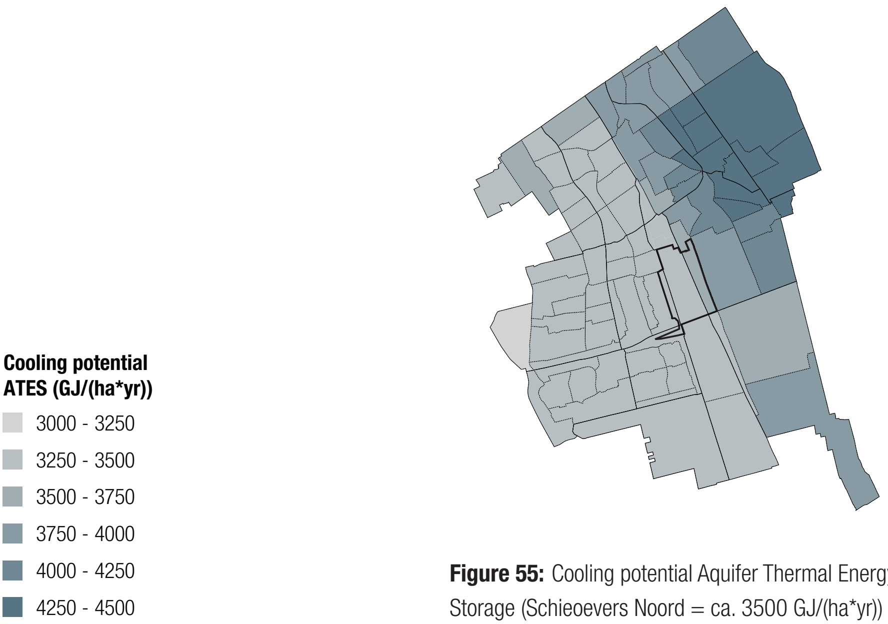
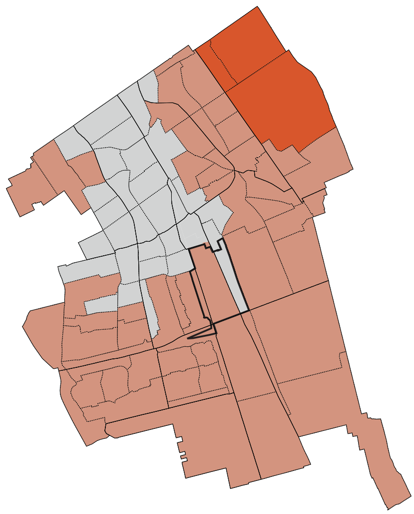


Figure 55: Cooling potential Aquifer Thermal Energy Storage (Schieoevers Noord = ca. 3500 GJ/(ha*yr))

In the development plan for Schieoevers Noord (Broekman, 2019), ATES systems combined with heat pumps are marked as one of the most favourable solutions for Schieoevers; another solution would be a hybrid system in which ATES systems are combined with a heat grid.

A second system combining the use of heat pumps with thermal energy from the subsurface is a Borehole Thermal Energy Storage system (BTES), also explained in further detail on page 172. The main difference between ATES and BTES systems is the way the underground is used. Whereas ATES systems directly use groundwater to exchange heat, BTES systems use another fluid running through ground loops – and thereby extracts heat and/or cold from the subsurface. In here, there is a difference between the heat and cold potential in the underground. The exact potentials for the different neighbourhoods in Delft are shown in Figure 56 and Figure 57.

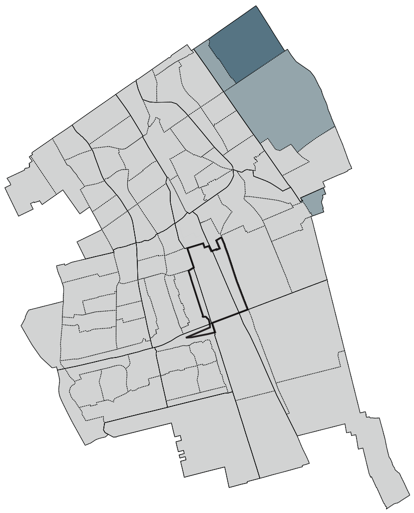
Whereas ATES systems are mainly applicable at the scale of a building block, BTES systems are feasible for individual houses or a small building block as well.



Heating potential BTES (GJ/(ha*yr))

- 1600 - 1620
- 1620 - 1640
- 1640 - 1660
- 1660 - 1680
- 1680 - 1700

Figure 56: Heating potential Borehole Thermal Energy Storage (Schieoevers Noord = ca. 1650 GJ/(ha*yr))



Cooling potential BTES (GJ/(ha*yr))

- 460 - 464
- 464 - 468
- 468 - 472
- 472 - 476
- 476 - 480

Figure 57: Cooling potential Aquifer Thermal Energy Storage (Schieoevers Noord = ca. 460 GJ/(ha*yr))

Opportunities for Schieoevers Noord

The development of Schieoevers Noord, as well as the location of the area, offer some specific potentials for the generation of (v)LT heat and cold. These potentials are aquathermal energy from the Schie (Figure 58), the potential application of asphalt collectors in the *Hartlijn* and the new *Schieweg* (Figure 59), and the potential application of solar collectors and/or PVT panels on the roofs and/or in the facades of the newly constructed buildings (Figure 60).

All three sources can either be used directly or can be used to regenerate ATES wells. Thermal energy extracted from surface water can both be heat or cold. Solar collectors and asphalt collectors can only generate heat. Since the temperature of these two systems is much higher than the heat stored in the heat well, it can also be used relatively efficiently for the heating of hot tap water.

The quantitative energy potential of the Schie is dependent on many factors: e.g. the volume of water which is used to generate energy (the entire canal – or a specific part; several hours or multiple days), the ΔT by which the surface water is cooled or heated due to extraction of heat or cold, and on the power of the heat pump. For both of the solar alternatives, the potential depends on the surface area at which either asphalt collectors or solar collectors are installed, the efficiency of these systems, and the number of sun hours and/or outdoor temperature.

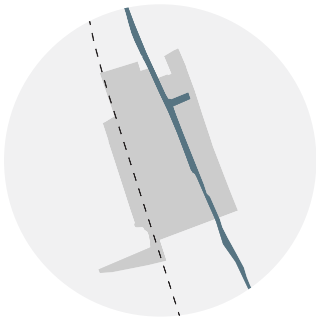


Figure 58: The Schie – aquathermal energy potential (from surface water)

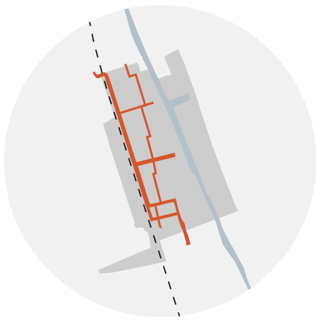


Figure 59: To be constructed roads as potential for asphalt collectors

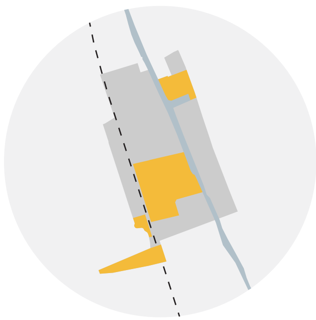


Figure 60: New buildings as potential for a.o. solar thermal energy

Choosing energy sources for adaptive development

As defined in Paragraph 6.2 and 6.3, the "scale of adaptivity" is the scale of the plot. The development of each plot can be seen as one individual step in the larger area development process. An energy source should be chosen, that fits this stepped area development approach. An energy source is needed, that fits the time horizon of developments, and that answer the energy demand both quantitatively and qualitatively. The primary source for plot developments is preferably sought in the row of the plot level, as shown at the start of this section – Figure 44 on page 128.

The energy sources with the largest quantitative potential for Schieoevers Noord, are ATES systems as well as the planned cascade grid from TU Delft to Voorhof with a possible return loop through Schieoevers Noord. The Leiding door het Midden is only a potential in case it is cascaded as well – newly built buildings can better be heated by LT heat so that HT and MT heat can be used for buildings that cannot be insulated that well (Tillie et al., 2009).

Since ATES systems also offer the potential for cooling – and they offer the potential to operate independently as a plot, this is seen as the most favourable source of heating (and cooling) for the different plot developments within the area development. The author wants to stress, that this decision is based on the information that is available at the moment. In case of developments that start after the construction of heat grids, the most favourable option might be different. Nevertheless, the scale at which ATES systems are applicable corresponds best with the scale of adaptivity in the development plan: a cluster of buildings.

For small developments (small plots or parts of plots) smaller-scale sources such as BTES, aquathermal energy, asphalt collectors, and solar collectors offer potential. All of these can also be used to regenerate the wells of an ATES system. In case it is constructed, a heat grid can also be seen as a system complementary to a (network of) ATES systems. Lastly, waste heat created within a plot can be a complementary heat potential, and as long as Hordijk and Prysmian continue their business – and keep producing excess heat – a connection to either of them creates a favourable situation for the energy balance in Schieoevers Noord as well.

Yet, the base for an adaptive development should be an energy secure system, controllable and operable at the level of the plot, independent of following developments: the Aquifer Thermal Energy Storage system.

6.5. Conclusion

This chapter explored the case study of Schieoevers Noord from multiple perspectives: by a spatial analysis of the area, by an analysis of the vision documents and plans that are used by the municipality, by an analysis of the stakeholders that are most closely involved in the developments, and an analysis of the potentials for sustainable energy in the area.

The first three parts of the analysis help to shape design challenges as formulated in Chapter 7 and the following design processes that will be described in Chapters 8 and 9. More importantly, these three sections create a deeper understanding of the physical area, of the ambitions and the status quo of the developments, and of the force field of actors. The fourth section answers SQ3: "*How do locally (or regionally) available sources of heat and cold fit the adaptive area development of Schieoevers Noord?*"

The *spatial analysis* has shown the strategic location of industrial area Schieoevers Noord within the Metropolitan Region Rotterdam-The Hague; the area is positioned on both the shipping route between Rotterdam and The Hague and crossed by the railway connecting these two cities. This shipping route – the canal Schie – as well as the railway and provincial road the Kruithuisweg, form a physical barrier within the area, separating it in four spatial entities. Schieoevers Noord currently is a mainly mono-functional area, focused on working/industry. Yet, on a city level, the area is located in a position that links a diversity of districts. Schieoevers Noord could potentially bridge residential areas and the TU campus and bridge the city centre to industrial area Schieoevers Zuid and the hinterland.

Distinctive for the area is the size of the "plot". The area is divided into 15 subareas: at this scale, developments are planned to and expected to take place. Plots mostly have one owner and/or one function. With a total surface area of 75 hectares for Schieoevers Noord, the average plot is large; plot developments will be impactful as a result.

Analysing the *development plan for Schieoevers Noord*, the most important element of the vision is the densification of the area to a mixed-use working-living environment, in which space is offered to the "making industry". This adds to a threefold urgency and/or ambition of the city of Delft: the need to add 15,000 houses to the city in the period up to 2040, the need to create 10,000 jobs within the same timeframe, and the ambition to become the "capital city of technology and innovation". The last can be catalysed by offering room for the making industry – an industry able to further develop innovations created at the TU Delft.

As has been stated in previous chapters, the area development is an adaptive process: the

Municipality of Delft sets out a "framework" within which development is allowed to take place. The framework is shaped by a framework map that mainly addresses the public space within the area, accompanied by a set of design guidelines addressing (future) building blocks. The developments will take place per plot; out of the 15 plots – 4 are selected to be developed until the year 2030. When approaching 2030 a plan for the following phase will be made. At this point in time, the order in which developments will take place is unpredictable – and some plots will transform more radical than others. So, the development plan has to be adaptive regarding the scale of the plot – which is named as the "grain-size" of adaptivity.

Concerning the *energy ambitions*, the baseline is set to develop energy-neutrally for at least the building-related energy. More ambitious is the vision to maximally contribute to the municipal sustainability ambitions: for Delft to become an energy-neutral city by the year 2050. Multiple scenarios exist for the provision of sustainable energy – collective systems within the area, together with other districts (TU Delft, Voorhof), or individual systems primarily based on Aquifer Thermal Energy Storage.

Many *stakeholders* are involved in the area development process of Schieoevers Noord, of whom the Municipality of Delft, the established companies in the area (united in BKS), and the project developers are the stakeholder groups with most power and interest in the development trajectory. The interest and power of these groups, however, are conflicting and complementary. The municipality has an interest in transforming the area to an area in which the share of residential real estate increases, yet the established companies mostly are the landowners – for whom the increase of inhabitants is a thread causing uncertainty regarding the continuation of their business. The developing parties are the ones that will finance developments and therefore have a financial interest in the developments, which might be a thread for public functions and/or the need for social housing in the area.

An important difference between these three stakeholder groups is their perception of *long-term and short-term*. Whereas the municipality sees the phase up to 2030 as a short-term, for companies 3 to 5 years can already be the long-term. For project developers, the long-term will correspond with the endpoint of a planned plot development.

Within the area development process, the municipality takes up many *different roles*: ranging from executor – in case of district facilities – to facilitator – in case of plot developments. Since the energy system for Schieoevers Noord could become either a district facility or a part of a plot development, the role of the municipality concerning the topic of energy is to be defined.

To answer SQ3, the sources of renewable energy that best fit the adaptive area development in Schieoevers Noord correspond to the grain-size of adaptivity within the area development process. Sources present at a larger scale could be valuable back-ups (e.g. for peak demands), sources present at smaller scales could be valuable as complementary sources of energy (e.g. for regeneration).

As a base for the development of an energy system for each plot development, Aquifer Thermal Energy Storage systems seem to be most suitable. The quantitative potential seems to be relatively large for Delft, at first sight. The system offers independency of other developments, and by using only the subsurface of the own plot – potentials for subsequent developments are not hindered. Furthermore, the supply of low-temperature heat fits newly built buildings, booster heat pumps can foresee in hot tap water. A large advantage of this system is the availability of a cold source. Men should only take into account that the demand for electricity will rise, on average and possibly in peaks as well.

Heat grids (either fed by geothermal energy by the TU source, or by industrial waste heat originating in Rotterdam) are a valuable potential as a back-up or as a complementary system. Aquathermal energy, solar thermal energy, and asphalt collectors offer the potential for regeneration of the heat and/or cold wells of an ATES system.

Ingredients for design brief

- The area of Schieoevers Noord is divided into 15 plots, which will partly be developed in a non-predictable order. Four will develop before 2030, an unknown number after 2030.
- The grain-size of adaptivity to incorporate in development plans (energy strategy) is the scale of the plot.
- A hard prerequisite for each plot development is to develop energy-neutral for the building-related energy; a more ambitious vision is to maximally contribute to the energy-neutrality of the city of Delft.
- For a successful area development, the three main stakeholder groups (Municipality of Delft, established companies, project developers) should find a way to work with their differing interests and power.
- The Municipality of Delft needs to define their role in the energy provision of SON: facilitating or executing.
- The use of ATES systems seems most suitable to foresee plot developments with sustainable energy: offering independence – organisation wise, as well as heat and cold. Thermal energy which is generated at larger scales could be used as a back-up, smaller-scale generation could be used for regeneration.

Box 3. Voorhof-Oost – first neighbourhood in Delft to be gas-free

The Ministry of Economic Affairs and Climate Policy initiated a programme called "*Green Deal Aardgasvrije Wijken*". Since The Netherlands has little experience with disconnecting neighbourhoods from the natural gas grid, the programme should accelerate the production of knowledge and experience. Local authorities play an important role in here. All municipalities that participate in the programme select a neighbourhood that they want to disconnect from the gas first – together with involved parties, the municipalities study feasible alternatives for the specific neighbourhoods.

The Municipality of Delft participates in the programme and selected the area of *Voorhof-Oost* – the eastern part of district Voorhof – to become the firs gas-free neighbourhood of Delft (Figure 61). Topographically, Voorhof-Oost and Schieoevers Noord have a certain piece of land in common: the spatial entity located along the Vulcanusweg. The strip with businesses and public functions, located at the edge of residential area Voorhof, and along the railway.

Voorhof has a large (potential) advantage: many buildings are currently heated by a gas-fed heat grid. Though, the infrastructure for room heating by a heat grid already exists. The strip along the Vulcanusweg, has been indicated by the development plan for Schieoevers Noord, to be developed after 2030 only. Renovations can take place, no transformations. The author, however, would state that retrofitting the residential buildings of Voorhof simultaneously with developments at the Vulcanusweg would offer the opportunity to seek for synergies in energy streams. Not only result-wise would that be beneficial for Delft, it also creates a great learning opportunity within the Green Deal.

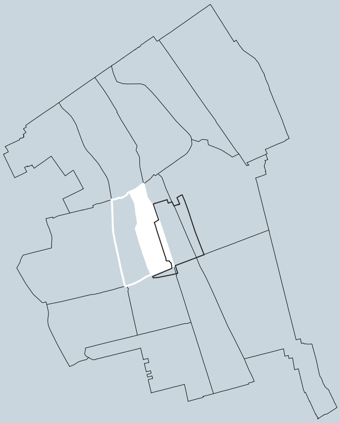


Figure 61: Voorhof-Oost (in white), the neighbour of Schieoevers Noord and part of the "*Green Deal aardgasvrije wijken*" on behalf of the Municipality of Delft

7.
Design brief

The previous chapters – on the concept of adaptivity (Chapter 4), energy planning methods (Chapter 5), and the case of Schieoevers Noord (Chapter 6) – formed the input to formulate possibility spaces for process interventions, aiming to improve the process of sustainable energy planning at the Municipality of Delft, by adding elements of adaptive approaches.

As discussed previously, the area of Schieoevers will be developed "organically", step by step, with a hard distinction between short-term developments and long-term developments – those that (are allowed to) take place before the year 2030 and those that could take place thereafter. The transformation process should be able to react to initiatives and developments in the area, the plan is adaptive and time-flexible. The scale or “grain size” of the required adaptivity in this plan, is stated to be the level of a plot or partial development. Schieoevers Noord is divided into 15 plots, of which the ones numbered as 3, 4, 8, and 12 will be developed first (Figure 63).

The development plan for the area development is stated to be an adaptive framework for development, yet it is to be explored what that implicates for future developments. As drawn in Figure 62, the framework with its concrete design guidelines is developed with the knowledge that three developments (at four plots) will take place on the short-term, with a long-term vision for the entire area in mind. Yet, the pathway after 2030 is open: a notion which on the one hand creates uncertainty for contemporary developments, but on the other hand, creates a pathway in which learning can take an important place and in which time is reserved to adapt the design guidelines – and the long-term vision itself if needed. In this context, it can be questioned, if – specified to the scope of sustainable heat and cold supply – the current design guidelines leave room for adaptation and guide the area development towards the set ambitions; that has to be explored as well.

When the above and the analysis of theory on adaptivity, on the presence of elements of adaptivity in existing approaches and methods for sustainable energy planning, and the analysis of the case study – its characteristics, plans, ambitions, stakeholders, and energy potentials are compared, a threefold design challenge can be formulated. An adaptive approach to energy planning needs to be designed, with special attention to the following.

1. A tool or method is desired, which supports the Municipality of Delft exploring and accepting uncertainties (unpredictabilities) that come with long-term processes. A tool that supports explication of the barriers

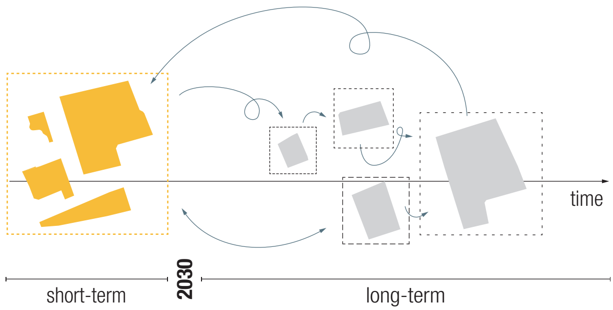


Figure 62: The framework for development of Schieoevers Noord and its design guidelines should evolve over time: it should be adapted

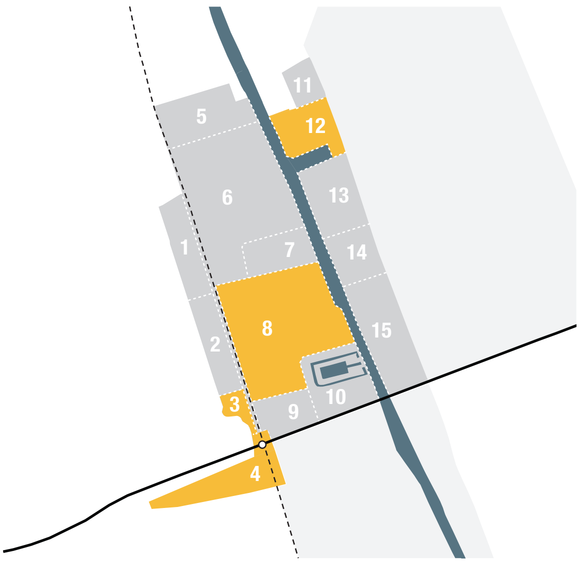


Figure 63: The 15 plots of Schieoevers Noord, those in yellow are to be developed (or to start developing) before 2030

that can exist or come into existence caused by uncertainties that are present right now, that could be present around 2030, or at any other point in between developments. The interlinkage between knowledge, plans and ambitions on spatial developments, programme and energy is of importance, making sure all of the fields that impact each other share their uncertainties.

2. An approach is to be set up, to iterate and adapt the guiding process of the area development and the development of the energy strategy on the long-term; building in learning-points in between developments, which make sure that the design guidelines keep fitting the developing area and the area development, and that barriers or uncertainties for new developments are spotted in time, to be able to cope with them.

3. The need for energy-based design guidelines is to be explored; if needed they should be designed. These guidelines intend to make sure spatial, functional, and energetic designs comply with the most important ambitions on energy for the whole development of Schieoevers Noord: being the realisation of developments which are energy-neutral for the building-related energy consumption (development plan Schieoevers Noord), and not hindering the municipal sustainability ambitions, which most importantly is the aim to be an energy-neutral city in 2050. These design guidelines should not be prescriptive, yet create conditions in which each imaginable development plan will positively contribute to a sustainable area development and a sustainable city.

The first and second design challenge are tackled in Chapter 9, creating a stepped approach for adaptive energy planning – including steps for the present and steps for the (far) future. A proposal for the third design challenge is described in Chapter 8, in which design guidelines are created, based on sustainable energy demand and supply – and how these fit into an adaptive – or organic – development process. A long-term process is needed, yet a good start-off not hindering the long-term should not be overlooked.

For the approach which is created and described in Chapter 9, it is of importance to not only focus on creating interventions concerning those factors of adaptivity that are currently too little exposed in existing approaches for energy planning; which formed the basis for design challenges 1 and 2. The factors which are already highlighted and for which tools and methods exist should be included too; yet no explicit design challenge exists here.

8.
Reciprocity of energy, space and function

The development of Schieoevers Noord is guided by a set of design guidelines: keeping options open for developer and owners while ensuring to realise a long-term vision. This chapter studies the need for spatial design guidelines which are based on the (local) energy balance of Schieoevers Noord and presents a proposal for guidelines which incorporates the reciprocity between spatial design, functional programme, and energy demand and supply.

Reflecting on the characteristic of adaptivity named as "*focus on conditions for development*", the following conditions for development should be incorporated in adaptive planning: securing the quality of life under a variety of potential development trajectories, generating context-sensitive flexibility in the pace and direction of development, and stimulating the emergence of socially desired development trajectories (Rauws, 2017). This chapter studies how the creation of energy-based design guidelines for plot developments in Schieoevers Noord can ensure living quality (for as far as energy is able to impact that), how flexibility in energy planning can be established, and how the area development trajectory can unfold into an impulse for Delft's energy transition.

In this chapter, firstly, the sustainable energy ambitions for Schieoevers Noord are discussed, after which an approach of calculating and designing with uncertainties in energy demand is set up. Key figures are gathered, used as input for heat balance calculations. The outcomes of these calculations are used as inputs for conceptual spatial designs – able to test how to build in thermal balance and to study which parameters are overlooked while calculating. With these results, design guidelines for Schieoevers Noord can be created, which then are compared to existing plans for plots in Schieoevers Noord. Thereby, sub-questions 4 and 5 can be answered: "*Which design guidelines for plot developments could be used by the Municipality of Delft, concerning the (local) energy balance of the plot, to establish adaptivity and energy-neutrality in the spatial and functional design of Schieoevers Noord?"* (SQ4), and *"What are the implications of these guidelines for existing spatial and functional design proposals for plot developments within Schieoevers Noord?"*. Central in each of the sections, is the reciprocity between energy, space, and function – reciprocity, since all parameters are open in a to be built area.

Since each of the plots will be developed at its own pace and moment in time, but some of the calculations require specific inputs, it is decided to use one specific plot as "case study" for thecalculations in this chapter. That plot is the plot referred to as "plot 8" or the Schiehallen – and is to be developed into the cluster called "Kabeldistrict". The plot is relatively large, as are the plans. This particular plot development, thereby, is impactful for Schieoevers Noord.

8.1. Energy ambitions for Schieoevers Noord

As described in Chapter 6 – the analysis of Schieoevers Noord – several ambitions concerning the energy consumption of Schieoevers Noord are set in the development plan, the environmental impact assessment, and several advisory reports. However, not all of these ambitions are similarly formulated, according to the author. For the entire city of Delft, the sustainability horizon consists of the ambition to be an energy-neutral city in 2050, which – as described in Chapter 2 – does not mean energy-neutral at the own ground, but the realisation of sustainable energy supply for the full energy demand.

The development plan for Schieoevers Noord, describes the principles for a plot development to be energy-neutrality for the building-related energy (heating, cooling, lighting, elevators); comfort – with special attention for cooling (without using air conditioning or related, regarding the sound production and high electricity use) (Broekman, 2019). Furthermore, the plan aims to find innovative and integrated solutions for (among others) energy – and sees for example opportunities for synergy in energy streams. Lastly, yet of high importance, the development of a plot may not hinder other parties or the potential for sustainable development of following plots.

The environmental impact assessment also states the ambition of Delft as a whole to become energy-neutral. Furthermore, it prescribes hard and soft "frameworks" or ambitions: the hard ones being the prevailing laws and regulations, and stated policy – which the plan must meet or the minimum ambition level; the soft ones are desires and add on to the minimum ambition levels. For a "sustainable environment", the hard frame is stated to be national and local energy policy and regulations, as well as not hindering the municipal sustainability ambitions; the soft framework is stated as delivering a maximal contribution to the municipal sustainability ambitions (Lindeboom & Verhoeven, 2018).

Consultant Metabolic adds the importance of reducing the energy demand to a demand lower than permitted by the current and new BENG regulations for low-energy building, to be able to meet the city ambitions to become energy-neutral by 2050 (Blok, et al., 2018).

Concerning heat and cold demand (low-temperature heat) of a development, building-related energy demand and the total energy demand comprise the same demand. However, building functions with a high usage-related electricity demand, or a demand for high-temperature heat, would not fall within the ambition of energy-neutrality in Schieoevers. The author's perspective is that this usage related electricity demand should also be incorporated in the area development for as far as possible since the area development will otherwise add onto the city's total energy demand and thereby increase the energy transition challenge. That is seen as hindering the road to energy-neutrality.

With the creation of energy-based design guidelines, the following principles are kept in mind in the remainder of this thesis. The development of a plot should be:

- Energy-neutral, for at least the building-related energy demand, and with the ambition to be energy-neutral for the full energy demand;
- Developed in such a way that following developments are not hindered concerning their local energy potentials;
- Developed with a notion of redundancy – allowing building functions to change, user numbers to change, and types of energy demands to vary over time – all to a limited degree.

8.2. Concept of the heat balance calculations

As described, of the three options for sustainable heat supply in Schieoevers Noord – Aquifer Thermal Energy Storage (ATES), heat grid, or a hybrid variant of the two – the scenario using ATES as main source of heating and cooling is preferred for several reasons. In the interview with environmental consultant Stijn van Liefland, several of the uncertainties concerning energy planning for the area development of Schieoevers Noord that he faced, were related to the construction of a heat grid – to the heat sources (geothermal energy, TU Delft) as well as to the exact locations. And if a heat grid is rolled out, then the timing may be problematic for the first developments in Schieoevers Noord – the construction of the grid will probably lag behind. Next to that, a heat grid can not foresee in cold, whereas an ATES system can.

So, an ATES system creates a state of independency for plot development and the subsurface in Delft and Schieoevers Noord is a source of energy with high potential. The local metabolism is used as starting-point for sustainable development. Following the principles for plot development, the total heat and cold demand should be generated sustainably without possibly hindering following developments, or redevelopments of existing companies for example. Thereby, a relation exists between what is build – plus the energy demand of these buildings – and the amount of energy that is available. Figure 64 shows the four parameters that create this relation: the locally available heat and cold capacity, the programme dependent heat and cold demand of buildings, the mixture of building functions, and the building density. It is important to note, that for an ATES system to function well on the longer term, the volume of water that is extracted from the heat source on a yearly basis,

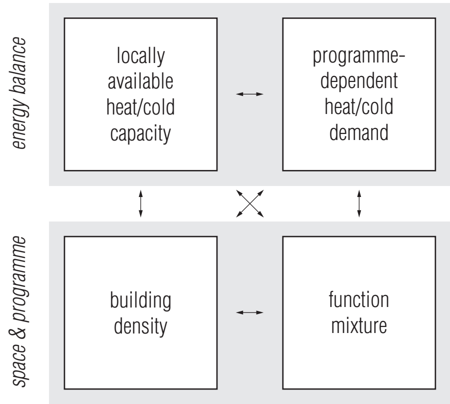


Figure 64: The parameters which largely determine the energy balance of the area development

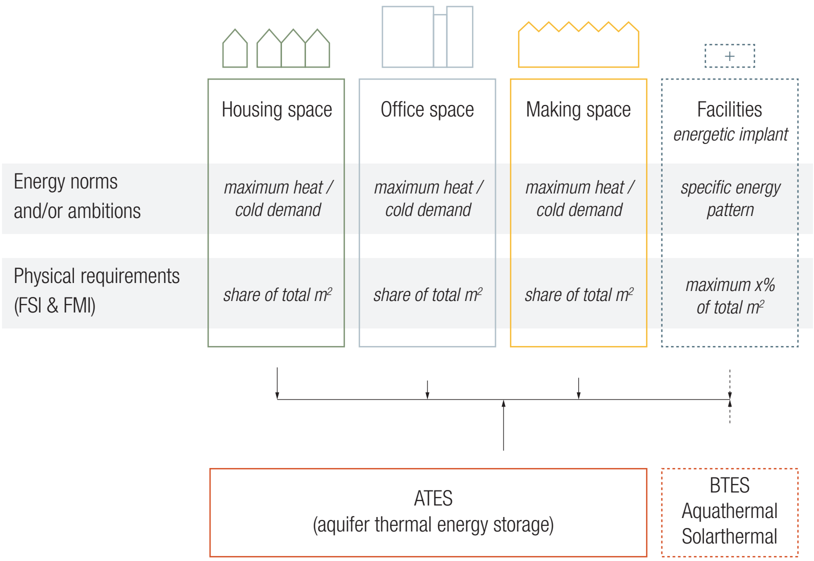


Figure 65: Schematic thermal energy balance for the intended spatial developments in Schieoevers Noord with the local energy potentials; ATES systems require a balance between heat and cold, whereas BTES systems do allow a disbalance.

should be the same as the volume extracted from the cold source – so ideally, the heat demand of the buildings connected to an ATES system, is equal to the cold demand of these same buildings. The subsurface has to be kept in balance.

Specifying these parameters for the case of Schieoevers Noord, the overview presented in Figure 65 forms the basis to calculate the opportunities and challenges for energy-neutral area development. The development of Schieoevers Noord is based on the urgency to answer a housing shortage and a need to increase the amount of jobs in the city of Delft; these jobs varying over education levels, and types of work. Three building typologies are created that will form the gross of the building stock which is to be added in Schieoevers Noord: *housing*, *offices*, and *making halls*. Each of these building typologies has its own characteristic energy demand pattern – resulting in heat and a cold demand. Housing typically has a higher heat demand than offices for example. Then, the development plan has certain aims concerning the building density, and the mixture of functions – which impacts the amount of square metres that are ideally built, and the ratio of presence of the three building typologies. Furthermore, as stated, an Aquifer Thermal Energy Storage system (including heat pumps) will form the basis of the energy supply – so the energy potential of this source is a parameter in the heat balance calculation. Lastly, the building functions can be complemented with so-called energetic implants, functions with an energy demand pattern that complements other functions; and the energy supply can be complemented by other sources – either with a generation potential on a smaller scale than the plot (e.g. BTES, solar thermal energy, or aqua thermal energy) or on a larger scale (such as a heat grid).

A balance between these four parameters can be created from different starting-points; as shown in Figure 66 on page 162. It is preferred in this project to determine the ideal building mix and/or density based on the local metabolism and energy demand of desired building functions. Reasoning the other way around is possible too: determining the desired building density and function mix first, followed by either a strategy to foresee in the corresponding energy demand, or a strategy to determine the maximum energy consumption for each building, while using the subsurface's heat and cold potential. In fact, it does not matter from which view point the energy balance is started – since it should be in balance to be net energy-neutral.

For the calculations that are discussed in this chapter, the following is used as a basis. Only energy from the shallow subsurface is used as available heat/cold potential; the desired function mix and density is used as an ambition – since these form the urgency to develop, and the energy demand is minimally on the ambition level of current building legislations. The calculations are executed with the aim to find out how much square meters, per function, per hectare could be realised using local sustainable heat and cold sources. The function mix and building density intended to be realised at plot 8 – the Kabeldistrict – are used.

A set of formulas is used to calculate, describing the mathematical relation between four variables, called H, O, M, and Xheat. To generate workable outcomes for a situation of four unknowns, a minimal of three equations has to be used. Since the outcomes of the calculations are used as input for spatial designs, three equations is preferred over four. Three equations result in a series of outcomes, leaving room for design choices, whereas a system of four linear equations would lead to one solution for each variable. So, three formulas are created. They are first shown, and afterwards it is explained how they could be filled in and adapted.

$$(1)\ \textit{heat demand housing} * H + \textit{heat demand office} * O + \textit{heat demand making} * M = \textit{heat capacity underground}$$

$$(2)\ \textit{cold demand housing} * H + \textit{cold demand office} * O + \textit{cold demand making} * M + \textit{Xheat} = \textit{cold capacity underground}$$

$$(3)\ \frac{FMI}{100} * \frac{H}{90} = \left(1 - \frac{FMI}{100}\right) * \frac{(M+O)}{60}$$

With:

> H = surface area housing (m²);
> O = surface area office (m²);
> M = surface area making (m²);
> Xheat = disbalance between heat and cold (kWh/yr) – a positive value indicates a residual heat demand for regeneration of the heat well, a negative value indicates a residual cold demand for regeneration of the cold well;
> FMI = Function Mixing Index, calculated by FMI = 100 ∗ fte / (fte + number of houses).

All heat and cold demands are expressed in kWh/(m²∗yr) and the heat/cold capacity of the underground is based on a surface area of 1 hectare (=10,000 m²). For the calculations, an average of 90 m² per house, and 60 m² per workspace is used – as is determined in the development plan for Schieoevers Noord.

The three formulas above form the basis for the heat balance calculations. The system of equations calculates the amount of square meters of different building functions in a certain mixture, which can be built while using only the local heat and cold capacity. The resulting

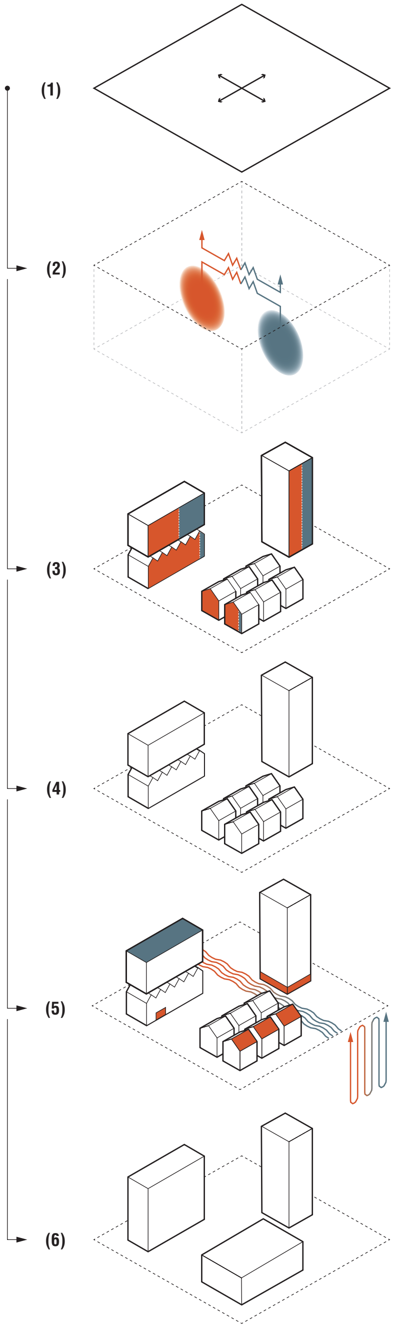


Figure 66: Reasoning of a sustainable energy balance based on locally available sources: (1) one hectare surface area is able to (2) deliver a certain heat and cold potential; (3) different desired building functions all have their specific energy demand (4) which could determine the mix in which they are built; (5) additional local heat sources determine redundancy and potentially additional energy supply, (6) resulting in a final building density which can be realised in a sustainable, local and secure way.

building density (expressed by the *FSI* – this term is explained later) can be calculated by summing up H, O, and M and divide it by 10,000 m². To increase the building density, or decrease the disbalance (Xheat), additional functions (energetic implants) can be added to the area, positively influencing the disbalance between heat and cold. Whereas the energy demand for the three main building functions is expressed in kWh/(m²*yr), the additional function has a set surface area, and thereby an energy demand expressed in kWh. Additional heat sources can be added to the equations as well. This would lead to the following adaptations to the first and second equation, note: the amount of variables, or unknowns stays the same. Varying the FMI is a way to influence the FSI and the thermal disbalance in the underground as well, yet simply asks for different input values in the third formula.

$$(1)\ heat\ demand\ housing * H + heat\ demand\ office * O + heat\ demand\ making * M + \boldsymbol{heat\ demand\ implant} = heat\ capacity\ underground + \boldsymbol{heat\ capacity\ additional\ heat\ source}$$

$$(2)\ cold\ demand\ housing * H + cold\ demand\ office * O + cold\ demand\ making * M + Xheat + \boldsymbol{cold\ demand\ implant} = cold\ capacity\ underground + \boldsymbol{cold\ capacity\ additional\ cold\ source}$$

8.3. Gathering of key figures

As the adaptive area development of Schieoevers Noord consists of future visions and some concrete plot developments that are designed at the moment, calculations on energy balances should be based on key figures representative at the moment of calculation; final designs are not there yet – and the future state of the full area development is unknown. To be able to generate insights in the reciprocity of energy potentials and demands, functional programme, and spatial design, up-to-date key figures are collected. The thermal energy demand (comprising both cold and low-temperature heat) of different building functions is explored in this paragraph, as well as the thermal energy potential of the area of Schieoevers Noord and the spatial indicators concerning building density and mixed-use development.

Thermal energy demand

Thermal energy demand is dependent on many design parameters as thermal insulation, orientation, window-to-wall ratio, etcetera. Furthermore, norms and regulations, as well as (low-/zero-)energy ambitions impact the energy demand of a building in a forced manner. The usage of a building (e.g. type of use, amount of users, time of use) partly determines the energy demand as well. The Municipality of Delft, in the development plan for Schieoevers Noord, set the ambition to realise buildings that are energy-neutral for the building-related energy demand; however, that does not directly determine the height of the energy demand.

The sources that are used to determine the expected energy demand of future buildings are, firstly, the BENG-norms (*Dutch*: Bijna Energie-Neutrale Gebouwen, *English*: Nearly Zero-Energy Buildings) (Ollongren, 2019). Secondly, the NTA 8800 (NEN, 2019) is used; the official Dutch determination method for the energy performance of buildings, in line with the Energy Performance of Buildings Directive by the EU. Lastly, key figures used by installation and energy consultancy firm Merosch are used, retrieved from a report written commissioned by the Municipality of Delft (Vlot & Van de Griendt, 2019). All key figures that are used, describe the energy demand on a yearly basis – daily data is not included.

At the point in time that the construction of the first new buildings in Schieoevers starts, the BENG norms most probably have replaced the current Building Decree. If not steered differently by the municipality, developers will be guided by these norms. From a cost efficiency point of view, it is assumed that the maximum allowed energy consumption will be the target.

BENG determines the Dutch requirements for the energy performance of buildings by three energy performance indicators (Rijksdienst voor Ondernemend Nederland, 2017):

- Maximum energy demand in kWh/m² per year (BENG-1);
- Maximum primary fossil energy consumption in kWh/m² per year (BENG-2);
- Minimum share of renewable energy in % (BENG-3).

The numerical value of these indicators differ per building function. The BENG-1 indicator distinguishes between building geometries and in case of residential buildings also between construction weights. This distinction on geometry is based on the ratio between floor area and building envelope area – introduced by problematic building typologies such as tiny houses and bungalows, which have a relatively large envelope area. For the density planned in Schieoevers Noord, the most strict norm will apply – except for the plot specifically assigned for a tiny house project.

The BENG-1 norms are used for calculations within this project, as it concerns the energy demand. As it is in the ambition of the graduation thesis that only renewable sources of energy are used, the BENG-2 and BENG-3 will be 0 kwh/m² of fossil energy, and a 100% share of renewable energy. The BENG-1 norms for the building functions housing, offices and shops are used; shown in Figure 67.

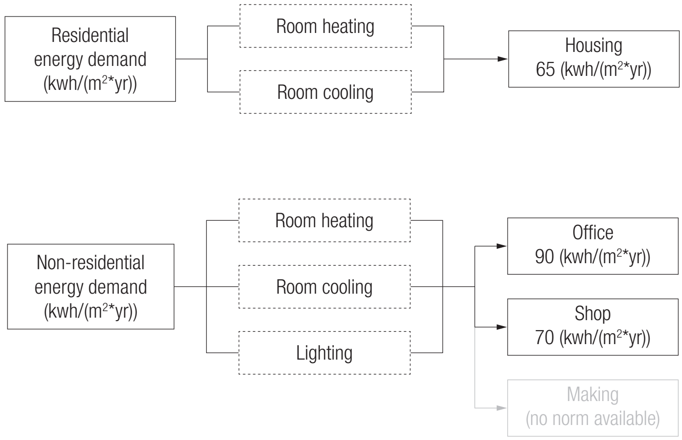


Figure 67: BENG-1 norms for housing, offices, and shops

Residential buildings and office spaces

The two primary functions planned to form the future of Schieoevers Noord, are housing and "working". Working is a broad term, in which different type of jobs and businesses are united. Schieoevers Noord should become an area complementary to the TU Delft campus; at the campus, research, development, design, and prototyping are central, Schieoevers Noord should be able to house enterprises that commercialise the TU Delft innovations – upscaling the innovation, making, and trading it. All in all, the development plan of Schieoevers Noord, describes possible working activities to be housed in the area, being production, R&D, storage, office, assembly, logistics, recycling, as well as education, art, and parking. Some of these activities create requirements for the public space, others for the buildings.

For calculating the heat and cold balance in Schieoevers, two types of buildings for "working" are included: office buildings (for more knowledge-intensive activities) and industrial spaces for "making industry" – also referred to as "making halls" – which houses processes of production, assembly, and possibly of recycling. The average floor space per job in Schieoevers is planned to be 60 m².

Housing is a bit more straightforward; as specified before, a housing shortage for mid-priced rental and owner-occupied buildings does exist in Delft. Target groups are knowledge-workers, who mostly do not live in Delft, graduates that mostly leave the city after graduation, and elderly, since the city is ageing. The realisation of social housing and student housing is part of the plans as well. An average of 90 m² per house is used by the municipality in the plans for Schieoevers Noord.

For housing and office buildings, the maximum allowed energy demand is written down in the BENG-1 norms (Figure 67). For housing, the maximum energy consumption per square meter on a yearly basis, is 65 kWh; for an office building, the norm is 90 kWh/(m²∗yr). Whereas this norm includes only energy used for room heating and cooling for housing; the norm for office buildings – and utility buildings in general – includes also the electrical energy consumption required for lighting (Ollongren, 2019; Rijksdienst voor Ondernemend Nederland, 2017). For offices, the energy demand required for lighting is estimated by the average number of hours that lighting is required (2500 hours per year (NEN, 2019)), and an average wattage of 7 W/m² (Van der Loos, 2016). This electricity use is extracted from the BENG-1 norm; the residue being the maximum energy demand for heating.

Both of the building functions, have an energy demand related to the usage of hot tap water as well – these can be retrieved from the NTA 8800. For housing, the calculation value for the heat demand for hot tap water which is used, is 856 kWh per year per person – corresponding to a usage of 40.29 litres of hot tap water (60°C) per person per day. This calculation value thereby is independent of the size of the house. For non-residential buildings, the hot tap water usage is related to the surface area, expressed as demand per square meter. For office buildings, the energy demand for hot tap water, is 1.4 kWh/(m²∗yr), corresponding to 0.065 litres per square meter per day.

As the calculations benefit from variables expressed in the same manner, the hot tap water demand for housing, is translated to a demand dependent of the surface area. The target group for the area, largely existing of one- and two-person households, was the base for the estimation of an average household size of 1.5 person. Together with an average house being 90 m², this makes an demand/m² of (856∗1.5)/90 = 14.3 kwh/(m²∗yr).

A last step, before these key figures can be used in heat-balance calculations for Schieoevers Noord, is the share of both heat and cold demand within the total heat and cold demands. For this distribution, no key figures or ratios are available in norms. The study of the in Chapter 5 described Rotterdam Energy Approach and Planning, however, created balances for heat and cold, for several building functions – these are used for calculating in this thesis (Tillie et al., 2009). For housing, the total heat and cold demand could be distributed over heat and cold with a ratio of 85% and 15% respectively. For offices this ratio would be 55% heat, 45% cold. For both housing and offices, hot tap water is included within these percentages. All of the above-mentioned key figures could also be retrieved from Table 4 on page 181.

Making industry

The making industry – preferably housed in industrial spaces, making halls – is a different and more complicated case. These industrial spaces are not incorporated in the BENG norms and the energy label system, since the building diversity in this category is enormous: part of the industrial building stock is fully climatized, and part is neither heated, cooled, or ventilated. Yet, (making) industry can be a large energy consumer. At the moment, the heating demand of the building typology is estimated to vary from 6 to 15 m^3 of gas used for heating per square meter per year (corresponding to 60-145 kwh/(m^2*yr)), cooling (if present) is incorporated in the electrical energy consumption (Niessink, Menkveld, & Sipma, 2017).

The Dutch Green Building Council calculated the maximum allowed average energy consumption of buildings in 2040, in line with the ambitions of the Paris Agreement. These calculations are based on a two-third energy saving scenario within the built environment, and a total availability of 610 Petajoule of renewable energy for The Netherlands. In this scenario, industrial halls which are cooled would be able to use 80 kWh/(m^2*yr) and halls which are not cooled, would be able to use 50 kWh/(m^2*yr). These numbers are an average of all buildings in 2040: existing ones, and new-built buildings (Dutch Green Building Council, n.d.).

The case of Schieoevers Noord addresses new buildings only (the old ones are left out of account). Therefore, different numbers are needed to use in calculations, and these are constructed as follows. Firstly, a distinction between electricity-based and heat-based making industry is made. In fact, the halls which can be occupied by either of these categories are not that different, yet the activities that take place influence the energy consumption to a large extent. Entrepreneurs that need heat for their production or "making" process, are mostly in need of high-temperature heat for their process, creating a high cooling demand, and a lowered heat demand, and an certain amount of low(er)-temperature waste heat. Entrepreneurs needing electricity, will have a much higher heat demand and a lower cooling demand – since the machines working on electricity do not produce large amount of heat. In the case of heat-based making industry, men can think of material production, whereas electricity-based making industry will mostly process materials into products.

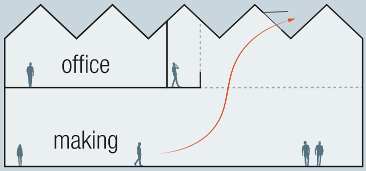
Looking to the target group of Schieoevers Noord – for the new buildings – electricity-based making industry seems the most suitable to upscale Delft innovations. Nevertheless, the market is unpredictable, and heat-based making industry can probably be housed in the same spaces. For calculations, though, the electricity-based making industry is taken into account.

Figure 68: Impression of the Fiction Factory making hall (source: www.fictionfactory.nl)

Key figures for this building typology and usage function, are based on a case study: the Fiction Factory, based in Amsterdam (Figure 68). This company was willing to give insight into their energy system. An explanation on this company and its energy system is included at page 169. The energy demand patterns can be summarised as follows. The hall, together with the office which is situated in the hall, is heated by a ground pump heating system, existing of 12 heat sources. The estimated power which is delivered by this system is 37.5 kWh/(m^2*yr) – which is the average value for the office and hall. Since the hall creates workspaces that are estimated to be three times larger than office workspaces, the estimated hot tap water demand is 0.5 kWh/(m^2*yr). The cold demand is estimated to be 2 kWh/(m^2*yr); a low value – since active cooling is only used at tropical days. These numbers can also be found in Table 4 on page 181.

Energetic implants

Since the building functions *housing*, *office*, and *making* all have a heat demand which is higher than the cold demand, additional functions demanding more cold than heat could create a more balanced consumption pattern. These functions, which have complementary heat and cold demand patterns, are also called “energetic implants” (Tillie et al., 2009). To balance the heat demanding functions – with building functions that would fit the developments of Schieoevers Noord – supermarkets and shops/small coffee bars would be realistic implants. Both have a higher cooling demand than heat demand; the supermarket also generates a lot of low-temperature waste heat, coming from the fridges used for product cooling.



Box 4. Fiction Factory: making industry Amsterdam North

With help of the Fiction Factory – a professional construction studio situated in Amsterdam – a profile could be set up for the energy demand pattern of spaces used by "making industry". The Fiction Factory manufactures theatre sceneries – the market they originate from – and build stands for trade fairs across Europe, as well as interiors for offices and shops of international (fashion) labels.

The energy demand of Fiction Factory can be seen as energy conscious – using low-temperature heating systems, fed with energy originating from ground source heat pumps; using groundwater for cooling; and generating the full electricity demand by over 1000 PV panels situated on the roof of the in 2009 built hall. The hall gives room to 2000 m² of making space at the ground floor and 1400 m² of office space, located at the first floor.

The ground source heat pump is connected to 12 ground loops, situated at a depth of 100 meters. Since the enterprise currently has outsourced the mapping of the actual heat demand, no final heat demand for the hall could be stated. Yet, the used surface area, and the presence of the number of 12 ground loops, enabled the author to do the following estimation. A the length of each loop is stated to be 25 meters, with a heat transfer rate of 35 W/m (Yanovshtchinsky, Huijbers, & Van den Dobbelsteen, 2012); with an estimated amount of heating days of 120, 10 hours a day – an average heat demand of 37.5 kWh/(m²*yr) for the total 3400 m² would be the case.

The hot tap water usage is estimated to be lower (per square meter) than in office buildings, since the hot water is used in the canteen only. The volume thereby will be comparable, yet less employees are present per square meter; the estimation is that a workspace in the making hall is three times larger than a spot in an office. Therefore, the estimated yearly hot tap water usage is stated to be 0.5 kWh/m².

Active cooling is only used in case of tropical days (>30°); for the rest of the year – natural ventilation by openable roof windows foresees in cooling: the hall is two . With 11 tropical days in 2019, 8 tropical days in 2018, and an average of 4 tropical days – the median is taken: 7.5 tropical days; with an estimated cooling time of 10 hours a day, this would lead to a cooling load of about 2 kWh/(m²*yr).

The supermarket belongs to the category of “shops” for the BENG-norms, making up a maximum energy demand for lighting, room heating and room cooling of maximum 70 kWh/m². The energy demand for lighting is estimated to be 8 W/m² (Van der Loos, 2016), turned on for 12 hours per day, 365 days on average – resulting in 35 kWh/(m²∗yr). The tap water demand is based on key figures for shops – corresponding to 1.4 kWh/(m²∗yr). The ratio between heat and cold demand is estimated to be 10% versus 90% (Tillie et al., 2009). Next to the building-related energy demand based on BENG, supermarkets typically have a high electricity demand, required for product cooling; and these fridges generate a lot of waste heat, which can be reused. Based on the graduation work of Nick ten Caat, the amount of heat produced by fridges is estimated to be 15 W/m², year round, 24 hours a day (Ten Caat, 2018); corresponding to over 130 kWh/(m²∗yr) of waste heat.

The shop or coffee bar is an energetic implant with a smaller impact on the heat balance of a cluster of buildings. The BENG-1 norm is equal to 70 kWh/(m²∗yr), equally to the supermarket. The lighting, with less hours (3100 a year), and a higher voltage (12 W/m²) adds up to a demand of 37 kWh/(m²∗yr) (NEN, 2019; Van der Loos, 2016). The ratio heating versus cooling, would be 35% and 65% respectively. The energy demand due to hot tap water usage, which is 1,4 kWh/(m²∗yr) for shops, is expected to be higher in coffee bars. Therefore, calculations are made with a doubled amount of energy consumption for hot tap water.

Since the addition of an extra variable in the heat balance calculations will lead to mathematical problems, for the energetic implants a set surface area is used. So, for example, when a supermarket is added to an area, 800 m² is added with the energy demand pattern of a supermarket. For shops, an energy demand corresponding to an average floor area of 100 m² is added to the heat balance. These numbers, are also to be found in Table 4 on page 181.

Electricity demand

To be able to determine the effect of adaptations in functional programme – such as a difference in mixture or the use of energetic implants – on the total energy balance, key figures for the electricity demand of the different functions are gathered as well. Houses use about 26 kWh/(m²∗yr) (De Jonge & Bloem, 2018); both offices as making industry are estimated to use about 60 kWh/(m²∗yr) (De Jonge & Bloem, 2018; Sipma & Rietkerk, 2016). For the energetic implants, the electricity demand is estimated as 254 kWh/(m²∗yr) for a supermarket, and 100 kWh/(m²∗yr) for a shop (Sipma & Rietkerk, 2016). All of these numbers are to be found in Table 4 on page 181 as well.

Thermal energy potential

The thermal energy potential which is used for the heat balance calculations, is based on a main heating and cooling system – Aquifer Thermal Energy Storage (ATES) – and a secondary system – Borehole Thermal Energy Storage (BTES); the working principles explained below. A study is done to the underground potential in Schieoevers Noord by IF Technology; the outcomes of this study are explained below, as well as the potential of other energy sources, able to regenerate the heat and cold wells used in an Aquifer Thermal Energy Storage system.

Principles of ATES and BTES

An Aquifer Thermal Energy Storage system is an open system, based on extraction and infiltration of thermal energy in aquifers – or water-retaining sand or gravel layers in the subsurface. An ATES system consists of a heat and a cold source or well. The subsurface has a relatively constant temperature of approximately 12°C, the wells get a temperature of about 6-8°C for the cold source, and 18-20°C in case of the heat source (Agentschap NL, 2011). A heat pump is coupled to the ATES system; in the winter this heat pump heats buildings with the heat that is extracted by pumping up hot ground water from the underground heat source – the ground water gets cool, and is infiltrated in the cold source. During summer, the water from the cold well is used for cooling – and the reheated water is injected back into the hot well, creating a cyclic process. Wells are generally situated between 20 and 250 meters below ground level. Two configurations are possible: either a doublet system, in which two sources are positioned horizontally next to each other at a certain distance, or a mono-well system – consisting of one source with two filters at different depths, creating a heat and cold well vertically positioned towards each other. Both the principle of a doublet and mono-well system are shown in Figure 69.1 and Figure 69.2.

To function as a reliable heating system, the heat and cold wells of an ATES system should be well-balanced: each summer, the amount of heat extracted in the winter should be regenerated by using energy from the cold source – and vice versa. When, for example, the heat demand on a yearly basis is larger than the cold demand, the heat source should be regenerated by other sources of heat – think of solar thermal energy, aqua thermal energy, or return pipes of a heat grid.

A Borehole Thermal Energy Source system (also referred to as ground source heat pumps) is comparable to the ATES system, yet this system is closed. Whereas the ATES system moves around ground water, a BTES system consists of a closed system of pipes, in which water

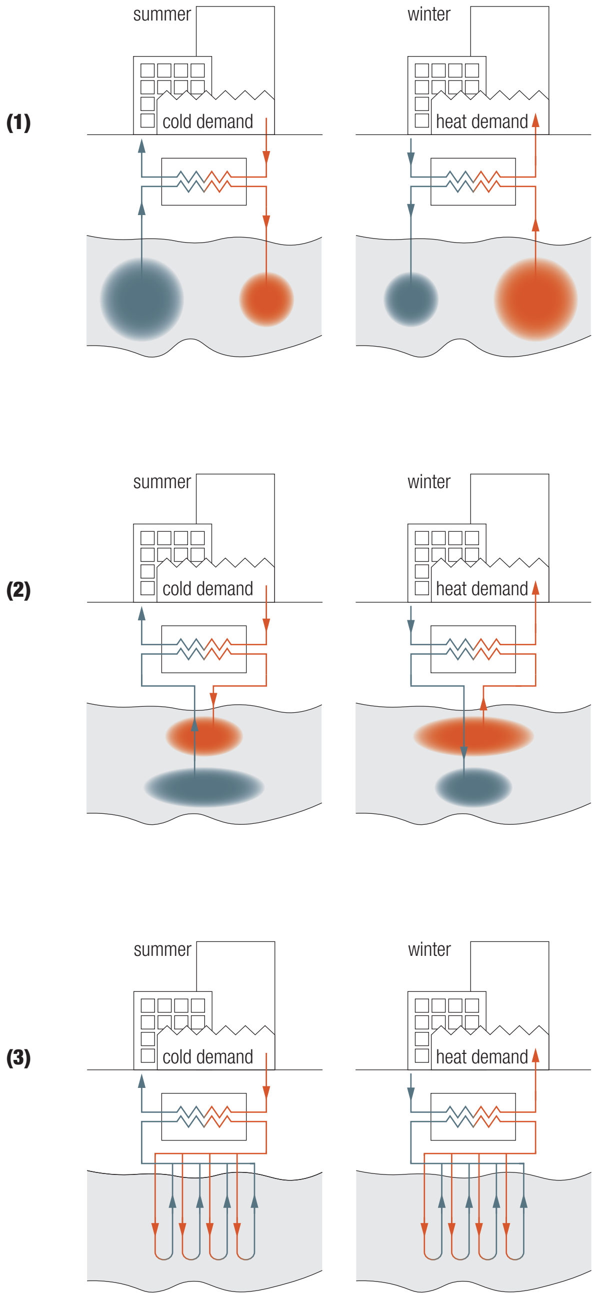


Figure 69: Heat and cold principles of Aquifer Thermal Energy Storage (ATES) in doublet systems (1) and mono-wells (2); and of Borehole Thermal Energy Storage (BTES)

containing non-toxic anti-freeze is circulated. The circulated liquid extracts either heat or cold from the underground, and transports it to a heat exchanger. In the winter situation, the heat exchanger transfers the heat towards the indoor heating system of a building, while a heat pump cools the circulating liquid to a temperature below the underground temperature. Thereby, the ground continuously transfers heat to the system; during the winter, the underground temperature will decrease, so the liquid should get colder to be able to absorb any heat. During summer, the circulated water will cool down by the underground temperature – this cold is transferred directly to the building by a heat exchanger, without the need for a heat pump. The pipes forming the BTES system, can be placed either vertically or horizontally in the sub surface. The system in generally installed less deep than ATES systems, at a depth of 20 to 50 meters (Yanovshtchinsky et al., 2012). The principle of room heating and cooling by BTES systems is graphically shown in Figure 69.3.

ATES and BTES capacity Schieoevers Noord

IF technology executed a study to the potential of ATES and BTES in Schieoevers Noord. Three scenarios are studied: maximum usage of open systems, maximum usage of closed systems, and a mixture of open and closed systems.

A schematic representation of the composition of the subsurface is shown in Figure 70. Three water-retaining layers could be distinguished, of which the second is divided in two due to the presence of layers of clay. In the calculations, only the upper part of the second layer is used. The first layer cannot be used for ATES systems, due to the limited height of the layer, as well as provincial regulations. For the scenario of maximum ATES usage, the second (2A) and third water-retaining layers are used – and wells ordered as doublets, which are most cost effective to optimally use the underground potential. The total potential heat supply (as well as cold supply) is 11,000 MWh/yr for the second layer (uncertainty +/- 15%), and 34,000 MWh/yr for the third layer (+/- 25%), which makes a total of 45,000 MWh/yr for both of the layers (+/-20%) and for the entire area of Schieoevers Noord. The sources, distributed evenly over the circa 68 hectares which Schieoevers Noord covers, would be able to create a heat and cold potential of 662 MWh/yr per hectare (De Jonge & Bloem, 2018). The yield of the ATES system is estimated to be 80%, which creates an energy supply of 529 MWh/yr per hectare (Bot & Zwamborn, 2013).

The scenario which maximises the BTES potential, estimates that 36 hectares of the total of 68 hectares of surface area, are suitable to install ground loops (between ground level and 230 meters depth) – corresponding to an amount of 6,400 loops which can be installed. This

Figure 70: Schematisation of the composition of the subsurface in Schieoevers Noord (De Jonge & Bloem, 2018)

scenario would generate a heat supply (and cold supply) of 52,000 MWh/yr (uncertainty +/- 15%). However, it is doubtful whether the installation of 6,400 plastic loops is a desirable scenario (De Jonge & Bloem, 2018).

The third scenario, combining ATES and BTES systems, would make use of the third water-retaining layer for the open systems (having a potential of 34,000 MWh/yr (+/-25%)) and of the first 150 meters below ground level for the installation of ground loops. Since the boreholes have to be drilled less deep – they can be placed with a smaller in-between distance. Therefore, 10,000 ground loops can be installed with a total yearly potential of 49,000 MWh (+/-15%). The third scenario thereby creates the largest heat and cold potential, being 83.000 MWh/yr (+/-20%). On average, this would generate a heat capacity of the local subsurface in Schieoevers Noord, of 1220 MWh/yr per hectare – with a yield of 80%, it would be 976 MWh/yr for each hectare (De Jonge & Bloem, 2018).

Regeneration of ATES wells

In case of a disbalance between heat demand and cold demand, on a yearly basis, one of the wells of an ATES system has to be regenerated. Due to the heat and cold demand patterns of the planned building functions in Schieoevers Noord, it is likely that the heat demand is larger than the cold demand. The report of IF technology proposes three possible sources of regeneration: thermal energy from surface water – since the Schie crosses the area, being a large body of water, and solar thermal collectors, both being sources to regenerate heat; in the case of a need to regenerate the cold source, dry coolers can be installed. Furthermore, a potential larger heat grid in Delft (TU campus, Voorhof), of which the return pipes can cross and supply (part of) Schieoevers Noord with low-temperature heat, could serve as a source of regeneration for the heat source. This return pipe, in the case it is realised, could also directly supply in part of the heat demand – creating an underground thermal balance in a different way.

The regeneration potential of a heat grid is hard to estimate. The capacity to regenerate the hot well with thermal energy extracted from the Schie is dependent on the volume of the Schie which is used, and the desired maximum temperature decrease which is a result of the heat extraction. One cubic meter of water, which is cooled by 1°C would be able to regenerate 1.16 kWh. Cooling the entire part of the Schie which crosses Schieoevers Noord – one time, by 1°C – would create a theoretical potential of heat regeneration of 140 MWh. Solar collectors are able to regenerate about 360 kWh/m² on a yearly basis – the total regeneration potential depends on the abundance of solar collector installations.

Furthermore, a more general report written by IF technology and DWA, proposes more options for regeneration of hot and cold wells. For Schieoevers, regeneration could be done by asphalt collectors – water-filled pipes running through a road surface, which absorb heat from the road. An additional advantage of this system, is that the pipes filled with relatively warm water during winter can prevent the road surface from freezing (and regenerate cold as well – if needed). Another option, which is not discussed directly in the context of Schieoevers, is the use of waste heat for regeneration. A company as Hordijk, which produces EPS packaging and is located at Schieoevers, use high-temperature heat for production processes; the waste heat could be used to regenerate the hot wells of an ATES system. Lastly, ATES systems can also be connected to each other; in case systems can complement each other in need for regeneration (DWA installatie- en energieadvies & IF Technology, 2012).

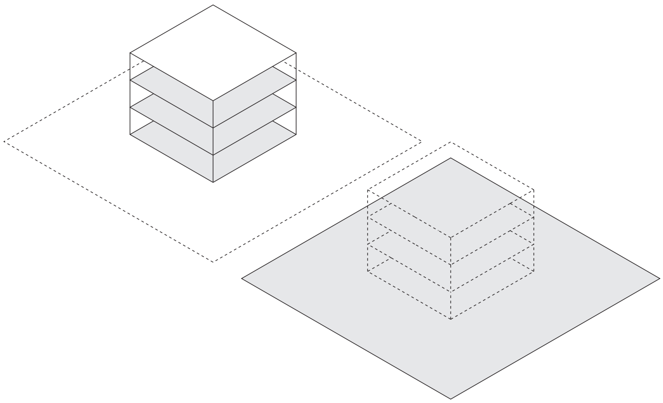


Figure 71: Floor Space Index (FSI); for the plot developments in Schieoevers Noord, FSI values between 0.8 and 2.75 are planned, corresponding with 8,000 to 27,500 m² gross floor area per hectare

Spatial parameters

The final energy demand of an area is to a large extent defined by how many buildings are built, and which buildings functions they house. In the formation of guidelines for the different plots, the Floor Space Index (FSI) is the most important parameter guiding the density of the area; the Function Mixing Index (FMI) is the factor which is guiding for the mixture of "housing" and "working".

Density

The Floor Space Index (Figure 71) is the ratio between the total gross floor area which is built and the area of the plot. The development plan of the municipality, communicates the vision of a high-density cluster close to the train station of Delft Zuid (or Delft Campus in the near future), with an FSI between 2 and 2.75. The other plots will have a much lower density (0.8-1.7) (Broekman, 2019). For the area of the Schiehallen, the calculation example, the intended FSI corresponds with a total floor area of 27,500 m² per hectare – or 330,000 m² for the full plot of 12 hectare.

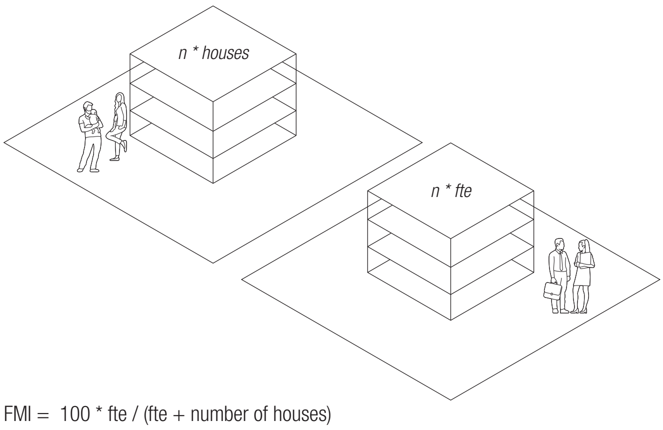


Figure 72: Function Mixing Index (FMI); for the plot developments in Schieoevers Noord, FMI values between 26 and 50 are planned; corresponding with 3.5 to 5 jobs per 10 houses

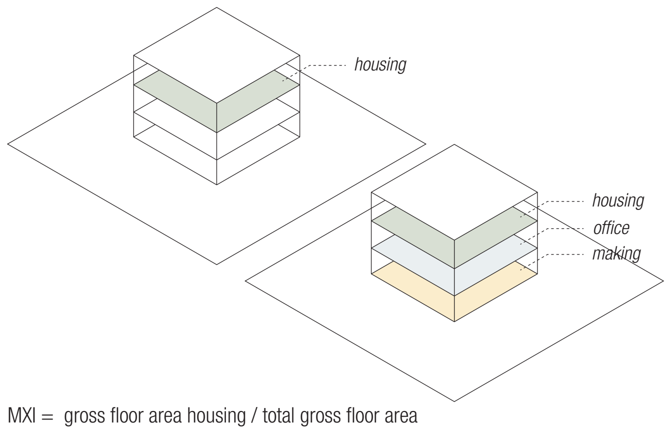


Figure 73: Mixed Use Index (MXI); for Schieoevers Noord, an average house is said to be 90 m^2, and average workspot 60 m^2 – together with the planned FMI, the MXI can be determined.

Function mix

Mixing building functions to create a lively urban area that both adds houses and jobs to the city of Delft, that could be seen as the most important aim of the development plan. The index used to indicate the ratio between housing and working, is the "Function Mixing Index", which describes the ratio between the number of jobs (fte) and the number of houses (Figure 72). Throughout the area, the intended FMI ranges between 26 and 50 – corresponding to 3.5 to 5 jobs per 10 houses; for the plot of the Schiehallen, the FMI is intended to be 30. The FMI should not be confused with the MXI (or Mixed Use Index) – a more common term to describe function mixing (Figure 73), which describes ratio between the housing floor area compared to the total gross floor area in a certain area. In this MXI, neighbourhood facilities are incorporated as well, which is not the case for the FMI . The FMI is an easy communicable index, compared to the MXI for the development of Schieoevers Noord, since the output is a number of jobs, and a number of houses. The plans can easily be compared to the challenges of the city: adding 15,000 houses and 10,000 jobs.

A note which counts for both the FSI and the FMI, is the following. The development plan created a vision for the full area, and the individual plots, translated to these two indicators. Yet, most of the plots are large – the plot of the Schiehallen takes up 12 hectares. Within these plots, the FSI and FMI vary: for example, close to the water, more houses are situated (lower FMI) and close to the railway more making halls are situated (higher FMI).

8.4. Results of the heat balance calculations

Paragraph 8.1 described the energy ambitions and requirements for plot developments, to develop in line with the long-term energy vision for Schieoevers Noord. Paragraph 8.2 described the calculations to be made and Paragraph 8.3 gathered a set of key figures to fill in the equations, the key figures are also shown in Table 4. This paragraph describes a series of calculations, following each other up. Table 3 shows the set of calculations, and which of the parameters are varied. The calculations together show the influence of the adaptation of parameters, on the energy balance of *one hectare* in Schieoevers Noord. The principle applies to every desired surface area, yet the shown numbers count for one hectare, specifically one hectare within the plot where the Kabeldistrict will be developed.

The results of the calculations are shown in graphs that deserve some explanation regarding the way to read them. Figure 74 shows an example of a graph. The graphs have two labelled vertical axes, the left one indicating the built programme in square meters, the right one

Table 3: Overview of calculations, used key figures and variables to be determined (x)

calculation	energy potential per ha (kWh/yr)	energy demand (kWh/(m²*yr))	FSI	FMI
0	x	BENG-1	2.75	30
a	ATES 529 MWh/yr	BENG-1	x	30
b	ATES 529 MWh/yr	BENG-1	x	26
c	ATES 529 MWh/yr	BENG-1	x	50
d	ATES 529 MWh/yr	lowered *(Vlot & Van de Griendt, 2019)*	x	30
e	ATES 529 MWh/yr	lowered *(Vlot & Van de Griendt, 2019)*	x	70
f	ATES + BTES 976 MWh/yr	lowered *(Vlot & Van de Griendt, 2019)*	x	30
g	ATES 529 MWh/yr	lowered *(Vlot & Van de Griendt, 2019)*	x	30 + 1 supermarket
h	ATES 529 MWh/yr	lowered *(Vlot & Van de Griendt, 2019)*	x	30 + 20 shops
i	ATES 529 MWh/yr	x	2.75	30

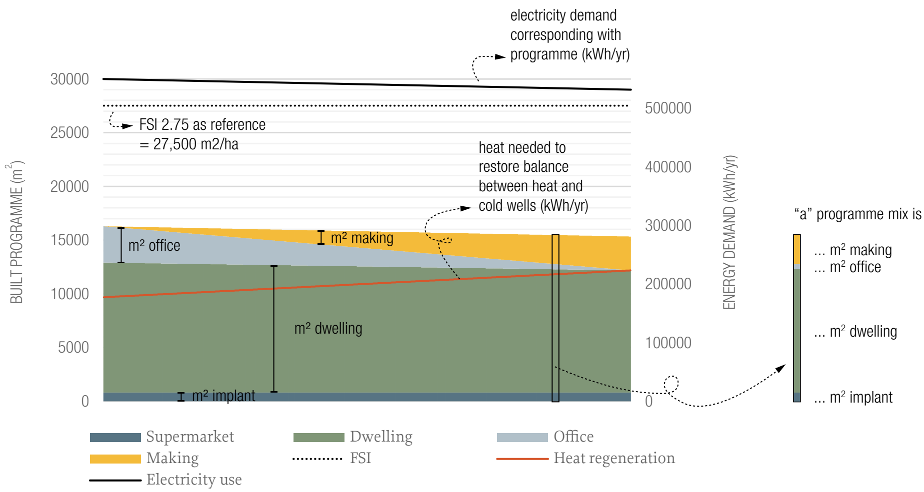


Figure 74: Explanation for the following set of graphs

indicating energy demand in kilowatt-hours per year. The horizontal axis is not labelled, since it is not representing a specific parameter. The graph should be read as "*each horizontal line which is drawn in the graph, represents a programme mixture which could be developed*". The different possibilities for programme mixtures differ from each other in the ratio between housing, offices and making (ratio housing-working is predefined for all of the calculations though), in disbalance between heat and cold demand, and electricity usage.

All of the calculations show the surface area of each building function that can be built, with the chosen FMI, energy demand and/or energy potential. The total surface area of houses, offices, and making spaces (as well as energetic implants if present) is read out at the left vertical axis. Furthermore, each graph has a black dotted horizontal line at 27,500 m² – as a reference to the FSI from the development plan. The values to be read out at the right axis, are the disbalance between heat and cold – named as "heat regeneration". Most of the calculations are based on making use of the full energy potential of the subsurface. As soon as the heat demand is larger than the cold demand, the heat well has to be regenerated in a different way. The thermal disbalance between heat and cold consumption thereby is the same as the need for regeneration of one of the wells. In all calculations, the heat demand is larger than the cold demand. In case the cold demand would be larger, the line would go across a negative quadrant of the graph. Lastly, the electricity demand by each of the programme mixes is indicated by a solid black line.

Table 4: Key figures and its sources used for the energy demand in upcoming heat balance calculations

Functions *Unit*	Type of usage of energy	Norm of reference	Key figure *kwh/(m² *yr)*
Residential (variable surface area R)	Room heating/cooling	BENG-1	65
	Hot tapwater	NTA 8800	856 kWh/(person*yr)
Office (variable surface area O)	Lighting	BENG-1	90
	Room heating/cooling	BENG-1	
	Hot tapwater	NTA 8800	1.4
Making (variable surface area M)	Room heating	-	based on Fiction Factory
	Room cooling		
	Hot tapwater		
	Waste heat machinery		
Supermarket (800 m²)	Lighting	BENG-1	70
	Room heating/cooling	BENG-1	
	Hot tapwater	NTA 8800	1.4
	Waste heat cooling	-	131.4
Shop (100 m²)	Lighting	BENG-1	70
	Room heating/cooling	BENG-1	
	Hot tapwater	NTA 8800	2.8

Energy demand	**% heat**	**% cold**	**heat demand/m2**	**cold demand/m2**	**total heat demand**	**total cold demand**	**electricity demand**
*kwh/(m^2 *yr)*	*%*	*%*	*kwh/(m^2 *yr)*	*kwh/(m^2 *yr)*	*kWh/yr*	*kWh/yr*	*kwh/(m^2 *yr)*
65 14.3	85	15	67.4	11.9	-	-	26
17.5 72.5 1.4	55	45	40.6	33.3	-	-	60
37.5 2 0.5 -	-	-	38	2	-	-	60
35 35 1.4 131.4	10	90	16.8	151	13424	120816	254
37.2 32.8 2.8	35	65	12.5	23.1	288	2314	100

Thermal balance of the primary building functions

Before calculating several realistic scenarios, it is explored what the traits of each of the building functions are. Thereby, it could be understood how each of these functions influences the energy balance of a mixed-use area. Following the rationale of building with the available thermal energy that could be offered by ATES systems, Figure 75 shows what could be built when a monofunctional program would be realised, by each of the primary building functions (housing, office, making) when built complying with the BENG norms (or equivalent for making industry). For these three monofunctional scenarios, the thermal disbalance (and thereby regeneration demand for the heat well), the realisable floor area, and the expected electricity consumption are shown.

As was already visible in Table 4, a housing function requires, relatively, a lot of heat and little cold. Thereby, the surface area that could be foreseen with energy retrieved from ATES systems is relatively low for a housing function. The thermal disbalance is relatively high, whereas the electricity demand is much lower than for the "working" functions. A residential neighbourhood with an FSI of 0.8 could be realised. Office buildings house the building function which is – on a yearly basis – most balanced since the heat demand and cold demand are close. A "business park" with an FSI of 1.3 could be heated and cooled by ATES systems. Making industry requires about the same amount of heating as offices, yet almost no cooling. Thereby, an ATES system could foresee about the same surface area of heat (FSI 1.4), but with an enormous thermal disbalance. The electricity use is comparable to office buildings as well.

Calculation 0

The first calculation is used as a baseline, studying what the energy demand of an hectare would be with the intended density and function mix as described in the development plan for Schieoevers Noord (FSI=2.75 and FMI=30). In case no energy-based guidelines are added to the development plan, it can be assumed that buildings will be delivered that perform according to the building regulations applicable at the moment of building – likely as close to the upper boundary as possible. Figure 76 on page 186 shows the outcome of this calculation; the graph is slightly different than the example graph concerning the values related to the right axis. Here, the heat demand and cold demand are shown, and the ATES potential as a reference value. *It can be seen that the total heat demand is about a factor three larger than the heat an ATES system can supply*, the cold demand is well below the potential. With an increase in making industry and a decrease in office buildings, the cold demand decreases.

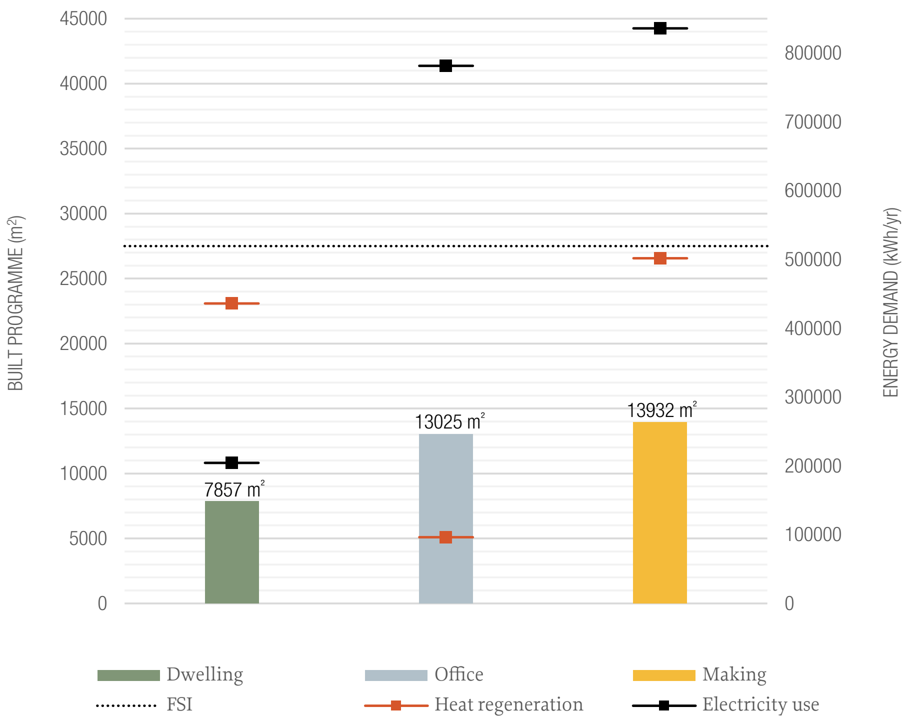


Figure 75: The traits of each building function

Calculation a, b, and c

The following set of calculations is based on the "reversed" principle: finding out what can be built, in case only heat extracted from the shallow subsurface is used (supplied by ATES systems). Calculation *a* (Figure 77) shows comparable results as the 0 calculation. By building with an FMI of 30, and BENG-norms as a basis for the energy demand, an FSI of about 0.9 can be reached.

Calculations *b* and *c* show the influence of the FMI on the energy balance of the hectare (Figure 78 and Figure 79 respectively). Calculation b uses the lowest FMI mentioned in the future vision in the development plan – being 26, calculation c uses the highest FMI – being 50. It can be seen, that with a larger share of working in the built programme, the relative heat demand decreases – and the FSI that could be realised increases slowly to a value of approximately 1. As said, due to the cooling demand of office buildings, the disbalance between heat and cold is smaller in case more offices are realised. Yet, with changing the function mix within the envisioned range, the desired FSI cannot be supplied with energy by ATES systems. Since all of the three main functions – dwelling, offices, and making – have a heat demand which is larger than their cold demand, no FMI exists which is able to create an actual heat balance with just these three functions as well.

Calculation d

Since adapting the ratio between working and housing does not have an impact which can realise a cluster of buildings with the desired density, another parameter has to be adapted. Calculation *d* changes the programme related energy demand, based on data that energy consultant Merosch uses in their energy vision for the area. Important to note, the report has been delivered after the latest definition of the BENG-norms (Vlot & Van de Griendt, 2019). The used key figures on heat and cold demand are displayed in Table 5 as well. An adaptation the autor made to the original data as used by Vlot and Van de Griendt, is the following. Merosch uses a single value for heat demand as well as cold demand for the category of "working", while they do describe the range of working which will be housed in the area. Since a larger heat demand is expected for making industry, and a larger cold demand for office buildings, the numbers are adapted to represent that – with the average of the key figures used in this report being the original key figure of Merosch.

Figure 80 shows the outcomes of this calculation – all of the options to build a mixed-use programme with an FMI of 30 and with a heat demand equalling the heat potential ATES

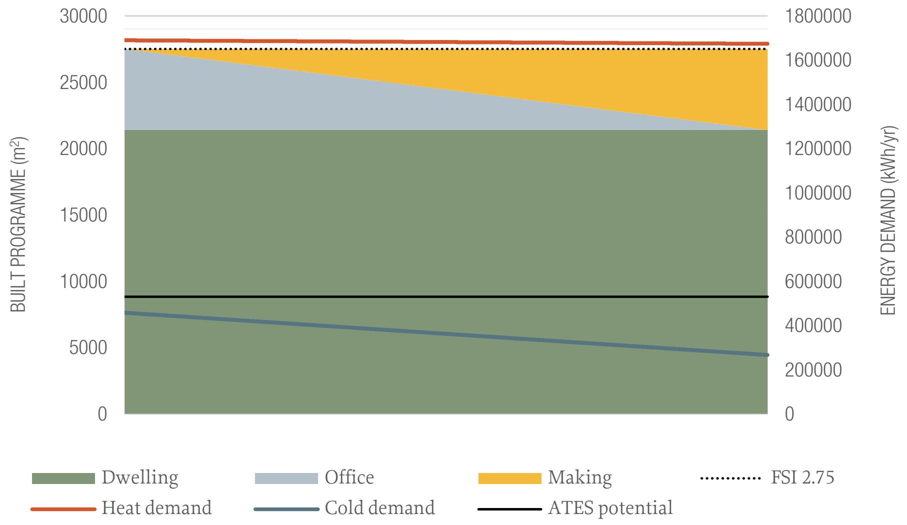


Figure 76: Calculation 0

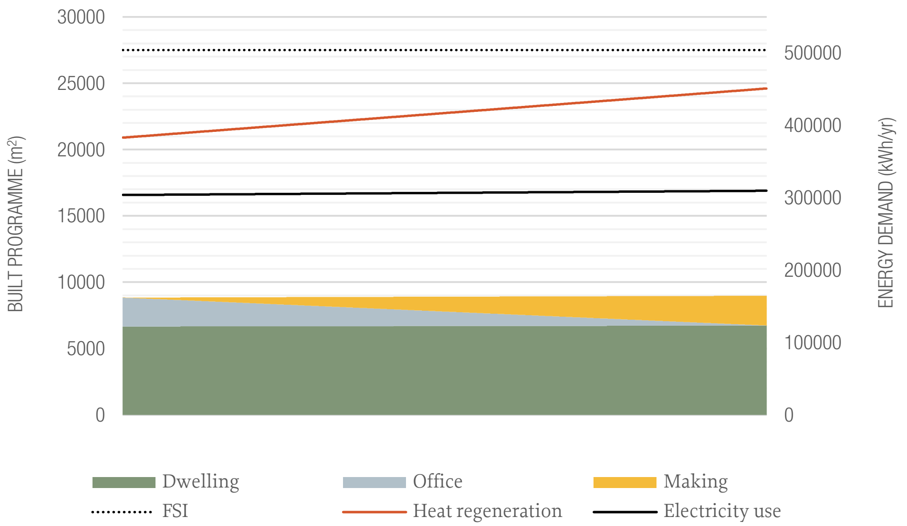


Figure 77: Calculation a

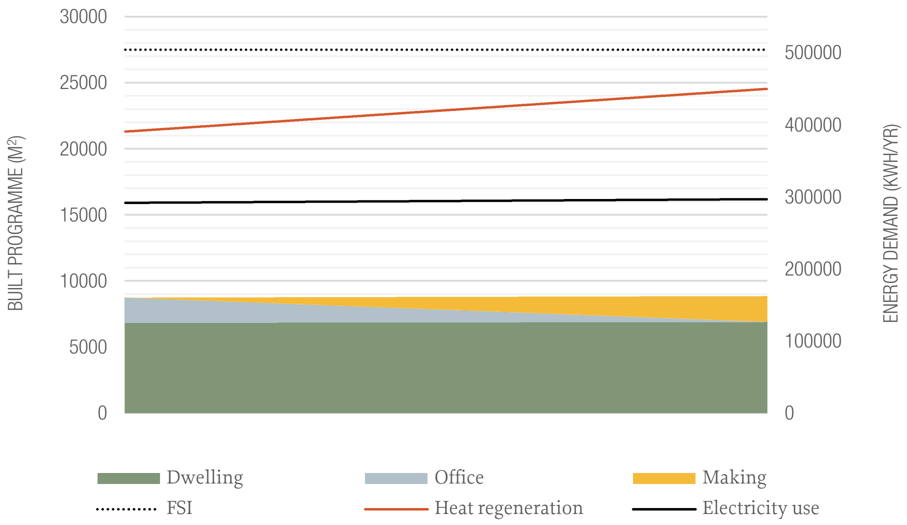


Figure 78: Calculation b

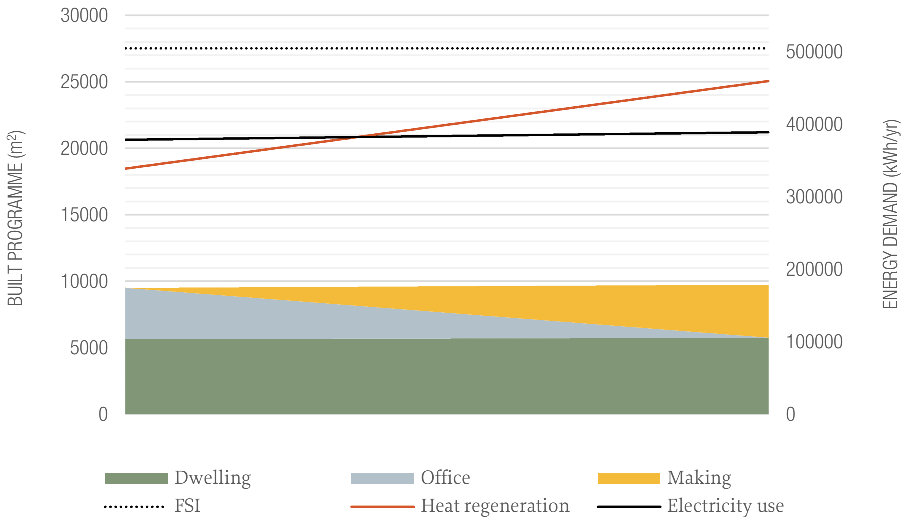


Figure 79: Calculation c

Table 5: Heat and cold demands based on consultancy firm Merosch (Vlot & Van de Griendt, 2019)

Functions	Type of usage of energy	heat total/m2	cold total/m2
Unit		*kWh/(m2*yr)*	*kWh/(m2*yr)*
Residential (variable surface area R)	Room heating/cooling	15	12
	Hot tapwater	20	
Office (variable surface area O)	Total	27	25
Making (variable surface area M)	Total	37	15

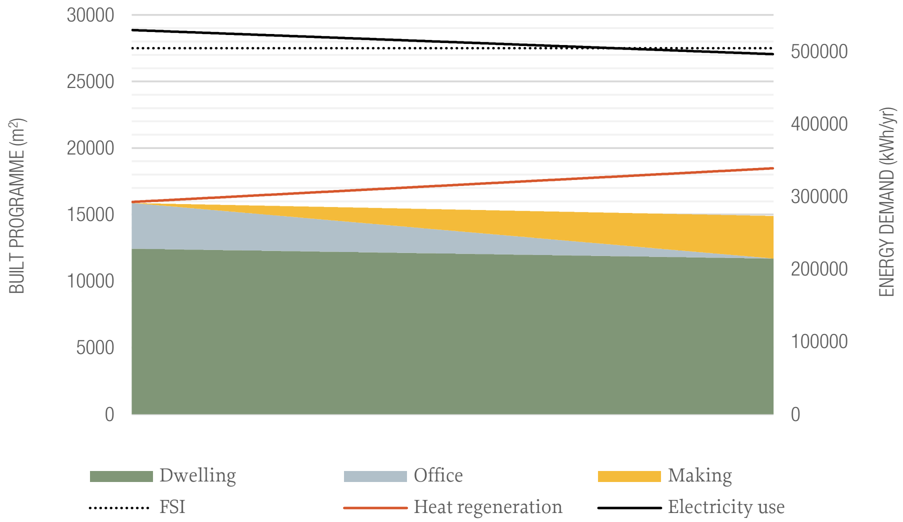


Figure 80: Calculation d

systems can supply in Schieoevers Noord. It can be seen that an FSI of about 1.5 can be realised with this decrease in energy demand: a step in the desired direction. These more ambitious key figures for the energy demand are used in the following calculations as well; the demand coming forth from the BENG-norms seems to be too large for high-density areas.

Calculation e

With the application of stricter ambitions concerning the energy demand of the primary building functions, as in calculation *d*, the following step is an investigation in which the function mix is changed to a value outside of the range mentioned in the development plan (which was 26-50). Calculation *e* shows the energy balance of a development with an FMI of 70. This FMI implicates an availability of 2.3 jobs (fte) for every house which is realised. Figure 81 shows the outcomes of this scenario. With this scenario, an FSI between 1.5 and 1.8 could be realised. As seen in Figure 75, the building function "office" requires little regeneration of heat whereas "making" requires much regeneration. Since the share of working is large in this calculation scenario, this difference is clearly visible in the graph. For the heat balance of the plot and building density, the scenario in which working is mainly realised by office buildings is most favourable. In case a larger share of making is realised, a lower electricity demand is expected. However, that is caused by the fact that a smaller overall surface area can be realised in that case.

Calculation f

A next parameter which could be adapted, is the amount of energy which is available for heating and cooling in Schieoevers Noord. Not the most efficient energy sources, yet an effective one, is the addition of Borehole Thermal Energy Storage systems, enlarging the total available energy to 976 MWh/yr per hectare – for both cold and heat. By almost doubling the energy supply, the results shown in Figure 82 on page 192 indicate a possible FSI of just below 3. A side note in here, is that the amount of heat which should be generated on a yearly basis is larger than the heat potential of an ATES system in Schieoevers Noord. Nevertheless, this graphs shows the possibility for the plot developed to the Kabeldistrict, to become energy-neutral (for heat and cold) and dense by using only energy from the shallow subsurface. The desirability of this strategy for sustainable energy provision though, could be a topic of discussion.

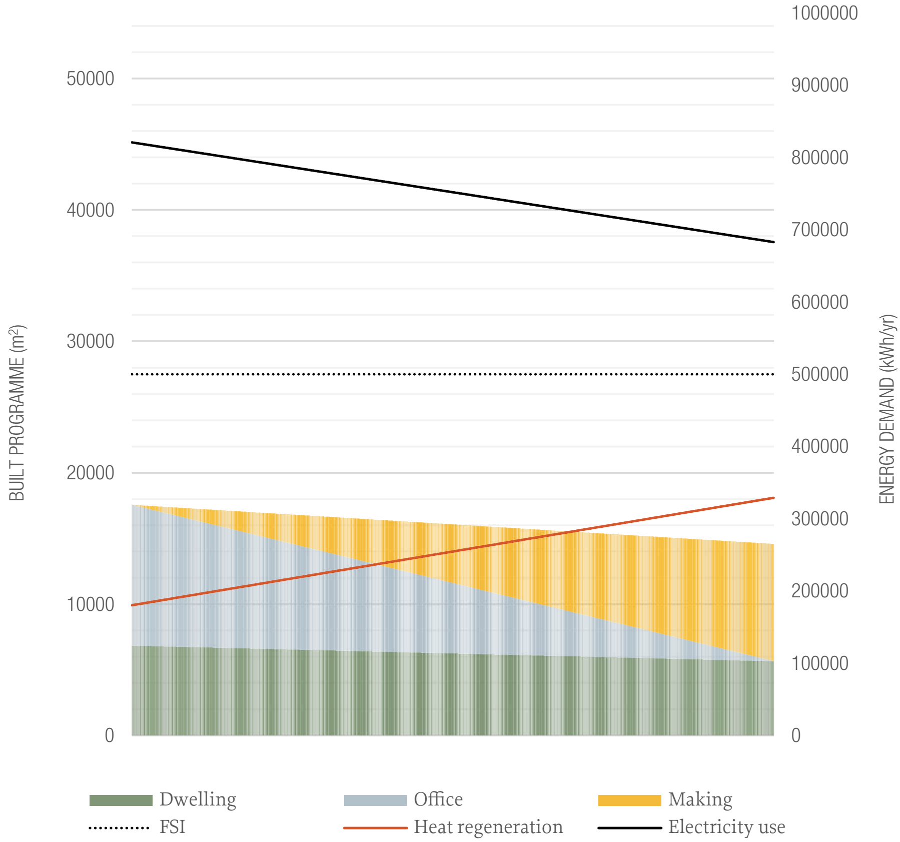


Figure 81: Calculation e

Calculation g and h

The next two calculations study the impact of the previously introduced concept of an energetic implant: a building function with a complementary energy demand pattern to the patterns of the primary functions. As discussed, a supermarket and a number of shops are studied as possible energetic implants. The results of the calculations in which one supermarket with a floor area of 800 m² is added to the programme are shown in Figure 83 on page 193; the results of 20 shops or 2000 m² of floor area dedicated to shops are presented in Figure 84 on page 194.

It could be seen that the electricity demand rises relatively much in both cases, but with an increased FSI to about 1.6 in case of the supermarket, and 1.7-1.8 in case of the shops. The disbalance between heat and cold is reduced as well; the supermarket as energetic implant is more effective in here. Since supermarkets generate a lot of waste heat – year round – a source of regeneration is added to the hectare. Shops have the same effect, but with a much lower cooling load. To reach the desired FSI of 2.75, energetic implants – with building functions both fitting the developments and taking up space in proportion to the total built floor area – will not be the only solution, though a step in the desired direction.

Calculation i

A last calculation which is made, is a simple one not shown in a graph: questioning what the average energy demand of a square meter should be in case the dense area (FSI 2.75) with the set function mix (FMI 30) would be using energy provided by an ATES system only. The following calculation, determines a maximum usage of thermal energy of 19 kWh/yr for each built square meter – on average.

$$\frac{529\ MWh/yr}{27{,}500\ m^2} = 19\ kWh/(m2 * yr)$$

In the ideal situation, the average of the square meters sticks on or below this value, with a balance in heat and cold demand. In that case, additional measures for regeneration of either heat or cold wells is prevented. Box 5 on page 196 puts the number in perspective: is it realistic to build with an average thermal energy demand of 19 kWh/(m²∗yr)?

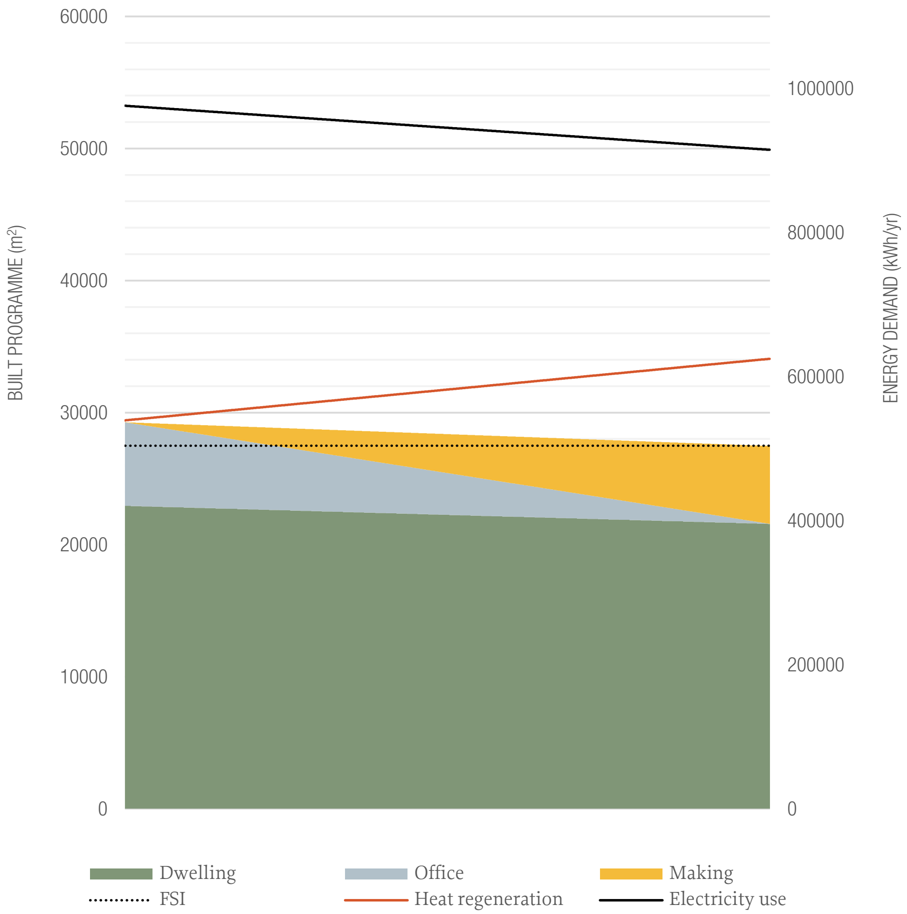


Figure 82: Calculation f

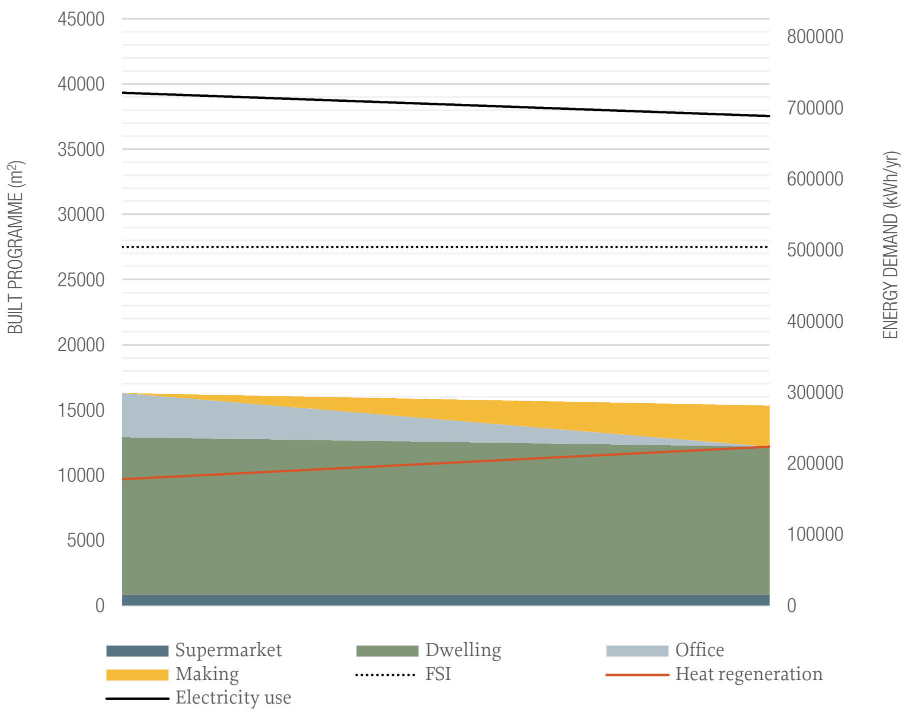


Figure 83: Calculation g

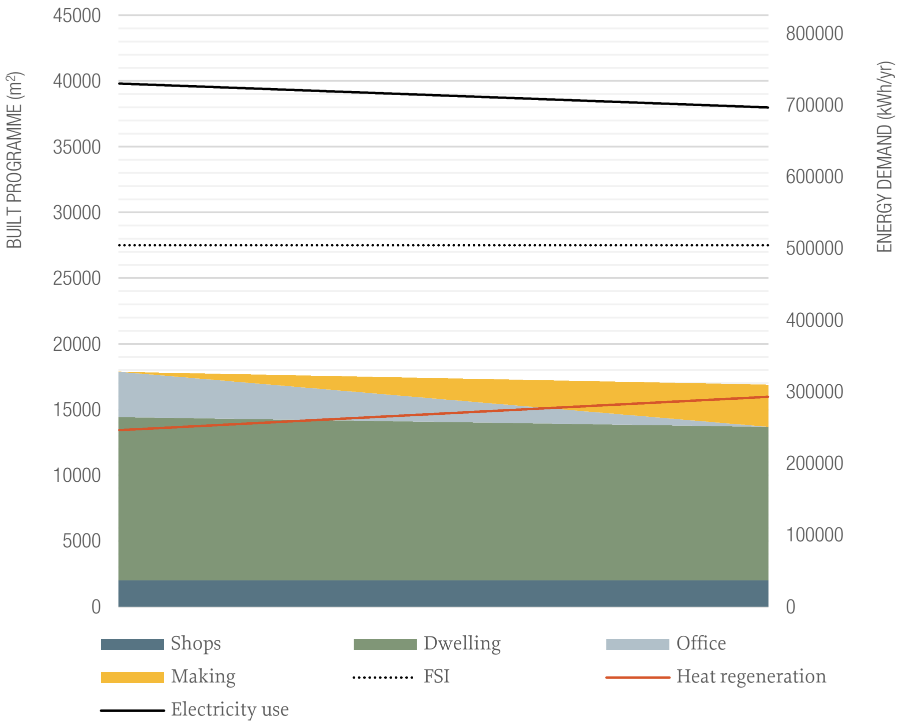


Figure 84: Calculation h

Comparison of results

Figure 85 and Figure 86 give a summary of the 10 calculations that are made. Figure 85 shows the final heat, cold and electricity demand for the different calculations together with the resulting amount of houses (average 90 m²) and jobs (average 60 m²) that can be realised. Figure 86 shows the energy demands for heat, cold, and electricity against the totally realisable surface area per primary building fucntion. For the ease of reading, the average heat and cold demands from all of the calculation scenarios is used – the bandwidth of these numbers is smaller than their mutual differences. Next to that, each scenario has a multitude of exact function mixtures - mainly differing on the share of making and offices.

The most important conclusion that could be drawn at this point, is that in case the desired FSI of 2.75 is realised, with an FMI of 30, and an energy consumption according to the BENG-norms, the energy demand is a factor three larger than the potential of an ATES system. *Being energy-neutral for the thermal energy demand is not possible on the own plot without the deployment of guidelines limiting the energy demand.* Most probably, micro generation by solar systems or asphalt collectors will not be sufficient to fill the gap between the potential of ATES systems and the energy demand of the intended high-density area. When no guidelines are deployed, the need for additional sources from outside the plot is inevitable, such as a connection to (a return pipe of) a district heating system, or the use of aquathermal energy from the canal Schie. The cold demand does not directly seem to be a problem for the defined functions and the near future.

This last point directs to a second conclusion: in all cases a high thermal disbalance exists. In case of the supermarket used as energetic implant, a disbalance still exist, yet a smaller one. To be able to maximally use the potential of Aquifer Thermal Energy Storage systems, the disbalance preferably is as small as possible. The studied energetic implants do have a desirable effect on the thermal energy balance, but the note should also be made that a much higher electricity demand is the consequence.

The calculations based on the key figures of Vlot and Van de Griendt (2019) show the effect of a decreased thermal energy demand, yet still these demands are too high, to be able to construct a high-density cluster (FSI 2.75) with ATES systems. The only studied option which actually is able to supply the same amount of energy as needed with the desired density and function mix, is the case in which BTES is used as supplementary heat and cold source. Thereby it could be concluded, that for the use of ATES systems as primary heat and cold sources, more ambitious norms for the thermal energy consumption are needed. If that is not desired, other sources of heat (and possibly cold) are needed.

Box 5. Is a thermal energy demand below 19 kWh/m² realistic?

A simple calculation, combining the ATES heat and cold potential per hectare with the intended FSI for the Kabeldistrict, shows the average thermal energy the ATES system could provide, for each square meter which is built. This thermal energy potential comes down to 19 kWh/m² per year– so an average of *19 kWh/m²* of cold and of heat for each square meter available in the subsurface of the own plot. The usage of hot tap water is – in principle – included in this number. Hypothetically, the maximum thermal energy demand of a building thereby could be *38 kWh/m²* per year – if exactly as much heat as cold as needed. To get a grip on this number, the thermal energy demand of two energy-neutral high-rise buildings (one residential and one office tower) is studied. Furthermore, light is shed on the energy norms of "passive houses".

The Edge, a large office building located in Amsterdam, is scoring high in BREEAM certification and can therefore be seen as a sustainable building. The design includes many elements inspired on passive building, such as the orientation towards the sun, the application of very thick glazing, and a strategically climatized atrium. An ATES system foresees in the full heat and cold demand, the energy needed to power the heat pumps connected to the ATES system are powered by PV cells. A back-up connection to the city's heat grid is realised for peak-demands. Many more energy conscious measures are taken, resulting in an average energy demand of *2.27 kwh/m²* (gross floor area) for the building which houses 39,673 m² of offices and 11,558 m² used for parking (OVG Real Estate, 2014).

The first residential high-rise tower delivered with an EPC of 0, De Spakler, is located in Amsterdam as well. The 73-meter tall building houses 160 apartments (50-75 m² each), 500 m² commercial space and parking space for 52 cars and about 250 bicycles. The EPC score is mainly reached by the large surface area filled with PV panels: about 2,500 m² – both at the roof and integrated in the façades. Furthermore, a connection to the district heating system and a well insulated façade are realised. The thermal energy demand of the tower is *30,1 kWh/m²* per year – excluding the energy demand related to hot tap water usage. It is estimated, that – if that had been the goal – an energy demand below 25 kWh/m² could have been realised relatively easily by lowering the amount of incoming solar heat and by improving the airtightness of the façade (Lente Akkoord, 2017).

Based on these case studies, it seems that office buildings are better suited to reach a low energy demand, than that residential buildings are. A third parameter for comparison, is the norm for passive building. A passive house can be classified as such, if the energy demand for room heating and cooling is maximally *15 kWh/m²* per year, and the total energy demand for the house (both building- and user-related energy demand; heating, cooling *and* electricity consumption) must not exceed 120 kWh/m² per year (Rijksdienst voor Ondernemend Nederland, n.d.).

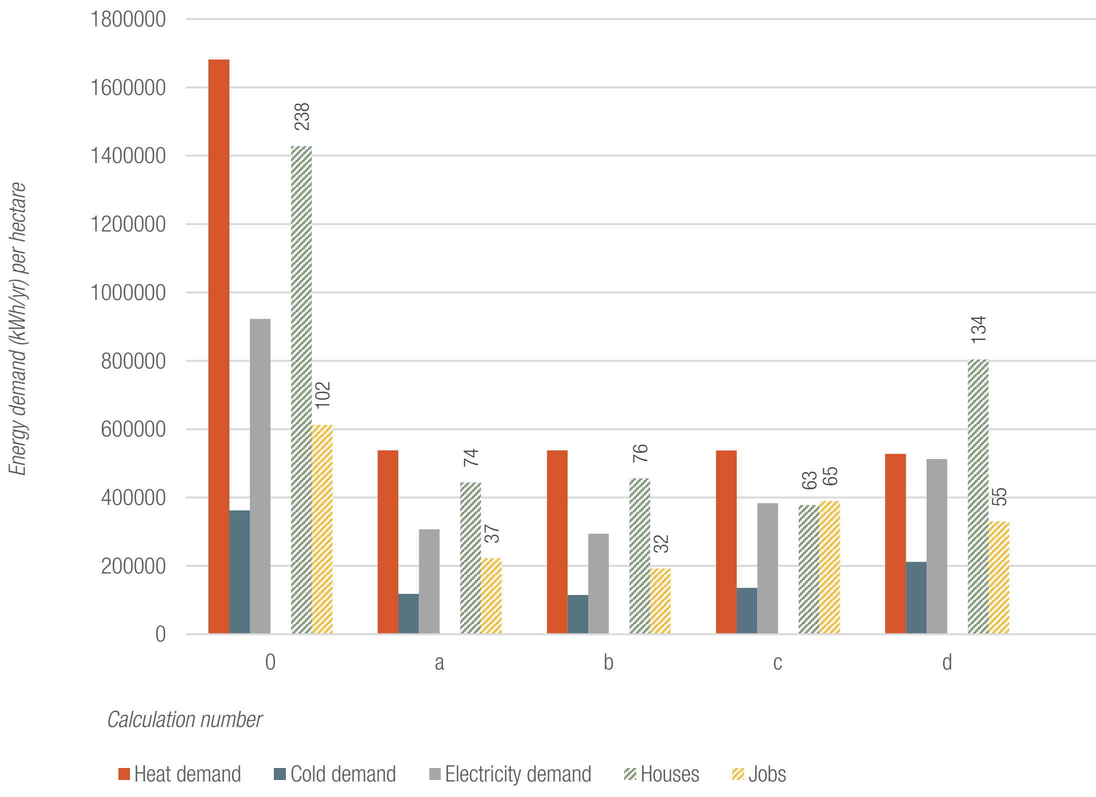
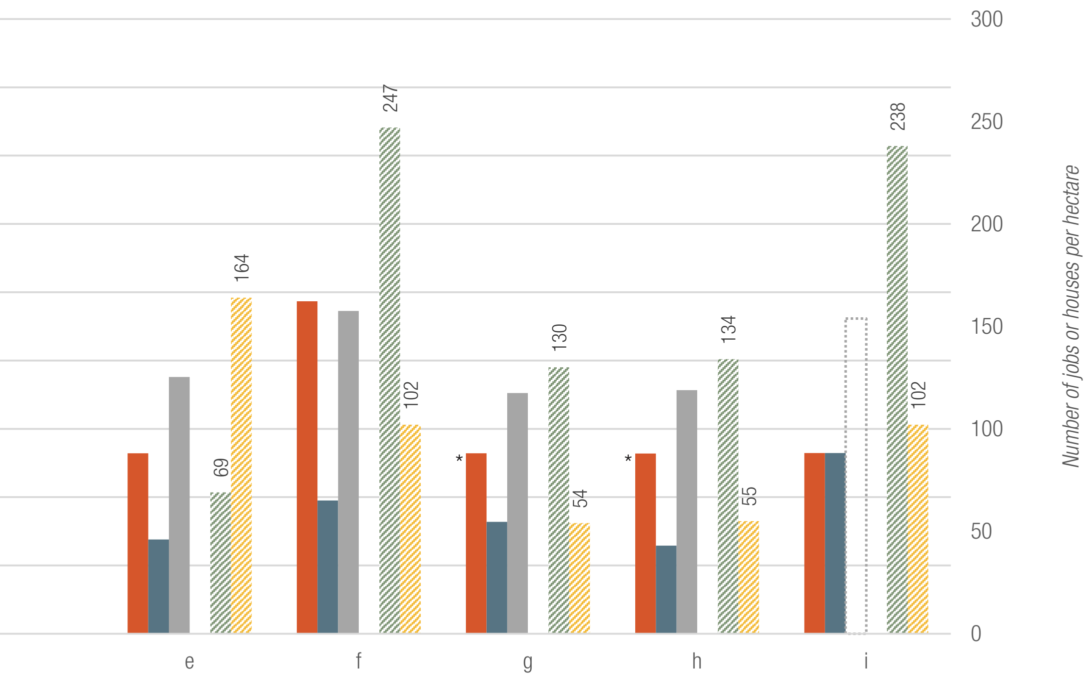


Figure 85: Concluding graph of the 10 calculations. The heat demand, cold demand, and electricity demand for each calculation have to be read from the left vertical axis, the number of houses and jobs have to be read from the right vertical axis. Calculation *i* did not define a programme, and therefore does not show a value for the electricity demand.



* The energy demand of calculation *g* also supplies the energy for a supermarket (800 m^2) which is included in the programme as energetic implant; the energy demand of calculation *h* includes the energy demand of 20 shops (totall surface area of 2000 m^2)

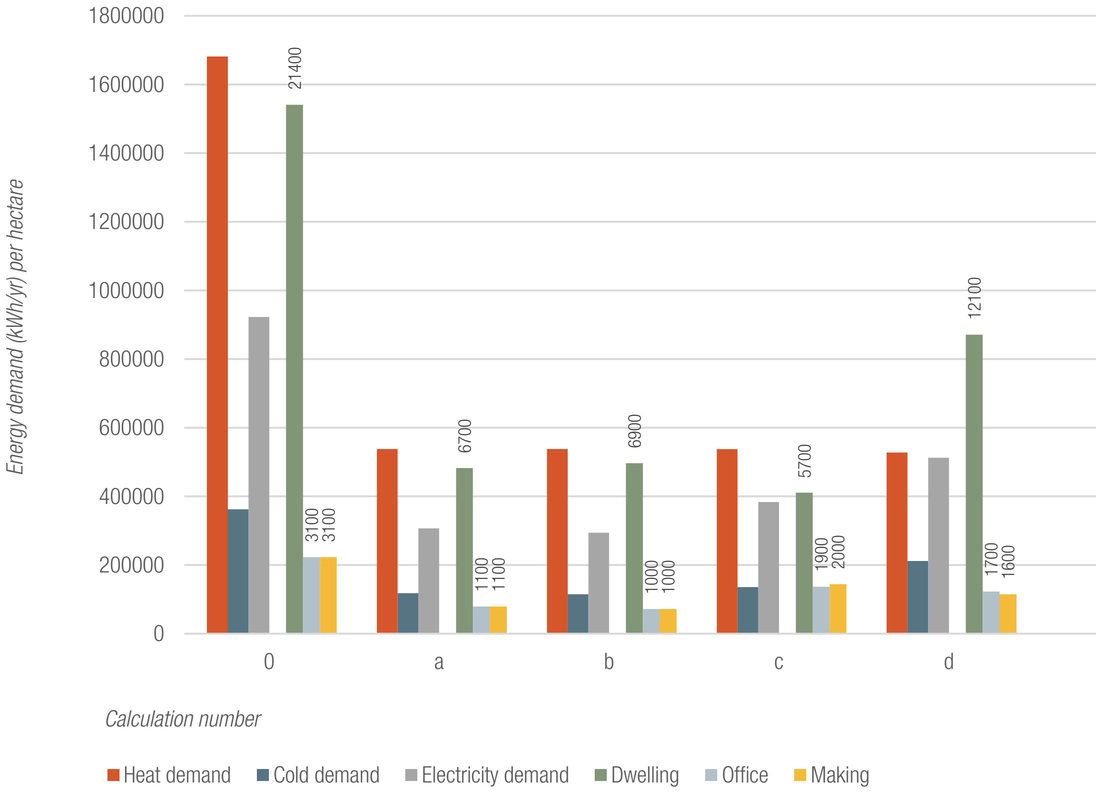
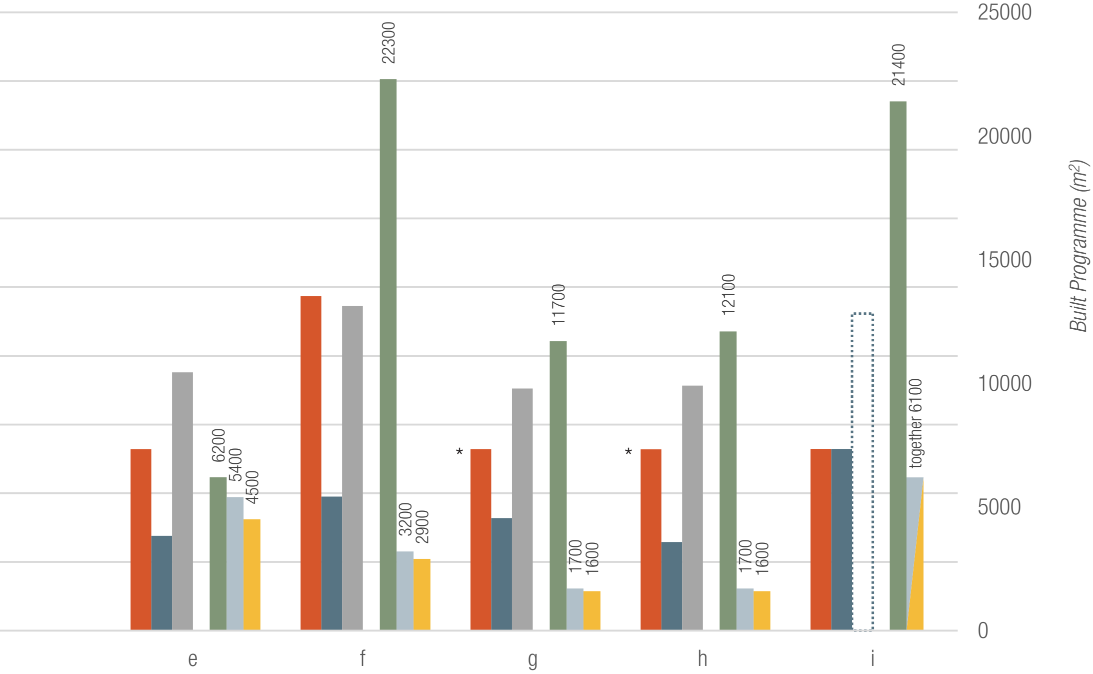


Figure 86: Concluding graph of the 10 calculations. The heat demand, cold demand, and electricity demand for each calculation have to be read from the left vertical axis, the buildable programme for housing, offices and making has to be read from the right vertical axis. Calculation *h* did not define a programme, and therefore does not show a value for the electricity demand.



* The energy demand of calculation *g* also supplies the energy for a supermarket (800 m²) which is included in the programme as energetic implant; the energy demand of calculation *h* includes the energy demand of 20 shops (totall surface area of 2000 m²)

8.5. Building with thermal balance

This paragraph explores what it implicates to build in thermal balance – or as close to thermal balance as possible – and to built (thermal) energy-neutral with resources available at the local scale. It is explored what would happen if the plot of the Schiehallen would start building according to BENG, or what could be realised when started from the intention to be energy-neutral at the own plot. The role of the plinth is explored, to investigate which function mixes are physical (im)possible. The influence of spatial design and density on the energy demand of buildings is explored, as well as the influence of the Open Space Ratio on the energy generation potential.

The previously discussed calculations generate insight in the energy balance corresponding to building densities and function mixes. The ratio working and living is a clearly set starting-point for the municipality – since the area development is grounded by a specific shortage of housing and need to increase the amount of jobs in the city of Delft. So, concerning the programme mix of each of the calculations, housing has the largest share of square meters in each variant, yet a focus on either making of office spaces creates a difference in the type of neighbourhood that could be realised.

To be able to discuss the impact of spatial design on the realisation of heat and cold balances and energy-neutral development in general, several design principles for streets and building blocks are created first. These are the basis for further discussion of the above introduced topics.

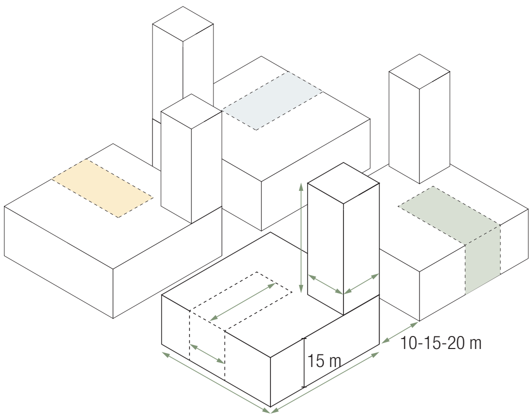


Figure 87: Principles for building blocks and in-between spaces

Building principles: building blocks, streets, and hectares

For the building blocks, a simple set of principles is created – shown in Figure 87. Based on the development plan for Schieoevers Noord, it is worked with a primary building layer up to 15 meters, and several cases of high rise topping-up these primary layers. All building blocks are opened at one side, leaving room for either logistics or courtyards. Functions can be mixed either horizontally (in adjacent buildings) or vertically (within the same building). Three street typologies are defined (their profiles are drawn in Figure 88, Figure 89, and Figure 90) and are described as follows.

(1) The *main street*, also called the “Hartlijn” in the development plan for Schieoevers Noord. The street is 20 meters wide and leaves room for a wide variety of programme: making or facilities as shops and supermarkets at the ground floor; offices are likely in the other floors of the primary building layer – and housing is situated in the high-rise.
(2) The *making street* has a width of 15 meters. A focus on working is present, mixed with facilities and offices at the ground floor, and either office space or living on the other floors. The in-between space facilitates industrial logistics.
(3) The *living street* is narrow and more quite, a width of 10 meters gives room to people that have to be in the street: to work on ground level, or to live on top. The in-between spaces are the longs of the building blocks: small oases for the residents,

Figure 91, Figure 92, and Figure 93 show how these street typologies and principles for building blocks create small clusters of buildings that together form a densely built hectare (FSI 2.75). All of the hectares house an equal amount of square meters, only with a different focus of working – more oriented to offices, or making – and with a different ratio between open space and building height – the wider streets house higher building blocks.

An additional function, which is not included in heat and cold balance calculations, but which is part of urban design, is (car) parking. A parking norm of 0.6 cars per household is used: a low and ambitious norm, since many other forms of mobility are available. Nevertheless, a dense area still asks for a lot of parking places. The author, therefore, is aware that parking introduces an additional building typology – since it is highly unlikely that all cars can and will be parked at street level. Since the impact on energy consumption is expected to be low, parking is left out of scope here.

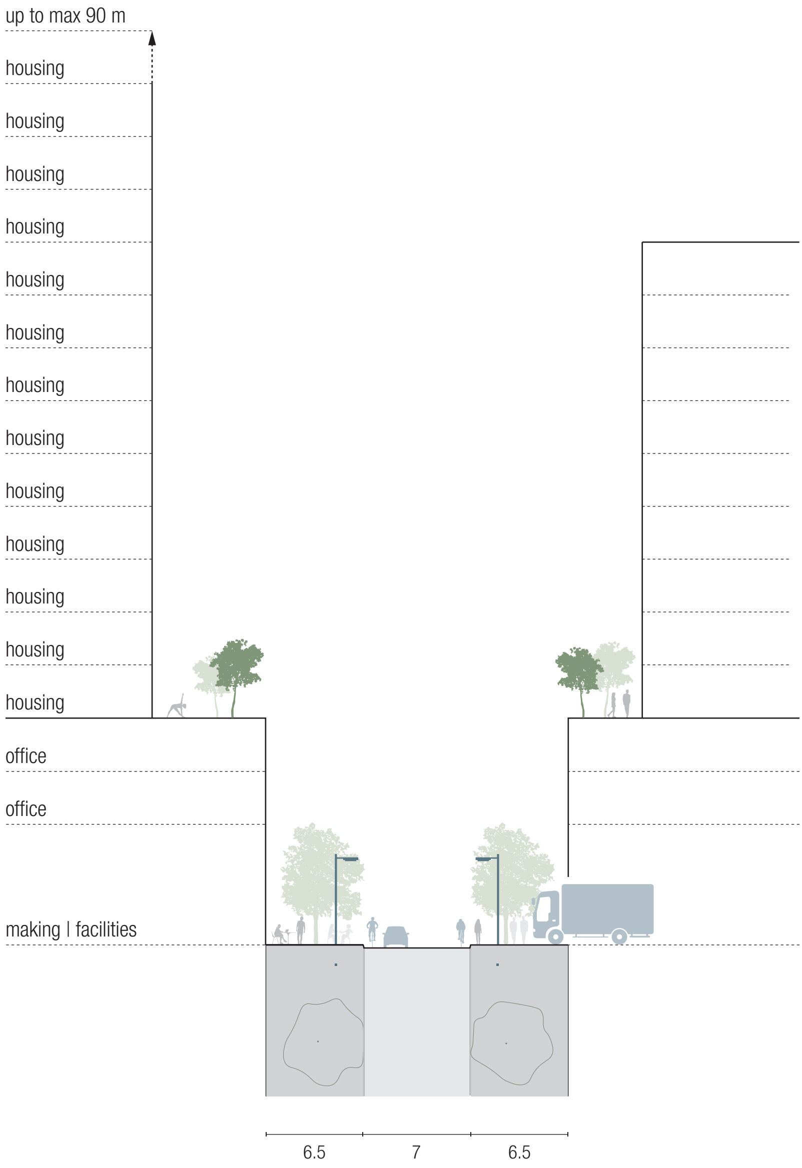


Figure 88: Profile of the “Hartlijn” or main street

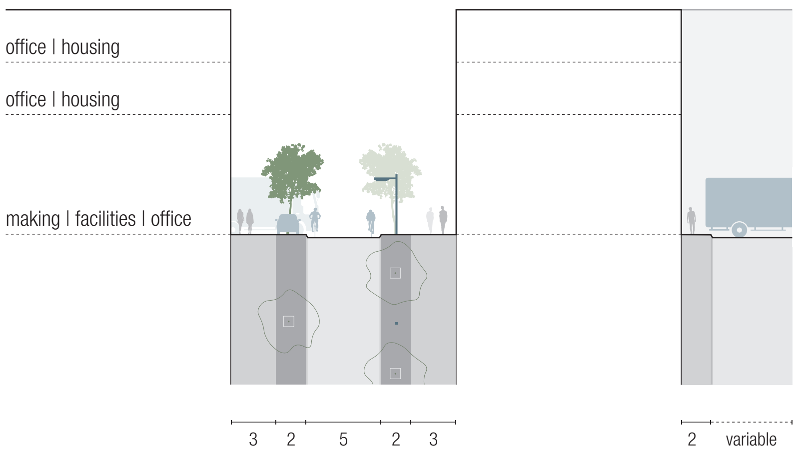


Figure 89: Profile of a “making street”

Figure 90: Profile of a “living street”

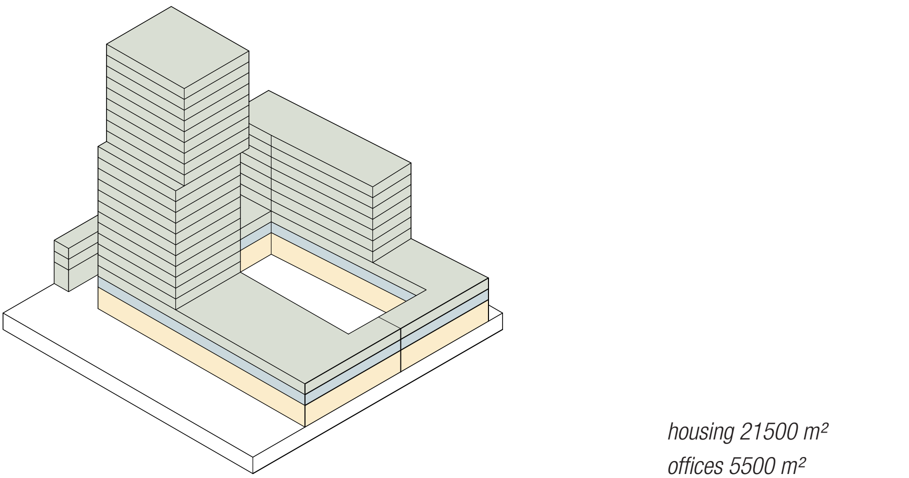
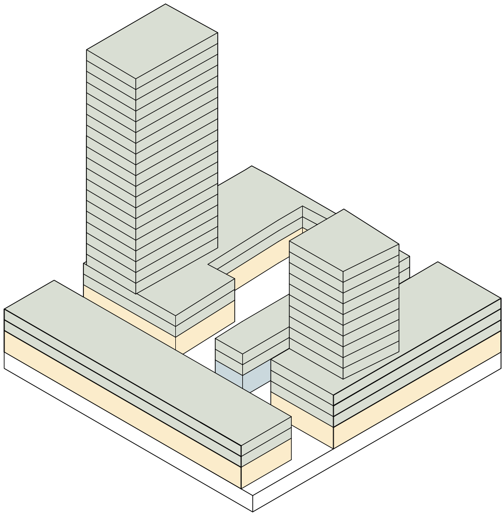
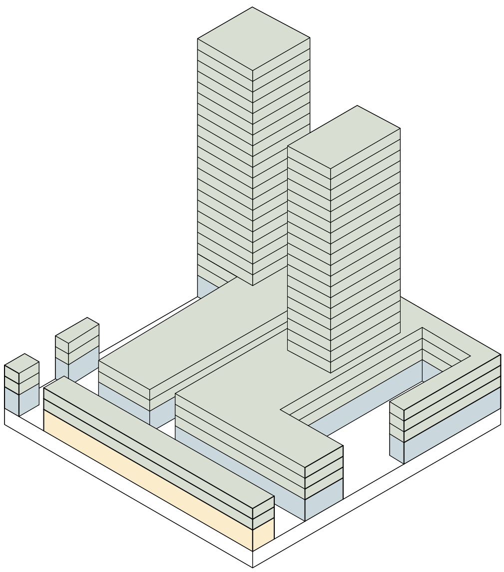


Figure 91: One hectare – including the Hartlijn



housing 21500 m^2
offices 500 m^2
making 5500 m^2

Figure 92: One hectare – including a making street



housing 21500 m^2
offices 3000 m^2
making 3000 m^2

Figure 93: One hectare – including a living street

The plinth

The largest concern for spatial planning and the aim to reduce the disbalance between heat and cold demand as far as possible, is the space available at ground level: the building plinths. Looking to the three primary building functions, also seen in the street section drawings, it could be stated that making industry requires space at ground level – due to the need for transportation and the (possible) use of heavy machinery. In a dense urban area, it is expected that for living, spaces which are not situated at the ground floor are preferred. For offices, each level is suitable in principle, yet for busy streets, spaces at the higher levels get the preference. It could thereby be concluded that no more making industry can be housed, than the surface area on ground level which is buildable. The programme mixes that create jobs in only the making industry, will not be able to be built – a certain amount of offices is always needed to fulfil in the FMI.

When the possible energetic implants are taken into account, being supermarkets and shops, these also prefer a spot a ground level: the supermarket for logistic reasons, shops since their public is most abundant at ground level. This creates a trade-off between space for making industry and for implants/district facilities as supermarkets and shops. The trade-off is further complicated by the different street typologies: the higher the buildings, the wider the streets, and thereby the smaller the total building surface area at ground level. Careful decisions need to be made on this topic.

An additional solution, is finding other energetic implants. The easiest one is the previously discussed category of heat-based making industry, alternated with the category of electricity-based making industry. Since these generate waste heat and on average need more cooling, their functioning as an implant is comparable to shops or supermarkets. The numerical impact of this building function on the heat and cold balance of the area should be calculated. Furthermore, energetic implants could be found, which functionally fit in the developed district and which could be housed on other levels than the ground floor. An example of which numerical values are not available, yet the authors hypothesis is an energy demand pattern with a relative large cold consumption could be found with a gym – since sporting people create a lot of heat. In mixed-use high-rise which is occupied by both housing and offices, a gym would be a complementary function fitting the area development.

Lastly, if the demand for making space is really high, the courtyard can be uplifted to the first floor, creating a lot of additional space at the ground floor. Thereby, logistics should be solved in a different manner, yet the options for natural ways of ventilation are reintroduced – when solutions for the noise production are found as well.

Spatial aspects influencing programme related energy demand

Comparing densely built areas to masses of people, it is easily understood that the closer all building functions are placed together, the smaller the heat demand in winter and the larger the cooling demand in summer. The heat losses in winter are minimised, yet the options to release heat during summer are minimised too.

Both in the interview with Octatube manager Eekhout, as well as in the mini case study to the Fiction Factory in Amsterdam, it became clear that the large halls which are in use by the making industry, are mostly naturally ventilated instead of actively cooled. However, when these making spaces are located in a dense and mixed-use urban area, the situation will change. The natural ventilation concept of the Fiction Factory, the use of openable roof windows, could not have been applied in case the space would have been situated at the ground floor of a larger building. A characteristic of hot air, is that it rises – this natural stack-effect makes roof ventilation very efficient for high spaces. In case of a closed roof, an active ventilation or cooling system will have to be applied. In the case of the making hall of Octatube, which mostly is ventilated by opening all doors, the following problem was introduced by the Eekhout, in case the surrounding area would be densified (as is on the planning for the next 10 years). When all doors are opened, noise created by the machinery used for production, will be hindering the surrounded neighbourhood. At this moment in time, the plot next to the making hall is unoccupied, so the problem does not exist. Other ways of ventilation or cooling should be introduced when the area is densified. So in short, it is expected that the cooling (and/or ventilation) demand of making industry will increase with an increase in building density.

Ground Space Index (GSI)

The last parameter in spatial design which impacts the energy balance, is the Ground Space Index: the ratio between the footprints of buildings and the surface area of the plot. As discussed, higher buildings come with wider streets, and thereby more open space. A consequence, is that with an increase of open space, the roof area will decrease, and thereby the potential to use roofs for the generation of energy. On the other hand, wider streets allow for other ways of energy generation – such as asphalt collectors. It is of importance for a planner and/or developer, to be aware of this causality.

8.6. Guidelines for energy conscious urban design

Based on all of the above, it can be concluded that the municipality should actively guide the developments from the perspective of energy-neutrality. If no additional guidelines are given, and the applicable building decree is used to direct the energy demand and supply, a dependency is created of external heat sources as - not yet constructed - heat grids.

Steering the developments towards energy-neutrality could be established by the creation of energy-based design guidelines. These guidelines should function as conditions for development, ensuring the development of an area with a high living quality, ensuring flexibility in energy planning, and ensuring the unfolding of a development trajectory towards the desired direction. More specifically, the energy-based guidelines should make it possible to develop the lively, dense mixed-use area which is desired, and to develop energy-neutral (for at least heat and cold, and desirably for electricity as well). Furthermore, the guidelines should not hinder a certain amount of flexibility in a plot development.

The four parameters that most importantly determine the energy balance of a plot are used as a basis for the creation of guidelines: the *locally available heat and cold capacity*, the *programme dependent heat and cold demand*, the *building density*, and *building function mixture*. It is seen in the calculations, that when all four parameters are defined individually – the FMI and FSI by the development plan, the demand by building regulations, and the supply by the intention to build with the energy available in the subsurface – a problem is created: the potential supply is smaller than the demand. In case it would have been concluded that the definition of all four parameters would *not* cause a problem, and would lead to energy-neutral developments, no additional guidelines have to be given. So, it could differ per plot in Schieoevers Noord *if* guidelines are needed, and *which* guidelines that should be – based on the vision for the specific plot, created by the municipality and/or the developing party.

The design guidelines are proposed to be defined as follows (guided by Figure 94). Firstly, for each of the parameters, either a specific value or a desired/realistic interval of values have to be chosen. The example in Figure 94 is based on the Kabeldistrict, for which an FMI of 30 and an FSI of 2.75 is filled in. In the current situation, the BENG norms would be used as a basis for the heat and cold demand, and since the construction of a heat grid still is uncertain, the heat and cold potential is based on Aquifer Thermal Energy Storage systems. As calculated in Paragraph 8.4 – this combination is not possible; either a shortage of heat exists, or the desired density is not reached. Since the municipality has a large urgency for the realisation of houses and jobs, the FSI and FMI are relatively rigid. The heat potential and heat demand, thereby, are the variables that could form the base of design guidelines.

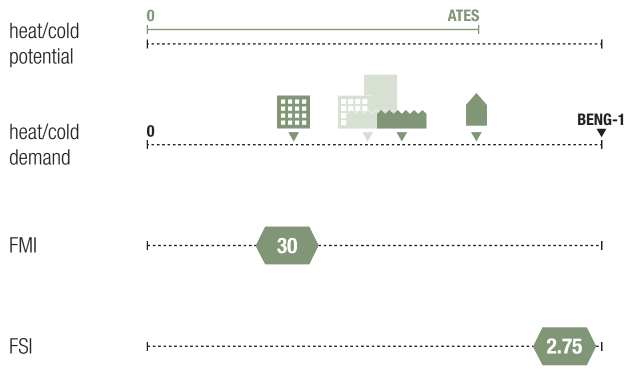


Figure 94: The four parameters determining the heat and cold balance of a plot, are the basis for the creation of energy-based design guidelines for Schieoevers Noord. For each plot, the municipality can (together with stakeholders) decide on which parameters to define and which to leave open. In case the definition of all of these axes creates a problem, a need for guidelines does exist.

In principle, only one of these two variables needs to be guided: when the demand is limited, the supply is indirectly limited as well and vice versa. By prescribing the use of a certain source of heat and/or cold, such as energy supplied by an ATES system, or an ATES plus a BTES system could be a guideline regulating the supply side of the balance. Thereby, a developer could build smartly and energy efficient, to be able to maximise the building volume with the available amount of energy. The other way around could also be guiding. The prescription of a maximum average thermal energy consumption of 19 kWh/(m²∗yr) also ensures that local potentials are not exceeded. In case the FSI or FMI are less strictly determined or are less problematic for energy-neutral developments, these can also be used for the creation of energy-based design guidelines.

For the plot development of the Kabeldistrict, regulating the development by an energy source prescriptions seems to be most suitable, since the area is relatively large, developed by one developing party (actually, a collaboration between two developers, yet acting as a consortium) and it creates the largest degree of freedom; this is illustrated in Paragraph 8.8. Regulating the energy balance based on the usage, would suit a development in which multiple developers are developing parallelly, or when the developments are phased over a long time-span; then each partial development should meet the restrictions on the average energy demand – it creates certainty for the municipality as well as for developing parties.

In case the function mixture is not too much predefined, a bandwidth could be given. For example, an area with the ambition to become a mix-used area, can get the freedom to play around with heat and cold balances. It might be necessary to still predefine a certain system, together with an FMI bandwidth. In case of non-defined ambitions regarding the FSI, it is expected that no guidelines are needed.

Lastly, the municipality could define a percentage of the total built area which might deviate from the zoning plan, when the area is used for the building of energetic implants. The municipality should decide here on the trade-off between the ambition to house the making industry, and housing energetic implants (other implants than heat-based making industry).

8.7. Energy, space and functions

The next seven pages (Figure 95 to Figure 98) combine the previously described calculation scenarios, with a study of building volumes that could be realised at the Kabeldistrict. Every spread shows a different scenario for the parameters determining the heat balance: the *locally available heat and cold capacity*, the *programme dependent heat and cold demand*, the *building density*, and *building function mixture*. A visual translation is made from the earlier shown graphs describing the buildable surface area to a physical building volume and profile. For the building volume, the building blocks as indicated by Broekman (2019) are used. The previously discussed street profiles have been applied: the *Hartlijn*, the *making street*, and the *living street*.

The reciprocity of energy, space, and building functions, comes down to the following relationships:

- The larger the energy potential, the more building volume can be realised
- The lower the energy demand, the more building volume can be realised
- The higher the FMI, the more building volume can be realised
- In case of a high share of offices; the higher the FMI, the lower the disbalance between heat and cold demand.
- The lower the intended FSI, the larger the chance that ATES systems will offer a sufficient energy potential
- The more energetic implants are applied, the lower the thermal disbalance

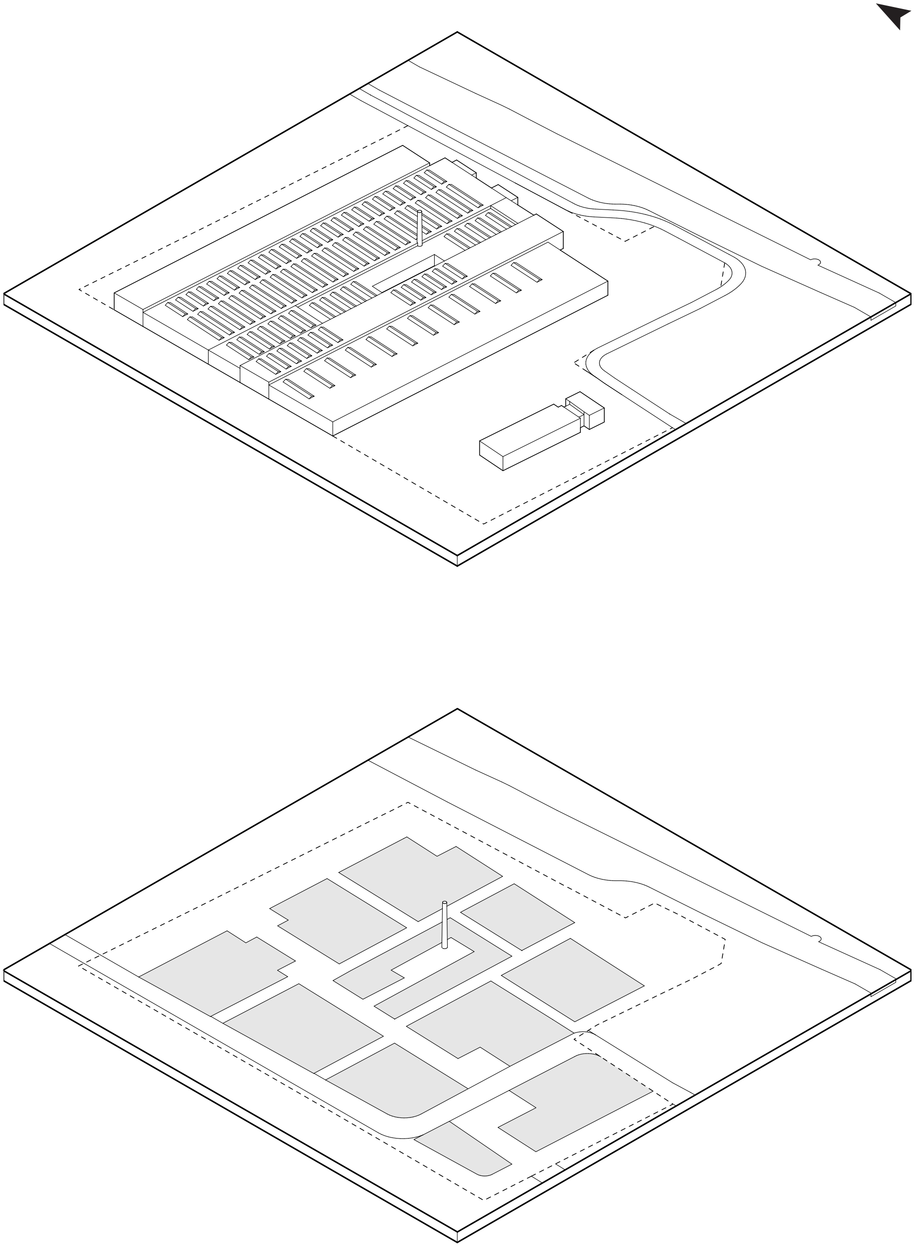
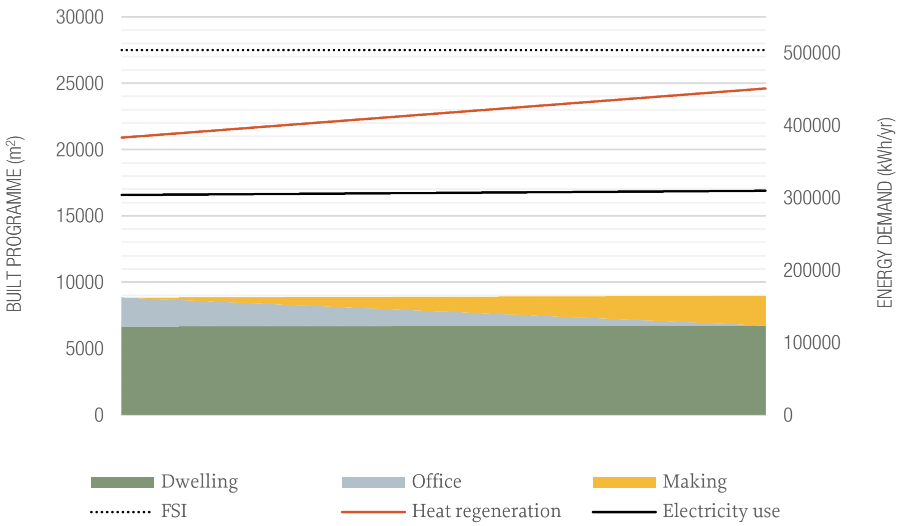
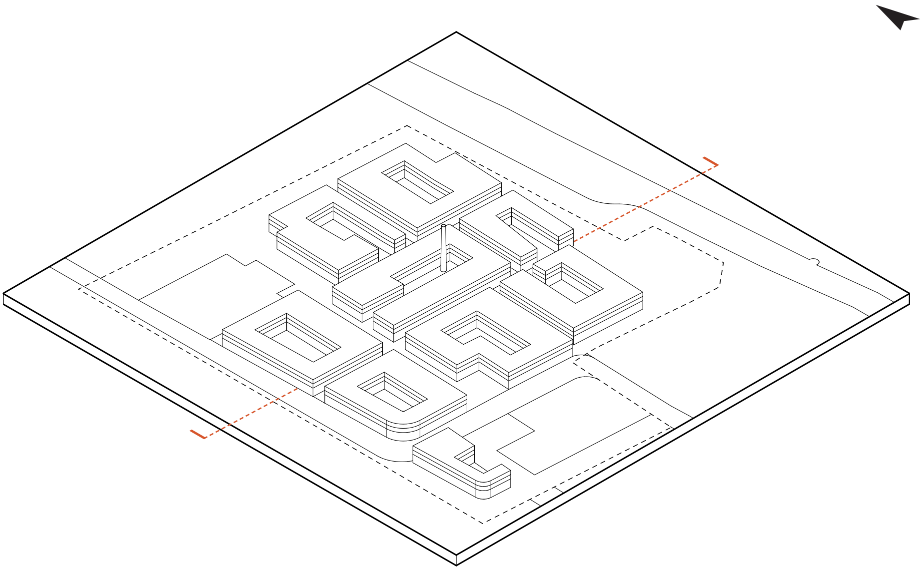


Figure 95: (top) The current situation of the Kabeldistrict, housing the Schiehallen and Suez, and (bottom) the indicated building blocks as published in the development plan for Schieoevers Noord


heat/cold potential
0
ATES
heat/cold demand
0
BENG-1
FMI
30
FSI
0.9


30000
25000
20000
15000
10000
5000
0
BUILT PROGRAMME (m²)
500000
400000
300000
200000
100000
0
ENERGY DEMAND (kWh/yr)
Dwelling
Office
Making
FSI
Heat regeneration
Electricity use



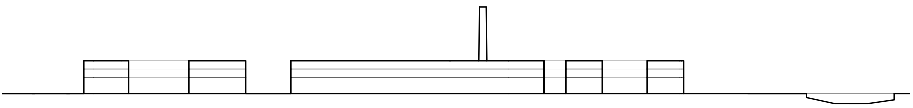
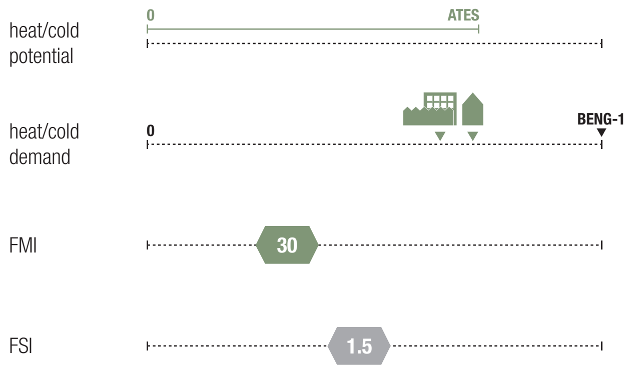
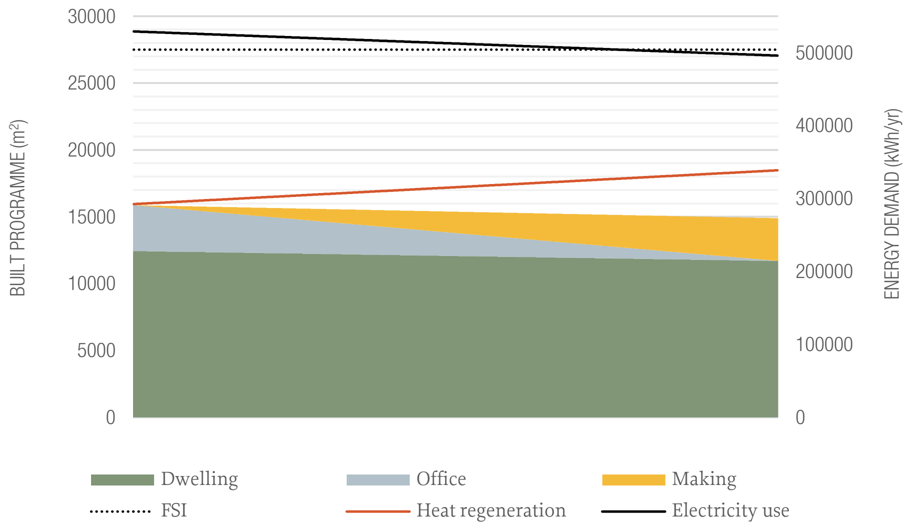
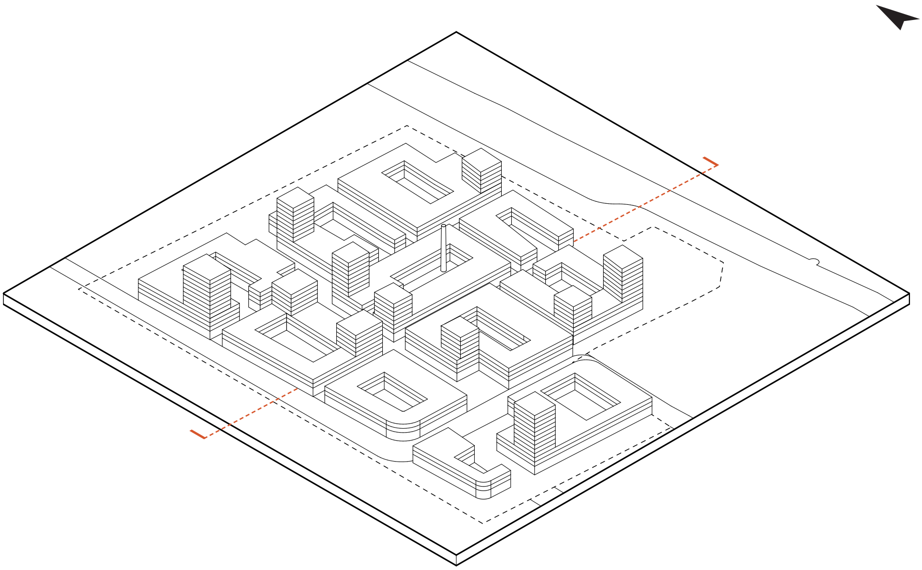


Figure 96: The Kabeldistrict when realised with ATES systems as primary source of thermal energy, BENG-1 norms as energy consumption, and an FMI of 30, resulting in an area with an FSI of 0.9

(top left) input values for the parameters of energy potential, energy demand, FMI, and FSI
(bottom left) range of possibilities for mixing dwelling, offices and working with the corresponding electricity consumption and disbalance between heat and cold demand
(top right) potential building volume that is able to be heated by ATES systems - FSI of 0.9
(bottom right) profile of the Kabeldistrict, a low-density area where people can comfortably live at ground level


heat/cold
potential
0
ATES
heat/cold
demand
0
BENG-1
FMI
30
FSI
1.5


30000
25000
20000
15000
10000
5000
0
500000
400000
300000
200000
100000
0
BUILT PROGRAMME (m²)
ENERGY DEMAND (kWh/yr)
Dwelling
Office
Making
FSI
Heat regeneration
Electricity use



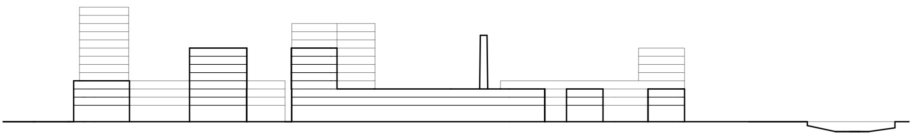


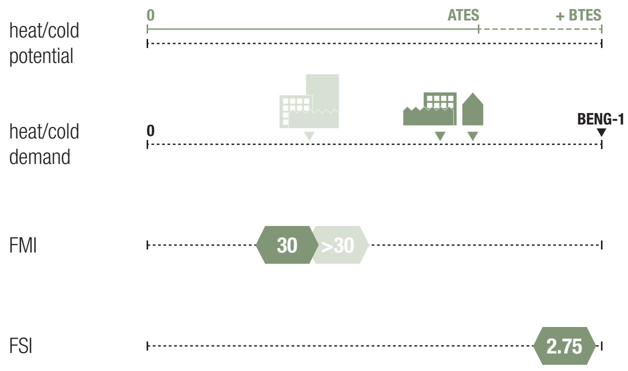
Figure 97: The Kabeldistrict when realised with ATES systems as primary source of thermal energy, a lower energy consumption than the BENG-1 norm allows, and an FMI of 30, resulting in an area with an FSI of 1.5

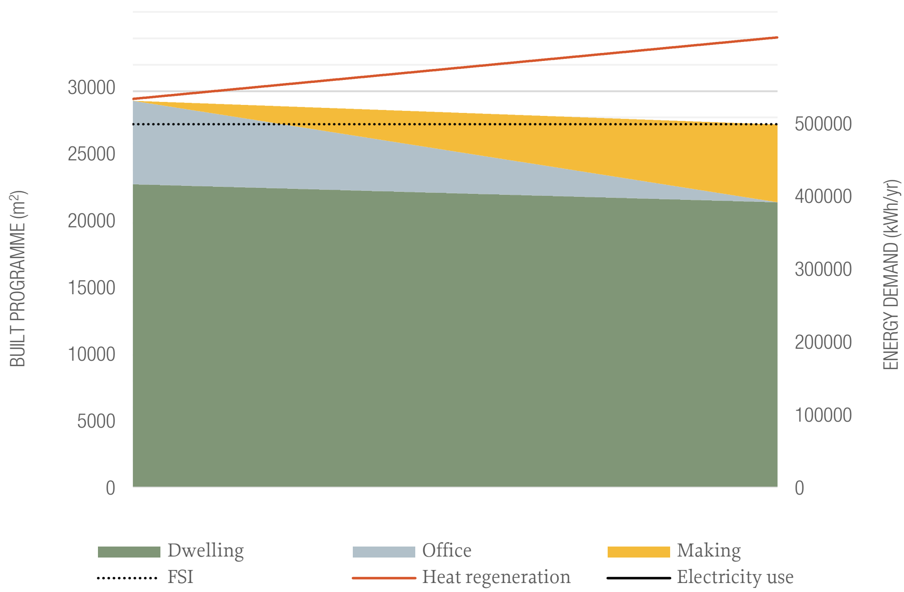
(top left) input values for the parameters of energy potential, energy demand, FMI, and FSI

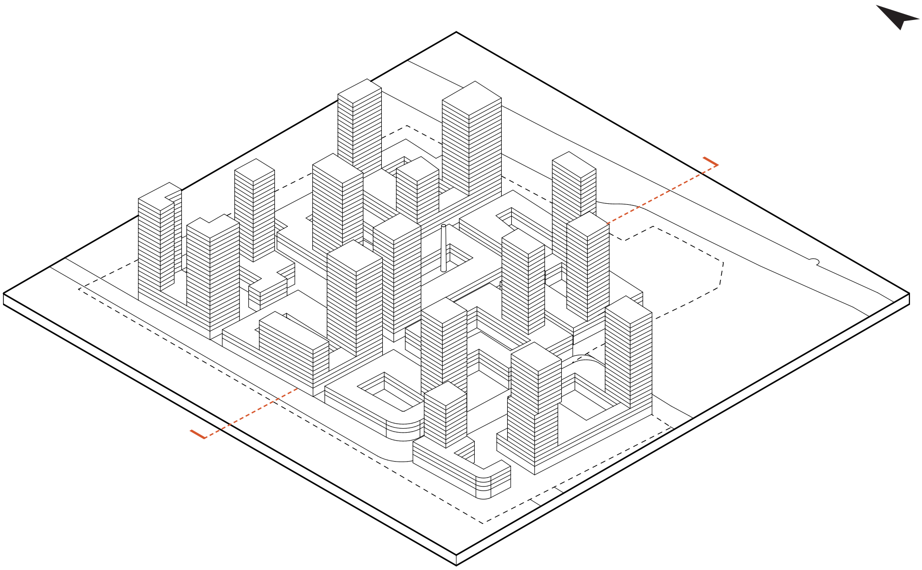
(bottom left) range of possibilities for mixing dwelling, offices and working with the corresponding electricity consumption and disbalance between heat and cold demand

(top right) potential building volume that is able to be heated by ATES systems - FSI of 1.5

(bottom right) profile of the Kabeldistrict, able to become a lively area where working and living go hand in hand


heat/cold
potential
0
ATES
+ BTES
heat/cold
demand
0
BENG-1
FMI
30
>30
FSI
2.75


BUILT PROGRAMME (m²)
30000
25000
20000
15000
10000
5000
0
500000
400000
300000
200000
100000
0
ENERGY DEMAND (kWh/yr)
Dwelling
Office
Making
FSI
Heat regeneration
Electricity use



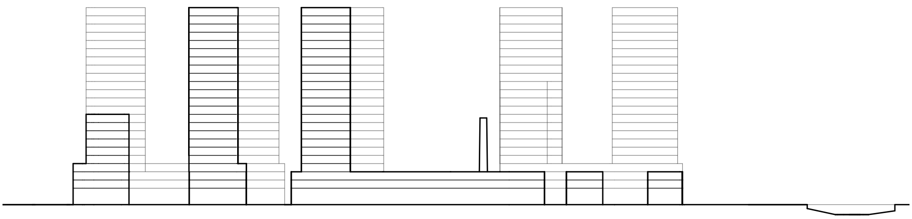


Figure 98: The Kabeldistrict when realised with ATES systems as primary source of thermal energy, complemented by BTES systems, a lower energy consumption than the BENG-1 norm allows, and an FMI of 30, resulting in an area with an FSI of 2.75

(top left) input values for the parameters of energy potential, energy demand, FMI, and FSI - with alternatives to the addition of BTES systems in light green (being the lowering of demand, or the increase of the FMI)
(bottom left) range of possibilities for mixing dwelling, offices and working; disbalance between heat and cold demand
(top right) potential building volume that is able to be heated by ATES systems - FSI of 1.5
(bottom right) profile of the Kabeldistrict, able to become a lively, high-density and mixed-use area

8.8. Energy strategy for the "Kabeldistrict"

This paragraph studies a potential energy strategy for the Kabeldistrict, based on the current plans for the plot. As retrieved from the interview with project developer *Kondor Wessels Vastgoed*, the most up-to-date plans for the Kabeldistrict comprise a building programme of approximately 350,000 m² (corresponding to an FSI of 2.9). This programme is divided into commercial real estate (61,000 m²), social real estate (48,000 m²) and residential real estate (245,000 m²). Furthermore, 41,000 m² is reserved for parking. The exact composition of the programme, however, is still discussed by the developing parties and the Municipality of Delft. According to the interview, the plot will be developed in different phases, aiming to be finished in about ten years. This section describes how the energy strategy for the Kabel district can adaptively be developed parallel to the spatial developments going on at the plot (Figure 99).

The design guideline which was proposed for the Kabeldistrict in Paragraph 8.6, is applied: the primary energy system for the development of the Kabeldistrict is the ATES system. Therefore, the energy demand for all of the functions has to be minimised to a degree which is ambitious yet feasible to construct. A next step is to exchange heat at a building, cluster, and plot level, to be able to use energy to its fullest potential. Whereas the calculations in Paragraph 8.4 looked to all of the heat and cold demands on a yearly basis, it is overlooked that functions might be able to exchange heat directly at certain moments in the year. Think of offices that start cooling when houses are still heated, or a supermarket/heat-based making industry that produces waste heat in winter as well. All of these measures should add to a situation in which the overground energy demand equals or is below the potential energy supply of the ATES system at this particular plot. The heat and cold wells are connected, forming one large system, which provides a much higher level of redundancy than a multitude of independent doublets.

The next challenge is to regenerate the heat wells of the ATES system since it is highly likely that a thermal disbalance between heat and cold exists. Currently, all three primary building functions require more heat than cold – causing this disbalance. Aquathermal energy is a potential with a high degree of flexibility: the plot is situated along the Schie, of which – if needed – a lot of energy could be retrieved in one year, while another year just needs a little. Solar thermal collectors could be integrated into roofs and façades during the construction of new buildings; asphalt collectors could be integrated into new roads during construction. The applicability of these three additional sources of heat (and cold) are visualised and quantified in Figure 101.

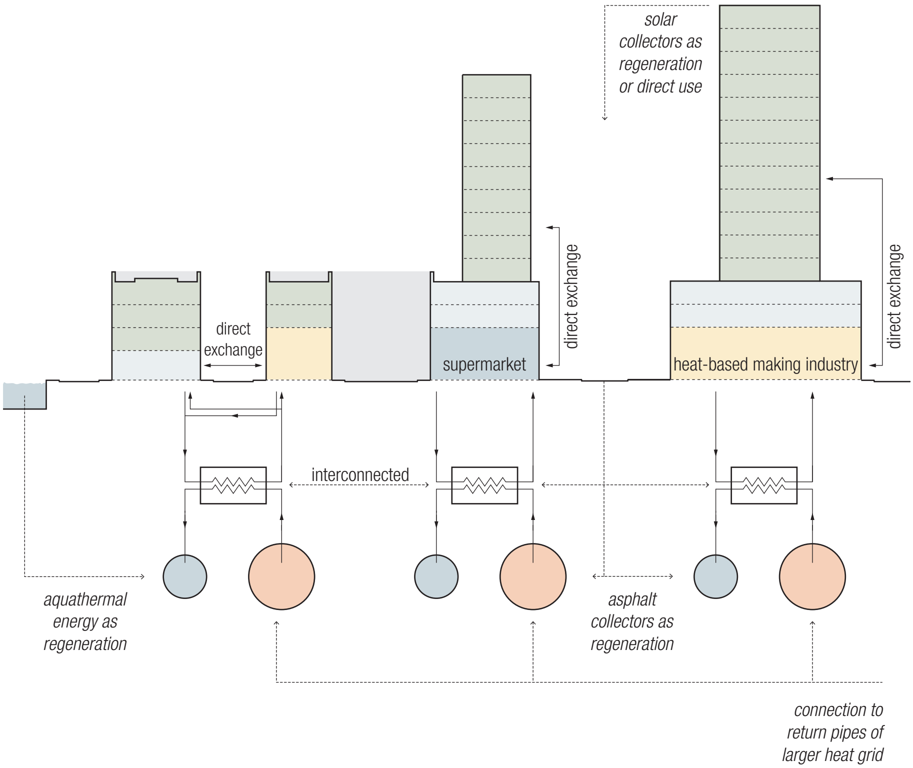


Figure 99: Energy system for the Kabeldistrict – a range of possibilities to build up a redundant system which maximises the potential of the ATES system. The building functions are indicated by colour: housing - green, offices - light blue, making halls - yellow, energetic implants - dark blue.

Lastly, if the opportunity arises in a few years, connecting the ATES system (already consisting of a multiplicity of heat and cold wells) to a larger-scale heat grid, would offer a great opportunity for the redundancy of the entire system. As long as it can be chosen to use either many or little of this energy, the connection is a good idea in any case. It offers potential to either regenerate heat wells or more efficiently produce hot tap water due to the higher temperature than provided by the heat wells of the ATES system.

In the case of connecting to a larger heat grid, the following design choice could be made. Since it is noticed in all calculations, that the heat demand of the primary programme is much higher than the cold demand, it could be chosen to dimension the ATES system on the cold demand (with a margin for the future growth of the cold demand). This could be decided as soon as a decision is made on a larger heat grid (fed with geothermal energy generated at the TU Delft, intended to be cascaded towards Voorhof, with a return pipe that has to cross Schieoevers somewhere (Box 6)). If thermal energy from this heat grid will be available, it can supply the rest of the heat demand. Since the Kabeldistrict will be built in different building phases, this decision will most probably be taken before the largest part of the Kabeldistrict will be delivered.

The developers should be careful with the scenario in which the first building phases deliver buildings with a too high heat demand, resulting in a lack of energy for the area as soon as the last buildings are delivered. When a total maximum energy demand for an area is predefined, it could be difficult to keep on track when the building process lasts for a decennium. An alternative is to let the ATES system grow parallel to the growth of the built area.

Adding value to the area by energy measures

The building volume as shown in Figure 100, does not indicate a design of the towers, nor the architectural vision of the author. It is simply the sum of the indicated building blocks, together with the spatial design guidelines dictating a lower part with a maximum height of 15 meters and (incidental) high-rise up to 90 meters. In the architectural design of the area, the architect can largely influence the atmosphere of the area, as can the spatial design for the public spaces.

The author wants to emphasise the presence of opportunities to connect the design of the public space, as well as in the design of the programmatic infill of the buildings, with energy exchange and energy generation. The construction of a supermarket, restaurant or shop that produces excess heat, which can be reused for room heating of houses, is an effective tool to balance the heat and cold demand in an area. Moreover, these functions could add to the liveability and thereby the quality of the Kabeldistrict. But more measures could add to the spatial and/or programmatic quality of the Kabeldistrict, while positively affecting the heat balance. An example already mentioned shortly before: a gym potentially offers a source of excess heat as well, because of its internal heat production. Strategically positioned on the top floor of one of the towers, a high-end gym looking out over Rotterdam and The Hague could be created - while heating its neighbouring houses.

Using a part of the Schie only for the extraction of aquathermal energy, the following opportunity is created. A large container could be placed in the water, along the edge of the Schie. When extracting cold in summer, the water gets heated - and the container could be turned into a swimming pool. When extracting heat in winter, the water gets extra cold and could potentially be used for ice skating. Since aquathermal energy would mostly be needed for regeneration of the heat well, the in-between season could be used for this regeneration, enabling the societal function of the system - the swimming pool - to create added value for the public space in summer.

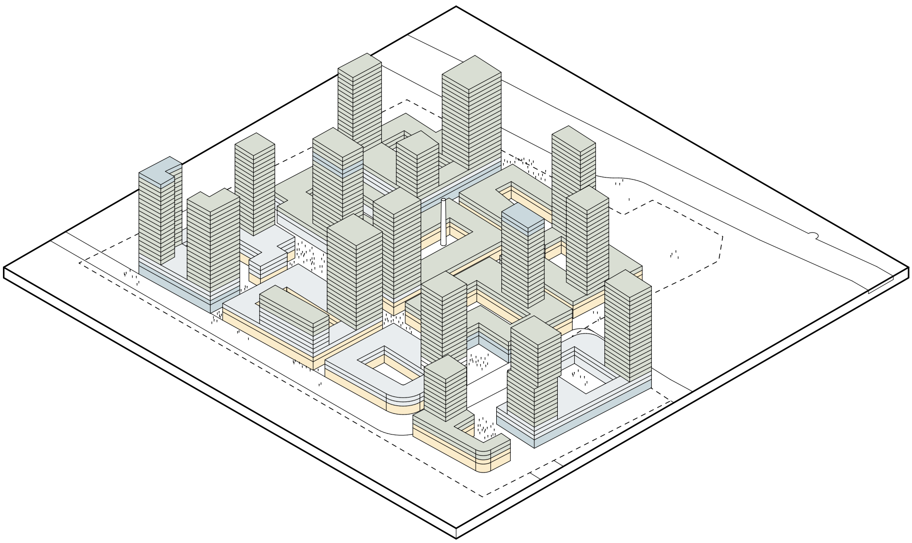
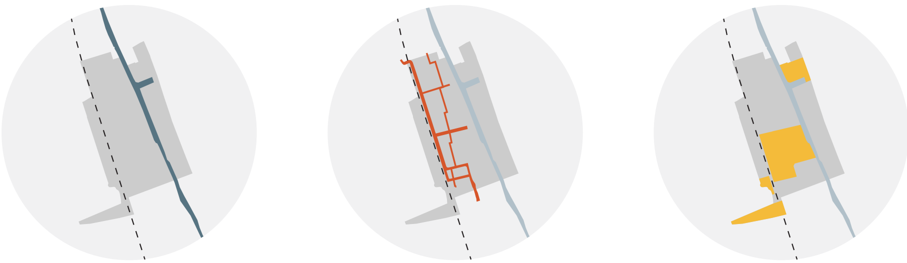


Figure 100: Mixing the three primary building functions - *housing*, *offices*, and *making halls* - with energetic implants creates an even more lively neighbourhood; what about a gym at the 25th floor?



Aquathermal potential
Available volume for Kabeldistrict
= 6300 m^2 * 3 m = 19,000 m^3
generation +/- 1.2 kWh per m^3
that is cooled or heated by 1°C

Potential asphalt collectors
Available surface area
relocated Schieweg = 11,000 m^2
Hartlijn = 10,000 m^2
generation +/- 140 kWh/(m^2*yr)

Solar thermal potential
Available roof area
high-rise = 9,400 m^2
low-rise = 37,000 m^2
generation +/- 360 kWh/(m^2*yr)

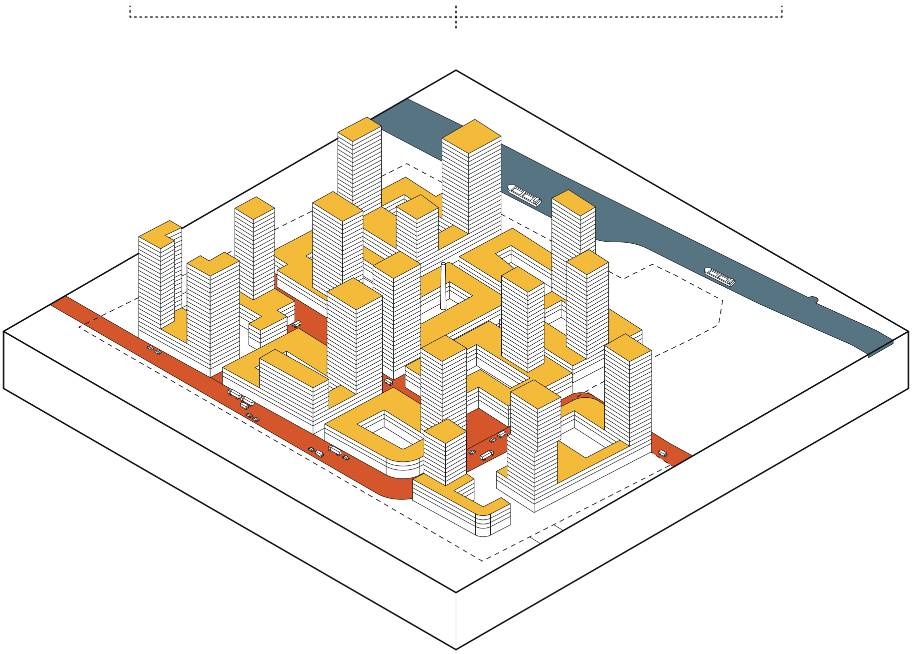


Figure 101: Energy system for the Kabeldistrict – a range of possibilities to regenerate and/or complement an ATES system, collectively able to create a redundant thermal energy supply

8.9. Conclusion

This chapter extensively studied (part of) the area development in Schieoevers Noord from an energy-neutrality perspective, aiming to understand the relation between energy, space, and programme – for Schieoevers, and specifically for the plot which will be developed into the Kabeldistrict. This study results in an answer on two of the sub-questions: SQ4 "*Which design guidelines for plot developments could be used by the Municipality of Delft, concerning the (local) energy balance of the plot, to establish adaptivity and energy-neutrality in the spatial and functional design of Schieoevers Noord?*" and SQ5 "*What are the implications of these guidelines for existing spatial and functional design proposals for plot developments within Schieoevers Noord?*".

For the creation of energy-based design guidelines, three principles were kept in mind for the development of the different plots within Schieoevers Noord. The development of each plot should be:

- energy-neutral, for at least the building-related energy demand, and with the ambition to be energy-neutral for the full energy demand;
- developed in such a way that following developments are not hindered concerning their local energy potentials;
- developed with a notion of redundancy.

The reciprocity of energy, space, and function is studied by heat and cold balances of one-hectare large cut-outs of the plot at which the Kabeldistrict will be developed. The balance is mainly determined by four parameters: the *locally available heat and cold capacity*, the *programme dependent heat and cold demand*, the *building density*, and *building function mixture*. The primary building functions to be included in the area development are *housing*, *offices*, and *making halls*.

It is seen that in case of realising a high density (FSI 2.75) and a mixed programme comprising a large share of housing, the BENG norms to be used from mid-2020 on, do not lead to a heat balance which can be closed on the scale of a plot – thermal energy from the subsurface does not suffice (neither ATES nor a combination of ATES and BTES systems). A function mix in which the share of "working" is enlarged, creates a more favourable situation, yet still insufficient, as does the application of energetic implants such as supermarkets and shops. To be able to create a (thermal) energy-neutral plot development in case of the Kabeldistrict, the energy demand should at least be much lower than the upper boundaries of the BENG norms. In each case, the heat demand is larger than the cold demand, so measures to regenerate the heat wells should be incorporated in the process of energy planning.

To be able to develop a plot in such a way, that the spatial and functional design is developed both energy-neutral, and fits an adaptive approach to energy planning, energy-based design guidelines are proposed, to guide the physical development (SQ4). These guidelines do not use a “one size fits all” philosophy: an approach is presented instead, to be able to establish the right guidelines for each plot, resulting in energy-neutral plots that do not hinder any of the neighbouring plots to develop in the same way.

The design guidelines should be applied at plot developments which have to cope with the same problems as described for the Kabeldistrict: a situation in which the individual definition of the four parameters (energy potential, energy demand, FSI, and FMI) is not able to lead to an energy-neutral heat balance at the level of the plot. In that case, for one of the parameters, a design guideline should be defined. For the definition of the guideline, a ratio between guidance and freedom has to be created which fits the specific plot development and its development process. For the development of the Kabeldistrict, it is proposed to define the use of ATES systems as the main source of heat and cold. That would correspond with a highly ambitious average energy supply of 19 kWh/(m^2*yr) for both heat and cold. The developer gets the freedom to design the area in a way that fits the vision, creates a good business model, and in a way that gets the most out of the ATES system.

Answering SQ5, the implications of the guidelines for existing spatial plans, are the following. High-density areas – especially those that have (planned) a large share of residential buildings – have a thermal energy demand that requires more ambitious planning than the prescribed BENG norms, to realise energy-neutrality. By prescribing ATES as a main system, instead of restricting the average energy demand, developers are stimulated to think in terms of heat and cold exchange between functions with a different energy demand pattern (both energetic implants, and the primary building functions). The smarter the design of building blocks or clusters, the more energy can be used below the line. Another implication could be the reconsideration of the function mix since a smaller share of housing corresponds to a lower overall energy demand. In the case of the Kabeldistrict, the final decision on the function-mix has to be made. An adaptation to a function-mix with a smaller share of housing and a larger share of offices might be better feasible from an energy perspective.

All in all, the chapter has shown the need for energy-based design guidelines to guide the development of a future-proof energy supply for Schieoevers Noord. Current design proposals for plots in Schieoevers Noord, are still in a stadium that programme mixes can be adapted, and strategical choices on energy supply have to be made. The design guidelines stimulate energy-conscious development, without compromising on the ambition to realise a lively, mixed-use and dense urban area.

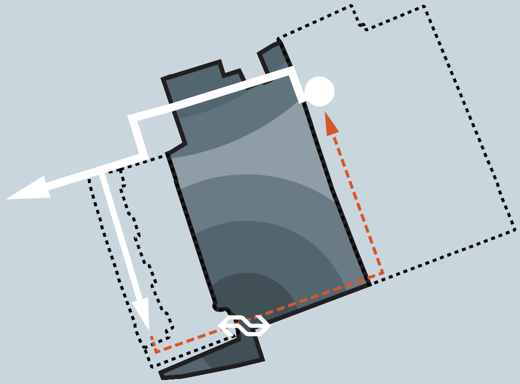


Figure 102: Intended building density by the Municipality of Delft, and proposed location (by author) of a return pipe for the planned heat grid

Box 6. Geothermal energy: TU campus and a cascade grid

Based on the outcomes of this chapter, the author wants to share an idea that can complement plot developments that are based on ATES systems. It is seen that the primary building functions of housing, offices, and making halls create a residual heat demand – no matter in which ratio they are combined. Energetic implants will not compensate for these differences, other sources of energy such as aquathermal energy, solar collectors, and asphalt collectors collectively could regenerate the heat wells of the ATES systems.

At the moment still an uncertainty, yet the plan to construct a geothermal well at the TU Delft is in an advanced stage. With the *Green Deal Aardgasvrije Wijken* as discussed in Box 3, the decision to connect Voorhof Oost to this geothermal well – by a cascade net – seems reasonable as well. In case both uncertainties will become realities, a return pipe running from Voorhof back to the TU Campus will certainly cross the area of Schieoevers Noord. Therefore, the author wants to share a piece of advice schematised in Figure 102.

The different shades of grey indicate the planned density, as published in the development plan for Schieoevers Noord. The highest density area is concentrated around the railway station Delft Campus. This chapter has shown the difficulty of developing energy-neutral when aiming to realise a high-density cluster of buildings. A favourable decision would be to locate the return pipe to the TU Delft as indicated with the orange arrow. Thereby, the high-density areas could benefit from the return heat, and thereby realise energy-neutral plans,. Limited distribution infrastructure has to be constructed, making the connection to this heat grid feasible.

9.

SON approach for adaptive energy planning

The previous chapter extensively described an intervention related to the establishment of conditions for (sustainable) development in Schieoevers Noord – corresponding with the third design challenge as described in the design brief. This chapter discusses the bigger picture: the integration of different characteristics of adaptivity in a planning process for sustainable energy at the Municipality of Delft - with regard to the area development of Schieoevers Noord. Furthermore, this chapter aims to make these characteristics of adaptivity specific by offering planners the right tools, thereby building up to the main research question: "*How could an adaptive approach to energy planning enable the Municipality of Delft to guide the development of a future-proof energy supply (heat and cold supply) for Schieoevers Noord?*".

It should be noted upfront, that ideally the approach which is created in this chapter – the "*Schieoevers Noord (SON) approach for adaptive energy planning*" – would already have been adopted in the phase of visioning. That part of the process has taken place up until six monts ago, until the delivery of the development plan. However, since the development process is a long-term process in which the industrial area of Schieoevers Noord is transformed step by step, adopting the approach in the current phase of the project is still useful. The area development trajectory is still at the very beginning; only 4 out of 15 plots are currently under development or planned to be developed in the upcoming years.

A workable process for adaptive energy planning should encompass all of the six characteristics of an adaptive process as identified in Chapter 4. The process that is designed and discussed in this chapter incorporates both characteristics for which tools already exist (as described in Chapter 5) as well as characteristics for which tools had to be designed. For the first and second design challenge, as described in the design brief (Chapter 7), specific tools or process interventions have to be designed for the exploration of uncertainties in the planning process (1st characteristic of adaptivity) and the systematics of process iterations (3rd characteristic of adaptivity). In Chapter 8, an interpretation was given of the creation of favourable conditions for development (4th characteristic), as an answer to the third design challenge. Both for the aspect of connecting long-term visions with short-term actions, and for integrating diverse knowledge of those involved (2nd and 6th characteristic) tools are abundant in existing approaches for energy planning. These tools will be mentioned in the description of the approach for adaptive energy planning in this chapter. Figure 103 on page 229 shows all of the characteristics of adaptivity and the chapters and/or paragraphs in which the tools have been or are described or designed.

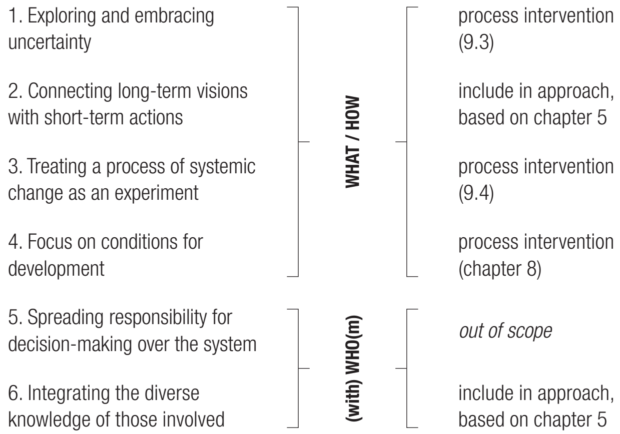


Figure 103: Link between characteristics of adaptivity and design interventions

As noted, the 5th characteristic, *spreading responsibilities for decision-making over the system*, is indicated as "out of scope" in Figure 103. Whereas the first four characteristics are related to process steps, and whereas the sixth indicates who should be included in the process, the fifth dictates who is in charge of the process and decision-making. The author wants to stress the importance of decentralised forms of decision-making, but sees no room for this element as part of a stepped approach for adaptive energy planning; it is about who is planning rather than how is planned. The author has the vision that the Municipality of Delft should strive for a system in which scales and specialisms come together in decision-making for a sustainable energy supply system in Schieoevers Noord and the city of Delft as a whole.

This chapter starts with the insights that the two interviewees at the Municipality of Delft shared on the composition of the project team and the presence of the six characteristics of adaptivity in the current process (9.1). Then, the design process of the stepped approach and the two proposals for process interventions concerning uncertainties and iterations are described (9.2). Subsequently, the proposed "*Schieoevers Noord approach for adaptive energy planning*" is presented (9.3) and the two steps for which tools are designed are explained in further detail – the explication of uncertainties (9.4) and the inclusion of a method for systematic iteration of the development plans (9.5). Paragraph 9.6 is dedicated to the validation of the proposed approach, by reflecting upon it with an employee of the Municipality of Delft; the chapter is concluded with a final note on the "Schieoevers Noord approach of adaptive energy planning" (9.7).

9.1. (Adaptive) planning at the Municipality of Delft

From the interviews with Derk van Schoten and Stijn van Liefland – both part of the project team Schieoevers Noord – the network depicted in Figure 104 could be sketched. This network visualises the body of planners concerned with the area development in Schieoevers Noord. The yellow dots indicate the core project team for Schieoevers Noord. This project team is composed of a project manager (Derk van Schoten) and five disciplines – *environment/ sustainability* (Stijn van Liefland), *spatial planning*, *economy*, *mobility*, and *housing/society*. The main consultant for the overarching development plan has been Marco Broekman (dark green). All of the planners have been collaborating with internal (light yellow) and external consultants (light green) in these different disciplines. This left part of the network, as shown in Figure 104, has been creating the development plan; according to Derk van Schoten, a total of 52 people has contributed to this plan. Then, the right part of the network shows a different network of employees of the municipality, who are responsible for the retrofitting and (micro-)generation of sustainable energy at the established companies in Schieoevers Noord, which are not developing.

Above this network of planners, *two hierarchical layers* exist: the director urban development and the city council. The director urban development forms the management layer above the area development team of Derk. The city council is the formal decision-maker. Formally, the project team of Schieoevers Noord presents a piece of advice to the council, who then needs to agree. In practice, however, the project team can make (most of) the decisions regarding the energy strategy of Schieoevers Noord. All decision-making as described in this report targets the project team, not the city council.

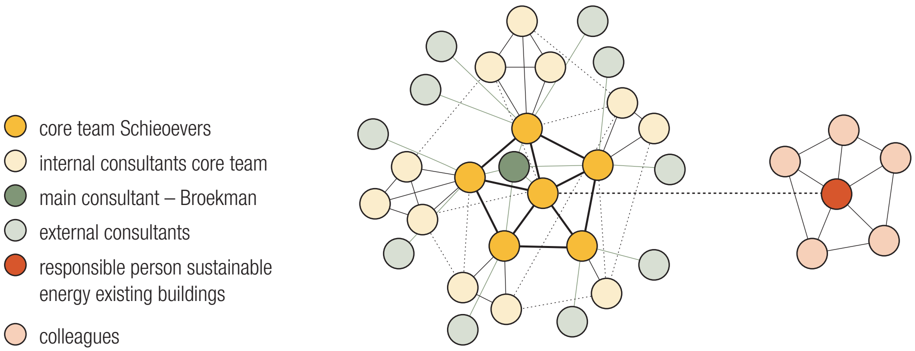


Figure 104: Energy planning network within the Municipality of Delft

Both of the interviews at the Municipality of Delft partly focused on the presence of the characteristics of adaptivity in the current planning practice – the main insights are shared here. The characteristics that were mostly discussed are the way the project team of Schieoevers Noord explores and copes with uncertainties, how the phase up to 2030 could be used to learn from in order to adapt for the phase after 2030, and how the integration of knowledge of diverse stakeholder groups was established in the participation process which took place between fall 2018 and late spring 2019.

The uncertainties that both of the interviewees mentioned, were already discussed in Paragraph 6.3. A short summary will be given here. Stijn van Liefland mentioned the uncertainty in the realisation of a regional heat grid crossing Delft. Furthermore, he mentioned the uncertainty in the realisation of a geothermal well of the TU Delft and in the potential realisation of a cascade net. Also developments of prices in the building sector as well as prices for the construction of ATES systems create uncertainty. The unknown energy demand and unknown phasing in the area development were confirmed as uncertainty as well. For Derk van Schoten, the most important uncerrtainty is whether the intended function-mix between living and making industry will succeed.

At the moment, the project team mostly copes with the energy-related uncertainties by planning for *non-regret* strategies. For example, Stijn foresees that the Kabeldistrict can start building and using ATES systems in the coming years. By the time regeneration of the wells is needed, it will be clear whether a regional or local heat grid will foresee in the regeneration demand, or whether aquathermal energy is needed. Furthermore, the team tries to cope with uncertainty regarding the function-mix by creating *favourable conditions* for making industry to be housed; think of the "gradient" in the spatial vision (*ruis*, *rumoer* and *rust*).

Regarding the characteristic of experimentation, Stijn van Liefland could tell that – concerning the topic of energy – no plan does exist yet on how to monitor and learn from the phase between now and 2030, in order to be able to adapt the development strategy for the area development after 2030.

The participation process related to the creation of the development plan was partly open for the public and partly organised for the closely connected stakeholders. Concerning the topic of energy, little new ideas have been gathered – which is explained by the municipality by the notion that energy is a topic requiring (a certain level) of expert knowledge. Regarding other topics, input has been gathered and has led to several adaptations within the development plan. The participation traject not only had the aim to gather information from the "outside world", but also to gain acceptance for the development plans.

9.2. Design of the stepped approach

For the design of an adaptive approach to energy planning, the gathered knowledge from all of the previous chapters as well as parts of the stakeholder interviews (as described above) is synthesised into a proposal for this adaptive approach. The process interventions presented in this chapter form the answer to the first and second design challenge, as formulated in Chapter 6. Summarising, based on the analysis of Chapter 5 and stakeholder interviews, a need exists for an approach to explore and explicate uncertainties concerning energy planning in the area development process. Next to that, an approach for systematic iteration on (most importantly) visions, strategies, actions, and design guidelines is needed.

To systematically include all information which was gathered earlier in the research process, a morphological chart was used. In this morphological chart (Table 6 on page 237), input from the theoretical framework, the review of energy planning approaches, the case study analysis, stakeholder interviews, and additional resources are collected, complemented with design ideas by the author. Whereas a morphological chart is intended to generate a set of optional designs, the different sources did generate a rather coherent set of design ideas – which made the author decide to create one intervention concerning uncertainties, and one regarding iterations.

As a next step, the stepped approach for adaptive energy planning, as well as the specific interventions regarding uncertainties and iterations have been reflected upon with someone from practice (from the Municipality of Delft, related to energy/sustainability, not directly linked to Schieoevers Noord). This reflection aimed to validate the proposed process. A semi-structured interview was held, which formed the input for a last iteration in the design process.

9.3. SON approach for adaptive energy planning

For the development of the *Schieoevers Noord approach for adaptive energy planning*, the two energy planning approaches that most clearly included the first four characters of adaptivity were taken as a basis. These approaches are the City-zen approach (follow-up of Energy Master Planning) and SREX, as described in Chapter 5. Both include clear steps for the construction of long-term visions, and the translation of these long-term visions into short-term actions. Both methods explore the present situation of the area (both the physical and societal system) and energetic status quo. Both methods also explore plans for the near future and explore (possible) far-future scenarios – the last step being a step in the direction of uncertainty exploration. Furthermore, with the organisation of *Roadshows*, the City-zen approach offers tools for participation, thinking beyond the creation of support and trying to stimulate cross-pollination between expert knowledge and local (lay) knowledge. The SREX method, on the other hand, gives a bit more support in the exploration of uncertainties, as well as a clear notion of iteration by the "rule" or recommendation to go through all planning steps several times.

A follow-up approach, striving to include characteristics of adaptivity, should contain a more extensive step for the exploration of uncertainties. In this step, it is not only important to identify uncertainties that come with external changes in the context, but also to identify uncertainties that come from interdependencies between stakeholders. Furthermore, a step for systematic iteration should be included – actually not a step, but a mechanism for iteration. Not only strategies and actions should be iterated upon, but the sustainable future vision might also ask for adaptations over time. Lastly, the design guidelines created in Chapter 8, shaping favourable conditions for development, should get a place in the approach. The focus on conditions for development should not be limitied to design guidelines, programmes or projecta by the municipality or subsidies for sustainability measures are also conditions that favour development .

Figure 105 shows the proposed approach for adaptive energy planning. Compared to the previously discussed methods (Chapter 5), the *Schieoevers Noord approach for adaptive energy planning* added a step for uncertainty analysis to complement the other analyses and proposes an "adaptive roadmap" to bridge the present state of the area and the sustainable future vision. The proposed step called "adaptive roadmap" is inspired by the City-zen approach. The step aims to create strategies and to plan interventions; it also focuses on the creation of favourable conditions for development. This adaptive roadmap should be regularly iterated upon. As with the other approaches, the last step on the time horizon is the sustainable future vision. The vision is formed after the analysis; during the uncertainty analysis it is studied which uncertainties hinder the creation of a detailed and inclusive plan. The adaptive roadmap is the bridge between the current system state and the future vision, in which the identified uncertainties are acknowledged. Both the vision and roadmap can change over time, as a response to changing future conditions.

The different steps are positioned on two axes, the x-axis representing time (present, near-future and far-future), the y-axis distinguishing between concrete and abstract. While iterating within the process of energy planning, the far-future will become a more near-future, and the previous plans for the near future will turn into presence. Abstract uncertainties will become more concrete over time or will become certainties: an everchanging dynamic.

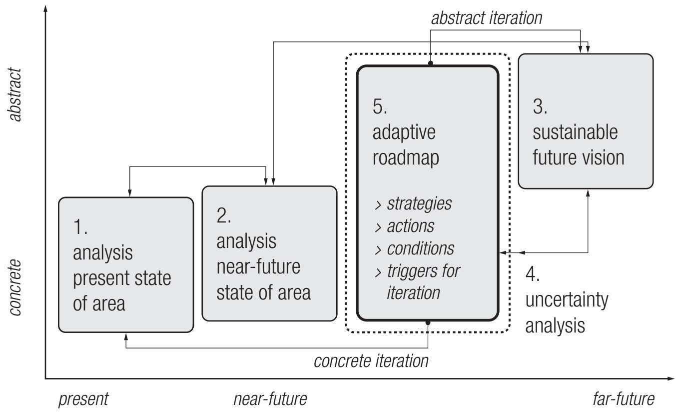


Figure 105: Proposed steps of "SON approach for adaptive energy planning"

The five steps can be described as follows:

1. Analyse the *present state of the area* and its context (energy, societal system, stakeholders);
2. Analyse concrete *plans for the near future*;
3. Define a desired sustainable *future vision*;
4. *Explore and explicate uncertainties*, coming from (far-)future scenarios and interdependencies between stakeholders;
5. (a) Create an *adaptive roadmap*, consisting of strategies, no-regret actions and conditions for development;
   (b) Define the points in time and/or *triggers for iteration** of these strategies, actions and conditions.

* *Repeat these five steps – in this order or a different order if preferred – when a predefined point in time/trigger is reached, and adapt the vision and/or the roadmap (> its strategies, actions, conditions, and triggers for iteration) to the new conditions of the area development process and/or the developments in the (local) energy system*

The characteristics of adaptivity are included as follows in the *Schieoevers Noord approach for adaptive energy planning*. Step 1 and 2 are a basis to define any kind of vision or strategy. Characteristic 1, *explore and embrace uncertainty*, is included in step 4. Step 3 forms the long-term vision mentioned in characteristic 2 (*connect long-term visions with short-term actions*). Step 5 connects the vision to short-term actions, describes a mechanism for iterations (3. *treat a process of systemic change as experiment*), and includes the *creation of conditions for development* (characteristic 4), along with strategies and actions. *Knowledge integration of a diverse stakeholder-group* is important in each of the phases, but mainly in step 3, the creation of a (broadly supported) vision, which includes a wide public. Since energy is a specialist topic, participation with the lay public does not necessarily thrive new ideas (interview SvL) – expert focus groups would be a more appropriate method for strategy making (step 5).

The analysis of uncertainties (step 4) is further elaborated upon in paragraph 9.3, step 5 – the mechanism for systematic iterations – in paragraph 9.4.

9.4. Explication of uncertainty

The need for tools to explore and explicate uncertainties throughout the process is both grounded in the literature study of Chapter 4, in the lack of tools to study uncertainties in existing methods for sustainable energy planning as described in Chapter 5, and in the stakeholder interviews of which the analysis is written down in Chapter 6. In order to be able to explore and explicate uncertainties it is important to create a common language: a way to get different perspectives and uncertainties on the same wavelength. Subsequently, it should be explored which barriers to taking actions or decisions are caused by the presence of uncertainties . This insight could provide a starting-point to take action.

The morphological chart, as displayed in Table 6, gives an overview of the different perspectives, tools, and ideas that are gathered concerning uncertainties in the previous chapters. It stands out that many aspects which are named in this table have to do with coping with uncertainties, rather than with exploring them. Therefore, some alternative sources have been consulted.

During stakeholder interviews at the Municipality of Delft, it was noteworthy that most of the uncertainties that were named are caused on a scale level that exceeds Schieoevers Noord. The uncertainties that were mentioned ranged from market-related developments (financial), to the interdependency of decisions concerning (regional) heat grids, and to the question whether the mixture between making industry and living will actually work out. Besides that, the author perceives the open-end of the area development trajectory as an important uncertainty for sustainable energy planning in Schieoevers Noord. Next to explication of uncertainties, creating a conversation which allows room for uncertainties of different wavelengths is of importance.

The cyclic approach of asking a set of five questions as used in the SREX methodology was a major source of inspiration for the proposed intervention. Another source of inspiration was an advisory report to the European Union which addresses (communication of) uncertainties, and names multiple approaches for the analysis of uncertainties. An example is the "Leidraad voor Omgaan met Onzekerheden" (*English*: guideline to cope with uncertainties) which is used by the Netherlands Environmental Assessment Agency (or *PBL*) (Group of Chief Scientific Advisors, 2019; PBL Planbureau voor de Leefomgeving, n.d.). This guideline consists of six questions to explicate uncertainties. The guideline can be used at or before the start of a project to give uncertainties the right position in a project; during a project to explore the most relevant uncertainties and their effects; and after a project to evaluate a process and its results.

Like the "leidraad" and the SREX methodology, the author would propose a set of questions to create a deeper understanding of the uncertainties at stake. Before introducing the set of questions, it should be determined in which setting the questions have to be answered. Since energy planning is seen as a topic which is highly interrelated with other fields of planning, it is suggested to put "uncertainty in energy planning" on the agenda of meetings with the core team of Schieoevers Noord, representing the core five disciplines of importance in the planning process for the area development (as mentioned earlier: *environment/sustainability*, *spatial planning*, *economy*, *mobility*, and *housing/society*). A cadence could be adopted in which the topic of uncertainty is discussed; for example twice a year with the option to bring it in as a topic when a large uncertainty (did) arise that specifically affects the field of energy. As the one responsible for the energy vision, the environmental consultant should be the one in charge of the conversation[1].

[1] Uncertainties do exist in many ways, as intensively discussed in Chapter 4. For the success of the area development, uncertainties present in all disciplines should be addressed and a different conversation facilitator than the environmental consultant might be desired. Yet, the thesis is scoped to "adaptive energy planning" – and so does the intervention targeting uncertainties. In practice, a wider adoption would be preferred; the author considers the set of questions presented in this paragraph as relevant for uncertainties related to other disciplined within the Schieoevers Noord project as well.

Table 6: Morphological chart – ordering ideas on the explication of uncertainties and on systematic iterations

	Theoretical framework	**Energy planning methods & approaches**	**Case study analysis**
Exploring and embracing uncertainty	• Narratives • Scenarios • *Dilemma thinking*	• *EMP: mapping barriers for implementation of energy measures* • *SREX: choose interventions which are independent of critical uncertainties* • *SREX: rounds of questions to guide a.o. the identification of lomg-term scenarios* • STEEP: Italian Flag method for uncertainty identification	• *The splitting in a phase before and after 2030 as a tool to take away uncertainty at stakeholders* • Step-by-step development to decrease uncertainty
Treating a process of systemic change as an experiment	• *Use of living labs (developments in SON until 2030 could be used as living labs)* • *Specification of trigger values or tipping points*	• Going through a set of questions multiple times, with a variable group of people	• *The environmental impact assessment involves a 2-yearly rhythm of monitoring* • *2030 as a marked point for reflection and adaptation*

NB: The table includes only specific tools or methods retrieved from literature, energy planning methods naming the importance of one of the characteristics of adaptivity are not included.

Stakeholder interviews	**Additional literature/ examples**	**Author's ideas**
• No direct input, yet interviews showed the *high diversity of uncertainties* named by stakeholders: the differences between SvL and DvS are large, indicating a different (role or person related) wave length.	• Based on (Group of Chief Scientific Advisors, 2019): checklists, questionnaires, uncertainty matrix • *Based on PBL (PBL, n.d.): set of questions applicable in different project phases*	• *Categorising of uncertainties makes them more communicable (abstract and concrete, long-term or solvable at a point in time, etc.)* • *All of the perspectives of the core team have to be present* • Use of question-cards
• *SvL names the monitoring rhythm written down in the MER, and the possibility to add energy monitoring measures in that rhythm* • DvS mentions the need to use up-to-date technologies	• -	• All of the perspectives of the core team have to be present, and are to be seen interrelated • *Trigger value: in case of plot-twist* • Use of (simplified) physical models and/ or drawings

The questions are divided into two categories: those explicating uncertainties, and those exploring the implications of uncertainties. The list of questions is aiming to be answered in dialogue and while seeing uncertainties in relation to each other. The proposed list of questions is as follows:

1. **Which uncertainty hinders the creation of a blueprint?**

Explication

2. Is the uncertainty created at the scale of Schieoevers Noord, or at a larger (or smaller) scale?
3. Is the uncertainty caused by interdependency of other stakeholders or an unknown (far-)future scenario?
4. Is the uncertainty temporary or permanent?

Implications

5. Which actions or decisions are hindered by the uncertainty?
6. How can the barrier for taking action or for making a decision be removed?

The question that is intended to open up the conversation is chosen since the desire or need for an adaptive development plan originates in the impossibility to create a blueprint for the area development of Schieoevers Noord. Describing which uncertainties hinder the blueprint planning, is expected to be a powerful tool for the municipality to start the conversation open and broad yet specific at the same time. Questions 2,3, and 4 make use of dilemma thinking: an uncertainty could be classified as either (a) or (b). Questions 5 and 6 focus on barriers that are created by the uncertainties. By opening up a dialogue on this topic, it could be decided collectively how to act upon this knowledge.

To give some example answers, the uncertainty regarding the construction of the geothermal well at the TU Delft and the connection of a (cascading) heat grid is used. Q1: this uncertainty is created at the scale of Delft (at least, the decision affects the energy policy and strategy of the city of Delft). Q2: the uncertainty is caused by an interdependency of the TU Delft and the network operator that is concerned with the heat grid in Voorhof. Q3: the uncertainty will only exist until the above-mentioned stakeholders take a definitive decision and start the construction. Q4: the heat potential of the (potential) heat grid cannot be incorporated in an energy strategy, although it might be the most efficient source. Q5: this barrier can be removed by "time" only; a non-regret action would be the following. ATES systems are desired anyway for their cooling potential, so they can be used as a primary system. Regeneration of the wells is needed after several years, which creates the needed time for the decision to be awaited, as well as for the exploration of other regeneration potentials.

9.5. Systematic iteration

The incentive for the inclusion of a mechanism for systematic iteration into an adaptive energy planning approach comes from the third characteristic of adaptivity: treating a process of systemic change as an experiment. Since the area development of Schieoevers Noord has a step-by-step development approach, an opportunity for learning by doing exists. Learning by doing implicates a constant revision of goals, rules and directions for future development (Foxon, Reed, & Stringer, 2009). Key in this revision or iteration are monitoring and evaluating. Every plot development can be seen as a learning opportunity for future developments. In the context of Schieoevers Noord, this can specifically be a learning opportunity for (the project-team at) the Municipality of Delft since they will be involved in all of the developments, whereas the established companies and project developers will not.

To plan the mechanism of iterations, several elements should be decided upon: what is to be iterated, when is it to be iterated, and by whom? What should be monitored to be able to iterate, and also when and by whom? In essence, the entire five-step approach as presented in paragraph 9.2 should be gone through for a holistic iteration. Did the present state or near-future state change in a way that impacts the future vision or the adaptive roadmap? Did new uncertainties come into existence? Did the future vision change? A particular focus should be paid on the iteration of step 5, the adaptive roadmap involving strategies for development (energy, spatial, programme), actions and conditions for development.

It is assumed that the municipality creates an extensive plan for reflection and future visioning around the year 2030, aiming to create a plan for the continuation of the area development. A mechanism for iterations that could be used in the period up to 2030 as well as in the period after 2030 is the following. The environmental impact assessment monitors the progress of the development and the – as the name indicates – environmental impact of the progressing area development with a bi-annual rhythm. Adaptations to the development plan that concern energy, could be made in the same rhythm. For iterations on strategies, actions, and guidelines, it is proposed to monitor the four parameters forming the energy balance of a development (energy potential, energy demand, FSI, FMI). These should be monitored at developments that are already in progress or delivered. Furthermore, technological innovations that can impact the energy potential or demand should be explored, as well as non-technical developments that could impact the energy balance. Figure 106 creates an indicative timeline for iteration.

Next to the "standard" rhythm of monitoring, an additional iteration should take place in case of a “plot twist” – the initiation of a new plot development which falls outside the

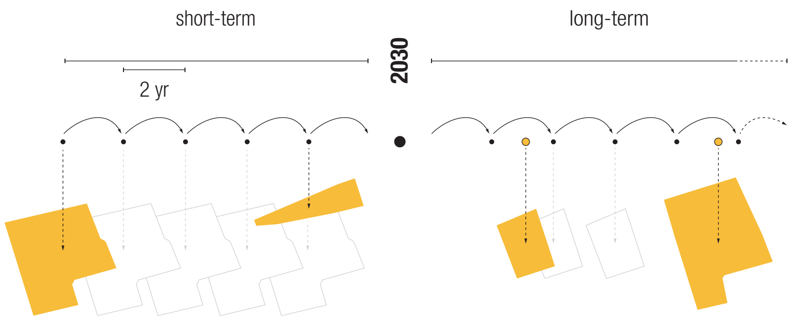


Figure 106: Proposed timeline for systematic iterations

normal iteration cadence. This "plot twist" could be seen as a trigger value to start up an iteration mechanism. In an early phase of a plot development, it should be defined whether energy-based design guidelines are needed for the development, and if so, how they could be defined. For the definition of these guidelines, the municipality could learn from previous processes on different levels. For example, evaluation of previous developments could lead to the adaptation of a numerical guideline guiding the maximum allowed energy consumption or to the adaptation of a guideline that imposes the use of a specific energy system.

Lastly, plot developments as the one of the Kabeldistrict are large (12 ha) and will be built in several phases spread over a time span of about ten years. The bi-annual monitoring rhythm could create opportunities for adaptation during the phase of construction.

So, who should monitor and who should redirect or adapt plans? To be able to monitor, it should be made sure that data exists on the energy demand of constructed buildings, and on the energy balance of ATES systems and other energy sources if applied. Monitoring in the form of data analysis and exploration of technological and non-technological developments could be done by an external party, which delivers a monitoring report to the municipality – to Stijn van Liefland in particular. From there on, it is essential to discuss the implications of these monitoring results in a multidisciplinary team: for this, the core team steering the developments in Schieoevers Noord is proposed. The impact of the evaluations of the energy demand and supply on the capacity for building density or on the function mixture in upcoming or currently developing plots should be determined collectively. Tools for this impact assessment could be the guidance by a set of questions, or the use of a physical model that can show the physical impact (FSI/FMI) of energetic evaluations.

9.6. Reflecting with practice: an iteration

To validate the *Schieoevers Noord (SON) approach for adaptive energy planning*, a semi-structured interview was held with a professional. The aim of this interview was to reflect upon the designed approach. The interviewed professional was Agnes van der Linden (AvdL), Partner in publiek ondernemen (*English*: partner in public entrepreneurship) at the Municipality of Delft. AvdL has a background in environmental consultancy within the Municipality of Delft and has wide experience in sustainability-related public-private partnerships as employee of the Municipality of Delft (e.g. in the project "Delft Energieneutraal 2050"). Her role and activities within the Municipality of Delft are not related to the area development of Schieoevers Noord, yet she has a broad view on planning processes within the city and within the municipal organ.

In the interview, the design approach for adaptive energy planning has been discussed. This paragraph discusses the main insights and possible adaptations to the stepped approach. The main topics that are addressed are the embracing of interdependencies and studying risks, the aspect of trust in a process or collaboration, the forming of a vision, and the distinction between monitoring numbers and evaluating collaborations.

When discussing the characteristics of adaptivity, AvdL directly noted that the municipality – or at least the discipline concerning environmental consultancy within the municipality – has been embracing and acknowledging for a long time that they are interdependent on others and need others to succeed; the direct impact of the municipality on themes as sustainable energy is limited, yet their exemplary role is of large importance. Furthermore, next to the importance of having a long-term vision, the aspect of trust in a collaboration was mentioned as a crucial aspect to work towards that vision.

Step 3 of the *SON approach for adaptive energy planning* is the creation of a sustainable future vision. Though, this vision mostly does not come forth from the analysis of a current state and near-future state of an area only. Two steps or elements can be added to the stepped approach, as foundations for the shaping of a (sustainable) long-term vision (Figure 107). Firstly, the history of the area can be an inspiration for the future. Collectively exploring the history of an area is also a means to create a sense of community – which is also favourable for a process of area development prone to uncertainties and interdependencies. Furthermore, sustainable future visions for an area development as Schieoevers Noord mostly relate to policy or visions on a larger scale (international, national, provincial, regional, municipal). The aspects of larger-scale visions that are relevant for the area development can be used to shape the vision of Schieoevers Noord (or another area development process).

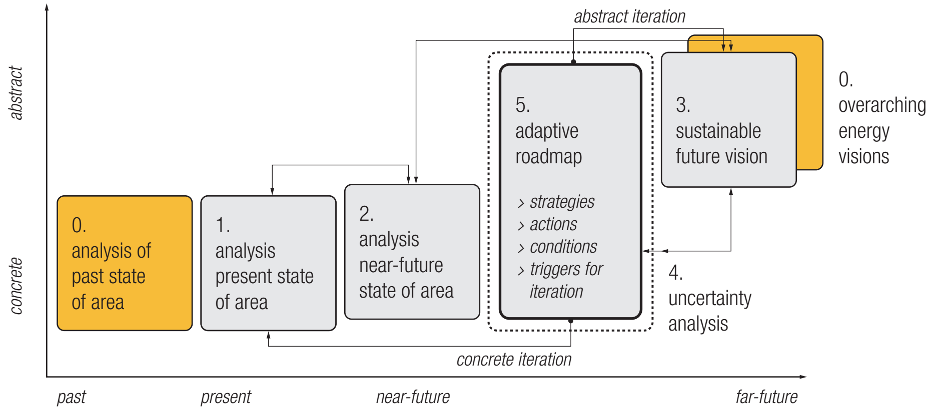


Figure 107: Proposed additional steps for the “SON approach for adaptive energy planning”

At the municipality of Delft, the connection of long-term visions with short-term actions mostly happens in the form of a 4-year implementation plan. Although focused on the long-term, the most concrete policy and action plans are created for the short-term. The gap that still exists between the end of these 4-year programmes and the year 2050 for example, does not create problems – since the context is highly dynamic. Planning for more than four years ahead is generally hard. The author, therefore, concludes that although the phase up to 2030 is marked as short-term for the developments in Schieoevers Noord, a lot of open ends will exist here too.

For the iteration mechanism, an interesting suggestion was done. AvL makes a distinction between two types of monitoring and evaluation: on the one hand, the effectiveness of measures can be monitored (mostly quantitative/numerical), and on the other hand, a collaboration process in an area development can be evaluated ("could we get more out of this collaboration?"). The first type of monitoring could answer whether the area development is on track regarding the sustainability/energy ambitions and whether energy-based design guidelines bring about the desired result[1] – which opens opportunities for improvement.

[1] AvdL mentioned, that the newest privacy legislation complicates the monitoring process of energy consumption. Since the implementation of this legislation, energy suppliers can not simply deliver data on the consumption of their clients. Yet, with the new developments in Schieoevers Noord, and the relatively limited amount of current users, it might be possible to make arrangements for monitoring in the area – to be able to learn by doing over the course of the area development.

The second type of evaluation is about learning together and improving a collaborative process. Together with AvdL, the author came to the following conclusion. For the first type of monitoring and iteration, the bi-annual cycle of the environmental impact assessment monitor might be sufficient; the second type is expected to be most valuable in case of an additional iteration ("plot twist").

During the interview, insights were obtained regarding the way the municipality generally copes with uncertainties. In preparation of each project, risks are explored – uncertainties are not specifically named, yet AvdL would think that uncertainties could generally be seen as risks as well. At the start of projects, an inventory is made concerning many disciplines – everyone prepares some "homework". Risks are explored at that point as well – regarding "what can you contribute?" and "what do you need to reach the goals?". Furthermore, AvdL suggests that in case of a project which is highly dependent on external stakeholders – as is the case in Schieoevers Noord – that these external stakeholders are consulted up front, to identify and map their uncertainties in an early stage (*note by author*: that fits the characteristic of adaptivity "integrate diverse knowledge" for the topic of uncertainty exploration).

The final topic, how to shape favourable conditions for development, is from the role of AvdL mainly shaped as the usage of people's willingness and energy to take action. Delft is a city full of entrepreneurial citizens with a lot of energy to act. Initiatives can be facilitated by making sure the municipality is accessible for these entrepreneurial citizens. Furthermore, a balance should be sought between the creation of rules and again the creation of trust.

9.7. Conclusion

In this chapter, a proposal is presented for the *Schieoevers Noord approach for adaptive energy planning* – which consists of a five-step approach covering the characteristics of adaptivity. Two tools to operationalise the approach have been presented: a tool to explore and embrace uncertainties in the planning process and a mechanism for iterations. Based on a reflection with someone from the municipal practice, two "foundation steps" or "step 0's" could be added to the five-step approach: an analysis of the past state of an area, as well as studying overarching energy visions. Whether the approach is valid while used in practice and whether these two additional steps are more widely supported, should be investigated in practice. After the design of the approach for adaptive energy planning it is possible to formulate an answer to the main research question of this thesis (written down in Chapter 10): "*How could an adaptive approach to energy planning enable the Municipality of Delft to guide the development of a future-proof energy supply (heat and cold supply) for Schieoevers Noord?*".

10.

Conclusion

This research aimed to create an approach which enables planners at the Municipality of Delft to make decisions on the future energy strategy for Schieoevers Noord, while the end state of the area development trajectory is unknown: a framework for adaptive planning. After having explored adaptive (energy) planning from multiple perspectives, this chapter draws conclusions.

The conclusion is built up out of four parts. The first part (Paragraph 10.1) concludes on the characteristics of an adaptive approach to energy planning (SQ1) and what aspects thereof are already applied in current approaches (SQ2). Paragraph 10.2 answers SQ3, regarding the fit between available sources of low-temperature heat and cold and the adaptive area development trajectory. Paragraph 10.3 presents the answer to SQ4 and SQ5: how energy-based design guidelines could establish desired conditions for developing energy-neutral plans and what these guidelines would imply for initiatives that are currently unfolding. Paragraph 10.4, lastly, concludes with the developed approach – *the Schieoevers Noord approach for adaptive energy planning* – and how this approach could guide the development of a sustainable energy supply system in Schieoevers Noord, answering the main research question: *"How could an adaptive approach to energy planning enable the Municipality of Delft to guide the development of a future-proof energy supply (heat and cold supply) for Schieoevers Noord?"*.

10.1. The adaptive process and its characteristics

Energy planning, or the creation of strategies for sustainable energy supply (heat and cold), in the context of open-ended area developments, has to cope with ontological uncertainties inherent to the longevity and open-end of these development processes. A planning strategy focused on adaptivity is explored as an answer to the uncertainty. The theoretical concept of adaptivity is described in a variety of literature, from a range of perspectives. Based on the literature study carried out in this project, the following definition is created: "*Adaptivity is the characteristic of a system or pathway to adapt or be adapted by system actors, as a response to changing (unforeseen) future conditions*".

To answer SQ1: "*Which drivers and barriers for adaptive (spatial) planning and adaptive (energy transition/climate) policy-making do exist according to literature?*", a set of six drivers is identified, also referred to as *characteristics* of adaptivity. Barriers were much less abundant in literature.

The six characteristics of adaptive procesesses are defined as:

1. explore and embrace uncertainty;
2. connect long-term visions with short-term actions;
3. treat a process of systemic change as experiment;
4. focus on conditions for development;
5. spread responsibility for decision-making over the system;
6. integrate the diverse knowledge of those involved.

Identified barriers mostly describe the opposite action as described in the set of drivers. Furthermore, for an adaptive process to be successful, it is important to find a certain balance between adaptivity and stability – to make sure the process progresses.

Six methods for urban and/or regional energy planning were reviewed on the presence of each of these characteristics, providing an answer to SQ2 – "*Which drivers of adaptivity are present in current, academic approaches for energy planning?*". Drivers, or characteristics, 2 and 6 were most abundant in literature; the appointing of responsibility for decision-making (characteristic 5) is left out of scope in existing methods and approaches. The other three characteristics are touched upon, however, no strategic tools to analyse uncertainties present in open-ended area developments are offered (characteristic 1). Whereas the need for process iterations is named regularly, the planning approaches are mostly not explicitly designed to be iterated and to be learnt from during the process in which plans have started to be carried out (characteristic 3). Lastly, conditions for development are subordinate to planning the actual energy and/or spatial system in the studied approaches (characteristic 4). For the design of an adaptive approach for energy planning, the studied planning approached offered a range of tools that can be implemented for the execution of process steps.

10.2. Fit between energy potentials and adaptivity

SQ3 is formulated as "*How do locally (or regionally) available sources of heat and cold fit the adaptive area development of Schieoevers Noord?*". The answer is built up in three steps: which sources of energy are available, what does "adaptive development" implicate in the context of Schieoevers Noord, and which source(s) fit the development best.

For (low-temperature) heat and cold supply to newly built buildings, several potentials exist in or close to Schieoevers Noord. Aquifer Thermal Energy Storage (ATES) systems have relatively high potentials in this part of The Netherlands. Furthermore, plans exist for a regional thermal backbone running from Rotterdam to The Hague – via Delft. Furthermore, a geothermal well is planned to be constructed by the TU Delft. Energy from this well could possibly be cascaded to the neighbourhood of Voorhof, which offers the potential for Schieoevers Noord to connect to the return pipe. The potentials are complemented by several smaller scale sources, such as low-temperature waste heat, aquathermal energy, the application of asphalt collectors and solar collectors, or the installation of ground loops.

The analysis of the case study also defined the so-called “scale of adaptivity”: the development plan is intended to be adaptable at the scale of the "plot". The municipality guides the area development; the realisation of the developments – which take place at the scale of a plot – is in hands of private parties. Adaptivity is required since it is unknown in which order plots will be developed, and which plots are or are not developed after all. Developments take place step-by-step: four plots will develop before 2030, the long-term perspective lays open.

So, all characteristics of adaptivity are applicable at the scale level of the plot. For example, a plot development could be seen as experiment, from which could be learnt for following plot developments. The source of heat (and cold) which fits this scale of adaptivity best, is the ATES system – heat and cold supplied by the subsurface located directly below the developed plot. When the underground is managed properly, this source can be used sustainably, and without hindering possible future developments. The ATES system establishes independence of other parties and of following developments; and offers the large benefit of cold supply. The ATES systems could be complemented by the named heat grids and by the smaller-scale sources (as means for back-up and/or regeneration).

10.3. Energy-based design guidelines

For the design of an adaptive approach to energy planning, three characteristics of adaptivity needed particular attention – the focus on conditions for development being one. Energy-based design guidelines are created to establish favourable conditions for development: incentives to develop energy-neutral plans, with the certainty of development quality. It is chosen to establish these conditions through design guidelines since that corresponds with the development plan for Schieoevers Noord. A study to the relation between energy, functional programme, and space (building volume), answers SQ4 and SQ5: "*Which design guidelines for plot developments could be used by the Municipality of Delft, concerning the (local) energy balance of the plot, to establish adaptivity and energy-neutrality in the spatial and functional design of Schieoevers Noord?*", and "*What are the implications of these guidelines for existing spatial and functional design proposals for plot developments within Schieoevers Noord?*".

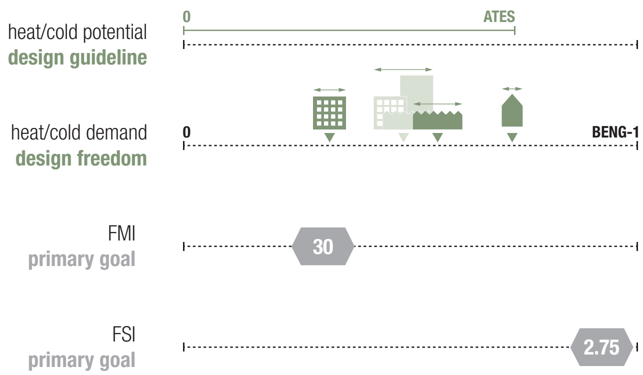


Figure 108: Proposal for energy-based design guidelines for the Kabeldistrict

The proposed guidelines do not use a "one size fits all" philosophy. An approach is presented instead, to be able to establish the right guidelines for each plot. The guidelines aim to result in energy-neutral plot developments, which do not hinder any of the neighbouring plots to develop in the exact same way.

Four parameters largely determine the thermal energy balance of a plot or development:

- the (locally available) heat and cold capacity;
- the programme-dependent heat and cold demand;
- the building function mixture (FMI); and
- the building density (FSI).

The primary building functions to be included in the area development are housing, offices, and making. Design guidelines should be applied to plot developments where the individual definition of the four parameters defining the energy balance is problematic.

In the study, the plot development for the Kabeldistrict is investigated in detail. Here, it is seen that one or more of the parameters create a problem when no additional guidelines are given. When buildings are constructed according to the building regulations which will apply from 2020 on, project developers will build as close to the maximum energy demand as allowed. With the intended FSI, the expected energy consumption is a factor 3 larger than the ATES potential. A quantitative mismatch derives. A qualitative problem is created in the following case. Due to the demand for hot tap water and low internal heat production, housing has a relatively large heat demand. A function mix with a large share of housing will thereby create a thermal disbalance in the subsurface. In this case, a design guideline should be defined for one of the parameters, to establish energy-neutral and future-proof developments. Based on the results generated in this research project, it is expected that guidelines are mainly needed for developments with a high density (FSI above 1-1.5 is approximated) and for developments with a large share of housing.

For the development of the Kabeldistrict, it is proposed to pre-define the use of ATES systems as the main source of heat and cold (Figure 108). That would correspond with a highly ambitious average energy supply of 19 kWh/($m^2 \ast yr$) for both heat and cold. The developer gets the freedom to design the area in a way that fits their vision, in a way that creates a good business model, and in a way that gets the most out of the ATES system – able to adapt the area's energy balance by the use of energetic implants, adapted function mixes, or forms of direct heat and cold exchange.

Current initiatives in Schieoevers Noord – specifically for the Kabeldistrict – are still in a stadium where programme mixes can be adapted and strategical choices on energy supply have to be made. The proposed design guidelines stimulate energy-conscious development, without compromising the ambition to realise a lively, mixed-use and dense urban area.

10.4. SON approach for adaptive energy planning

The *Schieoevers Noord approach for adaptive energy planning* proposes an alternative approach for energy planning – suitable for open-ended area developments, based on theoretic insights and the specific traits of the case study. The approach consists of five steps, including a mechanism for iterations. This five-step approach reflects the aim of the study by offering the core team of planners concerned with Schieoevers Noord an adaptive approach to energy planning. Thereby, they are enabled to create an adaptive energy plan which complements the adaptive development plan.

The approach is presented first, after which the main research question is anwered:

"*How could an adaptive approach to energy planning enable the Municipality of Delft to guide the development of a future-proof energy supply (heat and cold supply) for Schieoevers Noord?*".

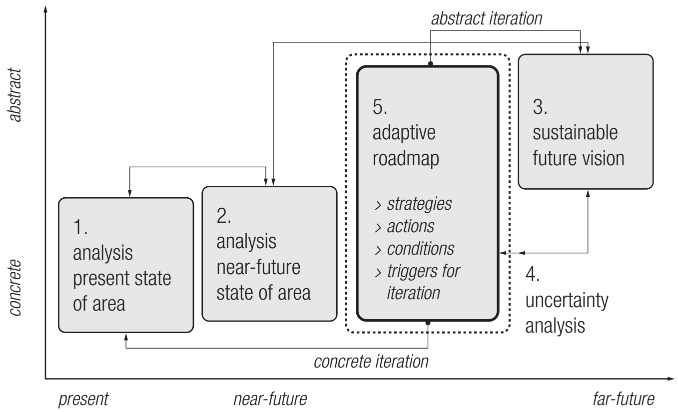


Figure 109: SON approach for adaptive energy planning

The five-step approach consists of the following steps, as is also shown in Figure 109:

1. analyse the present state of the area and its context (energy, societal system, stakeholders);
2. analyse concrete plans for the near future;
3. explore and explicate uncertainties, coming from (far-)future scenarios and interdependencies between stakeholders;
4. define a desired sustainable future vision;
5. (a) create an adaptive roadmap, consisting of strategies, no-regret actions and conditions for development;
(b) define the points in time and/or triggers for iteration of these strategies, actions and conditions.

These five steps cover the first four characteristics of adaptivity. The fifth lays out of the scope of a stepped planning approach since it questions which planner should make decisions. The sixth characteristic touches participation, this one does not need a step but is an integral principle in the adaptive energy planning process. Compared to existing energy planning approaches, the largest adaptation is the extension of the present-state analysis by a specific step for the exploration of uncertainties, as well as the proposal for an "adaptive roadmap". The City-zen method also presented a roadmap as a bridge between the present and the sustainable future vision – including strategies and interventions. Yet the adaptive roadmap has a more explicit focus on conditions for development as well, plus the prespecification of a learning or iterating mechanism. Furthermore, the dynamics of the future vision is specifically included in the approach: the vision is not a static dot on the horizon, yet a vision that can change as a response to changing future conditions.

For the explication of uncertainties and systematic iterations, the approach is extended by the creation of tools for the municipality. Uncertainties are explicated (and their implications are explored based on a set of six questions: (1) *Which uncertainty hinders the creation of a blueprint?;* questions 2-4 aim to explicate the uncertainty – (2) *Is the uncertainty created at the scale of Schieoevers Noord, or at a larger scale?;* (3) *Is the uncertainty caused by interdependency of other stakeholders or an unknown future scenario?;* (4) *Is the uncertainty temporary or permanent?;* questions 5 and 6 explore the implications of the uncertainty – (5) *Which actions or decisions are hindered by the uncertainty?;* (6) *How can the barrier to take action or to make a decision be removed?* For systematic iteration, a timeline is created, following the cadence of the parallel monitoring process for the environmental impact assessment, which is a cadence of bi-annual monitoring. The initiation of a new plot development is, next to that, specified as a trigger value for iteration – apart from the standard rhythm.

The design of the five-stepped approach for adaptive energy planning provides the following answer to the main research question, posed as "*How could an adaptive approach to energy planning enable the Municipality of Delft to guide the development of a future-proof energy supply (heat and cold supply) for Schieoevers Noord?*".

Besides more usual process steps as analysis and (sustainable) future visioning, the *Schieoevers Noord approach for adaptive energy planning* includes a specific analysis step for uncertainties as well as the creation of an adaptive roadmap: a set of strategies, actions and/or interventions, and development conditions, accompanied by a mechanism for iterations. By the integral analysis of uncertainties regarding energy planning – paying attention to understand them and their implications – non-regret measures can consciously be chosen. The inclusion of (knowledgeable) stakeholders sheds light on uncertainties from multiple perspectives. Furthermore, it is clarified whether uncertainties are ongoing or created by a decision to be made at a certain point in time – which could be incorporated in the mechanism for iterations. This mechanism for iteration ensures attention for learning; making maximum use of the gradual development approach that offers room for experimentation (technically and organisationally). The shift of focus to conditions for development – embodied into energy-based design guidelines – ensures the quality of developments: balancing control and freedom on the scale of plots. All of these process steps give the Municipality of Delft tools to direct the area development towards the envisioned future while being dependent on other parties and on many more uncontrollable factors.

11. Discussion

contributions

generalisation

transdisciplinarity

limitations

taxonomies of uncertainty

recommendations

The thesis project was carried out at the intersection of a newly developing paradigm of area development and one of today's largest societal challenges: the transition to an energy system based on renewables. Chapter 10 concluded the study, by answering how adaptive approaches can enable the Municipality of Delft to guide developments of sustainable energy systems in the case study area of Schieoevers Noord. This chapter discusses the contributions of the study to both scientific research and to practice (11.1), how the results can be generalised (11.2), how the different used research perspectives strengthen and cross-pollinate each other (11.3), it discusses the limitations of the study (11.4), it discusses ideas on the application of taxonomies for uncertainties in practice (11.5), and lastly, several ideas and recommendations for further research, for practice, and for the stakeholders involved in the development of Schieoevers Noord are discussed (11.6).

11.1. Contributions

Overall, the opening of a scientific perspective on the tension between energy planning and the currently evolving area development paradigm is seen as an important contribution of the research project, as well as the perspective on the difficulties in decision-making that come forth from this tension. The theoretical analysis of adaptivity is seen as a contribution to theory, the transparent and adaptable method to construct energy-based design guidelines for the area development is a contribution to practice. The proposed approach for adaptive energy planning is a contribution to theory and possibly to practice as well; the included tools for iterations and analysis of uncertainties are a contribution to practice as well. These contributions are explained in further detail below.

Contributions to theory

The main theoretical contribution of the thesis is the creation of a set of characteristics of the concept of adaptivity in a context of (sustainability-related) policy-making processes and/or (urban) planning processes. What an adaptive governance and/or planning process should look like has been described in literature before, yet the perspective of adaptivity in a process with a clear direction of movement was understudied, as well as adaptivity in a context of energy planning for more organic area development trajectories.

The review of the characteristics of adaptivity present in current methods for energy planning is seen as a valuable addition to the scientific field of energy planning methods and approaches. It creates insight into ways to extend current methods to make them more adaptive. The design of the *Schieoevers Noord approach for adaptive energy planning* has contributed to the research field concerned with energy planning in the same manner: concretely showing which steps could be added to existing methods to be better suitable for planning under uncertainty.

Furthermore, the transparent process on how to construct energy-based design guidelines for plot developments in Schieoevers Noord does not only generate insights for practice, but gives insight in the interdependency between parameters that are normally dealt with by spatial designers, architects and project developers, and parameters that are the responsibility of energy strategists and engineers.

Contributions to practice

The energy-based design guidelines created for Schieoevers Noord could potentially be valuable for the Municipality of Delft if it is decided to either adopt or further investigate them. The main contribution to practice is the insight in the tension between sustainability ambitions – developing energy-neutrally – and building regulations. These two elements get in tension as soon as high, urban densities are desired. The identification of four parameters that together largely determine the "switches" to turn, highlights opportunities for the Municipality of Delft to adapt or refine their development plan. Also, the (very specific) insight, that advisory reports which have stated that the ATES potential is sufficient to supply Schieoevers Noord (and the Kabeldistrict specifically) with low-temperature heat and cold, have been calculating with data on BENG norms which is out-dated by now is seen as a contribution. The adaptations in the proposed BENG norms which took place over the past year can be of large impact for developments in Schieoevers Noord.

Furthermore, the process interventions for uncertainty explication and systematic iterations can contribute to the municipal practice. Both interviews held at the municipality of Delft have shown the ambiguity and large diversity of uncertainties in the project and highlighted the fact that a plan for learning by doing, and for iterating and adapting the development plan has not been created yet.

11.2. Generalisation

For the generalisation of the research results, it is of importance to consider the role of the case study in the different research steps. Research steps which heavily rely on the case study are less generalisable than steps are less connected with the case study. A distinction is made between the theoretical framework, the design of the *Schieoevers Noord approach for adaptive energy planning* (including the interventions on the explication of uncertainties and on systematic iterations), and the proposed energy-based design guidelines for plot developments in Schieoevers Noord.

The theoretical framework, and the six identified characteristics of adaptive processes, are most widely applicable. The literature review has been scoped to adaptivity as a strategy to cope with (ontological) uncertainty, in the context of long-term change processes. Part of the included literature is written with an emphasis on urban planning or energy planning; a part is purely policy related. The author would dare to state, that planning processes related to sustainable urban environments, yet focusing on different societal challenges (think of climate adaptation, sustainable mobility), would be able to make use of the same six characteristics, since the intended process of system change is comparable, characterised by high levels of uncertainty and the complexity of an urban system. Furthermore, the theoretical framework is not bound to a specific governmental level – national, provincial, regional or municipal. It is, however, specifically written with a scope of The Netherlands, known for its control-oriented urban planning tradition.

The *Schieoevers Noord approach for adaptive energy planning* is based on the theoretical framework, on the assessment of current planning methods, and on the case study area of Schieoevers Noord. The five proposed steps are mostly leaning on theory, whereas the tools used to execute the steps are leaning more on the case study and stakeholder interviews. Thereby, the five steps will be generally applicable to the planning of urban energy transitions and/or the planning of energy systems in open-ended area developments. The proposed tools or interventions focused on the explication of uncertainties and the creation of a mechanism for iterations are more specifically designed for the case of Schieoevers Noord in Delft. It has been designed for the specific types of uncertainties the core project team Schieoevers Noord is facing as well as the evaluation rhythm of this specific process. The core ideas, however, are transferrable to other municipal project teams steering long-term area development processes. Exploring, explicating, discussing, and handling uncertainties is a key topic at each meeting table when complex cases are the topic. Iterating, learning from previous actions, is always important in case of complexity as well.

The energy-based design guidelines, and the process of creating these guidelines, are transferrable to other area development processes in the Netherlands which aim to develop into energy-neutral areas (at least energy-neutral for the heat and cold demand). In general, the use of guidelines is suitable for developments that are steered by a process that is neither integral, nor organic, but "somewhere in between" – where no blueprint is drawn, yet a clear vision is present. Guidelines could be powerful tools in processes where a municipality does not take up an executing role, but a directing or facilitating role. Guidelines based on the reciprocity of energy, space, and function are mostly useful when there is a challenge in one or more of these three aspects. The author could think of developments where high-density areas are created, areas that will accommodate a lot of different functions, areas with functions that require a lot of heat or cold, and areas with relatively low heat and cold potentials. When heat and cold are abundant, densities are low, and building functions consume a moderate amount of energy, building according to the current building decree, or in less than a year time the BENG norms[1], will be sufficient. In case either the heat and/or cold demand is high – e.g. due to the density or the (mix of) building functions – or the energy potential is low, guiding is needed to create energy-neutral clusters of buildings. Redeveloping areas, such as areas that are densified, or where functions are altered, could benefit from the insights in the relation between energy, space, and functions as well.

The design guidelines cannot (directly) be transferred towards other streams in the urban metabolism. The study explicitly focused on energy; thereby it cannot be generalised to streams as materials, water, or waste. These streams would ask for other parameters to be used as input for urban design guidelines. Comparing electricity to heat and cold, the following could be noticed. Transport of low-temperature heat and high-temperature cold is preferably limited, because of the relatively low efficiency – electricity is more easily transportable. The urgency to create a renewable heat and cold system is more locally bound. It could be an ambition to realise building blocks or neighbourhoods that are self-sufficient in electricity, yet that would require different design guidelines and underlying parameters then are used for the heat and cold balance in area development. Whereas heat and cold can be stored in aquifers, using the thermal capacity of groundwater, electricity requires different solutions for day-night storage and most importantly for interseasonal storage.

1 An additional note the author wants to make, is that consultants of the municipality, who have written reports on the energy provision of Schieoevers Noord before 2019, have calculated with the knowledge of the stricter ideas on BENG norms. Whereas the heat and cold potential of the subsurface was sufficient to foresee Schieoevers of sustainable heat and cold with these norms, with the new BENG norms, the situation has drastically changed, making 1-2 year old reports out-dated. Furthermore, as a second note, in January 2020 it was published that the BENG norms will not be used from July 2020 on, as planned, but from January 2021 on. The reason for this change is a delay in the calculation software.

11.3. Transdisciplinarity

The research perspective could only have become into existence, due to the author's education on multiple perspectives, and the joint graduation project in Building Technology and Science Communication. Whereas the author perceives double-degree master education as a form of multidisciplinary education, the Science Communication education – where students from different educational backgrounds collaborate intensively – is seen as interdisciplinary. In the first case, both disciplines have enriched the author, in the second case, disciplines can cross-pollinate each other. The graduation study, though, is seen as transdisciplinary: using scientific knowledge from the scientific fields of Science Communication, Building Technology, and Urbanism, and using knowledge from practice, related to the use of a case study and the execution of interviews.

The sixth characteristic of adaptivity pleads for the integration of diverse knowledge, for – according to the author – the same reason as complex problems ask for transdisciplinary approaches. When multiple domains, scales, types of knowledge, and perspectives are brought together, a more complete vision on the problem at stake can be formed. Understanding parts of a problem in relation to the whole, rather than understanding them in isolation, creates better opportunities to intervene.

In the case of this thesis, theory and practice are bridged, and so are the fields of Building Technology, Urban Metabolism, and Science Communication. Whereas Building Technology was the field where the problem arose and where a lot of knowledge on energy planning already exists, Science Communication got tools to study the theoretical background of the problem and offers perspectives on uncertainty and decision-making; Urban Metabolism offered ideas how to work from that what we know instead of that what we do not know. The three disciplines strengthen each other, able to create interventions that will contribute to complex problem-solving. The intersection of spatial planning and sustainable energy provision will have to deal with an abundance of wicked problems in the upcoming time, facing high levels of (ontological) uncertainty. These problems could not be solved from a technical perspective only. The thesis would suggest that transdisciplinary approaches will catalyse the process of problem-solving.

11.4. Limitations

The limitations of this study are discussed in relation to the *validity* of the study, the *reliability*, and the *scope*. Whereas the largest limitations for the theoretical framework and the design guidelines are related to reliability, the limitations concerning the process intervention mostly have to do with validity. Furthermore, it is also discussed whether the proposed approach for adaptive energy planning is "*adaptive enough*".

Validity

The main concern for the validity of the outcomes of the study is whether the designed process for adaptive energy planning and the corresponding interventions regarding uncertainty, iterations, and design guidelines, are *executable in practice* and whether they *lead to the desired results*. To validate the outcomes in practice is hard – since the interventions should positively impact a long-term process, not a short-term project or a single action or event. To validate the fit of the intervention with the common workflow of the municipality, an additional interview has been executed with Agnes van der Linden, employed by Municipality of Delft as "partner in public entrepreneurship". This lead to additional insights, as discussed in Chapter 9., yet is no ground to conclude that the *Schieoevers Noord approach for adaptive energy planning* is valid.

When reasoning with common sense – the question is whether adaptivity in the municipal planning process influences the quality of the energy system in Schieoevers Noord. The stepped approach, as well as the proposed interventions focused on explicating uncertainties and on systematic iterations, are expected to be highly unlikely to negatively impact the quality of the energy provision in Schieoevers Noord – yet that is not proven. When looking to an adaptive process as a whole, the question can be posed whether adaptivity legitimises postponing decisions. The answer should be no but could be yes. The goal of adaptivity is to increase the ability of decision-making, by the insight in what can be done or decided now, which connects to long-term visions. Part of that could be to decide that a certain decision needs to be postponed to a different moment. A nuance here is the difference between postponing a decision, and strategically deciding on non-regret measures and planning to make decisions at a later time, when the right information is available. In each situation, a clear vision that could be connected to the presence is indispensable, to be able to make strategic decisions.

Reliability

Concerning the literature study on the theoretical concept of adaptivity, there is an inherent limitation present in the formulation of the *search query*. The search query was formulated on the basis of exploratory research on adaptivity, and concepts that popped up in the literature read during that phase of the study, resulting in terms related to the concept adaptivity, terms related to transition and transformation in an urban and energy context, and terms related to uncertainty and complexity. However, the more in-depth investigation on classifications of uncertainty was executed thereafter. This investigation aimed to better understand the need for adaptivity. When the order of these research steps (studying uncertainty and preliminary literature study to the concept of adaptivity) would have been the other way around, the query would have been different, and would probably have led to a (partly) different set of literature. Due to time limits, the query as initially defined has been used for the literature study; no adaptations have been made after the investigation of uncertainty. Furthermore, over the course of the project, the author obtained a much better understanding of the term adaptivity, as well as the relation between the concept of adaptivity and related concepts (e.g. uncertainty, complexity, resilience, robustness). Therefore, when looking back at the process of formulating a search query and in-/ exclusion criteria, different choices would have been made when starting over.

Related to the *selected literature*, and as mentioned in the paragraph "contributions" no literature was found on energy planning in organic and/or open-ended strategies of urban planning. The cross-over of these topics seems to be a new field of study, which resulted in a set of literature that all described a part of the research field. Since all of the literature uses different perspectives, as well as abstraction levels, highly different sources are used to formulate a definition for adaptivity and a set of characteristics, which should be applicable in the specific context of this thesis.

The next limitation comes with the use of methods as *open coding* and *axial coding*. These methods are prone to the interpretation of the researcher. Since the research was executed by one person only, personal bias or personal way of working is present in the coding process. In theory, a different researcher, studying the same literature with the same research aim, could select different pieces of text in a process of open coding, and cluster all of these codes in different overarching categories. Nevertheless, by clustering all elements in a relatively small set of characteristics, the author believes that these overarching categories would largely be picked by other researchers as well. Some process elements fitting multiple of the characteristics are more prone to interpretation.

The process of creating the design guidelines for plot developments in Schieoevers Noord mainly is limited by the availability of (transparent) *key figures* concerning energy consumption of contemporary new built buildings.

Firstly, the author encountered the absence of “the” key figures describing the energy demand of buildings – how much heat does an average house need on a yearly basis, what is the ratio between heating and cooling demand of the average office building. The author is aware of the abundance of building parameters that influence an actual heating and cooling demand and, on top of that, the influence of the building’s user on the energy demand – yet it seemed to be impossible to generate a reliable set of key figures. An important indicator for the lack of reliable key figures is also illustrated by the creation of new buildings regulations (the BENG norms). An example: in summer 2018, the BENG-1 norm was planned to limit the energy demand for housing to 25 kWh/m² per year; in June 2019, the norm for housing was stretched to a maximum of 65 kWh for average buildings, and an even wider norm for deviating building shapes. If key figures for realistic energy demand values were unambiguous, the gap in this BENG norm probably would not have been a factor 2.5 over the course of one year only.

Secondly, the building typology that houses the “making industry” creates a limitation. Buildings that are housing industrial enterprises form a highly diverse typology since they house a diversity of industrial activities. As a result, key figures are not available and estimations are per definition not representative for the sector as a whole. In the interview with Bedrijvenkring Schieoevers, it became clear that most of the current companies housed in Schieoevers Noord fall within their definition of “making industry”. The municipality of Delft presents ambiguous notions on the making industry. In an interview, it was referred to as relatively heavy industry, but the framework map of the municipality excludes most of the current companies. Defining the sector leads to ambiguity, and so does the definition of the building typology and the energy demand pattern. In the end, calculation values are determined by a small case study to an existing company in the making industry. Here, a lot of estimations had to be done: the energy demand of the building had to be determined based on the number of ground sources in a ground source heat pump system; the demand had to be divided over office space surface area and making space surface area, and the cooling load had to be determined based on the number of tropic days. The estimation could not be verified by the case study company since they have no insight into their heat and cold demand.

Scope

Several decisions have been made concerning the scoping of the project. Thereby, elements are excluded which would have been valuable to incorporate, to form a more complete view on the area development.

Firstly, the thesis focused on those plots that are developed, corresponding to the way the municipality works with the area. Those plots that are not under development, are incorporated in another municipal sustainability programme, which is focused on the existing built environment. Nevertheless, from a sustainability perspective, the plots that are not developing, yet working on sustainability, can create opportunities for the area development. Think of companies producing waste heat, with the intention to continue their industrial processes for the upcoming years. This could be a source of energy, either directly or as regeneration of heat wells in ATES systems. Of course, this opportunity only counts, when the impermanence of the energy source is realised and redundancy strategies are incorporated.

Secondly, in interviews, it became clear that short-term and long-term have a different numerical meaning for the Municipality of Delft and the industry. Whereas the period up until 2030 is a relatively short-term for the municipality, companies see 3, 5 or sometimes 10 years as long-term. For the project developer of the Kabeldistrict, the delivery of this plan is perceived to mark the long-term – also being a period of about 10 years. This ambiguity is not explicitly taken into account, yet the stakeholders themselves are aware of the difference in perception.

Lastly, adaptivity is not applied to the technical side of an energy system. The scope is narrowed to the inclusion of steps to ensure adaptivity in the energy planning of the area development, with a long-term perspective incorporating following developments. If a plot is developed now, and its building functions change over time, this thesis does not present an answer for that, except the notions in Chapter 8, emphasising the need to think of redundancy if a certain percentage of building functions change. The study limits itself to the scale of a plot, and the creation of a future-proof solution for that plot when not drastically changed.

SON approach for adaptive energy planning - adaptive enough?

An adaptive approach to energy planning is proposed, to be able to make decisions regarding the energy provision of Schieoevers Noord - in the light of the open-ended area development trajectory that is going on in the area. Is the proposed approach adaptive enough? A question which could be answered partly with yes and partly with no.

The Schieoevers Noord approach for adaptive energy planning comprises five of the six characteristics of adaptivity that were identified. The approach is targeting planners at the municipality of Delft, within the project-team of Schieoevers Noord. When these planners execute all of the steps in the intended way, the process could certainly be described as adaptive.

The "no" relates to this fifth characteristic of adaptivity: "*spread responsibility for decision-making over the system*". The designed approach targets a team working on a defined project; however, in that phase of a project, it is already decided who is responsible for (what) decision-making. Mainly the vertical component of the spreading of responsibility might be problematic if it comes to the level of adaptiveness which is reached by the implementation of the approach. In the case of Delft, the team is composed of individuals, collaborating with internal and external parties, and hierarchically ordered below the city council and director urban development. If the project team for Schieoevers Noord forms the only link in a chain of decision-making that adopts an adaptive approach, friction might be created between different actors. The author expects that friction will arise between control-oriented decision-makers and the adaptivity-focused project team.

11.5. Taxonomies of uncertainty

A topic of discussion throughout the research project has been the quest for a taxonomy of uncertainties that could be applied in practice. In the theoretical framework, uncertainties have been classified according to its location, level, and nature. The nature of uncertainty determines the strategy of how to cope with the uncertainty. The thesis mainly focuses on ontic (also referred to as ontological) uncertainties: unpredictabilities or uncertainties due to variability (in the behaviour of natural and human systems). The classification helped the author to understand the need for adaptivity, and to understand that adaptive strategies do not cope with for example knowledge-related uncertainties.

However, when designing an intervention for practice focused on exploring uncertainties, this taxonomy has not been used. Since stakeholder interviews had shown the variety of uncertainties that stakeholders name, but also the difficulty with naming them, the taxonomy used in the thesis seems far too complicated for practice.

Several other taxonomies have been looked to. In the publication "Ruimtelijke verkenning Energie en Klimaat", attention has been paid to uncertainties in planning for the Dutch Energy Transition (Posad Spatial Strategies, 2018). Four categories of uncertainties are identified here: *future uncertainties* (demand, supply), *knowledge uncertainties* (technology, behaviour), *governance uncertainties* (NL, EU, global), and *resource uncertainties* (financial means, space, available manpower). According to the author, not all of the uncertainties present in the case of Schieoevers Noord could (mutually exclusive) be classified in these categories. This classification did not lead to the desired explication of uncertainties which is sought for.

For the process intervention, three "dilemmas" are created as a means to make uncertainties within the case of Schieoevers Noord more explicit, based on the uncertainties shared with the author during interviews. The themes of the dilemmas could be seen as categories, not based on a particular source of literature, but inspired by the year of research into adaptivity and uncertainty and by the case of Schieoevers Noord. The three dilemmas and categories being:

- the *scale* at which the uncertainty roots – uncertainty is either created within Schieoevers Noord (or the stakeholder network of Schieoevers Noord) or at a larger scale (city, region, national, international);
- the *directness* of uncertainty – uncertainty caused by a direct interdependency of other stakeholders or uncertainty caused by an unknown future scenario (indirect uncertainty); and
- the *temporality* of uncertainty – the uncertainty has an (identifiable) end-point, or the uncertainty is permanent.

When reflecting on the taxonomies of uncertainty, another interesting classification came along: the differentiation between reducible and irreducible uncertainty. Nikolaidis (2004, p. 5) defines uncertainty as "the gap between certainty and the present state of knowledge". Reducible uncertainty can be reduced by the acquiring of knowledge, irreducible uncertainty is that uncertainty that subsists when all possible knowledge is acquired. For the Municipality of Delft, this distinction could imply the question: "could we and or/a consultant study this uncertainty, or is it irreducible?".

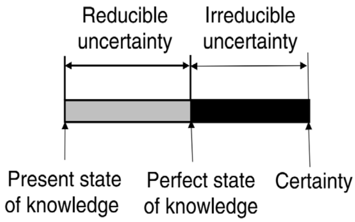


Figure 110: Classifying uncertainty – reducible versus irreducible uncertainty (Nikolaidis, 2004)

11.6. Recommendations

Several topics or questions are seen as interesting and desired to be further investigated. This paragraph highlights recommendations for further research, recommendations to the stakeholders of Schieoevers Noord, and recommendations for practice in general.

Recommendations for further research

A new paradigm in area development is evolving, of which a lot is unknown – research hereto will be executed for sure. The author aims to stress the importance of researching the position of energy visions and strategies in this paradigm – what is planned, what is spontaneous, what is public responsibility, what is private, what is actively steered, what can organically evolve? Herein, the reciprocity between energy, space, and function can be a starting point, to integrally research the energy transition as a challenge within this evolving paradigm.

Not only is the position of energy in the context of contemporary area development an understudied topic, but the same also applies for the role of adaptivity in the context of the energy transition. Literature on transition management touches the topic, as well as the concept of the resilience of sustainability transitions (Schilling, Wyss, & Binder, 2018). Yet, supporting policymakers in adaptively guiding the energy transition, may become a major topic of research for the upcoming years. The Climate Agreement stresses the need for climate policy to be adaptive, so consciousness concerning this topic exists in politics.

Exploration and explication of uncertainties as part of (municipal) planning processes, is a topic which is recommended to study in “living labs” (Steen & Van Bueren, 2017).

Theoretically, knowledge of uncertainty is abundant, yet in practice uncertainty still seems an uncomfortable topic. Extending the proposal for explicating uncertainties which is done in this thesis would, therefore, be recommendable.

Recommendations to practice in general

The study highlights a need for key figures concerning the minimum energy demand of a building (with a specified building function, within a reasonable range of buildability). The author's prospect is that these key figures will have values well below the BENG norms, but research should tell so. Furthermore, it is of importance that key figures on the building's energy demand should be divided into a share of cold demand and a share of heat demand.

Furthermore, with the ambitions of the Paris Agreement, sustainability ambitions of the Netherlands, and sustainability ambitions of the Municipality of Delft, it is needed that all types of buildings are limited in their energy consumption in a certain way. Regulations are a powerful tool, yet industrial spaces are not covered in current energy-related building regulations – and not in the new BENG norms either. Research should be done on how to regulate a diverse building typology as industrial spaces.

Recommendations to stakeholders of Schieoevers Noord

Next to the advice to adopt energy-based design guidelines concerning the heat and cold supply of plot developments, a recommendation is to study the possible extension of design guidelines for Schieoevers Noord, with rules concerning the electricity demand of buildings. The Municipality of Delft does have relatively little capacity for large-scale electricity generation since the city's built environment has mostly extended towards the borders. Therefore, it is recommended to make a contribution as large as possible with the development in Schieoevers, and design guidelines are a powerful tool to establish that.

A last piece of advice concerns the management of large-scale ATES systems, in which multiple doublets are connected, and to which several sources for regeneration are connected. In the case of the Kabeldistrict, such a system covers 12 hectares – asking for system management. Who takes responsibility for that? In this state of the area development, it would be valuable to decide on that. An additional benefit of central management of the energy system of plots/ Schieoevers Noord is the opportunity to monitor the system.

12.
Reflection

evolution of adaptivity

research & design

personal process

area development 3.0

This chapter reflects on four topics: the evolution of the concept adaptivity, the research process, the personal process, and the newly evolving paradigm in area development. Over time, the author was increasingly able to grasp the essence of the concept adaptivity, paragraph 12.1 gives insight into this process of evolution. Concerning the research process (12.2), it is reflected upon the relation between research and design and the role of adaptivity in the own process. The personal process (12.3) reflects on the relationship between research and ideology, between my personality and adaptivity, and on the master education. Lastly, it is reflected upon area development and the transition to renewable energy (12.4) to form a vision on the evolving field.

12.1. Evolution of adaptivity

Throughout the process, the concept of adaptivity was not only studied and defined, the scale and location in the system asking for adaptivity also became clearer. The quest for adaptivity started at the concept development plan, where the municipality introduced the term: consciously choosing to go through an adaptive process of area development, avoiding the creation of blueprints. The difference between an adaptive area development process and an area with a rapidly and constantly changing dynamics was not yet so clear. At that point in time, the author had dual aims: to both study adaptivity in the process and to design an adaptive energy system.

Technical or physical adaptivity in heat and cold systems did not turn out to be a critical node in the problem field. Puzzled by the concept, constantly and critically reflecting on the "why" of the concept adaptivity created a deeper understanding of both the specific case and the more generic theoretical understanding of adaptivity, uncertainty and complexity. In the end, studying the case study area and the process of the Municipality of Delft, enabled the author to grasp the "grain-size" of adaptivity in energy planning for this specific case: being the physical and organisational scale of plot developments. This grain-size corresponds to the position of the municipality in the development process of Schieoevers Noord. The municipality has a role on the level of a plot: creating a zoning plan (bestemmingsplan), granting building permits, and creating/providing design guidelines for each plot development. Next to that, the level of the individual plot development, is also the level at which important uncertainties and interdependencies do exist: is a landowner aiming to sell the plot, or to continue their business? What is going to happen when, and where?

12.2. Research and design

The research process integrated two Master programmes and three fields of study, with mentors representing Science Communication, Building Technology, and Urbanism. In both of the masters, design plays an important role – yet in a different way. In this paragraph, it is reflected upon the research process, by discussing the relation between research and design. Furthermore, it is touched upon the degree of adaptivity in the own research process.

Whereas in the field of Science Communication – or as it is to be named from next academic year on “Communication Design for Innovation” – design is used as a method to research complex problems; going through a design cycle to be able to study the problem field, define a problem, and to research solutions. At the Faculty of Architecture, on the other hand, the master track of Building Technology educates on the cutting edge of technological design and architectural design; here design is used as a method to come up with solutions for yet identified problems. During the master thesis, both ways of design are used: the research set-up is design-based research, with an extensive part of problem analysis – resulting in a design brief, for which design solutions are generated. This way of working created a constant dynamic between case study and theory, and between problem exploration and problem-solving.

The graduation process, to a large extent, ran parallel to the process in which the development plan for Schieoevers Noord was developed. Therefore, new information became available during the process, new observations, decisions and uncertainties constantly arose. On the one hand, it was difficult to deal with this dynamic – on the other hand, the dynamic also forced to think of the meaning of adaptivity, to keep switching between theory and practice, and to sharpen the problem statement, objectives and research questions. An example illustrating how new steps at the municipality first confused and then cleared the mind, is the following. At the closing event of the participation process, the decision to split the development process in a phase before and after 2030 was presented. At the evening, this was interpreted by the author as “letting go the value of adaptivity”. However, when reading the final development plan, it was already more clearly understood as a measure to be clear and pragmatic for the short-term – while still believing in adaptive development. So, no control-oriented strategy was suddenly adopted. After the execution of interviews, the differences in short-term and long-term for the different actors became clear, as well as the fact that the desire for this point in time which splits the short-term and long-term, originated from the Bedrijvenkring Schieoevers. The own research process had to deal with the processing of new and sometimes ambiguous information, asking for an adaptive attitude.

12.3. Personal process

A personal note that I would like to make is related to three themes: the tension between research and ideology, personal discomfort with uncertainty and adaptivity, and what I take away from multidisciplinary education.

Research and ideology

The first note, the tension between research and ideology, can be seen as my largest, and probably only concern of ethics that came across during the project. The process started from a fascination for the energy transition on an urban scale, and with the belief that this transition should be a priority in the society of today. During the research, when exploring perspectives from stakeholders, mainly financial interests seem to be in the way of sustainable decision-making. Personally, that could frustrate me at times. However, as a researcher – it is of importance to be both transparent and as unbiased as possible. In the report, the focus, therefore, lays on showing implications of decisions, rather than stating decisions to be right or wrong. Furthermore, it is shown how decisions fit in a bigger picture of sustainable development. As a researcher, I have been aware of my ideology and related bias from the start. The main research question has been the topic of focus, transparency and the inclusion of different perspectives a conscious effort. Nevertheless, in the end, I hope to have contributed to a sustainable future, by presenting decision-implications for sustainable energy strategies in area developments.

Adaptivity in the graduation project - or process

Secondly, which has been an important topic over the past year, is my personal discomfort with adaptivity. On the one hand, the topic intrigued me, on the other hand, my personality has had a hard time with uncertainties and acting adaptively. Naturally, I prefer to know what is going on and which steps have to be taken. This could have been a valuable contribution to the study though. Since many other people, which are in charge of decision-making in projects like the development of Schieoevers Noord, are not naturally comfortable with adaptivity either, the author identifies with people struggling with uncertainty in decision-making. Therefore, solutions had to be created that are (to be) workable for anyone. I believe, that the extensive study to the theme of adaptive planning enriched me and that it has empowered me to (better) accept uncertainties. Below, I shed light on some of my largest lessons learnt, the tools that helped me, and the struggles I faced.

Reflecting on the process, several "tools" have helped me to act adaptively. The literature study, and mainly the fact that adaptivity (partly) means that irreducible uncertainties should be accepted and worked with, gave the insight that there is no other option than accepting and embracing uncertainty. When making the analogy between graduation and area development, I approached the process according to an "area development 3.0" rationale as well: a process with a direction, a vision, yet without a predefined endstate. New information was welcome, and the shape of the outcome was defined halfway instead of upfront; an approach which was supported by the design-based research design.

Reflecting on the process, several decisions I have made or steps I have set caused struggles concerning adaptivity. Firstly, the open end of the study and a constant flow of new incoming information created a feeling of unease, yet also difficulties with writing. Because - what do you write when the prior parts, the following parts, and the part you work on will most surely change in a bit?

A "fault" I made, or at least an important lesson learnt, is the following. My personal pitfall is related to coping with uncertainty - in the wrong way. In case of uncertainty in the process or project, I tended to dive further in literature, policy documents, or different forms of knowledge. Yet, as the study has shown, epistemic uncertainties are reduced by doing more research, ontic uncertainties ask for adaptive approaches. With a reflecting eye, I can state that I often took up the wrong strategy to cope with uncertainty in the graduation process.

Multidisciplinary education

Lastly, I would like to make a note on how multidisciplinary master education, finalised by a more transdisciplinary research project, has enriched me as a student, a person, a researcher, and a starting professional. The time I spent as student at the Faculty of Architecture has shown me all of the different aspects which the sector involves, and it enabled me to think in concepts, to create strategies and designs, and to ground my design ideas by technical knowledge. Especially the master education stimulated me to think out-of-the-box, use my knowledge and design skills to come up with new technological ideas or applications. The master in Science Communication broadened my view on the world: both on science and technology, and on the working of societal systems. I have been taught and stimulated to approach problems from multiple perspectives and to scientifically underpin decisions I make. The cross-pollination of the fields in the master thesis has been extremely valuable for me, as well as the openness that I noticed in both of the disciplines. Working holistically or integrally is a central learning goal within architectural design projects – yet the extra level of integration – with the system which is impacted by design and in which decisions are made on design, is an added value the combination of the two master tracks has offered me. To be added here is the opportunity to add an urbanism perspective to my mentor team, an opportunity broadening the view of the thesis even further.

12.4. Area development 3.0

As a closing of this thesis project, a short reflection on the aspects considered as elementary for the evolving paradigm of "area development 3.0" is presented. The paradigm is searching to combine elements from both integral area development and organic area development approaches. The large challenges which are inherently part of this new era of area development – as discussed sustainability challenges, housing shortage, an ageing society – ask for more vision and steering than organic approaches. Parallelly, uncertainties are present, asking for a less control-oriented strategy than integral development.

So, the paradigm should be steering, yet leave room for unforeseen future conditions. Bottom-up strategies and top-down strategies should be bridged. Looking at the position of the energy transition within this paradigm, it should be noticed that large-scale decisions on energy infrastructure come with large costs, and technology is innovating rapidly. Decision-making, therefore, is a large responsibility: what is to be decided now – what can wait? The paradigm should – in my opinion – make sure that actions are taken right away, with conscious choices in what to do now, and what to do later – at a specific point in time or in the process. Area development will become more of a process, than a project – more open-ended, than based on blueprints, yet based on future visions. A cyclic rather than a linear approach, in which value is able to outweigh profit. Participation will get a different role, where large-scale participation processes are often used as a method to create support for plans, participation is more shifting to processes of co-creation. Taking all of the above into account, I would like to pose the following question.

Will this paradigm go down in history as "adaptive area development"?

References

Agentschap NL. (2011). *Energiezuinig koelen met warmte- en koudeosplag.*

Asselt, M. B. A. van, & Rotmans, J. (2002). Uncertainty in Integrated Assessment modelling. From positivism to pluralism. *Climatic Change, 54*(1–2), 75–105. https://doi.org/10.1023/A:1015783803445

Baumgartner, E., Bell, P., Brophy, S., Hoadley, C., Hsi, S., Joseph, D., ... Tabak, I. (2003). Design-Based Research: An Emerging Paradigm for Educational Inquiry. *Educational Researcher, 32*(1), 5–8. https://doi.org/10.3102/0013189X032001005

Blok, M., Streefland, T., & Haisma, R. (2018). *Duurzaam Schieoevers.*

Blom, T., & Dobbelsteen, A. van den. (2019). *CO2-roadmap TU Delft.*

Boodoo, Z., Mersmann, F., & Olsen, K. H. (2018). The implications of how climate funds conceptualize transformational change in developing countries. *Climate and Development, 10*(8), 673–686. https://doi.org/10.1080/17565529.2018.1442788

Bot, B., & Zwamborn, M. (2013). Open WKO-systemen A: Inleiding. *Stromingen, 19*(3&4), 83–92.

Bristol City Council. (2014). *D2.3 Guidelines for prioritising interventions.*

Broekman, M. (2018). *Concept Ontwikkelplan Schieoevers Noord Delft.*

Broekman, M. (2019). *Ontwikkelplan Schieoevers Noord Delft.*

Broersma, S., & Dobbelsteen, A. van den. (2018). *Roadmap for Amsterdam.*

Broersma, S., Fremouw, M., & Dobbelsteen, A. van den. (2011). *Synergie tussen regionale planning en exergie: SREX.*

Broersma, S., Fremouw, M., & Dobbelsteen, A. van den. (2013). Energy potential mapping: Visualising energy characteristics for the exergetic optimisation of the built environment. *Entropy, 15*(2), 490–506. https://doi.org/10.3390/e15020490

Brugnach, M., Dewulf, A., Pahl-wostl, C., & Taillieu, T. (2008). Toward a Relational Concept of Uncertainty: about Knowing Too Little, Knowing Too Differently, and Accepting Not to Know. *Ecology and Society*, *13*(2).

Bryman, A. (2012). *Social Research Methods* (4th ed.). Oxford University Press.

Buitelaar, E., Feenstra, S., Galle, M., Lekkerkerker, J., Sorel, N., & Tennekes, J. (2012). *Vormgeven aan de spontane stad: Belemmeringen en kansen voor organisch stedelijke herontwikkeling.* Den Haag/ Amsterdam: Planbureau voor de Leefomgeving/ Urhahn Urban Design.

Caat, P. N. ten. (2018). *Towards Energetic Circularity: greenhouse-supermarket-dwelling energy exchange.* TU Delft.

Campos, I. S., Alves, F. M., Dinis, J., Truninger, M., Vizinho, A., & Penha-Lopes, G. (2016). Climate adaptation, transitions, and socially innovative action-research approaches. *Ecology and Society*, *21*(1). https://doi.org/10.5751/ES-08059-210113

Cherp, A., Jewell, J., & Goldthau, A. (2011). Governing Global Energy: Systems, Transitions, Complexity. *Global Policy*, *2*(1), 75–88. https://doi.org/10.1111/j.1758-5899.2010.00059.x

Design Council. (2005). *Eleven lessons: managing design in eleven global trends A study of the design process.* London.

Dewey, J. (1927). *The public and its problems: An essay in political inquiry.* New York: Holt and Company.

Dobbelsteen, A. van den. (2008). Towards closed cycles – New strategy steps inspired by the Cradle to Cradle approach. *In Passive and Low Energy Architecture (PLEA*).

Dobbelsteen, A. van den, Broersma, S., & Stremke, S. (2011). Energy Potential Mapping for Energy-Producing Neighborhoods. *International Journal of Sustainable Building Technology and Urban Development*, *2*(2), 170–176. https://doi.org/10.5390/SUSB.2011.2.2.170

Dobbelsteen, A. van den, Broersma, S., Tillie, N., & Fremouw, M. (2014). The Energy Master Plan: Transition to self-sufficient city regions by means of an approach to local energy potentials. In *Proceedings PLEA2014.* Ahmedabad, India.

Dobbelsteen, A. van den, Martin, C. L., Keeffe, G., Pulselli, R. M., & Vandevyvere, H. (2018a). From problems to potentials-the urban energy transition of Gruž, Dubrovnik. *Energies*, *11*(4), 1–18. https://doi.org/10.3390/en11040922

Dobbelsteen, A. van den, Roggema, R., Tillie, N., Broersma, S., Fremouw, M., & Martin, C. L. (2018b). *Urban Energy Masterplanning—Approaches, Strategies, and Methods for the Energy Transition in Cities. Urban Energy Transition* (2nd ed.). Elsevier Ltd. https://doi.org/10.1016/B978-0-08-102074-6.00045-0

Dudovskiy, J. (n.d.). Exploratory Research. Retrieved January 7, 2019, from https://research-methodology.net/research-methodology/research-design/exploratory-research/

Duijvestein, C. A. J. (1993). *Denken in Systemen, Ontwerpen in Varianten.* Publikatieburo Bouwkunde.

Dutch Green Building Council. (n.d.). Paris Proof. Retrieved November 24, 2019, from https://www.dgbc.nl/themas/paris-proof

DWA installatie- en energieadvies, & IF Technology. (2012). *Onderzoek criteria energiebalans WKO.*

Entrop, A. G., & Brouwers, H. J. H. (2010). Assessing the sustainability of buildings using a framework of triad approaches. *Journal of Building Appraisal*, *5*(4), 293–310. https://doi.org/10.1057/jba.2009.36

Ferguson, B. C., Frantzeskaki, N., & Brown, R. R. (2013). A strategic program for transitioning to a Water Sensitive City. *Landscape and Urban Planning*, *117*, 32–45. https://doi.org/10.1016/j.landurbplan.2013.04.016

Foxon, T. J., Reed, M. S., & Stringer, L. C. (2009). Governing long-term social-ecological change: What can the adaptive management and transition management approaches learn from each other? *Environmental Policy and Governance*, *19*(1), 3–20. https://doi.org/10.1002/eet.496

Frankel, L., & Racine, M. (2010). The Complex Field of Research: for Design, through Design, and about Design. In *DRS Montreal—Design and Complexity* (pp. 518–529). https://doi.org/10.5114/amsik.2016.62333

Freeman, R., & Yearworth, M. (2017). Climate change and cities: problem structuring methods and critical perspectives on low-carbon districts. *Energy Research and Social Science*, *25*, 48–64. https://doi.org/10.1016/j.erss.2016.11.009

Gasunie. (2020). Capaciteit en temperatuur. Retrieved January 15, 2020, from https://www.warmtelinq.nl/contact/veelgestelde-vragen/capaciteit-en-temperatuur

Gemeente Delft. (2017). *Bouwen aan een duurzaam Delft – Strategische keuzes op weg naar 2040.*

Gemeente Delft, & KuiperCompagnons. (2018). *Delft 2040, Ruimte voor keuzes – Impactanalyse verstedelijkingsopgave Delft.*

Group of Chief Scientific Advisors. (2019). *Scientific advice to European Policy in a Complex World.*

Hajer, M., & Dassen, T. (2014). *Smart About Cities – Visualising the challenge for 21st century urbanism.* Rotterdam: nai010 publishers.

Hamarat, C., Kwakkel, J. H., & Pruyt, E. (2013). Adaptive Robust Design under deep uncertainty. *Technological Forecasting & Social Change*, *80*, 408–418. https://doi.org/10.1016/j.techfore.2012.10.004

Helleman, G. (2018). Vormgeven aan gebiedsontwikkeling 3.0. Retrieved October 10, 2019, from https://www.gebiedsontwikkeling.nu/artikelen/vormgeven-aan-gebiedsontwikkeling-30/

Hoogervorst, N. (2017). *Toekomstbeeld Klimaatneutrale warmtenetten in Nederland.* Den Haag.

Jonge, H. de. (2017). *Bodemenergieplan Nieuw Delft.*

Jonge, H. de, & Bloem, D. (2018). *Schieoevers Noord Delft – potentieelstudie bodemenergie.*

Kondor Wessels Vastgoed. (2019). Kabeldistrict Delft. Retrieved January 20, 2020, from https://www.kondorwessels.nl/nl/projectontwikkeling/detail/kabeldistrict-delft

Kupers, R., Faber, A., & Idenburg, A. (2015). *Wie is de wolf? Een systeemblik op de Nederlandse Energietransitie.*

Kwakkel, J. H., Walker, W. E., & Marchau, V. A. W. J. (2010). Classifying and communicating uncertainties in model-based policy analysis. *International Journal of Technology, Policy and Management*, *10*(4), 299. https://doi.org/10.1504/ijtpm.2010.036918

Leguijt, C., Hueting, D. H., & Wielders, L. M. L. (2011). *De weg naar een energieneutrale gemeente: Studie naar strategieën om de gemeente Delft energieneutraal te maken.* Delft.

Lente Akkoord. (2017). *Woningbouw volgens BENG: Do's en dont's voor bijna energieneutraal bouwen.*

Levin, K., Cashore, B., Bernstein, S., & Auld, G. (2007). Playing it forward: Path dependency, progressive incrementalism, and the "Super Wicked" problem of global climate change. In *48th Annual Meeting of the International Studies Association.* Chicago, IL, USA. https://doi.org/10.1088/1755-1307/6/0/502002

Li, F. G. N., & Pye, S. (2018). Uncertainty, politics, and technology: Expert perceptions on energy transitions in the United Kingdom. *Energy Research and Social Science*, *37*, 122–132. https://doi.org/10.1016/j.erss.2017.10.003

Lindeboom, H. W., & Verhoeven, J. J. (2018). *Milieueffectrapport Schieoevers Noord te Delft.*

Linnenluecke, M. K., Verreynne, M.-L., Villiers Scheepers, M. J. de, & Venter, C. (2017). A review of collaborative planning approaches for transformative change towards a sustainable future. *Journal of Cleaner Production*, *142*(4), 3212–3224. https://doi.org/10.1016/j.jclepro.2016.10.148

Loos, R. van der. (2016). *Referentie gebouwen BENG.*

Lysen, E. (1996). The Trias Energica: Solar Energy Strategies for Developing Countries. In A. Goetzberger and J. Luther (eds.) *Proceedings of the EUROSUN Conference.* Freiburg: DGS Sonnenenergie Verlags-GmbH.

Martin, B., & Hanington, B. (2012). *Universal Methods of Design – 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions.* Beverly: Rockport Publishers.

Ministery of Economic Affairs. (2016). *Energieagenda – Naar een CO2-arme energievoorziening.*

Moore, M.-L., Olsson, P., Nilsson, W., Rose, L., & Westley, F. R. (2018). Navigating emergence and system reflexivity as key transformative capacities: experiences from a Global Fellowship program. *Ecology and Society*, *23*(2). https://doi.org/10.5751/ES-10166-230238

NEN. (2019). *NTA 8800:2019-06 Energieprestatie van gebouwen – Bepalingsmethode.*

Niessink, R., Menkveld, M., & Sipma, J. (2017). *Verkenning utiliteitsbouw.*

Nikolaidis, E. (2004). Types of uncertainty in design decision making. In E. Nikolaidis, D. M. Ghiocel, & S. Singhal (Eds.), *Engineering Design Reliability Handbook*. Boca Raton: CRC Press. https://doi.org/10.1201/9780203483930.pt2

Ollongren, K. H. (2019). Nadere informatie over energiezuinige nieuwbouw (BENG) [Letter of government]. Retrieved November 24, 2019, from https://www.tweedekamer.nl/kamerstukken/kamervragen/detail?id=2019Z11778&did=2019D24272

OVG Real Estate. (2014). *Case Study The Edge*.

PBL Planbureau voor de Leefomgeving. (n.d.). Leidraad voor Omgaan met Onzekerheden. Retrieved December 6, 2019, from https://www.pbl.nl/leidraad-voor-omgaan-met-onzekerheden

Peter, C., & Swilling, M. (2014). Linking complexity and sustainability theories: Implications for modeling sustainability transitions. *Sustainability (Switzerland)*, *6*(3), 1594–1622. https://doi.org/10.3390/su6031594

Port of Rotterdam. (2019). Duurzame warmte regio Den Haag en glastuinbouw stap dichterbij. Retrieved January 15, 2020, from https://www.portofrotterdam.com/nl/nieuws-en-persberichten/duurzame-warmte-regio-den-haag-en-glastuinbouw-stap-dichterbij

Posad Spatial Strategies, FABRICations, H+N+S, Sijmons, D., Studio Marco Vermeulen, NRGlab, & Ruimtevolk. (2018). *Klimaat-Energie-Ruimte: Ruimtelijke Verkenning Energie en Klimaat*.

Rauws, W. (2017). Embracing Uncertainty Without Abandoning Planning: Exploring an Adaptive Planning Approach for Guiding Urban Transformations. *Disp*, *53*(1), 32–45. https://doi.org/10.1080/02513625.2017.1316539

Rauws, W., & Roo, G. de. (2016). Adaptive planning: Generating conditions for urban adaptability. Lessons from Dutch organic development strategies. *Environment and Planning B: Planning and Design*, *43*(6), 1052–1074. https://doi.org/10.1177/0265813516658886

Raynor, K. E., Doyon, A., & Beer, T. (2017). Collaborative planning, transitions management and design thinking: evaluating three participatory approaches to urban planning. *Australian Planner*, *54*(4), 215–224. https://doi.org/10.1080/07293682.2018.1477812

Regionale-energiestrategie.nl. (2018). *Handreiking Regionale Energie Strategieën*.

Rijksdienst voor Ondernemend Nederland. (n.d.). Wettelijke – gecertificeerde begrippen gebouwen. Retrieved December 6, 2019, from https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels/wettelijke/gecertificeerde-begrippen

Rijksdienst voor Ondernemend Nederland. (2017). *Handreiking BENG versie 2017.*

Rijksoverheid. (n.d.). Klimaatbeleid. Retrieved January 8, 2019, from https://www.rijksoverheid.nl/onderwerpen/klimaatverandering/klimaatbeleid

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a General Theory of Planning. *Policy Sciences*, *4*, 155–169.

Roggema, R. (n.d.). Swarm Planning. Retrieved January 8, 2019, from http://swarmplanning.com/index.html

Roggema, R. (2009). *Adaptation to Climate Change: A Spatial Challenge.* Dordrecht Heidelberg London New York: Springer.

Roggema, R. (2014). *Swarm Planning – The Development of a Planning Methodology to Deal with Climate Adaptation.* Dordrecht: Springer Science+Business Media. https://doi.org/10.1007/978-94-007-7152-9

Roorda, C., Wittmayer, J., Henneman, P., Steenbergen, F. van, Frantzeskaki, N., & Loorbach, D. (2014). *Transition Management in the Urban Context.* Rotterdam.

Ros, J. P. M., & Prins, A. G. (2014). Biomassa, wensen en grenzen. Den Haag: PBL Planbureau voor de Leefomgeving.

Rotmans, J., & Loorbach, D. (2009). Complexity and Transition Management. *Journal of Industrial Ecology*, *13*(2, SI), 184–196. https://doi.org/10.1111/j.1530-9290.2009.00116.x

Schilling, T., Wyss, R., & Binder, C. R. (2018). The Resilience of Sustainability Transitions. *Sustainability*, *10*(12). https://doi.org/10.3390/su10124593

Sharpe, B., Hodgson, A., Leicester, G., Lyon, A., & Fazey, I. (2016). Three horizons: A pathways practice for transformation. *Ecology and Society*, *21*(2). https://doi.org/10.5751/ES-08388-210247

Sijmons, D. (2017). *Energie & Ruimte – Een Nationaal Perspectief.* Vereniging Deltametropool.

Sipma, J. M., & Rietkerk, M. D. A. (2016). *Ontwikkeling energiekentallen utiliteitsgebouwen*.

Sociaal-Economische Raad. (2018). *Ontwerp van het Klimaatakkoord*. Den Haag.

Steen, K., & Bueren, E. van. (2017). A living lab. *Architectural Record*, *205*(11), 66–68. https://doi.org/10.1177/097172180801300202

STEEP: Systems Thinking for Efficient Energy Planning. (n.d.). Retrieved January 10, 2019, from https://www.cse.org.uk/projects/view/1244

Stremke, S., & Dobbelsteen, A. van den. (2013). *Sustainable Energy Landscapes: Designing, Planning, and Development*. Boca Raton: CRC Press.

Stremke, S., Kann, F. van, & Koh, J. (2012). Integrated Visions (Part I): Methodological Framework for Long-term Regional Design. *European Planning Studies*, *20*(2), 305–319. https://doi.org/10.1080/09654313.2012.650909

Stremke, S., Neven, K., & Boekel, A. (2011). Beyond uncertainties: How to envision long-term transformation of regions? In *Peer Reviewed Proceedings of the 12th annual International Conference on Information Technology in landscape Architecture: Digital Landscape Architecture 2011* (pp. 187–194).

Tillie, N., Dobbelsteen, A. van den, Doepel, S., Jager, W. de, Joubert, M., & Mayenburg, D. (2009). R*EAP Rotterdam Energy Approach and Planning – Towards CO2 – neutral urban development*.

University of Bristol. (2015). *D2.1 Energy Master Plan Process Model*.

Urhahn. (2015). *Strategiewijzer voor binnenstedelijke transformaties*.

Vlot, M., & Griendt, B. van de. (2019). *Energievisie Schieoevers Noord*.

Voß, J.-P., & Bornemann, B. (2011). The politics of reflexive governance: Challenges for designing adaptive management and transition management. *Ecology and Society*, *16*(2). https://doi.org/10.5751/ES-04051-160209

Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, Adaptability and Transformability in Social-ecological Systems. *Ecology and Society*, *9*(2). https://doi.org/10.1103/PhysRevLett.95.258101

Walker, W. E., Haasnoot, M., & Kwakkel, J. H. (2013). Adapt or Perish: A Review of Planning Approaches for Adaptation under Deep Uncertainty. *Sustainability*, *5*, 955–979. https://doi.org/10.3390/su5030955

Walker, W. E., Harremoes, P., Rotmans, J., Sluis, J. P. van der, Asselt, M. B. A. van, Janssen, P., & Krayer von Krauss, M. P. (2003). Defining Uncertainty: A Conceptual Basis for Uncertainty Management. *Integrated Assessment*, *4*(1), 5–17.

Westley, F., Olsson, P., Folke, C., Homer-Dixon, T., Vredenburg, H., Loorbach, D., ... Leeuw, S. van der. (2011). Tipping Toward Sustainability: Emerging Pathways of Transformation. *AMBIO*, *40*(7), 762–780. https://doi.org/10.1007/s13280-011-0186-9

Wittmayer, J. M., & Loorbach, D. (2016). Governing Transitions in Cities: Fostering Alternative Ideas, Practices, and Social Relations Through Transition Management. In S. Loorbach, D and Wittmayer, JM and Shiroyama, H and Fujino, J and Mizuguchi (Ed.), *Governance of Urban Sustainability Transitions: European and Asian experiences* (pp. 13–32). Tokyo: Springer Japan. https://doi.org/10.1007/978-4-431-55426-4_2

Yanovshtchinsky, V., & Dobbelsteen, A. van den. (2012). *Architectuur als klimaatmachine.* Amsterdam: Sun.

Yearworth, M. (2016). Sustainability as a 'super-wicked' problem; opportunities and limits for engineering methodology. *Intelligent Buildings International*, *8*(1), 37–47. https://doi.org/10.1080/17508975.2015.1109789

Zandvoort, M., Brugge, R. van der, Vlist, M. J. van der, & Brink, A. van den. (2019). Dealing with uncertainty in collaborative planning: developing adaptive strategies for the IJsselmeer. *Journal of Environmental Planning and Management, 62*(2), 248–265. https://doi.org/10.1080/09640568.2017.1409196

Zeeuw, F. de. (2018). *Zo werkt gebiedsontwikkeling.* Praktijkleerstoel Gebiedsontwikkeling TU Delft.

Sources of insight

Next to the referenced literature, consultancy reports, and policy documents, and the interviews referred to in the report, the author got information and inspiration which is used in a more implicit manner. These "sources of insight" are the attendance of several events during the participation process, talks to people, etcetera. Information or inspiration retrieved in these ways is not referred to directly, but they have shaped the authors view and understanding of the case study.

- *Stadsgesprek Making of Schieoevers (November 28, 2018).* The evening was moderated by TOP Delft, and consisted of a presentation by André Kuipers on sustainability, a presentation by Marco Broekman on the Concept Development Plan, a panel discussion with municipality, industrial entrepreneurs, representatives from TU Delft, and Marco Broekman, and the session was concluded by councilor Stephan Brandligt. The event got about 200 attendants.

- *Themabijeenkomst Duurzaamheid en Mobiliteit (April 3, 2019).* This evening was organised in 2 rounds of 4 subsessions; the author attended sessions on “energy” and “green and blue”. The subsessions had about 10-25 attendants each, enabling group conversations to take place.

- *Conversation with Stijn van Liefland (April 15, 2019).* After a meeting Stijn at the gathering on April 3rd, we had a one-to-one conversation. This conversation enabled the author to validate the problem definition, explore uncertainties present in practice, and to better understand the process and position of the municipality in the area development.

- *Slotbijeenkomst participatietraject Schieoevers Noord (May 7, 2019).* The closing event of the participation process, where adaptations in the development plan, as outcomes of the participation events were presented, and stakeholders were able to share thoughts.

- *Letters* by established companies to the municipality made the author understand their worries and uncertainties concerning the continuation of their business.

- Lastly, the years spent as a member and board member of student rowing association Proteus-Eretes, located in Schieoevers Noord, made me familiar with the dynamics, usage and physical properties of the area.

Appendix A: Interview guides stakeholder interviews

Four interviews have been carried out. Two interviews which were needed to retrieve information to be able to answer the main questions (1+2), and two interviews that gave insight in the context and that created understanding of the different perspectives on the area development (3+4). The fourth interview also provided insight in the status quo of the developments at the Kabeldistrict. The four interviews that were carried out, were held with:

1. Stijn van Liefland, environmental advisor in the project team Schieoevers Noord, at the Municipality of Delft
2. Derk van Schoten, project manager of the project team Schieoevers Noord, at the Municipality of Delft
3. Nils Eekhout and Jaap Langhout, board members of the Bedrijvenkring Schieoevers (BKS)
4. Thomas Piekhaar, project developer of the Kabeldistrict, Volker Wessels Vastgoed

The positions of the stakeholders within the area development process, is schematised in Figure 111: the Municipality of Delft sets out guidelines for development; Bedrijvenkring Schieoevers forms the physical context of the development and represents most of the plot owners; project developers push the boundaries the municipality sets, to be able to realise their ambitions.

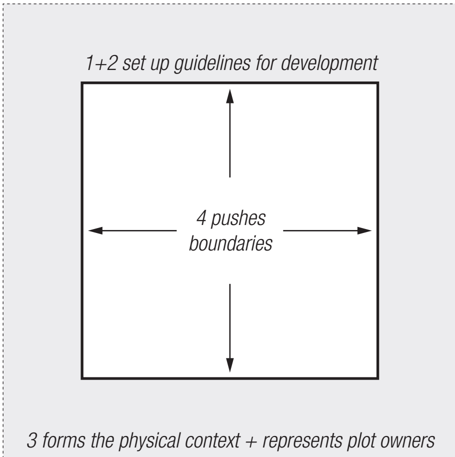


Figure 111: Schematic representation of the positions of the interviewed stakeholders in the area development force field

A.1. Interview protocol Stijn van Liefland

- 29 oktober 2019, Stijn van Liefland, 9:00-10:00, Stadskantoor Delft
- Allereerst bedankt dat je me wederom wilt helpen!
    - We zagen elkaar in april, toen voor een informeel en exploratief gesprek. Daaruit heb ik destijds kunnen vaststellen dat mijn afstudeeronderzoek daadwerkelijk gaat over een onderwerp, dat ook hier binnen de Gemeente Delft als probleem ervaren werd.
    - Dit interview kan mij op een iets “formelere” manier helpen bij twee onderdelen uit mijn onderzoek. Enerzijds de koppeling tussen mijn literatuur onderzoek, en de praktijk – anderzijds de “realisatie” stap; dat wat ik bedacht heb, kan dat toegepast worden en hoe?
- De data die ik verzamel met dit interview, zal alleen gebruikt worden voor mijn master scriptie, uitgevoerd voor de opleidingen Bouwkunde (bouwtechniek) en Science Communication, aan de TU Delft.
- Volgens mij ben je/bent u al redelijk op de hoogte van waar mijn project over gaat. Nog even in het kort. Het geplande ontwikkeltraject van Schieoevers Noord is organisch – of adaptief – ingestoken; ofwel stapsgewijze ontwikkeling waarbij het eindpunt onbekend is. De vraag die ik probeer op te lossen is hoe de gemeente Delft (en partijen in soortgelijke situaties) een duurzame energiestrategie voor een gebied kan opstellen (bijdragend aan de ambitie om een energie neutrale gemeente te zijn in 2050), als men helemaal niet weet hoe Schieoevers Noord eruit zal zien in 2050? Kortom: het plannen voor energie op het niveau van een wijk of stadsdeel vraagt om een eindbeeld, om zo de bijbehorende energievraag (kwalitatief en kwantitatief) in te kunnen schatten, een organisch ontwikkeltraject biedt dit eindbeeld niet. De kennis die ik vergaar en de conclusies die ik oplever, zijn gericht op het omgaan met deze factor onzekerheid/onvoorspelbaarheid binnen een proces dat doorlopen wordt om een energiestrategie op te stellen.
- Met dit interview wil ik graag informatie ophalen over wat u denkt over een adaptief ontwikkeltraject, de status quo wat betreft besluiten die genomen zijn omtrent de energiestrategie sinds het opleveren van het Ontwikkelplan, wil ik graag verkennen hoe mijn (mogelijke) oplossing binnen uw dagelijkse praktijk zou passen, en tussendoor raken we de RES en de warmtevisie van Delft ook nog even aan. Ik heb

een hele lijst vragen, we hoeven ze niet één voor één door; ik houd in de gaten dat ik op de meesten een antwoord krijg.

- Zou u het een probleem vinden als ik het gesprek opneem?
- Als u dat wilt, dan zorg ik ervoor dat de informatie geanonimiseerd wordt opgenomen in mijn rapport. Als dit niet hoeft, zou ik dan mogelijk quotes uit dit gesprek (vertaald naar het Engels) in mijn rapport op mogen nemen? Zo ja, vindt u het fijn om het transcript van dit interview te ontvangen? En ziet u graag de gebruikte quotes in voordat ik het rapport publiceer op de repository van de TU Delft/ inlever bij mijn begeleiders? Als u dit toch wilt, of nog vragen hebt, mag u me altijd even bellen of mailen.
- Ik stuur natuurlijk mijn rapport naar u op, en u bent van harte welkom om mijn afstudeerpresentatie bij te wonen (deze vindt eind januari/ begin februari plaats – als het allemaal goed gaat).

Deel 1 (Praktijk)

1. Zijn er sinds het uitbrengen van het ontwikkelplan nog besluiten genomen over de energievoorziening in Schieoevers Noord?
2. Hoe groot is het projectteam Schieoevers? En hoe integraal wordt er gewerkt? Hoe vinden groepsbesluiten plaats?
3. Project team Schieoevers: wanneer is het “project” afgelopen – en hoe wordt het proces vervolgens voortgezet binnen de organisatie van de gemeente op lange termijn?
    - Hoe zie je jouw rol binnen de ontwikkeling van Schieoevers Noord op de lange termijn?
4. Doe je ook andere wijkstrategieën (wbt energie)?
    - Wat zijn de grootste verschillen tussen bestaande wijken die bijv. van het gas af moeten en een ontwikkelplan als Schieoevers Noord?
5. Verwacht je dat de realisatie van een regionaal warmtenet zal slagen? En een Delfts warmtenet?
6. Wat te doen met plots die niet van gebruiksfunctie/eigenaar veranderen? Hoe gaan die mee in de energietransitie?
7. Hoe wordt de Vulcanusweg meegenomen in de ontwikkelingen van Voorhof-Oost (Delft heeft de ambitie om deze wijk als eerste in Delft volledig van het aardgas af te koppelen)?

8. Hoe wordt “energie neutraal in 2050” überhaupt gemonitord? Hoe weten we of we op koers zijn?

Deel 2 (Theorie)

Alle vragen mogen zoveel mogelijk aan de hand van de energiestrategie binnen SON beantwoord worden, of waar nodig algemeen over SON.

9. Hoe zou jij een adaptief of organisch ontwikkeltraject definiëren?
    - Zijn adaptief en organisch voor jou twee termen die hetzelfde omvatten? Zo nee, wat zijn de verschillen?
10. Is er een analyse gemaakt van de onzekerheden die samen hangen met de onbekende lange termijn?
    - Zijn onzekerheden “geaccepteerd” en wordt er mee gewerkt, of wordt er onderzocht hoe onzekerheden gereduceerd kunnen worden?
11. We hebben een lange termijn visie voor Delft en SON: hoe worden die gekoppeld aan concrete korte termijn acties?
12. Is er een plan om te leren van de fase tot 2030, om eventueel dingen anders te doen na 2030? Of wordt er al op kortere termijn geëvalueerd en “geleerd”?
13. Zijn er uitkomsten uit het participatietraject geweest die ofwel expliciet zijn meegenomen in het Ontwikkelplan, of ervoor gezorgd hebben dat bepaalde aspecten of ideeën verder onderzocht zijn?
14. Adaptiviteit of flexibiliteit: over welke schaal gaat het adaptieve ontwikkelplan nu eigenlijk? (plaatje 5 schalen uit OP)
15. In hoeverre sluit het OP nu aan bij de eerste stappen in de RES of de warmtevisie van de Gemeente Delft?
16. 16. Het document mbt de RES wat je me stuurde, schrijft dat “het regionale proces zich richtte op de regionale aspecten. En daarmee niet op lokale aangelegenheden, afwegingen of participatie en betrokkenheid”. De onzekerheid dat SON een onbekend einde heeft, is dus geen onzekerheid op regionaal niveau, dat komt pas boven water waar echt gebouwd gaat worden.
    - Met wat voor onzekerheden heeft de regio zelf te maken? Zou de regio een rol moeten spelen in het verkennen van lokale onzekerheden? En hoe gebeurt dit in de warmte visie van de Gemeente Delft?

Deel 3 (mijn interventie)

Dan wil ik kort even toelichten wat ik (o.a.) ga opleveren voor mijn project.

Ik stel voor om nog een (of meer) spelregel(s) toe te voegen voor elke deelontwikkeling, gebaseerd op warmte/koude. Op die manier wil ik ervoor zorgen dat elke deelontwikkeling niet meer energie gebruikt, dan dat er aan de directe omgeving onttrokken kan worden – en dan kan ieder plot dus met een gelijkwaardige uitgangspositie ontwikkeld worden. Vanuit het idee dat hoge temperatuur warmte sowieso niet nodig is voor nieuwbouw, en een WKO onafhankelijkheid creëert én de potentie in Delft gunstig is, heb ik die technologie als basis genomen, om zo te kijken hoeveel energie ter beschikking is per hectare, en wat je daar dan op zou kunnen bouwen. Op het moment dat de warmte en koude vraag van de gebruiksfuncties binnen een deelontwikkeling met elkaar in balans zijn (en idealiter ook nog deels direct uitgewisseld kunnen worden) – kan er meer gebouwd worden.

[Uitleggen aan de hand van figuur]

Dan heb ik nog 2 vragen:

17. Spelregels energie
    - Wat is je eerste reactie?
    - Wat zou je nodig hebben om dit te kunnen gebruiken als gemeente delft (mits de rekenkundige kant helemaal zou kloppen)? Wat voor soort output? Hoe implementeren in je beleid?
    - Als dit “klaar” zou zijn om te gebruiken; was het dan nu al te laat om zoiets in te kunnen zetten voor plots die al ontworpen worden? Hoe adaptief is het ontwikkelplan? Of zijn alle dingen die we nu leren in de periode tot 2030 pas daarna bruikbaar?
18. En dan nog over spelregels algemeen binnen het project Schieoevers Noord
    - Heeft de gemeente gevraagd naar een raamwerkkaart + stedenbouwkundige spelregels, of was dat het advies van Broekman in het kader van een adaptieve strategie?
    - Zijn de gestelde spelregels bindend?
    - Wie monitort of ontwerpers/ontwikkelaars zich hier aan houden?
    - Worden de regels bijgesteld, naar mate er meer inzicht is in de lange termijn ontwikkelingen van het gebied?

A.2. Interview protocol Derk van Schoten

- 1 november 2019, Derk van Schoten, 11:00-12:00, Stadskantoor Delft
- Allereerst bedankt dat u me wilt helpen!
- Ik had u over de mail natuurlijk al kort toegelicht waar mijn afstudeerproject over gaat, maar ik licht het graag nog even toe. Het geplande ontwikkeltraject van Schieoevers Noord is organisch – of adaptief – ingestoken; ofwel stapsgewijze ontwikkeling waarbij het eindpunt onbekend is. De vraag die ik probeer op te lossen is hoe de gemeente Delft (en partijen in soortgelijke situaties) een duurzame energiestrategie voor een gebied kan opstellen (bijdragend aan de ambitie om een energie neutrale gemeente te zijn in 2050), als men helemaal niet weet hoe Schieoevers Noord eruit zal zien in 2050? Kortom: het plannen voor energie op het niveau van een wijk of stadsdeel vraagt om een eindbeeld, om zo de bijbehorende energievraag (kwalitatief en kwantitatief) in te kunnen schatten, een organisch ontwikkeltraject biedt dit eindbeeld niet. De kennis die ik vergaar en de conclusies die ik oplever, zijn gericht op het omgaan met deze factor onzekerheid/onvoorspelbaarheid binnen een proces dat doorlopen wordt om een energiestrategie op te stellen.
- Ik heb Stijn eerder dit jaar en afgelopen dinsdag gesproken. Eerder dit jaar was meer exploratief, om mijn "probleem" te bevestigen, en deze week zijn we meer de diepte ingegaan.
- Met dit interview wil ik graag informatie ophalen over wat uw blik is op een adaptief ontwikkeltraject, de stappen die gezet zijn sinds het opleveren van het Ontwikkelplan, en wil ik graag verkennen hoe mijn (mogelijke) oplossing binnen uw dagelijkse praktijk zou passen. Ik heb een hele lijst vragen, we hoeven ze niet één voor één door; ik houd in de gaten dat ik op de meesten een antwoord krijg.
- De data die ik verzamel met dit interview, zal alleen gebruikt worden voor mijn master scriptie, uitgevoerd voor de opleidingen Bouwkunde (bouwtechniek) en Science Communication, aan de TU Delft.
- Zou u het een probleem vinden als ik het gesprek opneem?
- Als u dat wilt, dan zorg ik ervoor dat de informatie geanonimiseerd wordt opgenomen in mijn rapport. Als dit niet hoeft, zou ik dan mogelijk quotes uit dit gesprek (vertaald naar het Engels) in mijn rapport op mogen nemen? Zo ja, vindt u het fijn om het transcript van dit interview te ontvangen? En ziet u graag de gebruikte quotes

in voordat ik het rapport publiceer op de repository van de TU Delft/ inlever bij mijn begeleiders? Als u dit toch wilt, of nog vragen hebt, mag u me altijd even bellen of mailen.

- Ik stuur natuurlijk mijn rapport naar u op, en u bent van harte welkom om mijn afstudeerpresentatie bij te wonen (deze vindt eind januari/ begin februari plaats – als het allemaal goed gaat).

Deel 1 (Praktijk)

1. Kunt u wat vertellen over uw rol binnen het project Schieoevers Noord?
    - Full-time Schieoevers of ook andere werkzaamheden? Vanaf de start betrokken?
2. Hoe is het plan om Schieoevers Noord als een geheel te ontwikkelen (of in elk geval de ambitie tot ontwikkelen) ontstaan? En hoe zijn de “grenzen” van dit gebied bepaald?
3. Project team Schieoevers: wanneer is het “project” afgelopen – en hoe wordt het proces vervolgens voortgezet binnen de organisatie van de gemeente op lange termijn?
    - Hoe ziet u uw rol binnen de ontwikkeling van Schieoevers Noord op de lange termijn?
4. Zijn er sinds het uitbrengen van het ontwikkelplan nog strategische besluiten genomen?
5. Hoe is de besluitvorming georganiseerd?
6. Hoe kijkt u naar de relatie tussen de energietransitie en andere urgenties zoals de woningvraag die vraagt om ruimtelijke ontwikkeling?

Deel 2 (Theorie)

7. Hoe zou u een adaptief of organisch ontwikkeltraject definiëren?
    - Zijn adaptief en organisch voor u twee termen die hetzelfde omvatten? Zo nee, wat zijn de verschillen?
8. Waarom is er voor een adaptieve/organische ontwikkeling gekozen?

9. Over welke schaal gaat adaptiviteit in het ontwikkelplan? Stopt adaptiviteit bij de schaal van de deelontwikkelingen, of ook nog kleiner?
10. Is er een analyse gemaakt van de onzekerheden die samen hangen met de onbekende lange termijn?
    - Zijn onzekerheden “geaccepteerd” en wordt er mee gewerkt, of wordt er onderzocht hoe onzekerheden gereduceerd kunnen worden?
11. Het plan is verdeeld in een “korte termijn” tot 2030, en een “lange termijn” met geen bekend eindpunt. Er zijn natuurlijk een aantal deelgebieden aangewezen die tot 2030 gaan ontwikkelen, zijn er verder nog concrete acties op korte termijn gepland of mogelijk om aan de langetermijnvisie voor het gebied te werken?
12. Is er een plan om te leren van de fase tot 2030, om eventueel dingen anders te doen na 2030? Of wordt er al op kortere termijn geëvalueerd en “geleerd”?
13. Hoe heeft het participatietraject bijgedragen aan het ontwikkelen van het ontwikkelplan?
14. Hoe staat het project (of delen ervan) in verhouding tot gemeentelijk en/of regionaal beleid?

Deel 3 (mijn interventie)

Dan wil ik kort even toelichten wat ik (o.a.) ga opleveren voor mijn project.

Ik stel voor om nog een (of meer) spelregel(s) toe te voegen voor elke deelontwikkeling, gebaseerd op warmte/koude. Op die manier wil ik ervoor zorgen dat elke deelontwikkeling niet meer energie gebruikt, dan dat er aan de directe omgeving onttrokken kan worden – en dan kan ieder plot dus met een gelijkwaardige uitgangspositie ontwikkeld worden. Vanuit het idee dat hoge temperatuur warmte sowieso niet nodig is voor nieuwbouw, en een WKO onafhankelijkheid creëert én de potentie in Delft gunstig is, heb ik die technologie als basis genomen, om zo te kijken hoeveel energie ter beschikking is per hectare, en wat je daar dan op zou kunnen bouwen. Op het moment dat de warmte en koude vraag van de gebruiksfuncties binnen een deelontwikkeling met elkaar in balans zijn (en idealiter ook nog deels direct uitgewisseld kunnen worden) – kan er meer gebouwd worden.

[Uitleggen aan de hand van figuren]

Dan heb ik nog 2 vragen:

15. Spelregels energie
    - Wat is uw eerste reactie? Hoe staat u überhaupt tegenover het introduceren van spelregels op andere thema's dan bouwhoogtes/gebouweigenschappen en woon/werkfunctie gerelateerd?
    - Wat zou u nodig hebben om dit te kunnen gebruiken als gemeente delft (mits de rekenkundige kant helemaal zou kloppen)? Wat voor soort output? Hoe implementeren in het beleid?
16. En dan nog over spelregels algemeen binnen het project Schieoevers Noord
    - Heeft de gemeente gevraagd naar een raamwerkkaart + stedenbouwkundige spelregels, of was dat het advies van Broekman in het kader van een adaptieve strategie?
    - Zijn de gestelde spelregels bindend?
    - Wie monitort of ontwerpers/ontwikkelaars zich hier aan houden?
    - Worden de regels bijgesteld, naar mate er meer inzicht is in de lange termijn ontwikkelingen van het gebied?

A.3. Interview protocol Nils Eekhout

- 18 november 2019, Nils Eekhout, 10:30-11:30, Kantoor Octatube
- Allereerst bedankt dat u me wilt helpen!
- Ik had u over de mail natuurlijk al kort toegelicht waar mijn afstudeerproject over gaat, maar ik licht het graag nog even toe. Het geplande ontwikkeltraject van Schieoevers Noord is organisch – of adaptief – ingestoken; ofwel stapsgewijze ontwikkeling waarbij het eindpunt onbekend is. De vraag die ik probeer op te lossen is hoe de gemeente Delft (en partijen in soortgelijke situaties) een duurzame energiestrategie voor een gebied kan opstellen (bijdragend aan de ambitie om een energie neutrale gemeente te zijn in 2050), als men helemaal niet weet hoe Schieoevers Noord eruit zal zien in 2050? Kortom: het plannen voor energie op het niveau van een wijk of stadsdeel vraagt om een eindbeeld, om zo de bijbehorende energievraag (kwalitatief en kwantitatief) in te kunnen schatten, een organisch ontwikkeltraject biedt dit eindbeeld niet. De kennis die ik vergaar en de conclusies die ik oplever, zijn gericht op het omgaan met deze factor onzekerheid/onvoorspelbaarheid binnen een proces dat doorlopen wordt om een energiestrategie op te stellen.
- Ik heb ook twee interviews afgenomen bij de gemeente. Mijn project gaat over het opstellen van energiestrategieën – de gemeente is hiervoor geen opdrachtgever, maar wel probleemeigenaar, gezien de energieambities voor 2050.
- Met het interview vandaag, ben ik vooral benieuwd naar het perspectief vanuit de BKS – hoe de blik op de lange termijn is, en op het opgestelde ontwikkelplan. Wellicht kunt u zowel inzichten vanuit de gehele bedrijvenkring als vanuit Octatube met me delen? Daarnaast maak ik graag van de gelegenheid gebruik, om te informeren naar het energiegebruik van de maakhal van Octatube.
- De data die ik verzamel met dit interview, zal alleen gebruikt worden voor mijn master scriptie, uitgevoerd voor de opleidingen Bouwkunde (bouwtechniek) en Science Communication, aan de TU Delft.
- Zou u het een probleem vinden als ik het gesprek opneem?
- Ik ga het gesprek niet transcriberen, maar mocht ik toch een quote willen gebruiken, zou u dat goed vinden? Als u dat wilt, dan zorg ik ervoor dat de informatie geanonimiseerd wordt opgenomen in mijn rapport. Zo ja, vindt u het fijn om de gebruikte quotes in te zien voordat

ik het rapport publiceer op de repository van de TU Delft/ inlever bij mijn begeleiders? Als u dit toch wilt, of nog vragen hebt, mag u me altijd even bellen of mailen.
- Ik stuur natuurlijk mijn rapport naar u op, en u bent van harte welkom om mijn afstudeerpresentatie bij te wonen (deze vindt eind januari/ begin februari plaats – als het allemaal goed gaat).

Vragen

1. Hoe zou je "maakindustrie" definiëren? Welke bedrijven binnen Schieoevers Noord vallen daar wel en niet onder?
    - Octatube, als maakindustrie, past naar mijn idee goed binnen de lange termijn visie van de Gemeente Delft voor het gebied Schieoevers Noord – gezien alleen Octatube en Festo van de bedrijvigheid in de raamwerkkaart zijn opgenomen. Merk je binnen de BKS een verschil in kijk op de plannen tussen Octatube en andere bedrijven?
2. Hoe heeft het creëren van het ontwikkelplan voor Schieoevers Noord gespeeld binnen de organisatie? Het gaat natuurlijk een deel van de bedrijven aan (degenen op Noord), maar niet alle?
3. Staat de BKS positief tegenover het uiteindelijke ontwikkelplan? Gevoel dat de gemeente de ideeën en belangen van de BKS goed heeft meegenomen?
4. Uiteindelijk is er onderscheid gemaakt tussen ontwikkelingen tot en vanaf 2030; hoe kijkt BKS naar dat besluit?
    - Gemeente zegt: lange termijn voor een bedrijf is misschien 10 jaar – is dat zo? Worden deze 10 jaar gebruikt als "bedenktijd" – hoe ervaart de BKS dat?
5. Is er binnen de bedrijvenkring een verwachting hoe het gebied zich zal ontwikkelen? Is het rigide, gaan alleen de plots die nu ontwikkeld mogen worden ontwikkelen, of wordt het een geheel ontwikkeld woon-werkgebied?
6. Hoe staat BKS tegenover de ambitie om als Delft in 2050 een energie neutrale stad te zijn; wat ziet de BKS als hun rol daarin?
    - Met het oog op ontwikkelingen in Schieoevers – zullen eventuele energiemaatregelen uitgesteld worden? Of juist vervroegd?

7. Heeft Octatube zelf plannen om uit te breiden (ruimte in het OP – 4500m²)? Zouden zij dan openstaan om samen te werken op het vlak van energie met ontwikkelaars bijvoorbeeld?

Over de maakhal

8. Is de hal geïsoleerd? Zijn er te openen ramen?
9. Hoe wordt de maakhal verwarmd? Centraal of plaatselijk? Lucht, elektrische heaters, anders?
10. Wordt het over het jaar heen voornamelijk gekoeld of verwarmd? (kWh – kan je dat evt. opzoeken?)
    - Komt er veel warmte van de apparaten af?
    - Bij welke temperatuur koelen/verwarmen?
11. Plannen om verwarming/koeling te verduurzamen?

A.4. Interview protocol Thomas Piekhaar, Kondor Wessels

- 6 december 2019, Thomas Piekhaar, 9:30-10:30, Projectlocatie in de Schiehallen
- Allereerst bedankt dat u me wilt helpen!
- Ik had u over de mail natuurlijk al kort toegelicht waar mijn afstudeerproject over gaat, maar ik licht het graag nog even toe. Het geplande ontwikkeltraject van Schieoevers Noord is organisch – of adaptief – ingestoken; ofwel stapsgewijze ontwikkeling waarbij het eindpunt onbekend is. De vraag die ik probeer op te lossen is hoe de gemeente Delft (en partijen in soortgelijke situaties) een duurzame energiestrategie voor een gebied kan opstellen (bijdragend aan de ambitie om een energie neutrale gemeente te zijn in 2050), als men helemaal niet weet hoe Schieoevers Noord eruit zal zien in 2050? Kortom: het plannen voor energie op het niveau van een wijk of stadsdeel vraagt om een eindbeeld, om zo de bijbehorende energievraag (kwalitatief en kwantitatief) in te kunnen schatten, een organisch ontwikkeltraject biedt dit eindbeeld niet. De kennis die ik vergaar en de conclusies die ik oplever, zijn gericht op het omgaan met deze factor onzekerheid/onvoorspelbaarheid binnen een proces dat doorlopen wordt om een energiestrategie op te stellen.
- Ik heb ook twee interviews afgenomen bij de gemeente Delft, en ik heb gesproken met twee bestuurders van de Bedrijvenkring Schieoevers. Mijn project gaat over het opstellen van energiestrategieën – de gemeente is hiervoor geen opdrachtgever, maar wel probleemeigenaar, gezien de energieambities voor 2050.
- Met het interview vandaag, ben ik vooral benieuwd naar het perspectief op deze gebiedsontwikkeling vanuit een project ontwikkelaar.
- De data die ik verzamel met dit interview, zal alleen gebruikt worden voor mijn master scriptie, uitgevoerd voor de opleidingen Bouwkunde (bouwtechniek) en Science Communication, aan de TU Delft.
- Zou u het een probleem vinden als ik het gesprek opneem?
- Ik ga het gesprek niet transcriberen, maar mocht ik toch een quote willen gebruiken, zou u dat goed vinden? Als u dat wilt, dan zorg ik ervoor dat de gebruikte informatie geanonimiseerd wordt opgenomen in mijn rapport. Zo ja, vindt u het fijn om de gebruikte quotes in te zien voordat ik het rapport publiceer op de repository van de TU Delft/

inlever bij mijn begeleiders? Als u dit toch wilt, of nog vragen hebt, mag u me altijd even bellen of mailen.

- Ik stuur natuurlijk mijn rapport naar u op, en u bent van harte welkom om mijn afstudeerpresentatie bij te wonen (deze vindt eind januari/ begin februari plaats – als het allemaal goed gaat).

Introductie

1. Zou je me wat willen vertellen over jouw rol binnen de ontwikkeling van het Kabeldistrict? En over de rol van Kondor Wessels?
2. Hoe ziet het verloop van de ontwikkeling eruit? Ik weet dat er naar gestreefd wordt om het bestemmingsplan november volgend jaar af te hebben, wat is de prognose voor daarna – gefaseerd bouwen of juist in 1 keer, wanneer moet het klaar zijn? En hoe ziet dat er voor jullie uit qua organisatie?
3. Hoe zit de samenwerking met Amvest in elkaar? Wie heeft welke rol?

Proces (adaptief ontwikkelplan)

4. Hoe is het voor een ontwikkelaar om niet te weten wat er met naburige kavels gaat gebeuren in de komende decennia?
5. Wat voor onzekerheden of risico's zijn voor jullie van belang in het proces?
6. Hoe is de samenwerking met de gemeente Delft?
    - Vaker dit soort projecten gedaan: open-einde gebiedsontwikkelingen?
    - Hoe verschilt deze ontwikkeling, als deel van een "organische" gebiedsontwikkeling, van andere ontwikkelingen?
7. Heb je/jullie ervaring met het gebruik van spelregels in gebiedsontwikkelingen?
    - Welke spelregels gaan jullie als ontwikkelaar aan? En welke gaan naar de ontwerpers?
8. Hoe zijn jullie betrokken geweest in het participatie traject voor Schieoevers Noord?

Bouwplannen

9. Wat wordt het kabeldistrict voor wijk? Wat voor soort wonen, wat voor werken?
    - Innovatieve maakindustrie; wat verstaan jullie daaronder?
10. Ik las: circa 3000 woningen en 2000 banen; wat zijn er verder nog voor dingen gepland? Winkels? Supermarkt? Restaurantjes? Wat gebeurt er met parkeren? En hoeveel van het totale aantal m^2 is beschikbaar voor dergelijke voorzieningen?
11. Waarom een hogere dichtheid dan de 2.75 uit het ontwikkelplan?

Energie/Duurzaamheid

12. Wat is de rol van duurzaamheid en met name energie in het project?
    - Is dat een hoofdonderwerp/ambitie? Of doel om "gewoon" aan de BENG te gaan voldoen?
13. Ligt de realisatie van energie neutraal ontwikkelen meer bij de architect of bij de ontwikkelaar?
14. Trade-off kosten en duurzame energie? -> eerder investeren in besparen of meer opwek?

Voor mijn afstuderen heb ik gekeken wat het betekent om – voor wat betreft warmte en koude – energieneutraal te ontwikkelen in een stedelijk gebied met hoge dichtheid. Daarbij heb ik de parameters dichtheid, functiemenging, energievraag, en energiepotentie met elkaar verbonden en verschillende scenario's doorgerekend voor een fictieve ontwikkeling, per hectare. De uitkomst, is dat energieneutraal ontwikkelen niet gaat lukken op de eigen grond als de maximale BENG waarden gebruikt worden. Aanvullende voorzieningen als warmtenetten, maken de zaak natuurlijk anders, maar die liggen er niet op de (zeer) korte termijn. Mijn vraag is de volgende: Zouden jullie liever gestuurd worden door het opleggen van het gebruik van een bepaald systeem (zoals het gebruik van een WKO)? Of liever een strengere norm dan BENG wbt het energieverbruik per m^2? In het geval van het laatste – liever een gemiddelde voor alle functies, of een aanvullende norm op de BENG per functie?

Appendix B: Validation interview

One additional interview has been carried out for the validation of the "Schieoevers Noord approach for adaptive energy planning". The interview protocol is included here; the author started-off the interview with an open attitude, many other questions have been asked, and some of the prepared ones have not.

Interview protocol Agnes van der Linden

- 13 januari, 16.00, Stadskantoor Delft
- Allereerst bedankt dat u me wilt helpen, en op deze korte termijn beschikbaar was.
- [Kort introductie op mijn afstudeerproject]
- Eerder in mijn proces heb ik een aantal interviews afgenomen, met de BKS, met de projectontwikkelaar van de Schiehallen, en met uw collega's Stijn van Liefland en Derk van Schoten. Voor deze stap van reflectie was ik op zoek naar iemand die iets verder van het project Schieoevers af staat, maar wel weer hoe energie en gebiedsontwikkelingen in elkaar zitten. Vorige week gaf Andy van den Dobbelsteen aan dat ik u kon vragen. Dus ik ben erg blij dat het gelukt is om een afspraak te maken.
- Het doel van het gesprek wat ik vandaag met u voer, is het spiegelen van het proces en de invulling van verschillende processtappen die ik voor ogen heb om tot een adaptieve energiestrategie te komen, aan de praktijk. Om er op die manier achter te komen welke stappen al "standaard" uitgevoerd worden op een bepaalde manier, welke stappen nieuw zijn, en hoe deze een plek zouden kunnen krijgen in de praktijk.
- Ik zal de informatie die ik vandaag ophaal natuurlijk verwerken in mijn rapport. Ik ga geen transcript maken, maar om een goede samenvatting te kunnen schrijven zou ik het gesprek graag opnemen, zou u dat een probleem vinden? De samenvatting komt niet in mijn rapport, deze lever ik enkel in bij mijn begeleiders. Zou u het fijn vinden om de informatie die ik gebruik voor mijn rapport nog na te lezen voor ik het inlever? Mag ik uw naam noemen of wilt u graag dat ik de informatie anoniem verwerk?
- Als u het leuk zou vinden, bent u van harte welkom om mijn presentatie bij te wonen op 30 januari, en stuur ik u uiteraard graag mijn rapport op.

Introductie

1. Agnes zichzelf laten voorstellen
    - functie/ervaring/expertise binnen de gemeente Delft
    - betrokkenheid bij vorming van duurzaamheidsvisies/strategieën
2. Linda introduceert het afstudeerproject
    - Aanleiding
    - Onderzoeksvraag
    - Stukje theorie + casus analyse (6 factoren van adaptiviteit, schaal van adaptiviteit is het plot, WKO lijkt de warmte en koude bron die het beste bij een adaptief ontwikkelplan aansluit)
3. Linda introduceert methode (5 stappen), en benoemt
    - dat er over condities voor ontwikkeling nagedacht moet worden
    - dat onzekerheden keuzes in de weg staan
    - de noodzaak van iteraties om te kunnen leren van eerdere stappen

Punten voor reflectie/discussie – hoe werkt het in de praktijk van de gemeente wat betreft:

- Analyse van een strategische opgave? Intern of extern? Vanuit een groter visievormingsproces?
- Opstellen van een visie? Gaat het eigenlijk wel in die volgorde of wordt er eerst een visie gevormd en dan een analyse gedaan?
- (Hoe) worden onzekerheden in planningsprocessen geïdentificeerd? Door wie? In welk stadium van planvorming?
- (Hoe) worden onzekerheden meegenomen in het schrijven van strategieën of plannen?
- (Hoe) wordt de uitvoering van een strategie tussentijds geëvalueerd?

Kijkend naar wat ik voorstel:

- Om te kunnen itereren, moet je een soort “trigger value” hebben – bestaat er zoiets in de praktijk? Hoe gaat dat in zijn werk?
- Als gemeente wordt er – denk ik – heel vaak gedacht vanuit het creeren van gunstige condities om iets te laten ontwikkelen, in plaats van zelf actie te ondernemen. Hoe schep je van die gunstige condities, waarin mensen zelf actie ondernemen in de richting van de gemeentelijke visie?
- Om onzekerheden te kunnen verkennen, wat zijn dan de: juiste mensen/plek/atmosfeer/meetings
- Wat denk je over de vragen die ik heb opgeschreven? Zouden die kunnen helpen?

Appendix C: Interview transcripts and summaries

In total, five interviews have been carried out. The two interviews at the Municipality of Delft – the problem owner in the problem statement – have been used most intensively; they were transcribed to be able to reread in detail. The others have been summarised. *All of the transcripts are available at request, they are in possession by all of the graduation mentors.*

An overview of the transcripts and summaries:

1. Stijn van Liefland, Municipality of Delft – *transcript*
2. Derk van Schoten, Municipality of Delft – *transcript*
3. Nils Eekhout and Jaap Langhout, Bedrijvenkring Schieoevers – *summary*
4. Thomas Piekhaar, Kondor Wessels Vastgoed – *summary*
5. Agnes van der Linden (interview for validation) – *summary*

Directing the energy transition towards Paris – a complex challenge in itself. Guiding the development of a sustainable energy strategy in a developing area – that creates opportunities to move in the right direction. But what if the area is developing in an open-ended way, with a dot on the horizon further away than 2050 – a year marked by energy ambitions? How do you take strategic decisions regarding energy then?

The project *"energy planning for the unknown"* explores the tension between the planning of future-proof heat supply systems and the unpredictability of energy demands and potentials coming with open-ended area developments. Which decisions have to be taken? How to work with irreducible uncertainties? How to adapt to a constant flow of change?

The open-ended development process of the district Schieoevers Noord is studied in detail: an industrial area intended to be transformed into a mixed-use environment which facilitates both entrepreneurs and residents. Energy scenarios are studied, design guidelines are proposed and process interventions are created. All to be able to take strategic decisions on a future-proof energy system that fits an adaptive process of area development.