AUTONOMOUS OOSTERWOLD

Exploring the land-use, environmental impact and environmental risks of local essential service provision on different levels of autonomy

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Foreword

Even though a thesis and the construction of a home are entirely different undertakings, I find the projects in Oosterworld to be a good analogy for the process I went through during my research. When I began this research approximately 700 houses were built in Oosterwold and as it comes to an end another 300 households managed to build a home. As those households drew up the concepts of their new houses I similarly started finding the right storyline for this thesis. As they struggled to find the right construction system to realise their vision, I proposed a methodological framework. Parallels can be drawn between the hard labour of building and writing. In both cases one deals with (research) design mistakes, one gets lost in details and constantly finds creative ways to keep the structure standing, often leading to entirely different (built or written) results one initially had in mind.

I cannot say that this thesis 'stands as firm as a house' ('staat zo stevig als een huis' as we say in Dutch), but I certainly learned that sometimes one should be guided by the process rather than the end result. In that respect this thesis relates more to the process of organic urbanism; as it is built from the bottom-up it can indeed lead to crooked (story)lines or unfinished streets. More importantly, building a house can be a solitary process, whereas organic urbanism is always the product of a multitude of people. In this thesis those people were my mentors, Ulf and Ellen, who - despite the numerous storylines and various experiments - still took the time to recognize patterns within the chaos and managed to understand where the unfinished streets would lead.

If the inhabitants of Oosterworld can be happy in a built environment where everything remains unfinished, I can certainly enjoy the course this thesis took me through. I enjoyed the brainstorms, creative sessions and critics, because this process stimulated and pushed fundamental and complex ideas into a broad yet thorough final research. I hope you take this with you and enjoy this read (or ride).

Summary

Essential service systems are important to consider within spatial planning as they cater the fundamental needs of any built environment. Traditionally, these systems are provided in a centralized manner in the Netherlands. However, due to the recent rise of small-scale disperse systems and the acknowledgement of their benefits these are becoming a popular alternative. In particular local energy provision systems and to a lesser extent local wastewater treatment system are on the rise. Apart from the general challenges of having to design systems that can satisfy local demand for energy and wastewater treatment, spatial planners face an important novel dilemma: on what level should systems be integrated to achieve (partial) autonomy. Since essential service systems function as the bottom-layer of a spatial plan, the scale can have profound consequences for other aspects of spatial planning such as occupation, governance and metabolism.

In order to guide spatial planners in the design of local essential service systems, research is needed to understand the consequences of a certain level of autonomy on spatial planning to foster sustainable urban development. This research therefore explores the land-use, environmental impact and environmental risks that occur due to the implementation of local essential service systems as an argument for a preferred level of autonomy. In this endeavour the new developing neighbourhood Oosterwold is used as a case study. In Oosterwold inhabitants are expected to autonomously provide their energy and treat their wastewater in a large-scale experiment of bottom-up urban planning. Inhabitants can thereby decide on the level of autonomy. The currently partially developed neighbourhood therefore functions as a source of information and field of experimentation for future similar developments. From this, the following research question can be formulated: ***What are the land-use intensity, environmental impact and environmental risks associated with the provision of local essential services on different levels of autonomy in Oosterwold, and what recommendations follow from these insights for spatial planning?***

Based upon a literature review, site visits and interviews, it can be concluded that in Oosterwold there is an overrepresentation of essential service provision on household level. For wastewater only 20% of households treat their water communally and for energy provision there is no account of communal production or storage. This is mainly due to the flexibility and freedom individual essential service provision gives inhabitants to develop their own plot. Also, the connection to the national electricity grid as a back-up discourages energy self-sufficiency and cooperation. When considering the land-use, environmental impact and environmental risks, there are important benefits from storing energy or treating wastewater on a larger scale.

Based on the construction of three different scenarios – A. household level, B. street level and C. neighbourhood level – the consequences of essential service provision on different levels of autonomy in Oosterwold were researched. Different system iterations were explored using the maximization method (1. applying the most common techniques in Oosterwold, 2. the techniques with the lowest land-use, 3. and the techniques which are easiest to integrate into the agricultural landscape of

Oosterwold) creating a total of nine different designs. The differences between these designs show a number of general trends. A larger scale for wastewater treatment can reduce the land-use and environmental risks but can in some cases have a negative influence on the environmental impact. For energy storage, a larger scale reduces land-use though for production it can have a negative influence on the environmental risks and, in some cases, a negative influence on the environmental impact.

Based on these conclusions, it is important for Oosterwold to develop communal wastewater treatment to minimize the risk of groundwater pollution as the area is an important source of potable water. As this is difficult to combine with (individual) organic development, an alternative solution would be to implement composting individually as this poses less risks for ground water pollution. Furthermore, seasonal thermal heat storage should be considered, preferably on a communal scale, to improve the self-sufficiency and efficiency of energy provision. A smart electricity grid can facilitate the exchange of locally produced electricity and sharing of electricity storage. In this way bottom-up urban planning still allows for an individual approach with the benefit of communal wastewater treatment and energy storage.

For spatial planning in general, it is recommended to consider the possible systems and level of autonomy for the local provision of essential services, as it can have an effect on the land-use, environmental impact and environmental risks. As we have seen in Oosterwold, these are important to consider in order to prevent pollution, enhance efficiency or reduce the impact to ultimately ensure sustainable urban development on a local scale.

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1. Introduction

The decentralization of essential service provision and spatial planning

1.1 The decentralization of essential service systems

Essential services - such as food, materials, water, energy and waste - provide the basic needs for any type of settlement to survive and thrive (National Climate Assessment, 2014; Timmeren A. v., Heteronomie & Autonomie, 2006; UN Environment, 2017). The decentralization of essential service provision is increasingly seen as a key method to address challenges such as the exhaust of natural resources, pressures on the environment, or the high cost of resource transportation. In the Netherlands and many other modern countries, energy plants, wastewater treatment facilities, farming or water abstraction are mainly centralized, operating at a national or sub-national level. This is due to the high reliability, economies of scale and ease of operation which have proved useful and provided prosperity in many countries (Alanne & Saari, 2004; Daigger & Crawford, 2007; Poustie, et al., 2015).

In the last decades this centralized and traditional provision of essential services is increasingly seen as outdated and the cause of pressure on our natural environment (Quezada, Walton, & Sharma, 2016). Resources have to be transported over long distances resulting in losses and high operation and maintenance costs. Also, large-scale facilities are inflexible, and potential failures can have a large impact on economies, daily life or the environment (Falco & Webb, 2015; Alanne & Saari, 2004; Guo, Englehardt, & Wu, 2014; Siegrist, 2017; Meadows D. H., 2008). Therefore, the decentralization of essential services, with facilities operating on a smaller more local scale, is seen as a promising alternative (Timmeren A. v., 2006). Providing essential services on a local scale decreases the need for transport and the effects of a failure while increasing flexibility and the possibility to integrate different (renewable) resources or re-use resources in order to sustain our way of life (Daigger & Crawford, 2007; Siegrist, 2017; Suriyachan, Nitivattananon, & Amin, 2012; Falco & Webb, 2015; Phent, 2006; Lasseter, 2007).

With many people following this reasoning, we currently see an increase in the development of decentralized essential service provision in the Netherlands. Modern neighbourhoods such as Buiksloterham, Aardehuizen or Eva Lanxmeer incorporate innovative local essential service techniques, citizens initiate the development of wind turbines or wetlands, and government has the ambition to steadily increase the decentralized production of energy (RVO, 2013; Warbroek, 2019). In other words, decentralized facilities are predicted to play an increasingly important role in the future provision of essential services (Goldthau, 2014; Meadows D. H., 2008). Yet, the implications of this new future are still relatively unknown. As more and more local essential service provision takes place, these implications slowly start to become apparent (Falco & Webb, 2015; Phent, 2006; Daigger & Crawford, 2007; Makropoulos & Butler, 2010). This is also the case for the new neighbourhood Oosterwold where

1.2 Research gap: the implications of local essential service provision

The decentralization of essential services will require structural changes and impact the way people live and consume. Where centralized facilities benefit from many economies of scale, decentralized facilities are more prone to fluctuations and lack uniformity and consistency leading to diseconomies of scale (Mckenna, 2017). Also, centralized facilities can be placed out of sight while decentralized facilities exist in the centre of communities (Warbroek, 2019). Furthermore, centralized facilities are managed and maintained by experts whereas decentralized facilities rely on an inexperienced group of citizens (Alanne & Saari, 2004). This poses many questions, particularly around spatial planning. Where should we integrate essential service techniques? Should we integrate them on a household scale or cooperate with the entire community? And how can we safely implement and manage essential service systems on a local scale when non-expert citizens are in charge? So far, literature has mainly focused on the emergence of decentralized essential service systems and the opportunities they entail, without adressing the consequences for the built environment and their residents (Wolsink, 2018; Adil & Ko, 2016; Warbroek, 2019). In order to successfully and sustainably implement essential service systems on a local scale it is vital to understand their impact on the built environment. This understanding can support decision making and design considering the type of system, scale of application or how and by whom these systems should be governed or operated.

1.3 Research aim: exploring the implications of local essential service provision

Starting from the notion that in the future essential service provision will increasingly be managed on a local scale, this research aims to explore the consequences of this decentralization. In particular, it aims to explore the land-use intensity, environmental impact and risks associated with essential service systems as these are seen as important contributors to the success of these systems and have an effect on spatial planning (Warbroek, 2019). In doing so, this research aims to provide valuable insights for spatial planning which is defined as the distribution of space between people or activities through practice or policies. The aim of this research is therefore to provide conclusions that can be used in discussions about the implementation of local essential service systems possibly improving the decision or design process. To limit the scope of this research and provide relevant conclusions for practice, the neighbourhood Oosterwold is used as a case study.

1.4 Case study: Oosterwold

In order to improve our understanding of the consequences of local essential service provision, the neighbourhood Oosterwold is used as a case study. In Oosterwold inhabitants are fully responsible for the development of homes, plots and streets as well as the provision of essential services, departing from the general practice of top-down urban planning. This results in a large variation of different solutions for essential service provision using different types of systems and different

A. Decentralized and centralized energy provision (Photo by author,2020,Oud-Alblas) ▶

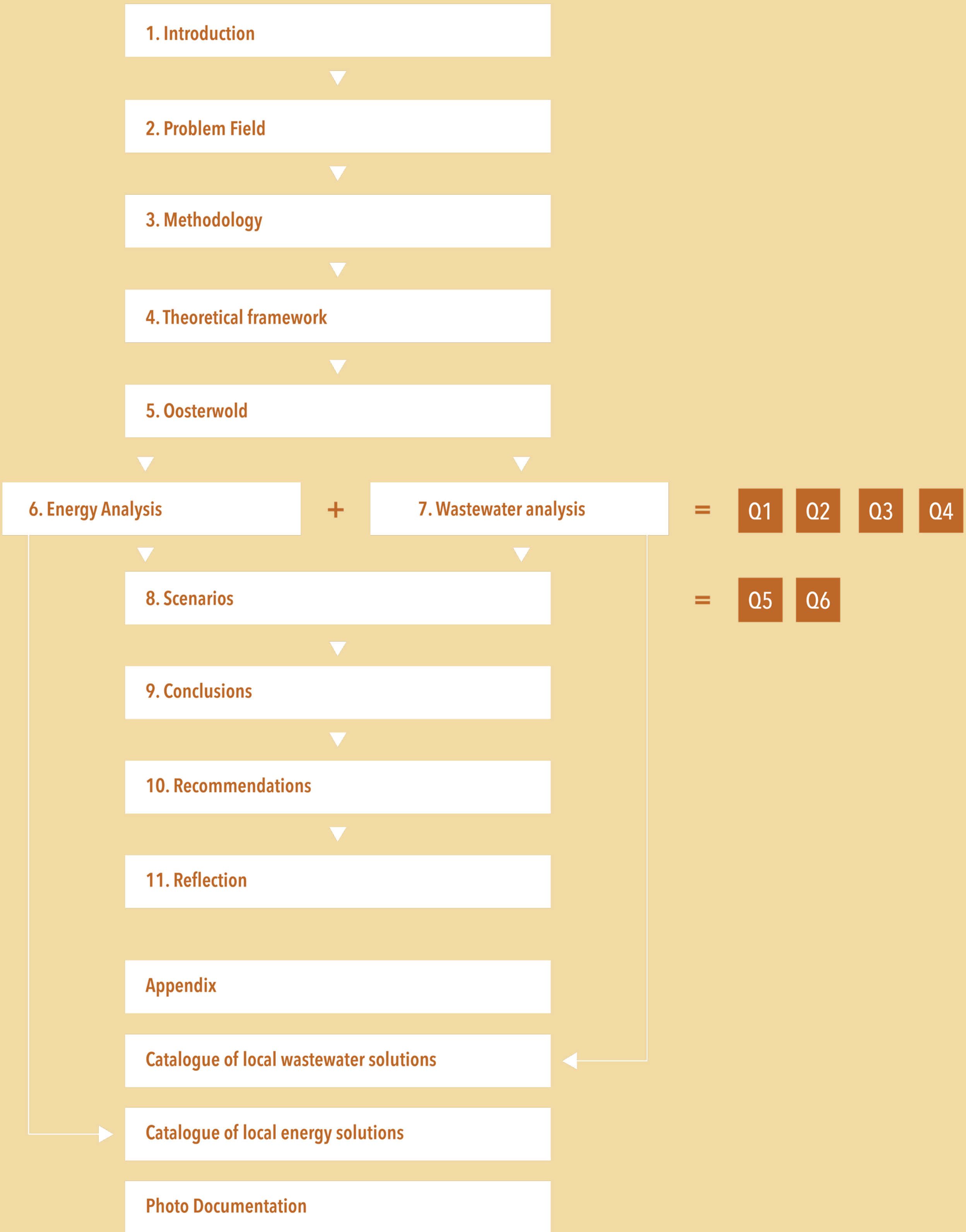

Markermeer
Flevopolder
Almere
Almere
Phase 1
Since 2015
Phase 2
From 2021
Oosterwold
Huizen
0 m
500 m
1000 m
N

scales of implementation as inhabitants can choose to work together or develop individually. The 1000 households that have been developed in the past decade provide an understanding of these different practices and their consequences. Simultaneously, the remaining 14.000 households that will be developed in the future in the second phase of the neighborhood may benefit from this research.

1.5 Relevance: input for decision and design processes surrounding local essential service systems

This research is first and foremost relevant for future spatial planning in Oosterwold as the local government or inhabitants can use the results to improve the decision or design process regarding essential services. These (design) decisions can relate to the type of system, the scale of implementations or the specific location of a system. Furthermore, the local government can use the results to implement or improve policies regarding essential services in Oosterwold in order to guide inhabitants and foster sustainable development. Similar future initiatives or developments can use this research for similar reasons.

On a larger scale, this research can be relevant for the profession of spatial planning. Due to an increase in local essential service provision, spatial planners are required to understand what the consequences are of local essential service provision in order to successfully and sustainably integrate these systems within the built-environment (Moroni & Tricarico, 2018). This research can aid in closing the existing research gap, opening up the conversation and reflecting on the current practice of implementing essential service. Furthermore, it can contribute to the discussion on the viability of organic urban planning in relation to essential service provision.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1.6 Main research questions

The main research question that guides this research is as follows:

RQ: What are the land-use intensity, environmental impact and environmental risks associated with the provision of local essential services on different levels of autonomy in Oosterwold, and what recommendations follow from these insights for spatial planning?

The main research question is further broken down into five sub-questions which are all answered in corresponding chapters. Together these chapters and corresponding sub-questions address the main research question.

Q1: What are the advantages and disadvantages of providing local essential services compared to the common centralized essential service provision in the Netherlands?

Q2: What is the impact of local essential service provision on land-use intensity, environmental impact and environmental risks?

Q3: How are essential services provided in Oosterwold and what patterns have emerged?

Q4: What are the possible systems for the provision of essential services in Oosterwold?

Q5: What are relevant scenarios for the level of autonomy of future essential service provision in Oosterwold?

Q6: What are the land-use intensity, environmental impact and environmental risks of essential service provision in Oosterwold based on different scenarios?

1.7 Reading guide

Following this chapter, chapter two describes the challenges of implementing local essential service systems from the perspective of spatial planning. In the third chapter we discuss the main methods used during this research and the desired outcomes. In chapter four the leading theories – self-organization theory and system theory - behind the research and the (local) provision of essential services are explored. Chapter five briefly introduces the neighbourhood Oosterwold and the concept of organic urbanism. In chapter six and seven, local essential service provision is analysed in theory and in practice in Oosterwold. Chapter six discusses energy production while chapter seven discusses wastewater treatment. The catalogues of solution are a product of these chapters and important input for the next chapter. These chapters answer the first four research questions (Q1, Q2, Q3 and Q4). In Chapter eight a research by design approach is used in order to answer Q4 and Q5. In chapter nine the conclusions to research questions are summarized. Chapter ten lists a number of important recommendations for spatial planning and Oosterwold based on the conclusions. The last chapter reflects on the research process and methods used within this research.

The challange of implementing essential service systems

2.1 The decentralization of essential service systems

A local, more integrated approach towards essential service systems is seen as an answer to the growing demand for circular, renewable and sustainable essential service provision. The decentralization of energy production and wastewater management has been advocated by many influential writers since the 1970's (Phent, 2006, p. 11). Now that the technological possibilities have caught up with the philosophy, the decentralization of essential service systems – especially in energy production - is becoming an actual trend in many parts of the world as well as in the Netherlands. We see this for example in the increase in energy cooperations from their introduction in the 90's towards around 280 in 2012 (Schwencke, 2012). The decentralization of wastewater treatment and energy production requires a deep structural change in the relationship between the state and civil society (Max-Neef, 1991). Researchers agree that in order to implement decentralized facilities, government has to cooperate with local actors (citizens) or hand over part of the responsibility for essential service provision (Adil & Ko, 2016; Wolsink, 2018; Brown, Cloke, & Harrison, 2015). Decentralization is therefore often combined with the privatization of essential service provision, consumers are becoming 'prosumers'. This is also why the Climate Deal in the Netherlands strives towards 50% local ownership of wind and solar technology for energy production.

2.2 The decentralization of essential service systems and spatial planning

The aforementioned decentralization of essential service provision has consequences for the profession of spatial planning. Essential services used to be delivered through a network of cables or pipes leading towards wastewater treatment or energy production units at the fringe of society: out of sight and out of mind. With local essential service provision these units are placed at the centre of communities which means they need to be taken into account during the design. Furthermore, these small-scale systems have to satisfy local consumption patterns and conditions and provide a similar reliability compared to centralized provision. This requires spatial planners to acquire in-depth knowledge regarding essential service provision in order to safely and sustainably implement these small-scale systems. As a result, essential service provision is becoming a new field of research and work for spatial planners often with the aim of designing and creating coherent and integrated essential service systems in tune with the built environment (Moroni & Tricarico, 2018).

2.3 The urban metabolism framework and essential service provision

Understanding the flows of resources and waste within an urban area is usually the first step towards understanding the systems that facilitate these flows. To understand these resource flows and consequently essential service provision, spatial planners make use of the Urban Metabolism (UM) framework. An Urban Metabolism (UM) framework or model facilitates the analysis and description of the resource flows within an urban area, often in relation to ecological, social or spatial processes (Dijst, 2018). It does so through a quantification of energy or material flows. The Urban Metabolism framework was first developed in the 1960's in a response to the environmental damage of cities and deteriorating living condition in cities. (Kennedy, 2007). The aim of UM research is that by studying and understanding the relationship between urban areas and consumption, the concept of UM can generate possibilities for change and improvement and increase the sustainability of an area (Pincetl, Bunje, & Holmes, 2012). Essential service systems are in this case the systems that facilitate this relationship.

2.4 A lack of knowledge regarding the dynamics of local essential service systems

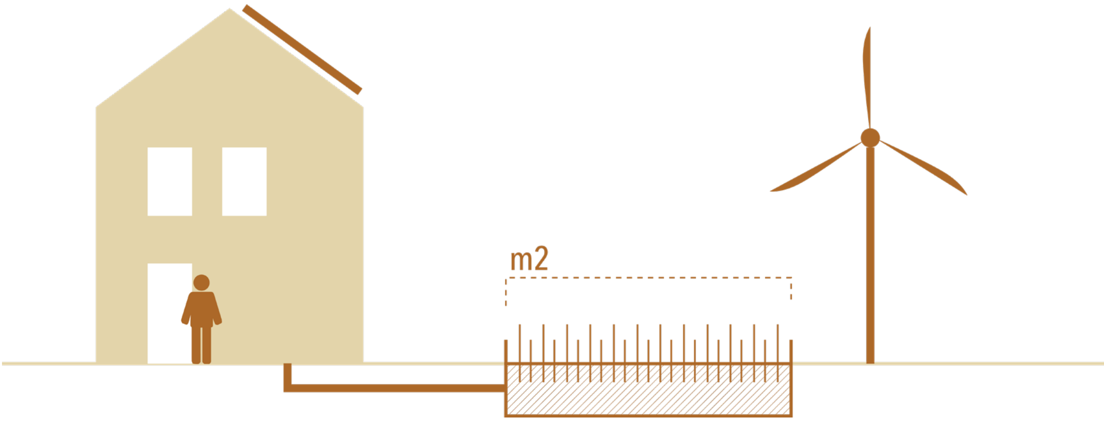
The UM framework can provide clarity on the resource consumption and accompanying essential service systems of an area, however, the UM framework has been criticized for its relative lack of providing practical information for decision-making and design (Longato, Lucertini, Fontana, & Musco, 2019). This leaves spatial planners without the necessary tools to implement and understand local essential service systems. Academic literature focusses mainly on the emergence of local essential service provision and the possible advantages of this trend. Researchers thereby neglect the possible disadvantages, the diversity of system possibilities or differences between scales and the general impact of local essential service systems on the built environment and their residents (Adil & Ko, 2016; Wolsink, 2018). In other words, current frameworks and literature available to spatial planners do not comprise the dynamics of local essential service provision. Consequently, spatial planners are at a loss when it comes to safely and sustainably integrating essential service systems within a community, determining their scale of application or applying systems that dovetail with local conditions.

2.5 The challenges of implementing local essential service systems

There are multiple challenges that arise in spatial planning when implementing essential service systems directly within the built environment. Three important challenges that have provided the base for this research are mentioned below: pressures on land-use, the impact on the environment and the environmental risks associated with essential service provision. Every challenge is accompanied by an indicator used within this research in order to explore this challenge and provide guidance for spatial planning, particularly in Oosterwold. These challenges provide an important framework for choosing a particular system and scale of application depending on the environment.

2.5.1 Pressures on land-use

Land is a scarce resource especially in the densely built environment of the Netherlands. The possibility for a local approach to essential services is therefore often constrained by the amount of available land (Energie & Ruimte, 2017). This is a challenge because many novel forms of energy production require higher amounts of land compared to the traditional energy infrastructure in the Netherlands. Both for energy production and wastewater treatment the land use is higher compared to centralized systems. This poses a challenge for the implementation of essential services in spatial planning and makes land-use an important factor to consider. However, there is a lack of up to date information on land-use which needs to be addressed in order to enable pragmatic policies and planning of local essential service systems (Boer, et al., 2015).



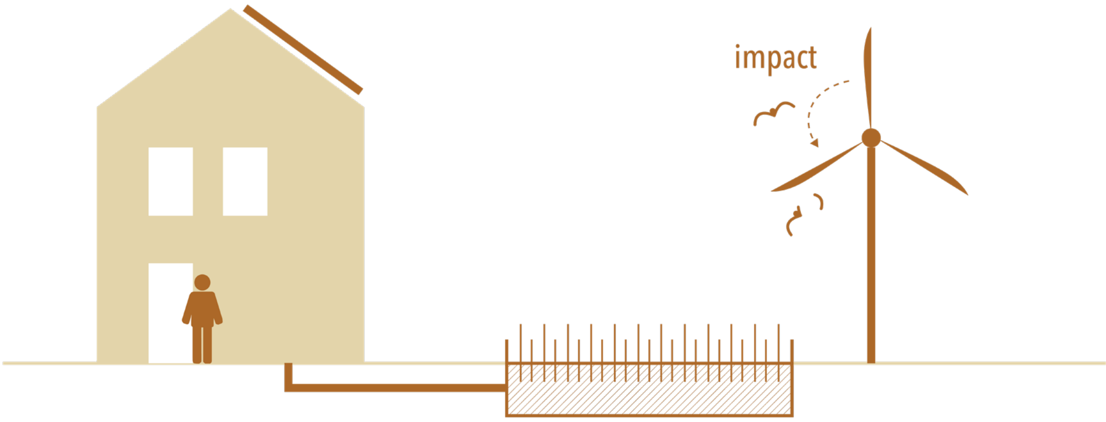
3. Considering land-use while implementing essential services

Land-use intensity

Land-use intensity is introduced as a parameter indicating the impact of essential services on the landscape. The land-use intensity is an indicator for the productive capacity of the land when a certain technology is used. For example, the total amount of energy (kWh) which can be generated on one square meter can indicate the land-use intensity of solar panels. When combined with the consumption, the total land-use can be calculated. Land-use intensity is used rather than land-use given the relative ease of comparing different land-use intensities as it directly refers to the land-use efficiency of an essential service system. The land-use intensity can therefore be a powerful tool to understand the impact on the landscape and is often used as a measure for sustainability (McManus & Haughton, 2006).

2.5.2 Impact on the environment

Even though more renewable, circular or natural techniques for wastewater treatment or energy production are associated with a decreasing impact on the environment, every technology will end up affecting the landscape or environment (Wolsink, 2018). Moreover, the increase in vicinity towards households makes determining the environmental impact even more important. Where large-scale wastewater treatment facilities or power plants are often placed at the periphery, local techniques are placed at the centre of households or communities. Both the impact on citizens, due to sounds, increased visibility or smell, and the impact on the environment, due to pollution or ecological damage, are important factors to consider. For example, according to Wolsink (2018), the visual impact of local energy production is one of the main obstructions for the implementation of solar and wind energy. By understanding the environmental impacts, negative impacts can be avoided through an adjustment of planning procedure (Delicado, Figueiredo, & Silva, 2016).



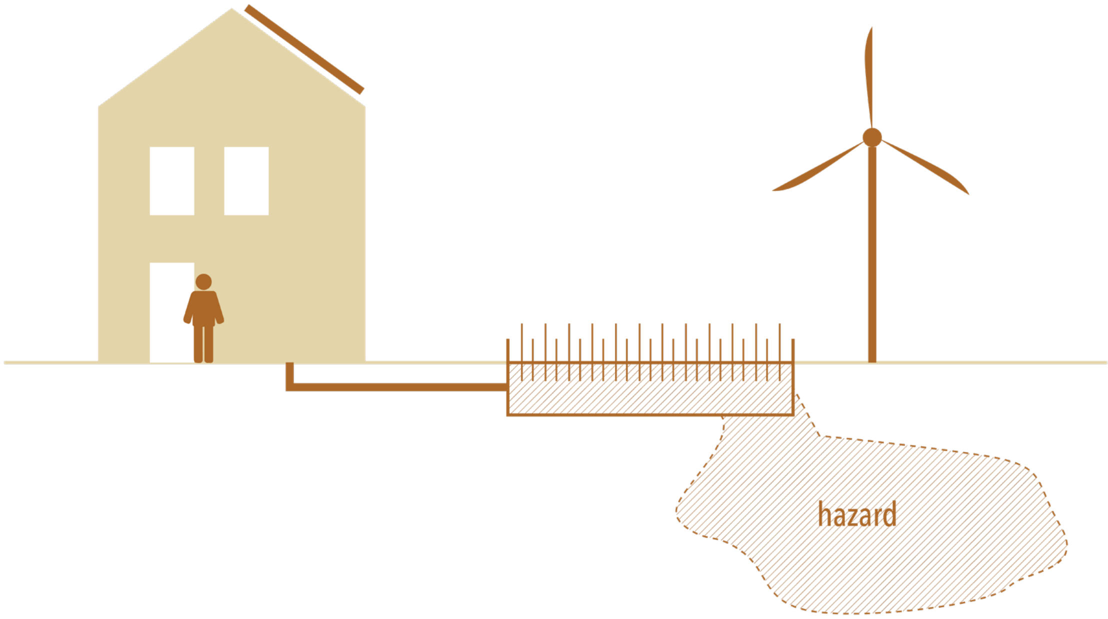
4. Considering the environmental impact while implementing essential services

Environmental impact

In identifying potential impacts related to the physical, chemical, biological, cultural and socio-economic components of the total environment, an assessment of the environmental impact can be made (Mareddy, 2017). In this research we focus on the impact that directly affects the people in the surrounding environment or the degradation of ecology. This means the aspects visibility, odour, air quality, noise and ecological degradation are explored (Delicado, Figueiredo, & Silva, 2016). The indirect impacts are not assessed as these are made elsewhere during construction, mining or waste disposal (Letcher & Fthenakis, 2018).

2.5.3 Possible environmental hazards

Failures within essential service provision can create environmental hazards that should be avoided (Rathnayaka, Potdar, & Ou, 2012). This is especially important within a local setting as people live in the vicinity of these systems. Risk management is therefore an important aspect when implementing essential service system. On top of that, local actors have limited knowledge on the dynamics of essential service provision such as maintenance and monitoring or the placement of technologies according to their risks. Furthermore, most technologies for local essential service provision are novel and policies to prevent hazards are not always in place. The environmental risks are spatially relevant as they can provide input for a safe distance or application of material and therefore provide the necessary protection for inhabitants and the environment (Basta, 2012).



5. Considering the environmental impact while implementing essential services

Environmental risks

Environmental hazards are related to the environmental impact of essential service provision, however, the impact is a general consequence of the implementation of essential service while a hazard is a potential consequence in case a failure occurs. Environmental hazards can create negative consequences both for the environment or the health of nearby inhabitants (Basta, 2012). To fully understand the risks of an environmental hazard and apply adequate risk management through spatial planning, it is important to estimate the possible level of damage and the probability it will occur (Stephenson, 2008). This probability is mainly based upon the chance of failure within a system or failure due to the human-technology interaction.

Exploring local essential service provision

The goal of this research is to explore the land-use intensity, environmental impact and environmental risks of essential service systems and how these change on certain levels of autonomy in Oosterwold. In order to fulfil this goal a number of methods and approaches are used to generate data and draw conclusions. The following paragraphs explain the research type, methodological approach and methods used within this research.

3.1 Research type: Exploratory Research

This research is conducted through an explorative approach. Exploratory research is used to "tackle new problems on which little or no previous research has been done" (Brown, 2006, p. 43). It does not intend on providing definite solutions but more an exploration of research questions (M. Saunders, 2012). In doing so, exploratory research provides a more extensive overview of existing knowledge or knowledge gaps, and provides a practical basis for further, possibly more conclusive, research (Jaeger & Halliday, 1998). The reason for this approach is twofold. Firstly, spatial planning is usually carried out by prescriptive forms of planning and research but more recently the profession is moving towards more exploratory forms of research. This is due to the rapid changes in economic, environmental and social conditions that are hindering prescriptive planning and encouraging a more flexible and experimental approach (Balducci, Boelens, Hillier, Nyseth, & Wilkinson, 2011). Especially in Oosterwold this is apparent as the neighbourhood has an organic bottom-up planning approach with high levels of uncertainty and with limited or no involvement of spatial planners. Secondly, local provision of essential services is a new approach within the Netherlands. This has led to the introduction of many new technologies which pose new challenges and research areas where spatial planners could play a role. Due to the novelty of this approach, there is little prior general knowledge, data or research available.

Even though exploratory research can provide a good understanding and basis for further research, there are two limitations that should be considered and reflected upon. First of all, due to the lack of prior research and data, exploratory research generally consists of small sample sizes and findings. Generalizing the findings or providing definite conclusions is therefore impossible or more difficult limiting the relevance of the research (University of South California, 2020). Secondly, the flexible but unstructured research approach leads to tentative results which reduces the value for decision makers (Balducci, Boelens, Hillier, Nyseth, & Wilkinson, 2011). In both cases, it is important to present a transparent data collection process, discuss the relevance and validity of conclusions and differentiate between the theoretical relevance and practical relevance (if there is any). Therefore, for every chapter the range of theoretical (or practical) knowledge that was explored is shortly discussed and evaluated at the end of the research.

3.2 Methodological approach

The topic of local essential service systems within spatial planning is explored through two methodological approaches: case study research and research by design. Both approaches complement each other as the case study is used as a base to conduct research by design.

3.2.1 Case study

This research is conducted through the use of a single case study: Oosterwold. Within case study research, the researcher tries to fully understand the complexity and context of one specific situation in order to answer research questions (Bryman, 2012). The reason case study research is adopted within this research is firstly due to its effective combination with exploratory research. Case studies offer breadth and diversity in terms of data collection and can reveal different perspectives on one research topic. The search for answers to research questions can be facilitated through the recognition of patterns in the collected data (Birch, 2012). This can provide a good base for defining questions and hypotheses for further research as is generally the case with exploratory research (Yin, 2003). Secondly, case studies are a natural tool and more than appropriate research strategy for the practice-based discipline of spatial planning (Birch, 2012). A case study is appropriate for dealing with a subject that is “context dependent, complex, unusual, or where there is some ambiguity” which is often the case in spatial planning (Adolphus, 2011). This is also important in this research as the land-use, environmental impact and environmental risks associated with the implementation of local essential service provision, depend upon a specific context. Lastly, the usage of a case study increases the practical relevance of this research. The conclusions made at the end of this research should be useful for the further development of Oosterwold.

Even though case study research is a useful and applicable tool for this research, there are two drawbacks around this approach. First of all, it can decrease the overall theoretical relevance as the research becomes more context specific. By studying Oosterwold, conclusions can become too specific or ambiguous for the general profession of spatial planning. Especially since Oosterwold adopts a different approach to spatial planning (organic urbanism) compared to conventional spatial planning in the Netherlands. A clear distinction is therefore made between context-specific recommendations for Oosterwold and general recommendations for spatial planning. Also, a single case study cannot yield sufficient volume of evidence to support general conclusions (Birch, 2012). However, in this particular case, Oosterwold represents a collection of multiple case studies. Due to its unconventional spatial planning methods, the neighbourhood harbours a large diversity of different approaches with respect to essential service systems. This is why the adoption of a single and unique case study within this research is still seen as a valid choice to provide reliable answers to research questions. Information on the case study is provided in chapter 5 ‘Oosterwold’.

3.2.2 Research by Design

A ‘research by design’ approach is used in order to explore different possible futures for essential service provision and provide insight into the research topic. Research by design uses design as a method to produce new knowledge about the world (Hauberg, 2011). J. Hauberg (2011, p. 46) explains research by design as "the possibility of expressing the qualitative aspects of the world and adding something new to the existing through experiments and proposals." However, not all research that involves design follow the research by design form. According to R. Roggema (2016): "[Research by design] occurs when the designing is used as a means of exploring the spatial possibilities of and developing a new programmatic infill for a given site." Research by design makes the research process reflective and helps the researcher to fully grasp the complexity of the research topic. It helps to formulate answers or define trends where the answers wouldn't be found with regular research thinking (Roggema, 2016). Due to the experimental nature of research by design and its goal to provide insight or define trends, it is an appropriate approach for exploratory research (Tjeerd Plomp; Nienke Nieveen, 2007). Furthermore, the method is often used when dealing with complexity and uncertainty and is therefore an important method of inquiry within urban planning as the necessity to create new knowledge and innovate is widely experienced (Hauberg, 2011). Research by design is therefore seen as a valuable tool in research and decision making and applied within this research to explore the design of essential service systems.

3.3 Methodological framework

A number of qualitative and quantitative methods are used in order to conduct explorative research into the integration of essential services within the built environment. The choice for using mixed methods stems from the idea that a single methodology would limit the exploration of all components within the research topic. Multiple literature reviews are used to approach the topic and understand the theories, present body of knowledge and background of the case study when it comes to the implementation of local essential services. Site visits and interviews were used to explore the development of essential service systems in the case study Oosterwold. Scenario planning and the maximization method were used in order to conduct research by design and further explore the research topic.

3.3.1 Literature review

In general, it is important to build new research on existing knowledge (Snyder, 2019). Within explorative research specifically, it is important to provide an overview of existing knowledge and gain insight into the research gaps. A literature review is in this case a useful tool to uncover what has been written on a subject or topic (Paré & Kitsiou, 2017; Snyder, 2019). It can both provide a background analysis and create an overview of existing research to guide decision-making in research or practice. In this research, a 'semi-systematic literature review' is adopted which moves beyond the limitation of searching for relevant information within a single discipline but explores literature from multiple disciplines (Snyder, 2019). This type of literature review is used since the topic touches upon multiple disciplines and research is generally scarce. The search within one single discipline or field of knowledge would therefore hinder the explorative approach that is taken within this research. Furthermore, spatial planning is a multi-disciplinary profession and therefore a semi-systematic literature review can provide relevant conclusions for the profession.

A limitation of semi-structured literature reviews is that covering broad topics and different types of studies can dilute the research goal and jeopardize the validity of the research. This can be mitigated by adopting a transparent research process enabling the reader to "assess whether the arguments made were reasonable" (Snyder, 2019). This transparency is founded by defining the scope of the literature review and addressing the sources on which remarks are based. The method is used in multiple chapters. In chapter 4 it is used to understand the different theories surrounding the implementation of local essential services. In chapter 5 it is used to understand the case study Oosterwold. Chapter 6 and 7 are also supported by a literature review to understand the decentralization of wastewater treatment and energy production as well as the associated changes in land-use, environmental impact and environmental risks.

3.3.2 Site visits

In this research, site visits are used to explore Oosterwold and gather information on the neighbourhood. Site visits or field work is a method with which information is gathered about a topic by visiting a site for a limited amount of time and reporting on the experience or observations (Lawrenz, Keiser, & Lavoie, 2003). Through observations of physical traces on a site or area, data can be gathered and analysed in order to answer research questions. Specific data collection methods used during observations are photographs, maps and simple counting which are also used within this research (Zeisel, 1981). This method is often used in environment behaviour research and spatial planning with the goal of understanding how people use space and make decisions considering their surroundings (Zeisel, 1981). Since Oosterwold develops organically, the implementation of essential service systems is unstructured and diverse. Moreover, there is no (public) data on the implementation and development of essential service systems in Oosterwold. Only through site visits and physical observations it is therefore possible to understand and collect data on essential service provision in Oosterwold.

An important limitation of site visits is the guarantee of validity as observations can quickly become biased by the researcher. By taking time to prepare site visits and create transparent documentation afterwards this can be mitigated (Zeisel, 1981). The conclusions of the site visit can be found in chapter 6 and 7 and a photo documentation of the site visits is provided in the additional booklet 'Photo Documentation'.

3.3.3 Interviews

Interviews are used in order to develop a qualitative and quantitative understanding of the implementation process of essential services in Oosterwold. Through conducting an interview, insight from a person on a particular topic can be included (Wilson, 2012). Within this research both semi-structured interviews and structured interviews were conducted.

Two semi-structured interviews were conducted in order to generate an understanding of the perspectives from government (the 'area team') on the provision of essential services, and from an

inhabitant as these are the two main players in the development of essential services in Oosterwold. Semi-structured interviews incorporate both open-ended and more theoretically driven questions that are clearly connected to the purpose of the research (Galletta, 2013). This interview method suits explorative research as the researcher is less restricted in the exploration of the topic during an interview compared to structured interviews. Questions are generally open-ended in order to create space for the participant to share his or her experience. However, they strongly guide the participants towards the theme and purpose of the research (Galletta, 2013). This produces a set of qualitative data that can be compared and analysed. Analysing and comparing data from different unstructured interviews is seen as a challenge and limitation of this research method due to the differences in the articulation of answers and experiences between respondents (Wilson, 2012). An open and transparent data generalization process can link answers of respondents without losing the validity of this research method. However, in this research the interviews were not used to understand the differences between perspectives, but rather to further understand and explore the insights found during site visits and in documents. Therefore, interviews were not compared but summarized and used as a source of information to support other evidence. The results can be found in Appendix 1.2 and 1.3.

Structured interviews were used in the form of a survey which was conducted to understand the result of the development of essential services in Oosterwold as there was no available data on this matter. A structured interview incorporated a fixed set of questions and answers (Rowley, 2012). This fixation of questions and answers ensures the generation of quantitative data if answers are analysed. The challenge in structured interviews is to ensure the questions and answers reflect the possible perspectives of the respondent. One way to ensure this is to add the possibility for an open answer to the list of possible answers (Rowley, 2012). The validity of this research method increases alongside the number of respondents (or the 'response rate'). In this research only five inhabitants have responded to the survey which makes the validity questionable. Therefore, the results of this research method were not taken into account apart from the 'open' answers. The results are still presented within Appendix 1.3.

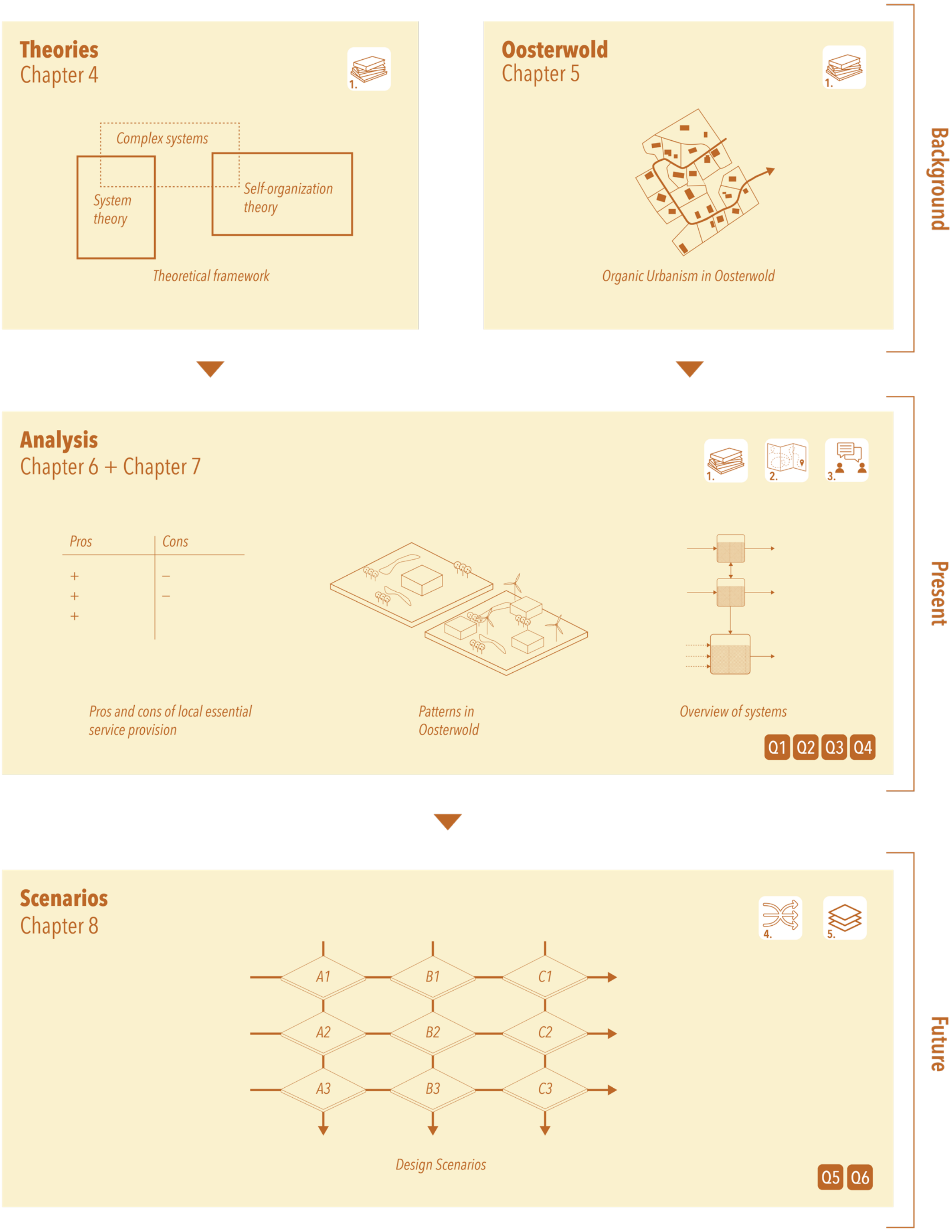
3.3.4 Scenario planning

Scenario planning is used to determine a set of relevant scenarios for the future development of essential service systems in Oosterwold. It is part of the research by design approach further exploring the possibilities of essential service provision. Scenario planning is an often-used method within urban planning due to the usefulness of the tool to define the uncertainty and complexity of a (future) urban area (Ljubenovic, Mitkovic, & Mitkovic, 2014). Through intuitive logics based on complex socio-technical factors, a set of scenarios is generated (Ljubenovic, Mitkovic, & Mitkovic, 2014, p. 84). The method encourages strategic thinking and helps to overcome limitations with the goal of improving decision making or design (Goodspeed, 2017). There are two types of scenario planning methods: normative and exploratory. Normative scenario planning seeks to generate one preferred scenario by analysing multiple options and is the most common form of scenario planning. It assumes a large degree of control in the future. More recently, scholars are adopting exploratory scenario planning with the goal of generating information rather than providing a preferred scenario. Here the method is based upon the uncertainties and lack of control in the future and looks at the factors that can influence the decision-making process rather than the other way around (Avin & Godspeed, 2020). This type of scenario planning is adopted as this research also seeks to explore rather than to provide solid answers and conclusions. As Oosterwold develops organically the future is highly uncertain and the implementation of essential services (and impacts of this implementation) depends upon factors outside of the decision-making process within government.

There are two important aspects of scenario planning that need to be considered to provide the necessary validity and increase the relevance of conclusions. First, the consistency between the different scenarios is an important factor in order to compare different findings (Ljubenovic, Mitkovic, & Mitkovic, 2014). In other words, the variables that are not important to the research but can result in a change of the outcome need to be 'fixed'. This is especially challenging and time-consuming in exploratory scenario planning as the definition and search for variables is more complex compared to normative scenario planning (Avin & Godspeed, 2020). A transparent and clear definition of the 'fixed' variables is therefore necessary in order to prove the consistency and validity of the scenarios. These variables are defined in chapter 8 and appendix 3.2. Secondly, the plausibility of scenarios is important in order to create relevant conclusions for the situation at hand. The plausibility of scenarios can be increased by conducting a (morphological) analysis of the current situation (Ljubenovic, Mitkovic, & Mitkovic, 2014). If this is not possible, which is often the case in exploratory scenario planning, Avin & Goodspeed (2020) stipulate the inclusion of important stakeholders during the formation of spatial scenarios to provide a direction or give feedback. In this research however, it is possible to conduct an analysis as part of Oosterwold is already developed. This analysis can be found in chapter 6 and 7. The scenarios that were explored within this research can be found in chapter 8. In total, three different scenarios were defined.

3.3.5 Maximization method

The maximization method is used within this research to explore and understand the spatial implementation of essential service systems. The maximization method is a useful tool for the implementation of essential service systems as it connects environmental themes - such as wastewater treatment and energy production - with the spatial elements of an area. Generally, the maximization method is used within an urban design process to foster sustainable development by incorporating a broad range of environmental themes (flora and fauna, landscape and soil, water, traffic, energy, household waste, residential environment and materials) at the initial phase of a design process (Roo, Visser, & Zuidema, 2012). This assures all design choices are in coherence with the environment and geared towards sustainable development (Eijk, 2001). The maximization method consists of four phases: location analysis, maximization of different themes, environmental optimization and the integration within the urban design (Roo, Visser, & Zuidema, 2012). The location analysis gathers the necessary information and explores the chosen environmental themes. The maximization phase explores how the different themes can be 'maximized' according to their spatial implementation and sustainability (however this is defined). The optimization phase combines the different themes into one 'optimized' spatial plan. This optimized spatial plan can be combined or



6. Methodological Framework

used as an informational layer for the eventual urban design in the last phase. By applying this method and implementing essential service systems within the built environment, the consequences (land-use, environmental impact and environmental risks) of wastewater treatment and energy production can be understood.

The limitation of this method is the general denial of other (important) aspects within the design process when the focus is solely placed on environmental themes (Eijk, 2001). Within practice this is seen as a problem and the method is therefore rendered irrelevant. Within research, however, this aspect can become an advantage as it is possible to understand and explore a single subject without the interference of other themes. This limitation is therefore convenient for this research where the focus lies on the exploration of the consequences of essential service systems rather than their practical implementation. The maximization method is applied in chapter 8. In total, three different maximizations are conducted. Combined with the different scenarios this leads to nine different designs.

3.4 Methodological framework

The methodological framework provides an overview of the methods used within the different parts of this research. The research can be split into a background phase which consists of the two following chapters, an analysis of the present in chapter 6 and 7, and future scenarios in chapter 8. The background is mainly supported by literature studies, the analysis by literature studies, interviews and site visits and the scenarios by scenario planning and the maximization method (see top right corner). The results due to the used methodologies are visualized within each box. This answers the sub-research questions presented in the down right corner and consequently answers the main research question.

3.5 Summary

To conclude, this research tries to explore the relationship between essential service systems on a certain level of autonomy and the consequences for the land-use intensity, environmental impact and environmental risks in the neighbourhood Oosterwold. Due to the limited data and available research on this topic, exploratory research is used to achieve an understanding of the topic. A case study provides the necessary practical insight as theoretical data is scarce. A literature review, interviews and site visits are used to collect data and draw conclusions considering the research topic and case study. A research by design approach is adopted as this approach allows for experimentation with the collected data. Scenario planning and the maximization method allow for this experimentation. The largest limitation of exploratory research and many of the methods provided is the gathering of data as the large scope (due to the limited available research) can dilute conclusions and become subject to bias of the researcher. A transparent research process and strong evaluation at the end of the research can secure the validity of the research and expand its relevance.

Self-organization of essential service systems

The overarching aim of this research is to foster sustainable urban planning through the implementation of essential services. Sustainable urban planning is however a broad topic and many different theories, approaches and definitions exist. In this theoretical framework we therefore start with the general definition and approach towards sustainability in sub-chapter 4.1 and why small-scale and local essential service provision is seen to foster sustainable development through the concepts of ecological autarky and appropriate technology. These concepts and the phenomena of local essential service provision can be understood and explored through self-organization theory (4.2) and system theory (4.3). Both theories are used within this research to explore essential service provision in Oosterwold. The information presented within this theoretical framework is based upon literature research.

4.1 Sustainability: a balance between population, affluence and technology

The past two centuries people are becoming increasingly worried about the impact of human activity on the environment and how this influences the capacity of that environment to provide resources and shelter. It started with Thomas Malthus who described the potential dangers of exponential population growth while food supply would only grow in a linear pace and was limited by the total earth capacity (An Essay on the principles of Population, 1798). He stated that "the power of population is indefinitely greater than the power in the earth to produce subsistence for man" (Malthus, 1798, p. 13). In 'A road to survival' (1948) William Vogt came to identical conclusions and was convinced that only population control could prevent an environmental (and therefore human) disaster. The planet would always be confined to a maximum carrying capacity which could run out and have serious consequences for humanity (Mann, 2019). The popularity of the book gave birth to the environmental movement which produced scholars like Rachel Carson who wrote 'Silent Spring' (1962), Paul Ehrlich with 'The population bomb' (1968) and Donella Meadows and her team with 'Limits to growth' (1972). Especially in the last two decades the environmental movement has gained momentum due to the trending debate on climate change. In order to understand this dynamic between humans and their environment, and more particularly to understand the human impact on the environment, Barry Commoner, Paul R. Ehrlich and John Holdren developed a mathematical equation to describe this relation (Karplus & Kissinger, 2014):

*Impact = Population * Affluence * Technology*

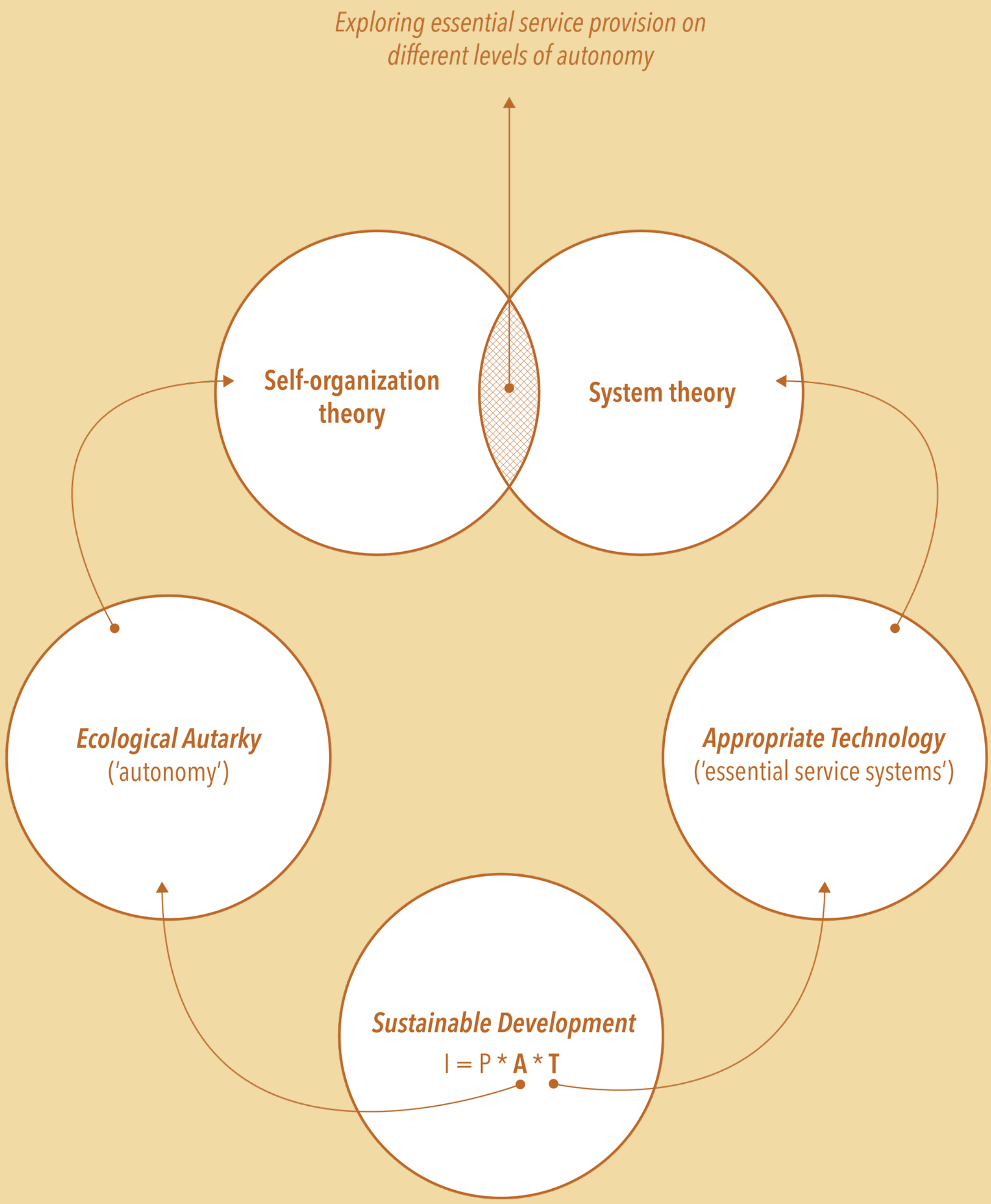
In this notation the population, affluence (consumption) and the efficiency of technology are described to play a role in the impact of humans on their environment. In order to reduce this environmental impact and increase the sustainability of society, either population, affluence or technology has to change. The concepts of 'ecological autarky' is focused on the decrease or restriction of affluence while the concept of 'appropriate technology' is focused on finding efficient and integrated technology. Both concepts explain the increasing attention towards local essential service provision.

4.1.1 Reducing affluence through 'ecological autarky'

Ecological autarky refers to a state of autonomy, self-sufficiency, or independence of the environment or ecology outside certain spatial boundaries (Godfrey, 2008). This means someone or a group of people is dependent on the capacities of their own defined environment to provide sustenance, resources or ecosystem services. Relying solely on a particular part of the environment arguably leads to a consideration of affluence because it prohibits the consumption of resources outside of that boundary and therefore prevents overconsumption (M. F. van Dartel, 2014). Simply put, ecological autarky is the privatization of the environment and resources. In this way the environment is maintained because people are directly affected by the consequences if their affluence exceeds the maximum carrying capacity. There is critique on the concept of ecological autarky, specifically on the feasibility, desirability and overall increase in sustainability when applied (M. F. van Dartel, 2014; Timmeren A. v., 2007). How realistic is it that boundaries are properly drawn according to a fair share of resources? And is privatization desirable? And if people over-consume within their boundaries, similar to what we are doing right now, then how is that sustainable? Particularly in a privatized world it is difficult to pass legislation regarding more sustainable practice (Timmeren A. v., 2007). Even so, the concept has been embraced by the environmental movement and widely applied by policy makers who seek to increase the sustainability of households, cities or even countries through the application of ecological autarky. This is also the case in Oosterwold where autonomy or self-sufficiency is seen as the key strategy that makes the neighbourhood sustainable. Whether inhabitants cooperate with others or choose to be autonomous on their own, ecological autarky is the goal.

4.1.2 Improving technology through 'appropriate technology'

The concept of 'appropriate technology' can be defined as a technological solution that is "compatible with local, cultural, and economic conditions (i.e., the human, material and cultural resources of the economy), and utilizes locally available materials and energy resources, with tools and processes maintained and operationally controlled by the local population" (Hazeltine & Bull, 2003). This relates to the question of technology in the equation of human impact posed above. Appropriate technology is focused on a small human-scale application of technology. By going back to a human scale, human needs and relationships are again at the heart of society which fosters a response of stewardship to the environment. The concept is drawn from the 'small is beautiful' ideology which strives to empower people and communities a reaction towards the ongoing centralization and globalization (Schumacher, 1973). According to this ideology large-scale existing structures should be reconsidered or even demolished creating new identities, a larger freedom of expression for the individual and less dependency on large complex institutions (Timmeren, Röling, & Tawil, 2005). Even though the concept of appropriate technology and ideology of 'small is beautiful' became widely accepted, the application of technology was still difficult due to the complexity of implementing technology on a small scale and the low level of robustness of techniques on this level (Zelenika & Pearce, 2011). The recent increase in more robust and small-scale varieties of technology (such as solar panels, household CHP's or compost toilets) has decreased these concerns and led to an increase in the implementation of 'appropriate technology'.



7. Illustration of the theoretical framework as presented within this chapter

4.2 Self-organization theory

From a general point of view, self-organization describes the spontaneous emergence of order out of disorder (Boonstra & Rauws, 2016). This order is the product of interactions between parts of or elements of a system. This process is always spontaneous, autonomous, and locally driven without any external influence (Heylighen, 2001). The process of self-organization was first discovered in mathematics and mainly applied in the natural sciences (Zhang, 2016). Here it fostered research such as the emergence of thermodynamic systems in physics (Prigogine, Bingen, & Jeener, 1977) or the reproduction and self-maintenance of ecosystems in biology (F.G.Varela, H.R.Maturana, & R.Uribe, 1974). The organization of atoms or parts were the main focus of these studies. However, later self-organization was also adopted in the social sciences where it predominantly received attention from economics and sociology (Zhang, 2016). In these studies atoms became agents widening the concept and usage of self-organization.

In the field of spatial planning the theory of self-organization is both used from a natural and social point of perspective. Especially in the last decades self-organization theory has become popular as urban planners use the theory in order to explore the uncertainties and complexities of urban planning (Boonstra & Boelens, 2011; Meerkerk, Boonstra, & Edelenbos, 2011; Zhang, 2016). Where uncertainty and complexity were previously countered by rigid (often top-down) design, nowadays urban planners increasingly celebrate uncertainty and complexity as it is seen to create diversity and variability which can lead to urban vitality (Boonstra & Rauws, Conceptualizing Self-organization in Urban Planning, 2016). Therefore, self-organization is seen as a helpful theory in understanding this complexity to unravel the underlying mechanisms of urban dynamics and spatial transformations and eventually improve urban planning and design (Portugali, 2013). Self-organization is for example applied to patterns in traffic flows, the movement of pedestrians or the formation of slums. In this research self-organization theory is used to understand the different patterns that emerge in essential service provision in Oosterwold. These patterns are a consequence of the interactions between inhabitants and their decisions surrounding essentials service provision. The specific systems used for the provision of essential services are explored through system theory.

4.3 System theory

System theory describes the behaviour and organization of a system in order to understand the workings of natural or man-made structures (Stichweh, 2007). System theory was developed in 1940 in the fields of biology, physiology, information theory and cybernetics (Stichweh, 2007). It was in these fields that researches could no longer solely look at the elements in order to understand phenomena, but also had to describe their relation to each other. The goal of system theory is therefore to describe the dynamics, constraints or conditions of different interrelated elements in order to understand their inner workings.

The definition of a system is that it is an "interconnected set of elements that is coherently organized in a way that achieves something" (Meadows, 2008, p. 12). This means that a system must consist of three things to be defined as a system: elements, interconnections and a function or purpose (Meadows, 2008, p. 12). Elements can both be physical or non-physical but are the building blocks of a system. The interconnections are the relationship between those elements, how they communicate or interact. The function or purpose of a system describes why the system is made up of certain elements and interconnections. It is the sheer reason for its existence. Understanding these three things generates a general understanding of a system.

In system theory there are a number of concepts that describe the dynamics of systems and therefore generate an understanding of that system. The most commonly used concepts in system theory are 'stocks' and 'flows' (Meadows, 2008). The 'stocks' usually refer to the elements within a system where there is an accumulation of material. Depending on the system and subject of study this material is defined and depending on the time of study the quantity of this material can be determined. Through time, stocks of material can change through 'flows'. Flows are the movement of material from stock to stock over time and describe the interrelations between elements. The stocks and flows and quantity thereof depend on the function or purpose of the system. Through defining the elements, interconnections and purpose of a system and analysing the stocks and flows within that system it is possible to generate an understanding of the inner workings of systems.

4.3.1 System theory in relation to ecological autarky and appropriate technology

As explained, ecological autarky is the drawing of a (spatial) boundary on the environment which defines the type and amount of ecological resources available to a certain group of people or function. If ecological autarky is applied to a system, this means a boundary is drawn around that system which demarcates a limit to the system's internal components and processes. This means the system becomes autonomous in its function or purpose of ecological processes outside that boundary. The system in this case, refers to the elements that cater the stocks and flows of ecological resources, in order to provide essential services to the neighbourhood. This means that stocks and flows are also contained within the drawn boundaries.

The stocks and flows are usually guided by technology which refers back to the concept of 'appropriate technology'. In the context of system theory, appropriate technology refers to the technological systems that provide resources or treat waste, essential for the survival of local communities. This is done through a set of elements (such as a wind turbine, toilet or aquifer) that are interconnected (for example through sewers, wires or hot water pipes) to provide essential services (such as wastewater treatment or energy production).

Organic urbanism and essential service provision

The Netherlands has always been known for its top-down approach to urban planning and many citizens are proud of this history as it is seen to be the reason for the efficiency, prosperity and liveability the country enjoys (Collinson, 2011). Vast amounts of houses, streets, cities and countryside alike have been meticulously planned and designed. Together they have created the perfect stamp-like landscape that is best appreciated from above. Particularly in the Flevopolder this passion for top-down design is visible. The Flevopolder, a large piece of land at the heart of the Netherlands reclaimed out of lake IJsselmeer in the 50s and 60s, is a neatly divided landscape with straight rows of planted trees and windmills, perfectly rectangular plots of potato fields and new towns resembling the accuracy and structure of a micro-chip. However, currently a small virus has erupted amidst the straight crop fields in the middle of the Flevopolder dismantling the ordered structures into chaos. It is the start of a new-town of around 15.000 households on 4363 hectares which radically opposes the top-down planning paradigm: Oosterwold. In Oosterwold the inhabitants themselves will develop its houses, plots and streets fostering a spontaneous and ad-hoc urban planning process. On top of that comes the production and management of essential services. This usually only entails the construction of infrastructure or 'life lines' to large centralized facilities but in the case of Oosterwold inhabitants will have to figure out a way to do this locally and autonomously.

Before we dive into essential service provision in Oosterwold, it is important to understand this peculiar form of spatial planning in relation to the conventional planning process in the Netherlands. This is explained using the concept of 'organic urbanism' in sub-chapter 5.1. In sub-chapter 5.2 we dive into how this concept is executed in practice in Oosterwold through its main principles and rules. These rules and principles result in a particular development strategy for essential services which is explained in sub-chapter 5.3. Using urban planning literature considering organic urbanism and literature describing the vision of Oosterwold, these paragraphs establish an understanding of spatial planning and essential service provision in Oosterwold functioning as the background for the following chapters.

5.1 The ideology behind Oosterwold: Organic Urbanism

The unusual urban development that is practiced in Oosterwold was initially instigated by a social democrat politician, Adri Duivesteijn, with a love for organic urban development. He noticed that Dutch citizens as the end-user of buildings had been degraded to mere consumers instead of being active participants in the process of city making. Drawing on examples from mega cities such as Bangkok, Santos or Lima where city planning was basic or even absent, he was convinced that citizen initiatives in the built environment are the main force behind diverse, inclusive, sustainable and economically vital urban plans (Duivesteijn, 2011). This notion is also supported in theory where bottom-up planning arguably enhances diversity in functions, aesthetics and income as homes are a direct reflection of a citizens needs and therefore a direct reflection of the needs of society (Feary, 2015; Samson, 2018; Kramer, De zelfbouwstad aan de stadsrand, 2016). It is also the philosophy behind the notion of 'organic urbanism'.

Organic urbanism emerged in the late twentieth century in reaction to top-down planning focussing on the result rather than the process of urban development (Dembski, 2018). According to this new paradigm, urban growth should be ‘organic’ or developed ‘bottom-up’ and focussed on the process rather than the end result (Ritsema, Kompier, Berg, Waard, & Vinke, 2005). This flexible approach allows for spontaneous and informal developments which can react to a world which is changing with an increasing velocity. Furthermore, if cities are built by its residents, it automatically corresponds to the needs of these residents and reflects their diversity (Schilders, 2010). Arguably this also leads to a more sustainable form of housing since the houses are completely attuned to their inhabitants reducing excess space, material and heating (Wilde, 2018). Private commissioning can also induce innovation resulting in new construction techniques or material usage as well as teach citizens skills and knowledge (Oosterman, 2015; Collinson, 2011). Lastly it can reduce costs as no developers are needed (Feary, 2015) and increase the velocity of development as there is no need to wait until 70% of a project is sold (RVO, 2019).

To implement this bottom-up ideology, Adri Duivesteijn looked for solace in the Flevopolder. Here most of the land is owned by the government and abundantly available (Duivesteijn, 2011). Apart from that the Flevopolder and particularly Almere have always functioned as a laboratory for urban planning in the Netherlands due to the reasons stated above. Its neighbourhood development often mirrors the exact urban societal trends that prevailed in a certain decade since government and urban planners never had to deal with any kind of obstruction and instead could design housing based on whatever ideology prevailed in their minds. Today the prevailing ideology preaches a high level of citizen involvement and freedom. This is visible in recent neighbourhood developments in Almere such as: ‘De Buitenkans’, ‘Noorderplassen West’, ‘Homeruskwartier’ and ‘De Fantasie’. All of these neighbourhoods were in part developed by citizens and all of them were seen as a success. However, these neighbourhoods as well as other comparable bottom-up neighbourhoods in the Netherlands (e.g. IJburg, Zeeburgereiland, Steigereiland, Buiksloterham, Roombeek, Leonidas, Schutterstraat and Nieuw Leyden) only consider the design and creation of houses as a task for citizens. In these cases infrastructure, urban planning and essential services are still designed and managed top-down. However, with completely ‘organic’ urban development, as Duivesteijn pictured, infrastructure, urban planning and essential services are also left to citizens. At first this radical idea was not supported, but the economic crisis in 2008 and the large housing shortage, especially within the Amsterdam Metropolitan Area, pushed the municipality to deploy this alternative form of urban development. In this way they did not need large investors and could start developing right away in order to meet the housing quota. In 2012 the plans for a new neighbourhood became official: the municipality of Almere in cooperation with the municipality of Zeewolde would organically develop 15.000 households in the middle of the Flevopolder.

E. A representational map of the area according to the design rules (MVRDV, 2012)

D. Oosterwold as a natural agricultural landscape (MVRDV, 2012)

5.2 Oosterwold from ideology to practice: Principles and rules

Why organic urban development could be an answer to the challenges posed above was clear, however, how this type of development should be facilitated was much more difficult. From the start it was clear that this complete abandonment of urban planning required an exemption of many (spatial) laws to avoid a bureaucratic catastrophe. This was not necessarily difficult as the Netherlands is expecting a reform in environmental law in 2020 (the 'Omgevingswet') which considerably liberalizes many aspects of spatial planning (Rijksoverheid, 2019). Therefore, Oosterwold could provide as an experiment to test this new law which provides the neighborhood with many exemptions from current laws. To guarantee as little governmental influence during the process as possible and to secure the discussed qualities of the neighbourhood the municipalities decided on six principles (Borkent, 2013):

1. ***Oosterwold offers maximum freedom to initiatives;***
2. ***Oosterwold develops organically;***
3. ***Oosterwold is a continuous natural landscape;***
4. ***Oosterwold has urban farming as a natural structure;***
5. ***Oosterwold is sustainable and self-sufficient;***
6. ***Oosterwold is financially stable;***

The first two principles reflect the guarantee of little government influence while the third and fourth principle were made to reflect the agricultural landscape that was present at the chosen location. In this way the municipalities tried to justify the transformation of a large agricultural area into a living area. The fifth and sixth principles state are to make sure the new neighbourhood is not dependent on government support when it comes to essential service and financial aid to avoid large investments for infrastructure or subsidies from a municipality perspective. Together these principles create the utopian vision of a self-organizing, self-sufficient and feasible neighbourhood.

To implement this vision and its six principles requires a new set of rules. More importantly it requires a shift in balance between the responsibility of the government towards the responsibility of citizens. Government in this case is not only the municipalities Almere and Zeewolde but also the Central Government Real-Estate Agency, the Province of Flevoland and the Water agency Zuiderzeeland (Gebiedsteam Oosterwold, 2018). Together with a team of designers (MVRDV, Hofstra Heersche and Sweco) they created a strategy deploying a set of rules that clearly describes this relationship and the responsibility of inhabitants in executing the vision:

1. ***People design Oosterwold***
   Not the government but citizens decide how Oosterwold develops.

2. ***Free choice of building plot***
   The size, shape and place of a plot is free of restrictions. Only places that are marked for future infrastructure are off limits.

3. ***Fixed distribution of space***
   The area of Oosterwold has a fixed distributions: 20% buildings (both housing and office space), 50% agriculture and the rest is reserved for roads, nature and water. All plots combined should always have this distribution.

4. ***Different types of building plots with a specific distribution of space***
   There are to types of building plots that have a different land distribution than normal plots: a landscape plot (mainly public nature) and an agriculture plot (mainly urban farming).

5. ***Freedom and restrictions for building***
   Buildings have a FAR (Floor Aria Ratio) of 0,5 and are surrounded by natural structures.

6. ***Co-building infrastructure***
   The government will remain responsible for the main infrastructure (national and provincial roads and canals). The development of a local transport network is the responsibility of inhabitants.

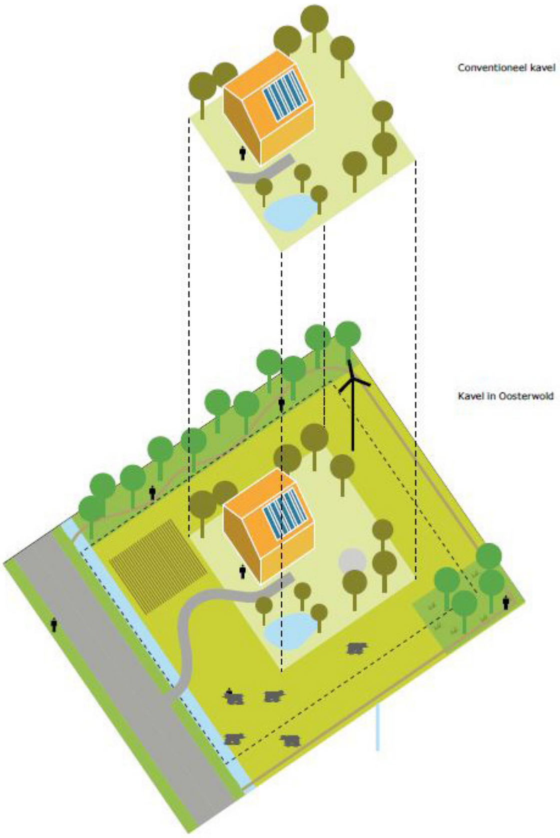
7. ***Oosterwold is green***
   More than two thirds of Oosterwold will be reserved for natural areas such as agriculture, forest, gardens or recreational nature.

8. ***Plots are self-sufficient***
   Every initiator is responsible, alone or together, for water management, water waste management and energy production in the most sustainable way possible.

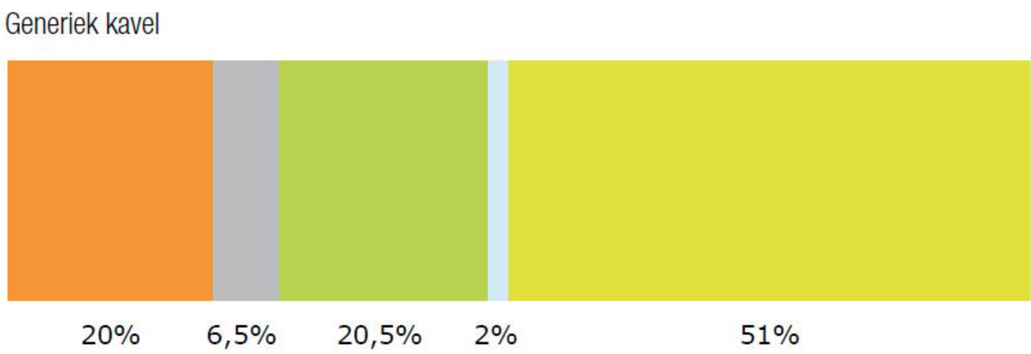
9. ***Plots are financially stable***
   Every plot has to be developed without financial aid from government.

10. ***Public investments are paid for by initiators***
    Initiators pay a fee for public investments when buying a plot. This will be used to create public infrastructure and services when enough people live within a certain area.

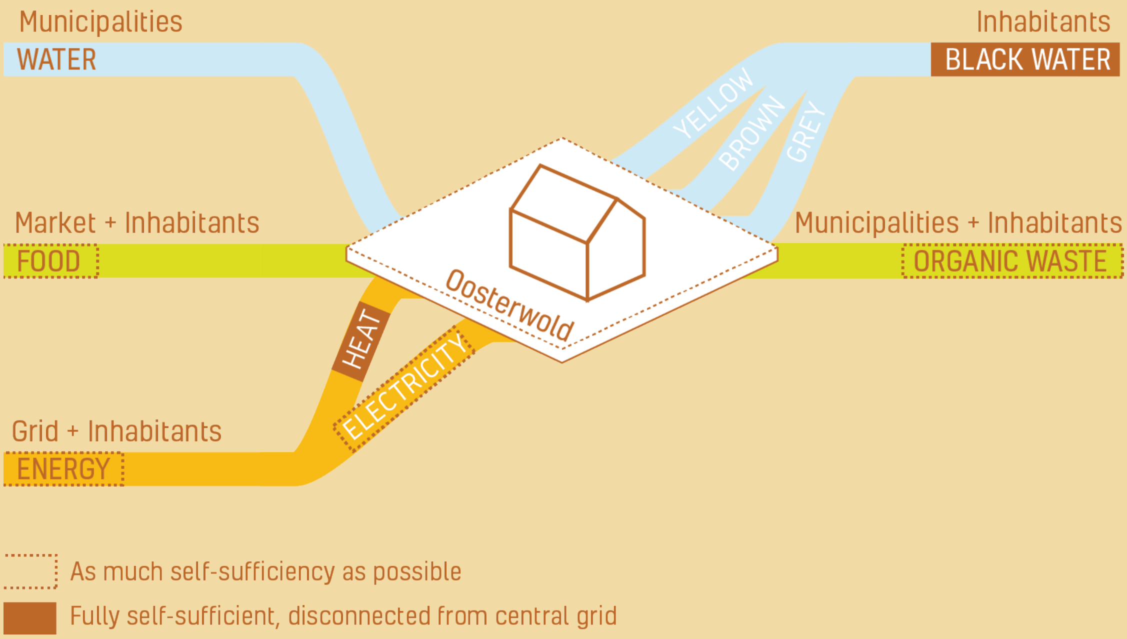
In order to conceive the future neighbourhood MVRDV created a few indicatory maps and images based on these ten rules. The rules are formally legalized in binding laws (the ‘Bestemmingsplan’) issued by the government (Gemeente Almere, 2018). To make sure these principles are followed during the process and to guide the citizens in the development of the neighbourhood, an area director (‘gebiedsregisseur’) was appointed (Gebiedsteam Oosterwold, 2018). Together with a team the area director guides the communication between different parties and is responsible for enforcing the rules.



F. An Oosterwold plot with essential services embedded in the spatial program compared to a standard Dutch plot (Structuurvisie, 2013)



G. Fixed distribution of space for a generic plot



8. Autonomy in essential services in Oosterwold (illustration by author)

5.3 Oosterwold and essential services: A self-sufficient neighbourhood

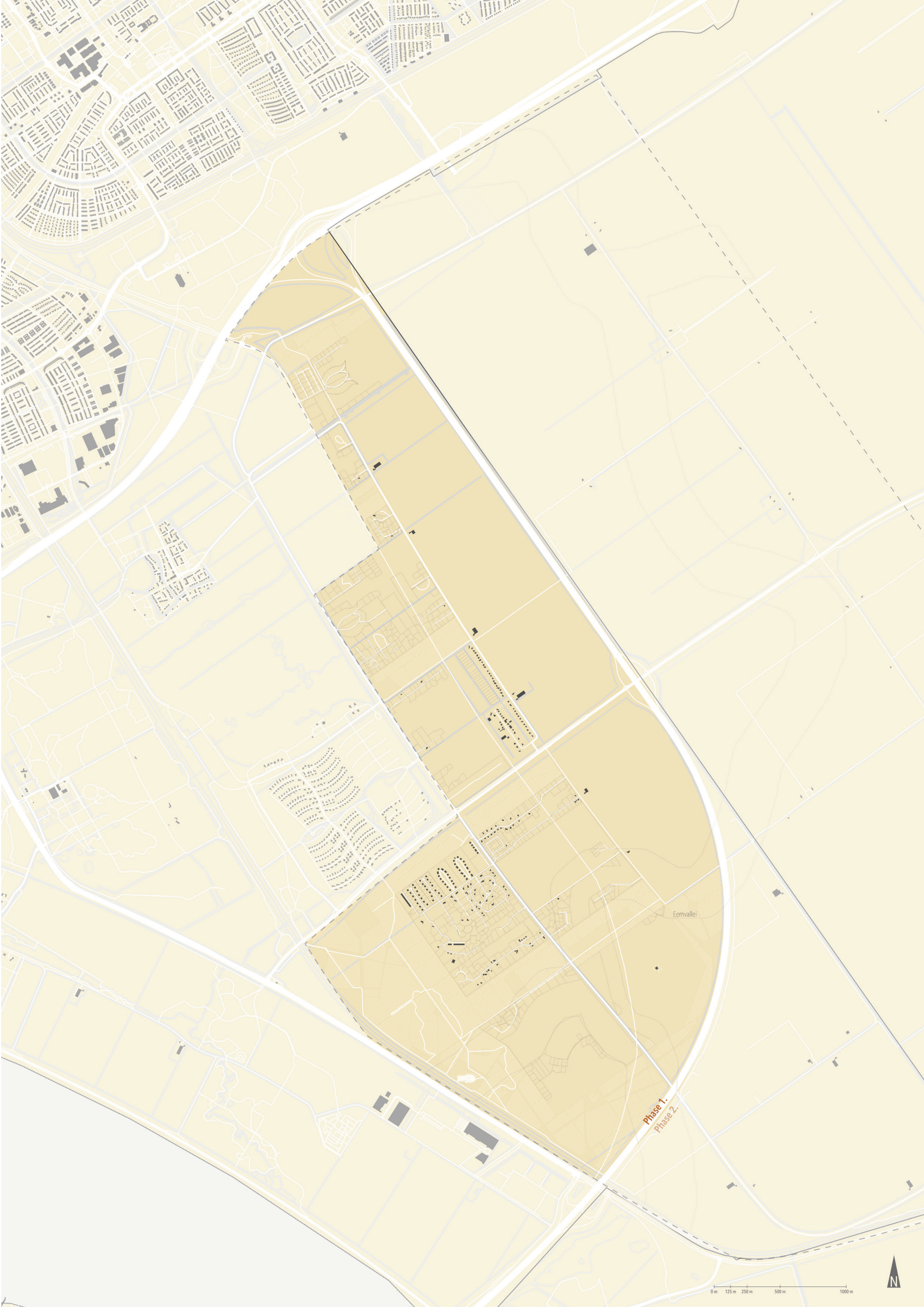
Where in other neighbourhoods the government has a large say when it comes to planning essential services and the associated infrastructure, in Oosterwold the design and management are left to inhabitants. Only in this way, the neighbourhood can grow organically as infrastructure often implies the construction of roads and large facilities. A traditionally planned road and infrastructure network would heavily impede on the spatial freedom and require large investments which are both in direct contradiction with the first and sixth principle of Oosterwold. Rule number 8 is the reason why Oosterwold is chosen as case study: inhabitants are responsible for their own wastewater treatment and energy production. Other essential services such as the production of food are also embedded in rule 3, but this is outside the scope of this research. In the rules the type and scale of wastewater treatment or energy production are not defined which leaves huge freedom in the design of essential service systems. There is a large variety of systems and techniques possible in order to manage wastewater treatment and energy production, and inhabitants can choose to develop their own systems or with their neighbours. Although the rules state inhabitants are responsible for their own energy production, in practice this is not seen as feasible. Inhabitants are still connected to the electricity grid as full autonomy would jeopardize the stability of electricity supply (Werkmaatschappij Almere-Oosterwold, 2013). Figure 8 shows in which essential services inhabitants are expected to be self-sufficient.

5.4 Oosterwold today

At this point in time around 1000 households have been established in scattered clusters among the agricultural landscape. These households are part of the first development phase of the neighbourhoods which has room for around 5000 households. The second phase is projected to start around 2020 and has room for around 10.000 households. The map only portrays a snapshot of the area as the neighbourhood is in constant development. Self-sufficiency is for many inhabitants one of the key reasons for choosing Oosterwold (Ruimtevolk, 2016). There is a large diversity in plots, houses and materials as well as in essential service systems. There are different types of wetlands, biogas generators, solar panels, air heat pumps or wood burners, all for the purification of wastewater or generation of electricity and heating. Sometimes inhabitants have co-developed a row of houses forming a small entity of consistency within the large sea of diversity. For some this reduces the burden of developing a house, plot and street as well as the accompanying essential service systems by simply choosing a 'catalogue home'. For others it was an opportunity to develop something out of the ordinary: a form of co-housing or a community with like-minded people.

According to some Oosterwold is merely another face of Almere (Kramer, De zelfbouwstad aan de stadsrand, 2016). Harsher critics call it an 'ersatz city' or 'a soulless architectural Legoland' (Collinson, 2011) and maybe the biggest blow came from its own initiator Adri Duivesteijn who called it 'a sum of gated communities only without its fences' (Kramer, De pioniersgeest waart opnieuw rond, bouwen in Almere Oosterwold, 2019). On the other side are the admirers who call it an example of sustainable development or a genuinely workable alternative for urban planning (Collinson, 2011). Most people linger around the middle only guessing at what Oosterwold is or will become: a slum? a typical bedroom community? simply urban sprawl? Or a sustainable utopia? One thing is certain, this experiment has taken the discussion on organic urbanism, citizen responsibility and local essential service provision a step further and can at least provide insightful examples for this research and future similar projects.

9. A map of Oosterwold currently (illustration by author adapted from Maak Oosterwold, 2019) ▶


Eemvallei
Phase 1.
Phase 2.
0 m
125 m
250 m
500 m
1000 m
N

Local energy production

In this chapter local energy provision is analysed in the Netherlands and in Oosterwold, in order to provide a base for the development of scenarios and following maximizations in chapter 8. First, energy provision and how it is organized in the Netherlands, particularly for domestic use, is explored in 6.1. This is done by using data on energy provision in the Netherlands from EBN ('Energie Beheer Nederland') and literature on the recent history of energy provision in order to understand the current approach to energy provision. Second, the decentralization of energy provision is studied highlighting the advantages and disadvantages of this trend in 6.2. Since the advantages and disadvantages are sparsely studied, a wide range of international literature is used, mostly within the profession of urban planning or asset management engineering. Together 6.1 and 6.2 answer the first research question for energy provision:

Q1: What are the advantages and disadvantages of providing local essential services compared to the common centralized essential service provision in the Netherlands?

In sub-chapter 6.3 the effect of the shift towards local energy provision on the land-use, environmental impact and environmental hazards is studied. This increases our understanding of what local essential service provision will demand from spatial planning. Furthermore, the change in land-use, environmental impact and environmental hazards compared to a centralized provision of energy can potentially reveal economies of scale that need to be taken into account in chapter 8. This answers research question 2 for energy provision:

Q2: What is the impact of local essential service provision on land-use intensity, environmental impact and environmental risks?

Fourthly, in 6.4 the focus is on Oosterwold to provide a practical foundation for understanding local essential service provision. The vision, current situation and future prognoses are explored using documentation from the municipality Almere, site visits and interviews with inhabitants and a member of the area team. The neighbourhood is expected to have a high diversity of systems and solutions for energy provision due to the organic urban development. To understand this self-organizing process the most common approaches and patterns are identified. This answers the third research question for energy provision:

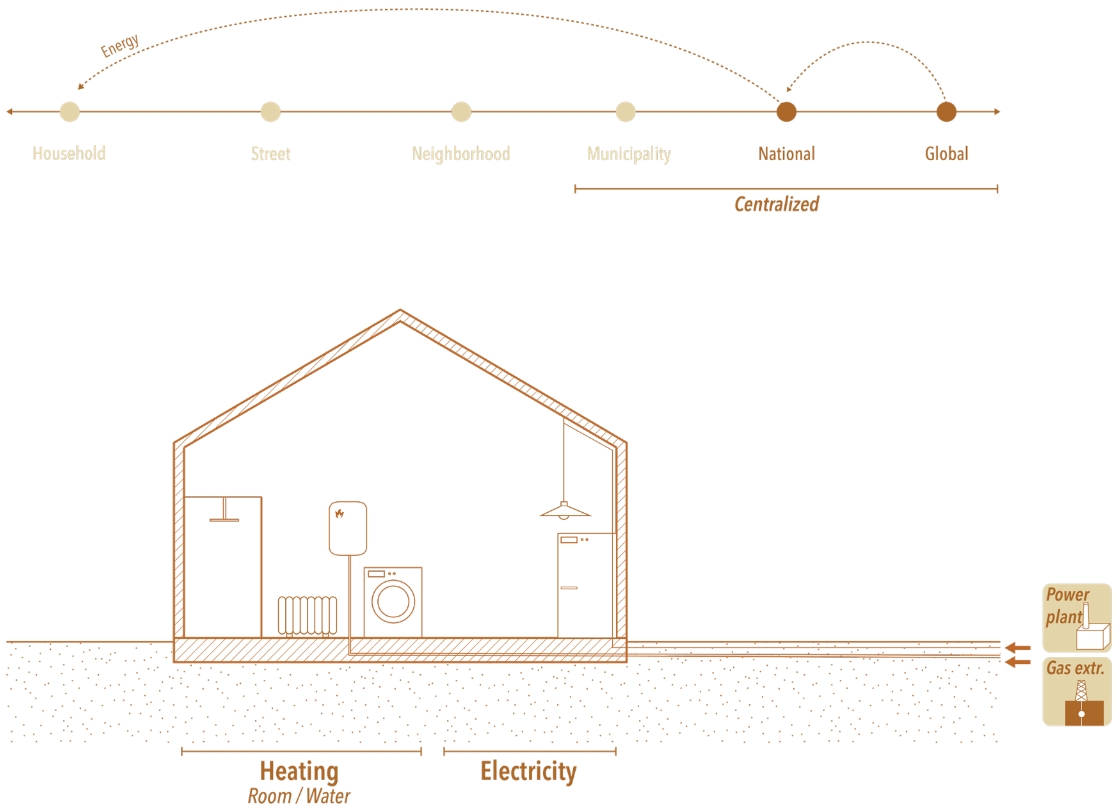
Q3: How are essential services provided in Oosterwold and what patterns have emerged?

The last sub-chapter 6.5 gives an overview the energy provision systems available for the production, transport and storage of energy. The systems that are suitable for Oosterwold are researched in-depth considering their land-use, environmental impact and environmental risks. To create an in-depth understanding of these systems a wide range of international and Dutch literature is used supported by data from practice. This answers the fourth research question for energy provision:

Q4: What are the possible systems for the provision of essential services in Oosterwold?

6.1 Energy provision in the Netherlands

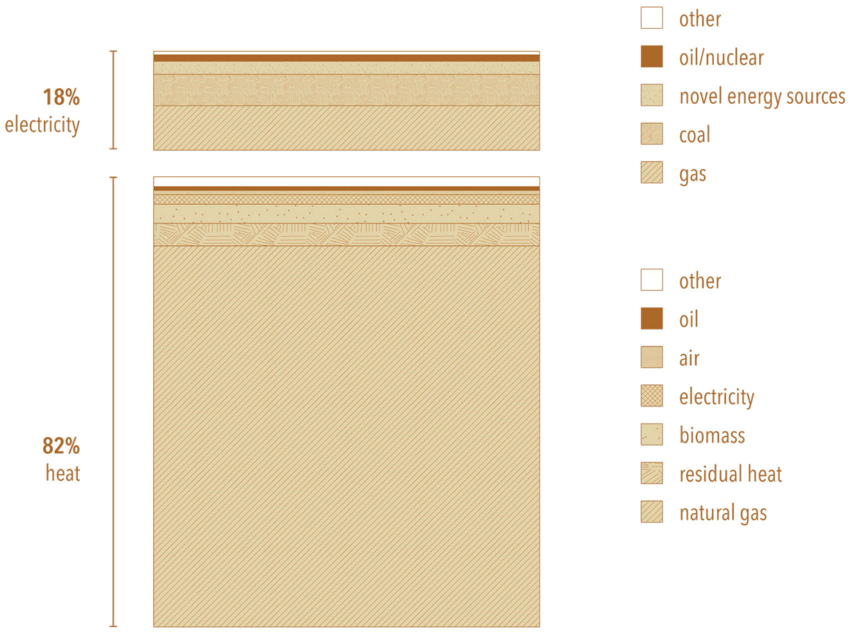
In order to understand the dynamics of decentralized energy systems and the difference with the Energy is used in many different facets of society and seen as the ground pillar for economic growth and prosperity. In the Netherlands, the total energy production is used as an important resource in industry (46%), domestic use (28%), for mobility (20%) and in agriculture (6%). In order to continuously provide security of supply, the strategy for energy production is often based upon abundance and reliability. This is the reason why most of the world is hooked on fossil fuels as these have a high energy density and are easy to store. In the Netherlands the production of energy is also mainly facilitated by a range of fossil fuels such as gas (41 %), oil (39%) and coal (12%). However, recently, also other 'novel' resources have been introduced such as biomass (4%), wind (1%) and in small part solar, geothermal and residual heat. Nuclear also plays a small role (1%) in energy production (EBN, 2017). The heavy reliance on fossil fuels and the importance of energy reliability have fostered a centralized approach towards energy production. Transport networks are facilitated by utility companies while energy production is managed by large-scale private companies. Before the liberalization of 2004 both the transport and production were managed by utility companies (Klooster, Schillemans, & Warringa, 2005).



10. Most common approach to household energy provision based on centralized resources

H. Energy production on a local scale using photovoltaic or thermal solar panels (photo by author, Oosterwold) ▶

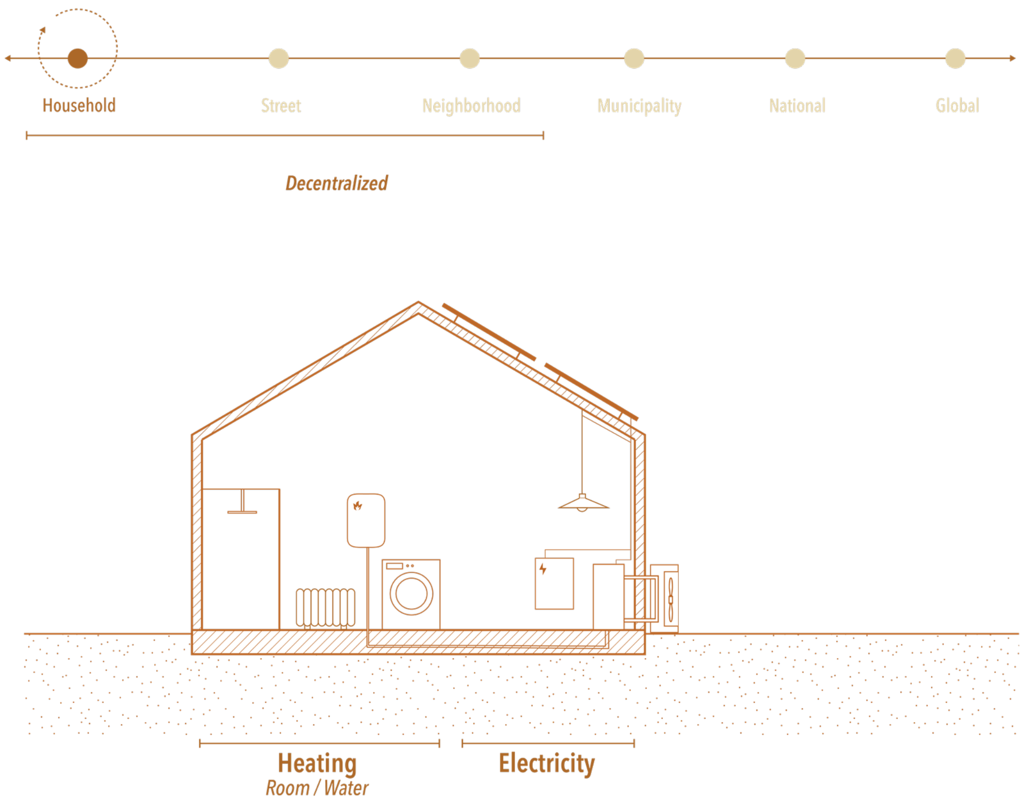
The centralized approach towards energy production is also visible in the provision of energy for households. Energy is mainly used for room and water heating (around 82 %) and the remainder is used in the form of electricity (around 18 %) (EBN, 2017). In an average household the provision of heat is by the usage of natural gas (85%) and in small part through residual heat (5%), biomass (4%), electricity (2%), air (1%) or oil (1%). Most homes are attached to a centralized network that provides one of these resources and subsequently burn the resource (in the case of gas) or simply abstract the heat (with residual heat). Electricity is facilitated through a mixture of gas (45%), coal (32%), the novel energy sources mentioned above (13%) and oil or nuclear (7%) (EBN, 2017). Large power plants combust these resources (gas, coal, biomass and oil) in order to produce electricity. Wind energy and nuclear energy use different methods but produce similar results. Through power lines this electricity is transported to homes and consumed.



11. Distribution of energy resources for the production of heat and electricity for households in the Netherlands

6.2 Local energy production and its advantages and disadvantages

The increasing resource conflicts tied to fossil fuels, the depletion of fossil fuels and fear for climate change have led to a search for a carbon neutral energy system (Adil & Ko, 2016). This has led to the recent rise of novel energy resources such as wind energy, solar energy, geothermal energy, biomass or energy from air. These 'renewable' sources are often diffuse and difficult to concentrate in large power plants which leads to a decentralization of energy production and to active involvement of private individuals or cooperatives willing to invest in these resources (Hentschel, Ketter, & Collins, 2018). At the same time the costs for decentralized energy techniques are rapidly dropping to a point that they are closing in on traditional energy sources (Hirscha, Paraga, & Guerrerob, 2018). Both trends have fostered the rise of local energy provision. In local energy provision both the production and consumption of energy take place on a local scale using local resources. In this way, local energy production can provide (partial) autonomy from centralized production or decision making.



12. Example of a decentralized system for the provision of energy

6.2.1 Advantages

There are many advantages of the decentralization of energy production. Firstly, the shift from fossil fuels to novel energy sources comes with the utilization of local energy sources that previously were left untouched. Secondly, the reduction of long-distance energy transport thereby avoiding energy losses (Lasseter, 2007). Thirdly, the flexibility and adaptability of energy production is increased due to the increased number of energy sources and increased number of facilities (Falco & Webb, 2015). Fourthly, if designed properly, decentralized energy production can be integrated within the environment which increases the multifunctionality of space and decreases overall land-use (Falco & Webb, 2015). Lastly, local energy production stimulates social capital and cohesion due to an increased level of control at a local level (Alanne & Saari, 2004).

+ *Utilization of local energy sources*
+ *Reduction of energy losses due to long distance transport*
+ *Higher flexibility and adaptability*
+ *Can be integrated within the environment*
+ *Stimulation of social capital and cohesion*

6.2.2 Disadvantages

The many advantages of local energy production have partially fostered the rise in local energy production, however, there are also disadvantages to a decentralized energy system. As explained above the costs of decentralized systems are declining, but local energy production and storage are still relatively capital intensive (Falco & Webb, 2015). Secondly, locally harvested energy sources are commonly weather dependent and fluctuate in energy production. This means local energy provision largely depends on the capacity for storage, both for heating and electricity. On top of this, the averaging effect of large groups of consumers is gone, which further increases the need for storage and smart control systems (Alanne & Saari, 2004). Thirdly, new energy production methods (such as energy production from solar energy) often require more land compared to energy production based on fossil fuels. Due to these disadvantages, local energy provision is not always the solution, but rather a strategy that can be executed in specific areas (Phent, 2006).

- *local energy production and storage systems are capital intensive*
- *local energy sources are often weather dependent causing fluctuations*
- *lack of averaging effect decreasing the efficiency of systems*
- *higher land-use*

6.3 The land-use intensity, environmental impacts and risks associated with local energy production

As explained in the problem field, there are three main challenges that are important for the integration of essential service systems within the built environment. The following paragraphs describe how these indicators play a role in local energy production.

6.3.1 Land-use intensity

As described in the disadvantages of local energy production, the land-use intensity of local energy production technologies is relatively low. Where fossil (and nuclear) resources are delivered from point resources like wells or mines, local renewable resources emerge on every square meter of the earth's surface in the form of solar radiation and/or bioresources (Stoeglehner, Niemetz, & Kettl, 2011). Only vertical geothermal energy provision uses a point resource. This leads to a concern for a lack of space when it comes to the implementation of local energy technologies (Falco & Webb, 2015, p. 52). Furthermore, energy provision based on renewable resources, such as solar and wind, are highly variable due to changing climate conditions. Without sufficient energy storage the land-use intensity decreases even further to compensate the loss of energy. Creating sufficient energy storage for electricity, however, is difficult due to the limited capacity of storage and storage costs (Falco & Webb, 2015, p. 52). Due to these challenges it remains difficult to provide enough space if energy autonomy is the goal.

6.3.2 Environmental impact

The environmental impact of new energy technologies is seen as an important consideration when implementing these in close proximity to communities in order to avoid negative impacts and ensure environmental and social justice (Delicado, Figueiredo, & Silva, 2016; Saidur, Rahim, Islam, & Solangi, 2011). Combined with the high amount of land-use, energy technologies can have a considerate impact on the landscape and therefore a considerate impact on local communities or ecology. As an example, concerns for the environmental impact of wind, solar and geothermal energy often hinder the siting of these technologies and are therefore important to consider in spatial planning (Chiabrando, Fabrizio, & Garnero, 2009). The environmental impact in energy production varies and depends on the technique and sometimes on the scale of application (Wolsink, 2007).

6.3.3 Environmental risk management

The local production of energy contains risks that are important to address even though the hazard might be lower compared to large scale energy production. As explained in the problem field, local essential service provision is relatively novel, often executed by inexperienced citizens and placed in the vicinity of communities which makes risk assessment an important part of integrating local energy provision. In energy production these assumptions are true. The systems used for local energy production are relatively novel techniques with the exception of solar energy (Phent, 2006). It is not always the type of system or resource that is novel, but sometimes simply the small scale on which the system is applied. Furthermore, local residents are inexperienced while local energy production system are often complex, especially with the application of smart control systems (Phent, 2006; Alanne & Saari, 2004). Local energy systems are also placed in the vicinity of homes and communities to reduce the transport distance to a minimum to prevent transport losses (Lasseter, 2007). Lastly, local energy production methods are diverse (e.g. solar, wind, geothermal, air or biomass energy) creating fragmented information and a lack of uniformity and consistency which makes it difficult to assess risks (Alanne & Saari, 2004). These aspects can potentially increase the environmental risks associated with energy production and need to be considered in the planning process.

6.4 Energy production in Oosterwold

The following paragraphs describe the vision on energy in Oosterwold as was found in documents presented by the initiators. The present situation of energy provision in Oosterwold is analysed through maps, observations during visits, interviews and blogs. The last paragraphs describe the future of energy provision in Oosterwold.

6.4.1 Vision on energy production in Oosterwold

In the development strategy for Oosterwold the neighbourhood should be a self-sustaining neighbourhood when it comes to the production of energy. In other words, “every inhabitant or community produces its own energy for heating, cooling, lighting and other industrial or agricultural processes” (Werkmaatschappij Almere-Oosterwold, 2013, p. 172). In the best-case scenario, the neighbourhood will even produce surplus energy for neighbour communities. Following the development strategy this is accomplished through the use of geothermal energy, solar energy, wind energy, energy from air and biomass. On an individual level the emphasis lies on the diversity of techniques and possible exchange of electricity through a smart grid. On a communal level the emphasis lies on the usage of biomass and waste for the production of heat and electricity which can be distributed through a micro heat network (Werkmaatschappij Almere-Oosterwold, 2013). Interestingly, there is no mention of any kind of storage technique even though this is a critical component of any local energy system which strives to be self-sufficient (Zvoleff, Kocaman, Huh, & Modi, 2009). Furthermore, the emphasis on biomass for communal energy production is not clear and most likely based on a supposed business case, not on the large availability of biomass as the area is too small to produce a sufficient amount for heating and electricity.

There are two major restrictions for the production of energy in Oosterwold (Werkmaatschappij Almere-Oosterwold, 2013). The first restriction considers the groundwater source for potable water that is underneath the area and prohibits any drilling due to a possible risk of pollution. This means geothermal energy production is limited by a maximum depth which decreases the amount of potential heat production (TNO, 2016). The second restriction considers the application of wind energy in the area. In Oosterwold only small-scale wind turbines that can be mounted to the roof are allowed. There is no explanation for this restriction. Due to these restrictions it is relatively difficult to create a state of self-sufficiency as geothermal energy and wind energy are two of the most constant sources of energy through the seasons. As a result, energy provision is mainly based on solar energy resulting in a high amount of land-use. This is acknowledged in the development strategy as it is mentioned that most likely not every plot will be able to provide enough energy to be self-sufficient.

To conclude, even though the ambition in Oosterwold is to produce enough energy to cover their own consumption, the lack of mentioning energy storage and the restrictions send a mixed message. How and where the energy production takes place and whether there is enough to create a self-sufficient neighbourhood is explained in the following paragraph.

6.4.2 Present energy provision in Oosterwold

During observations in the neighbourhood there were many signs of people producing their own energy, however, all inhabitants are still connected to the national electricity grid. According to inhabitants this is because without the connection to the national grid, it is not possible to generate enough energy in winter seasons (Bouwen in Oosterwold, 2015). This shows that self-sufficiency or autonomy in Oosterwold is currently not achieved contradictory to what was envisioned. This might be due to a discrepancy in the definition of self-sufficiency as the neighbourhood might produce enough energy to cover the yearly demand but does not produce enough energy to cover the monthly demand due to fluctuations in demand and production.

The following paragraphs show the essential service systems that were found in Oosterwold during site visits and their scale level of application.

Systems

Through observations, a survey, and documentational research the following energy production techniques were found in Oosterwold. This is only a limited view of the techniques used and does not provide an overview as many techniques may be found inside homes outside of the view of outsiders and many houses were still developing. The techniques that were found are stated below.

Production of electricity

So far only photovoltaic panels were found to provide electricity in the neighbourhood. There was no application of wind energy in the neighbourhood. Electricity storage was also not found but this is often placed inside homes or batteries of electric cars are utilized.

Production of heat

Air heat pumps were often found around the neighbourhood, but this can be due to their visible appearance. There are households that have applied geothermal systems, as this was found on private blogs, but it is difficult to estimate the percentage of inhabitants that have applied this technique as it is hidden underground. Furthermore, there are some outlets visible on roofs that suggest the usage of biomass burners and one biogas tank was found in the neighbourhood. Heat storage was not found.

Scale of application or levels of autonomy

J. Photovoltaic panels and a heat pump (photo by author, Oosterwold)

I. Solar panels and what looks like an outlet for a biomass burner (photo by author, Oosterwold)

L. Solar thermal panels and a heat pump (photo by author, Oosterwold)

K. Transformer to connect households to the national electricity grid (photo by author, Oosterwold)

Even though the development strategy of Oosterwold mentions communal energy production, so far there are no signs of inhabitants working together to supply their energy demand. Even projects that were communally developed do not share electricity production. During site visits there was one inhabitant that mentioned the implementation of shared electricity storage might be interesting but overall there were no initiatives found that suggested a step in this direction.

6.4.3 Future energy production in Oosterwold

Currently, there are little challenges surrounding energy production in Oosterwold due to the connection to the grid and absence of monitoring. However, there are still many opportunities to increase self-sufficiency in phase 2 or to increase energy self-sufficiency in phase 1. In the survey most participants indicated an interest in shared storage and there are still opportunities to implement (small-scale) wind energy (see Appendix 1.3). Furthermore, communal energy production will be increasingly stimulated by the area team (see Appendix 1.1 for the interview with a member of the area team).

6.5 Available local energy systems

According to system theory, a system consists of a purpose, elements and interconnections (see system theory 4.3). The purpose is in this case the provision of energy (heat and electricity) to match the demand for energy. Energy production and storage are the elements within an energy system and transport is the interconnection between these elements. In this sub-chapter the production (6.5.1), storage (6.5.2) and transport (6.5.3) are further explored in order to understand their role in the energy system as a whole and ultimately understand their impact on spatial planning. The available systems that cater these functions are described in the 'Catalogue of local energy solutions' alongside their land-use, environmental impact and risks.

6.5.1 Production

Energy production is focused at producing electricity, heat or a combination of both. In households, electricity is used to power appliances, for the production of heat and/or to enable transport. Heat is used to heat buildings and provide hot water for domestic used. The production of energy can be facilitated by a wide range of energy sources and systems. At the moment four types of (renewable) energy sources are dominant when it comes to local energy production: solar, wind, air, geothermal and biomass. Energy from fossil fuels, hydropower, tidal power, nuclear power and hydrogen are also important sources but generally require large scale systems and top-down planning due to the size of sources or necessity for economies of scale and the general absence of these sources within a local context. The optimum type of energy production system depends on the local available sources for energy production and the constraints of the environment. The challenge of energy production using local resources is that they are often prone to climate or seasonal fluctuations. The combination of different systems, such as solar and wind, can potentially establish a more constant production of energy. The following techniques can be found within the catalogue of local energy solutions:

E1 Photovoltaic system
E2 Thermal solar energy system
E3 Wind turbine
E4 Geothermal energy systems
E5 Thermal energy from air
E6 Energy from biomass (CHP)

6.5.2 Storage

Increased dependence on renewable energy sources as explained above, will result in reduced security of supply due to fluctuations in ambient conditions. Furthermore, energy demand generally fluctuates according to seasonal changes. Storage can balance variations in power supply and demand and is therefore paramount to safeguard continuous power or heat supply. The optimum type of storage is governed by the response time and duration of supply. For electricity storage there are three types of mechanisms that can store electricity: electro-chemical storage (the most commonly used batteries and high in power density), redox-flow batteries (relatively novel type of battery) and mechanical storage (not commonly used and low in power density). Water is the most common medium for heat storage. Both underground storage or above ground storage of water is used to contain hot or cold water depending on the demand. Other less commonly used or novel heat storage systems use rock, molten salts, salt hydrate or liquid air. The following techniques can be found within the catalogue of local energy solutions:

E7 Lithium-ion battery
E8 Vanadium-redox flow battery
E9 Mechanical storage
E10 Seasonal thermal energy storage

6.5.3 Transport

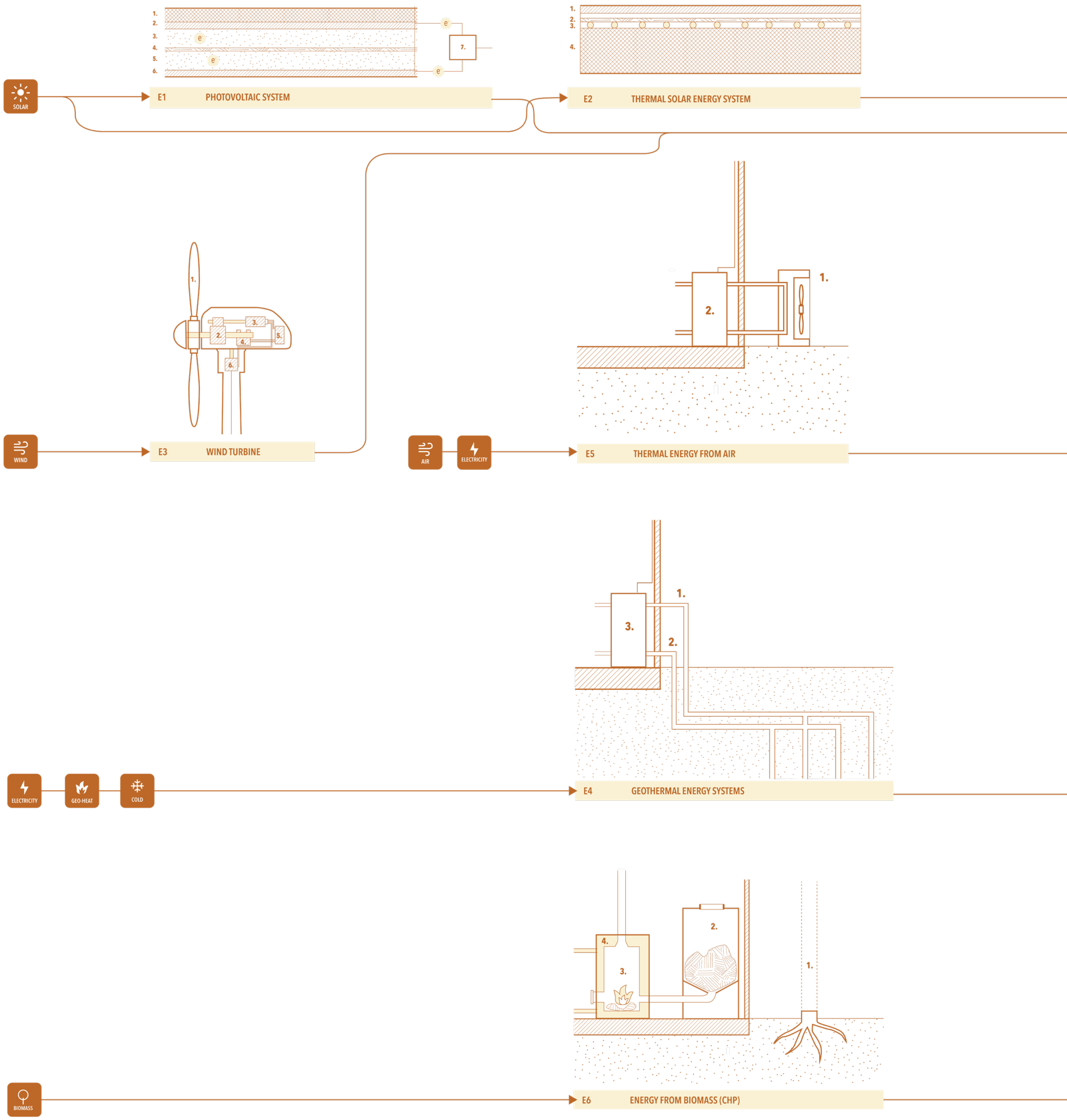
Transport of energy facilitates the exchange of energy between production systems, storage systems and households. For electricity transport, an alternating current is produced which permits bidirectional exchange of electricity. Thermal energy is transported by pumping hot water from one place to another. The challenge of transporting and exchanging locally produced or stored energy, is the fluctuations in production and storage capacity due to the usage of renewable energy sources combined with the fluctuations of domestic demand. To balance and support these functions, new transport systems use electronic power conditioning to stir a 'smart' distribution of energy and possibly smart consumption of energy. Both heat and electricity transport are included in the catalogue:

E11 (Smart) Low-voltage electricity grid
E12 (Smart) Low-temperature heat grid

Production

electricity

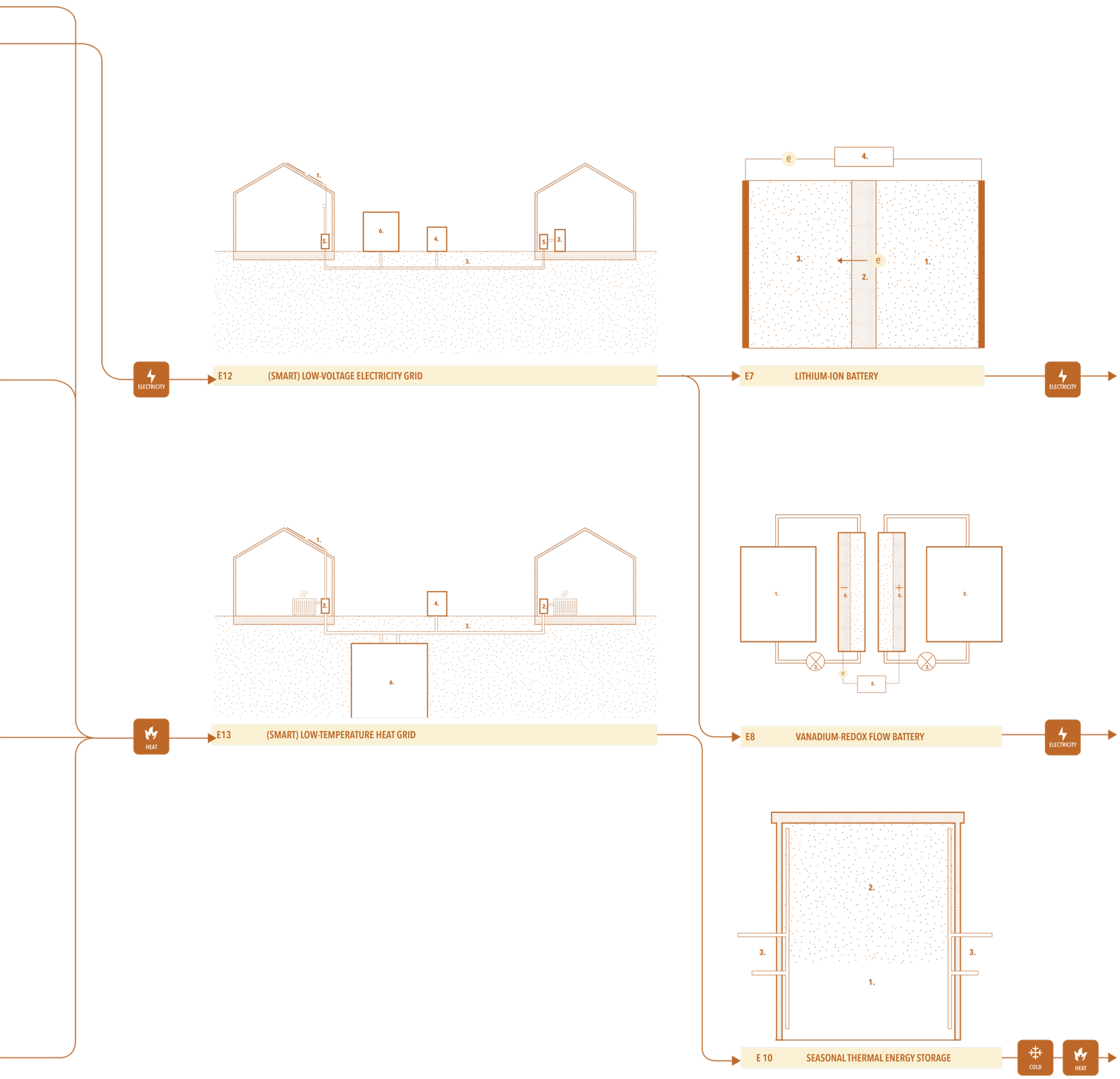
heat



13. Overview of the energy systems applicable in Oosterwold and that can be found within the catalogue

Transport

Storage



Local wastewater treatment

In this chapter local wastewater treatment is analysed in the Netherlands and in Oosterwold, in order to provide a base for the development of scenarios and following maximizations in chapter 8. First, wastewater treatment and wastewater contents are explored in 7.1. alongside the centralized approach to wastewater treatment in the Netherlands. This is done by using literature on wastewater treatment and contents in general and on wastewater treatment in the Netherlands from Dutch knowledge institutions such as STOWA ('Stichting Toegepast Onderzoek Waterbeheer'). Second, the decentralization of wastewater treatment is studied highlighting the advantages and disadvantages in 7.2. Since the advantages and disadvantages are sparsely studied, a wide range of international literature is used, mostly within the profession of urban planning or asset management engineering. Together 7.1 and 7.2 answer the first research question for wastewater treatment:

Q1: What are the advantages and disadvantages of providing local essential services compared to the common centralized essential service provision in the Netherlands?

In sub-chapter 7.3 the effect of the shift towards local wastewater treatment on the land-use, environmental impact and environmental hazards is studied. This increases our understanding of what local wastewater treatment will demand from spatial planning. Furthermore, the change in land-use, environmental impact and environmental hazards compared to a centralized provision of energy can potentially reveal economies of scale that need to be taken into account in chapter 8. This answers research question 2 for wastewater treatment:

Q2: What is the impact of local essential service provision on land-use intensity, environmental impact and environmental risks?

Fourthly, in 6.4 the focus is on Oosterwold to provide a practical foundation for understanding local wastewater treatment. The vision, current situation and future prognoses are explored using documentation from the municipality Almere, site visits and interviews with inhabitants and a member of the area team. The neighbourhood is expected to have a high diversity of systems and solutions for wastewater treatment due to the organic urban development. To understand this self-organizing process the most common approaches and patterns are identified. This answers the third research question for wastewater treatment:

Q3: How are essential services provided in Oosterwold and what patterns have emerged?

The last sub-chapter 7.5 gives an overview the wastewater treatment systems available for the treatment and transport of wastewater. The systems that are suitable for Oosterwold are researched in-depth considering their land-use, environmental impact and environmental risks. To create an in-depth understanding of these systems a wide range of international and Dutch literature is used supported by data from practice. This answers the fourth research question for energy provision:

Q4: What are the possible systems for the provision of essential services in Oosterwold?

7.1 Wastewater and wastewater treatment

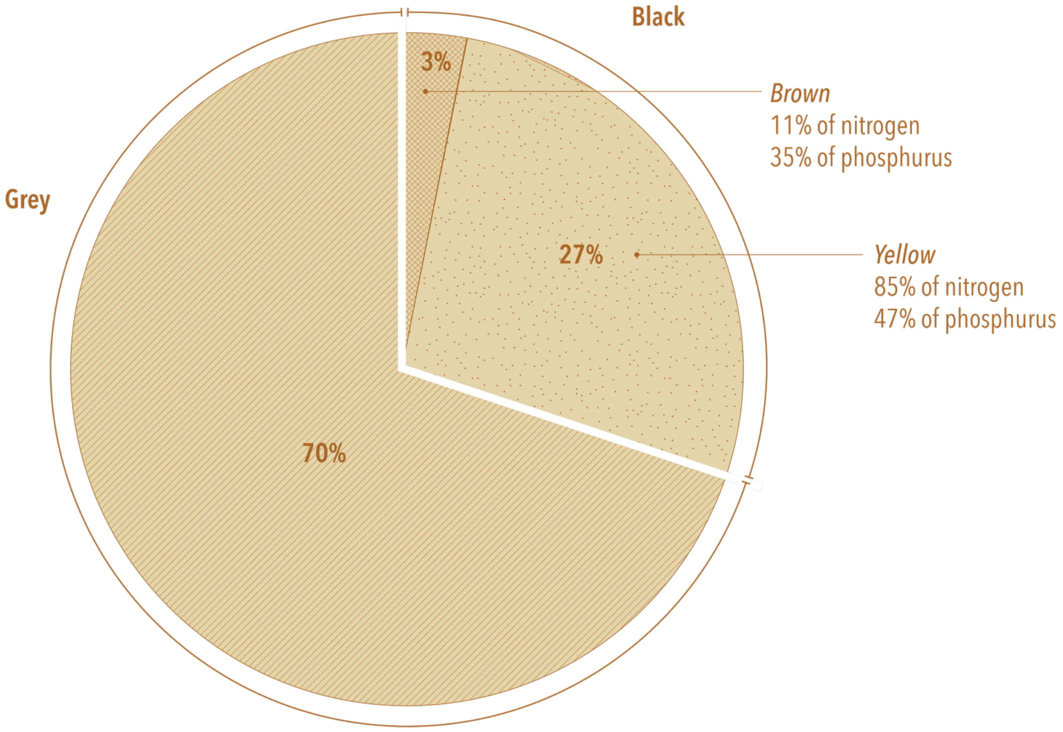
In order to understand the dynamics of decentralized wastewater systems and the difference with the current practice, the following paragraphs will grant a short introduction wastewater and wastewater treatment with regard to household wastewater treatment.

7.1.1 Wastewater contents and pollutants

In general, wastewater is the polluted water that originates from households, institutions and industries as a result of water consumption, and often mixed with rainwater discharge from streets and infiltrated groundwater. These different wastewater streams are conventionally mixed in one large batch of wastewater. The composition of rainwater and concentrations of pollutants depends on the pollution load and amount of water with which the pollutant is mixed. In general, the main pollutants in wastewater are:

- *Phosphorus (P)*
- *Nitrogen (N)*
- *Heavy metals (such as zinc or copper)*
- *Pathogens*

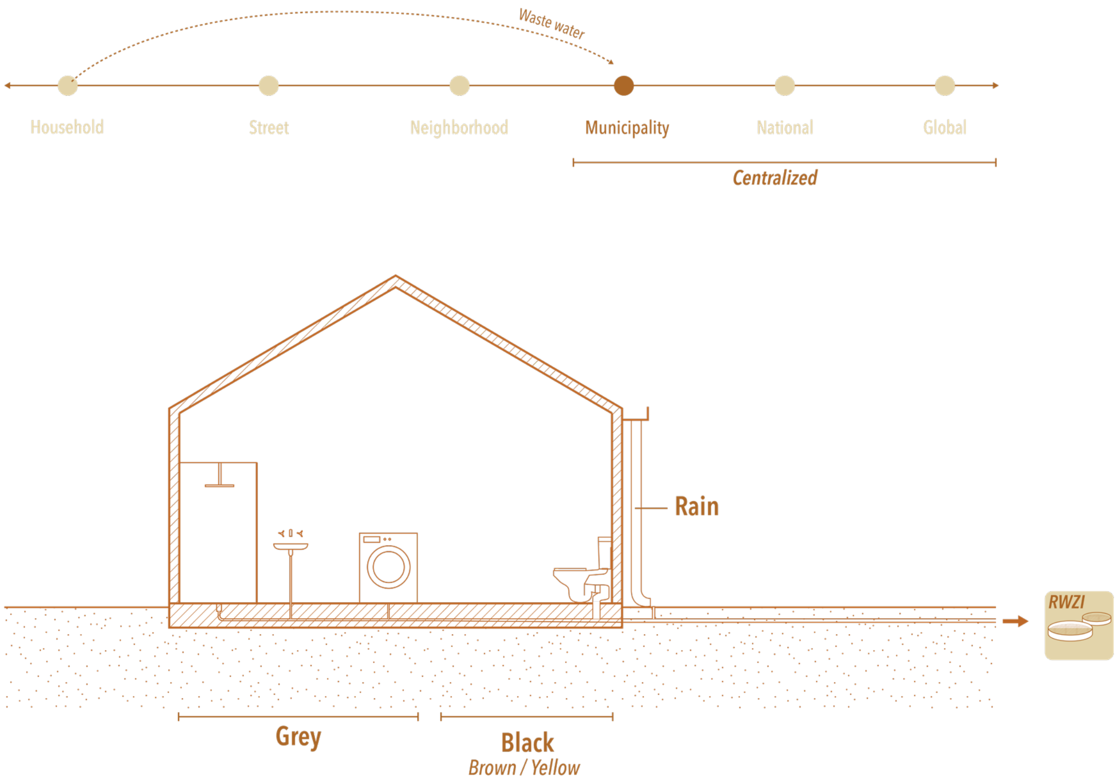
Rainwater is the largest contributor to the stream of wastewater but contains little to no pollutants and therefore dilutes the wastewater (Henze & Comeau, 2008). Household wastewater has the highest content of pollutants. Household wastewater is often divided in two different streams regarding the specific function and pollutant load: black and grey wastewater. Black wastewater is the combination of flush water, faeces and urine that originated from toilet and has the highest pollutant load (Swart, 2008, p. 21). Sometimes blackwater is again separated into brown (faeces) and yellow (urine) water. Brown water mainly contributes to the load of organic substance, heavy metals, pathogens, around 11% of nitrogen and 35 % of phosphorus. Yellow water contains the highest amount of nitrogen (85%) and phosphorus (47%). The remaining part of the pollutants can be found in grey water which originated from all other sources such as washing machines, kitchen sinks or showers. Here it is mostly soaps and detergents that contribute to the amount of phosphorus and nitrogen, but it is low in content and more diluted. In total around 30% of household wastewater is black water and 70% is grey water.



14. Household wastewater contents

7.1.2 Wastewater treatment in the Netherlands

As wastewater contains chemicals and pathogens, treatment is needed in order to mitigate public health and environmental risks (Siegrist, 2017). This notion has set in since the 1960's and has led to the widespread development of wastewater treatment facilities. Before that, wastewater was directly discharged into open water. Nowadays 99% of households in the Netherlands are attached to a sewer system and centralized treatment facility. The fact that most sewage systems are built on municipal scale can be attributed to the level of responsibility and expertise, favourable landscape conditions in the Netherlands, and foremost the perceived advantages of centralized treatment systems (Gastkemper & Buntsma, 2015). Large-scale facilities are perceived to have a high technical reliability compared to small scale facilities (Poustie, et al., 2015). They are also efficient since diurnal and daily variations are reduced due to the averaging effect of the sheer size of large-scale systems making them economically attractive (Daigger & Crawford, 2007).

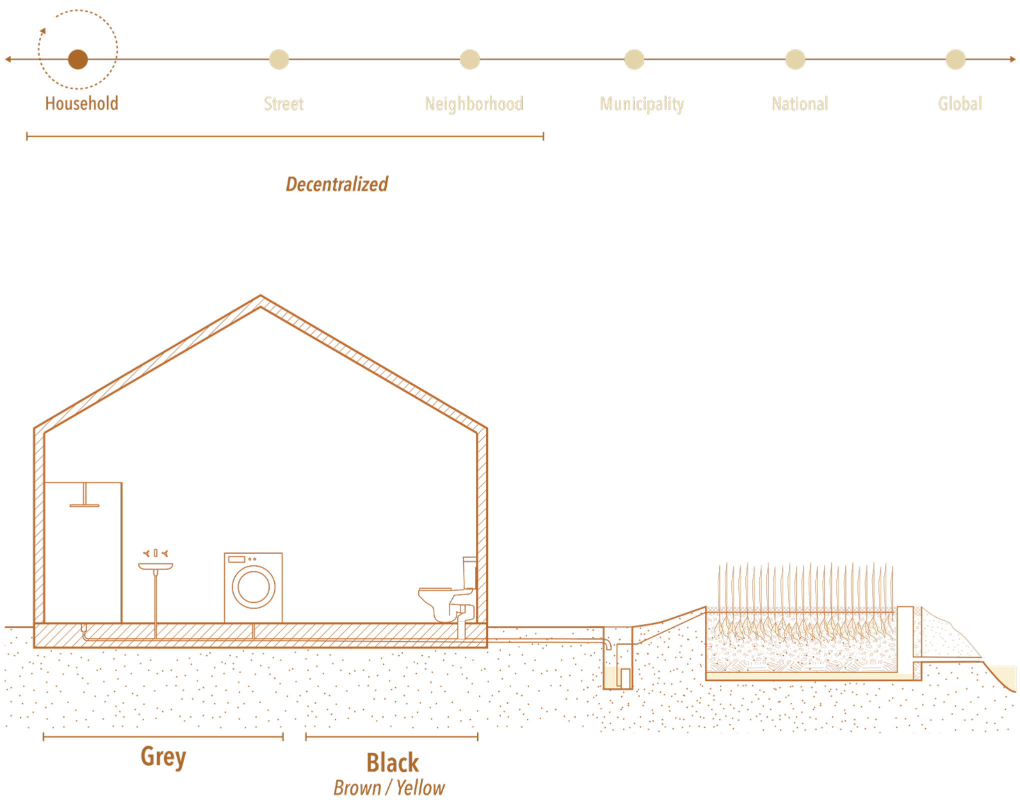


15. Centralized wastewater treatment system from a household perspective

However, there are also a number of challenges that come with centralized and large-scale facilities. First of all, conventional treatment methods combine the transport and treatment of wastewater and rainwater resulting in the dischargement of untreated water into rivers and coastal zones due to sewer overflows in case of heavy rainfall with consequences for public health and ecosystems (Siegrist, 2017). Secondly, the combination of these two streams results in a low nutrient content (which is derived from household wastewater) making wastewater treatment facilities less efficient as well as prohibiting the possibilities for resource recovery (Poustie, et al., 2015). On top of that, the economies of scale found in centralized wastewater treatment systems are often counterbalanced by the high costs of a distribution or collection network, especially in low density areas (Guo, Englehardt, & Wu, 2014; Gastkemper & Buntsma, 2015). Additionally, the technique used for the treatment of wastewater is energy intensive and therefore costly (Clevering- Loeffen, 2011). The aforementioned challenges have led to a search for improvements and the consideration of a different approach to wastewater treatment.

7.2 Local wastewater treatment and its advantages and disadvantages

A local approach towards wastewater treatment is considered as a solution to the challenges of centralized treatment. The reason that this is considered in the first place, is due to the fact that local treatment options have emerged and developed to worthy alternatives. Previously decentralized treatment techniques could only conduct primary treatment (often in the form of septic tanks) but nowadays there are many techniques on the market that provide primary, secondary and tertiary treatment (Potz, 2012). Furthermore, there have been a number of bottom-up initiatives (in the Netherlands and more often abroad) that have experimented with wastewater treatment on a local scale providing research opportunities and assurance. These initiatives include neighbourhoods like Eva Lanxmeer in Culemborg, Aardehuizen in Olst, Bewust Wonen Werken Boschveld in s'Hertogenbosch and many others. These early adapters have demonstrated the advantages that come with local wastewater treatment.



16. An example of a local wastewater treatment system at household level

7.2.1 Advantages

There are a number of advantages that arise with local wastewater treatment. Firstly, local wastewater systems can be more efficient due to the decrease in sewage transport. This results in decreased maintenance, construction and electricity demand for pumping resulting in cost reductions and resource preservation (Daigger & Crawford, 2007). In these systems it is easier to create conditions which foster the reclamation and reuse of resources (Capodaglio, 2017; Siegrist, 2017). Particularly in wastewater this is interesting considering the amount of valuable resources that are present, such as heat (Wit, R. de Graaf, & Debucquoy, 2018), struvite (Postma, Mulder, Hulst, & Kampschreur, 2012), compost (Elferink & Vlaar, 2010), biogas (Grant, 2014), water (Almuktar, Abed, & Scholz, 2018) or cellulose (Mulder, et al., 2016). Secondly, local wastewater treatment facilities are more flexible and adaptable due to the increase in facilities and the diversity of methods available. Thirdly, local wastewater treatment systems can be integrated within the environment and act as public amenities contributing to the ecological value of the area and encouraging the multifunctional use of land (Suriyachan, Nitivattananon, & Amin, 2012; Potz, 2012). Lastly, if citizens are included in the process or if part of the responsibilities are handed to local citizens, this can increase awareness and a sense of ownership, and include important local perspectives in the decision-making process (Damman, Helness, Grindvoll, & Sun, 2019). However, even though these advantages make a good case for wastewater treatment, there are also a number of disadvantages.

+ *Decreased transport of wastewater leading to a decrease in cost, maintenance and electricity use*
+ *Easier to reclaim and reuse resources found in wastewater*
+ *Higher flexibility and adaptability*
+ *Easier to integrate within the environment*
+ *Increase in awareness and a sense of ownership*

7.2.2 Disadvantages

There are a number of disadvantages of local wastewater treatment. First of all, local wastewater treatment has to deal with higher fluctuations when it comes to the inflow of wastewater (Gastkemper & Buntsma, 2015). The averaging effect of wastewater inflow that is present in large-scale wastewater treatment is less present in small-scale wastewater treatment resulting in higher uncertainties. Especially for wastewater this is a problem given that treatment is bound by biological processes which rely on bacteria growth. These bacteria are dependent for their survival on the organic content of wastewater which is present in black water. At times of reduced 'production' of black water, bacteria populations can therefore diminish, decreasing the overall potential for treatment. If the production of black water is subsequently increased, the bacteria population might be too limited to be able to properly treat the wastewater. In other words, local treatment needs to account for higher fluctuations in wastewater with the risk of sub-optimal treatment (Weirich, Silverstein, & Rajagopalan, 2011). Second, small-scale techniques commonly have a higher land-use than the techniques used for centralized treatment (Potz, 2012). Centralized treatment is often based on mechanical treatment, which uses aeration to increase bacteria growth and consequently less land-use. On a local scale this technique is also available but other more 'natural' techniques such as wetland are available which covers a larger area than mechanical treatment. Moreover, due to higher fluctuations, as explained above, local wastewater treatment systems need more redundancy to mitigate these fluctuations which results in a higher land-use. Lastly, local wastewater treatment is often integrated near or in the centre of communities. This can pose greater risks for public health when treatment systems fail

M. Local wastewater treatment (wetland) (photo by author, Oosterwold) ▶

or are wrongly installed or maintained by inhabitants instead of experts. (Johnson & Pflugh, 2008). Monitoring and adequate action in case of pollution are therefore more difficult.

- *Higher fluctuations of influent due to a decrease in the averaging effect*
- *Higher land-use compared to large-scale facilities*
- *Local systems are in the vicinity of communities posing greater health risks*

7.3 The land-use intensity, environmental impacts and risks associated with local wastewater treatment

As explained in the problem field, there are three main indicators that are important for the integration of essential service systems within the built environment. The following paragraphs discuss these indicators for local wastewater treatment.

7.3.1 Land-use intensity

The land-use intensity of wastewater treatment depends on the technique and amount of energy that is added during the process of wastewater treatment. If energy is added, extra aeration occurs resulting in a higher land-use intensity (Potz, 2012). This is also what is done with centralized treatment though at high energy costs. When aeration is not applied, and more natural techniques are used (such as wetlands), land-use can increase. This can be an issue with the integration of wastewater treatment systems in an urban environment especially when land availability is low (He, et al., 2018). Furthermore, due to the absence of the averaging effect on a small scale as explained in the previous paragraph, local wastewater treatment needs more land anyhow (Gastkemper & Buntsma, 2015).

7.3.2 Environmental impact

Wastewater treatment in general can emit odour and gasses due to the decomposition of wastewater or sound as a result of the aerating of wastewater. This is not different for local wastewater treatment, however, the important difference is again the proximity to households which can cause nuisance. As an example, odour is one of the major environmental issues and is considered the main cause of disturbance noticed by nearby inhabitants (Zarra, Naddeo, Reiser, & Belgiorno, 2008).

7.3.3 Risks

With the treatment of wastewater there is always the risk of failure which can lead to pollution of the environment and jeopardize public health. With local wastewater treatment the risks are smaller due to the size of the treatment facility, however, there is also an increased risk around mismanagement and failure. Inexperienced and dispersed ownership as well as a diversity of techniques can increase the likelihood of mismanagement. Failure and late detection is therefore more likely which leads to higher consequences for the environment (Fane, et al., 2004). Furthermore, the higher fluctuations discussed in the previous paragraphs, can lead to a higher failure rate in wastewater treatment and therefore a higher risk. In general, the risks of local wastewater treatment might be more important as the consequences have a direct impact on nearby citizens, particularly if ground water is polluted (Fane, et al., 2004).

7.4 Wastewater treatment in Oosterwold

The consequences of local wastewater treatment for spatial planning as mentioned above are compared to the current situation in Oosterwold. Currently around 1000 households are developed or under development giving us an insight into some of these implications. This information is gathered using interviews, maps, observations during visits and available literature.

7.4.1 Vision wastewater treatment Oosterwold

In the development strategy for Oosterwold, wastewater treatment is seen as the full responsibility of inhabitants. Furthermore, wastewater separation (into grey, brown and yellow) and the reuse of resources is encouraged: "Yellow water can be filtered to remove traces of medicine and used to develop struvite, a fertilizer for agriculture. Brown water can be fermented to produce energy. Grey water can be treated producing water that can be used during gardening." (Werkmaatschappij Almere- Oosterwold, 2013, p. 170). The choice for local wastewater treatment is mainly a result of the organic urban development which would be hampered by centralized treatment as this demands top-down urban planning. Even though inhabitants are responsible for their own wastewater treatment, the municipality and the waterboard are still officially responsible for the quality of effluent as is prescribed in the law. To tackle this issue, inhabitants are obliged to meet a certain demand for the quality effluent they produce which is monitored by the waterboard in order to sustain similar qualities of wastewater treatment (Waterschap Zuiderzeeland, 2017). The quality of effluent is defined according to the risk of pollution or contamination when it comes to ecology and public health. The risk for pollution of the environment is high as the area is also an important potable water source. Therefore, local wastewater treatment in Oosterwold has to abide to the highest standards regarding the quality of effluent which means the heaviest techniques for treatment are used. The quality of effluent from inhabitants is regularly checked and if the effluent does not meet the requirements, fines will follow.

7.4.2 Patterns within development of wastewater treatment in Oosterwold

The following paragraphs explain the patterns found in phase 1 of Oosterwold for wastewater treatment. Through an understanding of these patterns we can generate an understanding of the processes behind wastewater treatment in Oosterwold and provide input for the scenario development in 8.1.

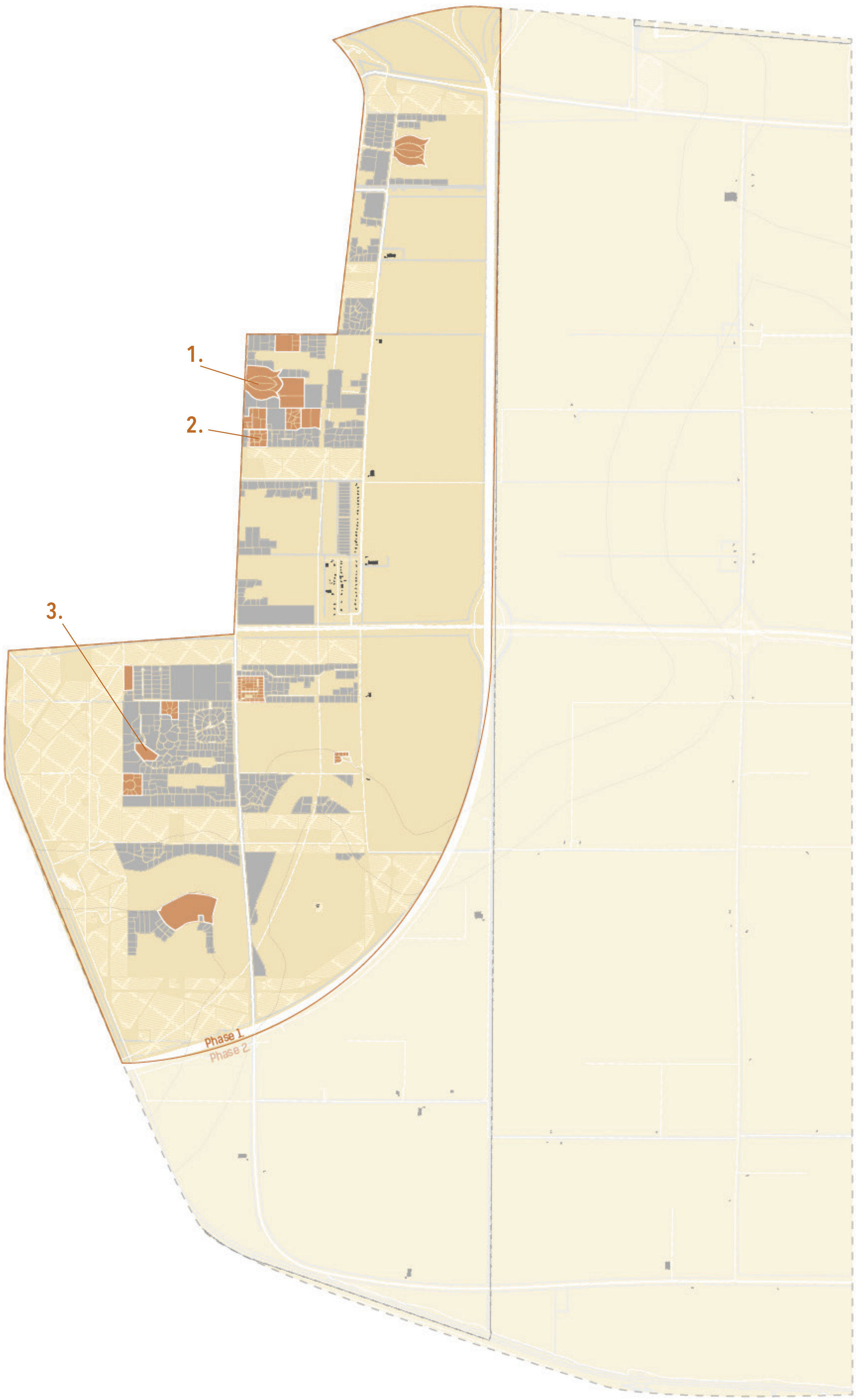
Systems

The most common wastewater treatment systems found in Oosterwold are (vertical) wetlands. During observations these are relatively easy to spot as they are built above ground. Mechanical treatment is also used in Oosterwold as one of the other options for wastewater treatment. These units are built

O. Communal wastewater treatment nr. 1

P. Communal wastewater treatment nr. 2

N. Communal wastewater treatment from left/top to bottom nr.1-3 (photo by author)



17. Communal wastewater treatment (orange) and individual treament (grey) in Oosterwold

underground, but their maintenance inlets are visible above ground. Both treatment techniques treat both black and grey water. It is possible to install a composting toilet and compost chamber, but these are placed inside and therefore difficult to spot. There is at least one household who has employed a composting toilet (Abspoel, 2016).

Levels of autonomy

In Oosterwold wastewater is mainly managed on an individual level: around 80 % is treated on a household level while 20 % is treated communally (see Figure 17). Wastewater treatment at a household level is popular for a few reasons. First of all, when the neighbourhood develops organically, it is easier to develop individual treatment as this reduces the negotiation time spent with neighbours, and inhabitants do not have to wait until their neighbours have developed their plot before they can use the toilet. One inhabitant mentioned "we already spend a large portion of our time agreeing with neighbours on creating a road infrastructure, we were therefore not keen to add wastewater treatment to the discussion as well". Secondly, the implementation of sewers in Oosterwold is expensive as households are often far apart due to the low-density of the building and the area is subject to soil subsidence (Werkmaatschappij Almere-Oosterwold, 2013). Consequently, transport becomes expensive due to the relatively long pipe lengths, the higher maintenance cost, maintenance of sewer systems and heavy material required for repairs. Thirdly, as local wastewater treatment often cannot withstand harsh detergents, inhabitants are hesitant to trust each other as they have no (or not yet a) rapport with their neighbours during the development phase. During an interview an inhabitant of Oosterwold stated that people who develop together, especially with their family, gravitate towards communal wastewater due to a situation of mutual trust, which is not the case for newcomers. Even if they would want to create communal wastewater treatment, it is difficult to contact future neighbours as the area team will not provide their contact details (see Appendix 1.3). As a result of these considerations, there are no individually developed plots which have chosen communal wastewater treatment in Oosterwold based on observations. For future developments it is therefore important to create a cooperative platform where people can join forces.

Communal wastewater treatment is sometimes present in communally developed plots. The reason why people develop communal wastewater treatment is generally to reduce the cost of construction and to improve the workings of a wastewater treatment system (see Appendix 1. Interview Yolanda). It is also relatively easier to develop communal wastewater treatment if all houses are built around the same time and houses can be placed closer together to reduce the cost of implementing a sewer system.

7.4.3 Current challenges

During the monitoring of wastewater treatment systems, it was found that 66 out of 80 wastewater treatment systems in Oosterwold produced an effluent that did not meet the requirements (Oosterwold.info, 2016). This was not the result of wastewater disposal behaviour of inhabitants, but rather the result of the incapability of systems to handle large fluctuations in wastewater inflow (CEW, 2019). Therefore, the low-quality effluent was mainly found in individual treatment systems as these experience the largest fluctuations. As these faulty systems lead to pollution while the area is an important potable water source, there is reason for concern.

7.4.4 Future wastewater treatment in Oosterwold

Due to the challenges with individual wastewater treatment, the future of wastewater treatment in Oosterwold is up for discussion. The area team has already decided to stimulate communal wastewater treatment to try and improve the quality of effluent (see Appendix 1. Interview Yolanda), and the leading company for wastewater treatment systems in Oosterwold has replaced most of their systems. However, if the quality effluent will not improve, the neighbourhood will most likely be attached to a large-scale wastewater treatment system. Whether this will be developed within the neighbourhood or households will be attached to a nearby system is not yet clear (Omroep Flevoland, 2019).

7.5 Available local wastewater systems

According to system theory, a system consists of a purpose, elements and interconnections (see system theory 4.3). The purpose is in this case the provision of energy (heat and electricity) to match the demand for energy. Energy production and storage are the elements within an energy system and transport is the interconnection between these elements. In this sub-chapter the production (7.5.1), storage (7.5.2) and transport (7.5.3) are further explored in order to understand their role in the energy system as a whole and ultimately understand their impact on spatial planning. The available systems that cater these functions are described in the 'Catalogue of local wastewater solutions' alongside their land-use, environmental impact and risks.

7.5.1 Treatment of wastewater

The purpose of the treatment unit is to eliminate the harmful substances (as mentioned above) in wastewater. Decentralized wastewater treatment units are subdivided into four categories that indicate to which degree waste water is purified (Potz, 2012):

Type 1	*Basic wastewater collection, little treatment,*
Type 2	*Also removes suspended solids,*
Type 3A	*Also removes nitrogen,*
Type 3B	*Also removes phosphorus.*

To get to the level of treated water as mentioned above, the wastewater treatment systems in Oosterwold have to be a type 3B (Waterschap Zuiderzeeland, 2017). In general, there are three methods to treat wastewater (Potz, 2012):

1. Physical	*sedimentation or filtration*
2. Chemical	*binding substances with chemicals so that they settle*
3. Biological	*waste is broken down by bacteria and/or absorbed by plants*

Most type 3B wastewater treatment systems are based on a combination of these three methods (Potz, 2012). There are roughly two types of systems that can deliver high quality treatment: mechanical treatment and natural treatment. In mechanical treatment the conditions for wastewater treatment are automated whereas in natural treatment plants are used for the treatment of wastewater. The following techniques can be found within the catalogue of local wastewater treatment solutions:

W1	*Composting chamber*
W2	*Septic tank*
W3	*Biogas Reactor / Digester*
W4	*Wetland*
W5	*Living machine*
W6	*Mechanical treatment or activated sludge*

7.5.2 Collection of wastewater

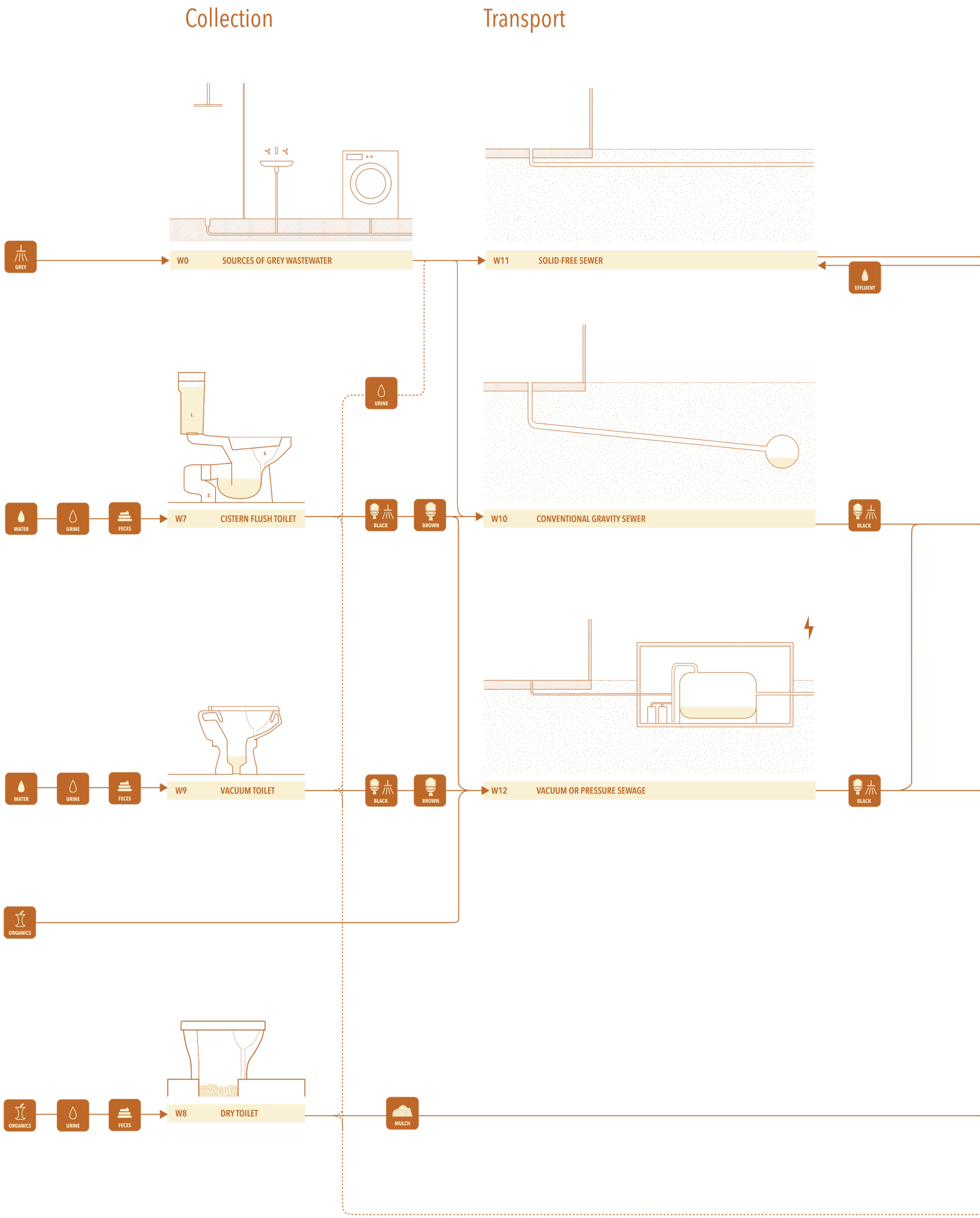
Grey wastewater is collected through a wide variety of products (shower, washing machine or sinks) while black wastewater is commonly collected through toilets. Whether a collection system collects wastewater streams (black, brown, yellow or grey) separately or combined greatly influences the type of treatment and possibility for resources recovery in a later phase (SSWM, 2018). The collection of grey water is of little importance as there are no valuable contents in grey wastewater and the water is only lightly polluted. For black water this is different as there are possibilities for resource recovery and the pollution content is high. It is therefore important to mention the different possible techniques for the collection of black wastewater, however, due to the fact that they are integrated within households and do not play a role in spatial planning they are not evaluated for their land-use, environmental impact and environmental risks. The following techniques can be found within the catalogue of local wastewater treatment solutions:

W7 *Cistern Flush Toilets*
W8 *Dry toilet*
W9 *Vacuum or pressure toilet*

7.5.3 Transport of wastewater

Sewage systems connect collection points and wastewater treatment units. The type of sewage systems depends on the technology for the collection of wastewater. Conventional wastewater transport in the Netherlands combine the collection of rainwater, grey water and black in one sewer system. More recently the separate collection and treatment of these waste streams is pursued to encourage resource recovery and separate treatment. Wastewater transport is facilitated using gravity, pumping or suction. It is also possible to simply collect wastewater without the use of a sewer system. This is possible in the case of composting. The following techniques can be found within the catalogue of local wastewater treatment solutions:

W10 *Conventional sewer*
W11 *Solid-free gravitational sewer*
W12 *Vacuum sewer*

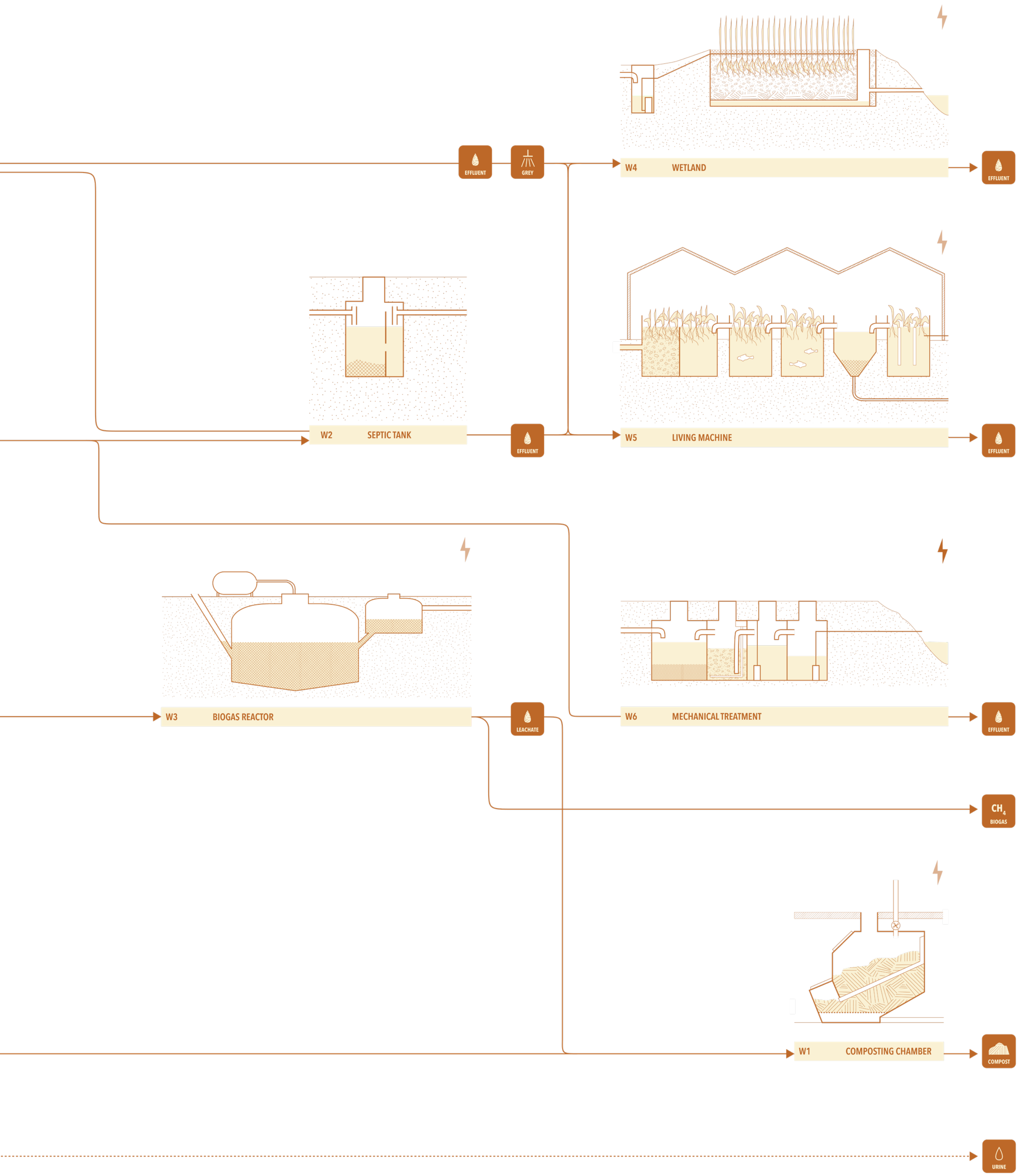


18. Overview of the wastewater treatment systems applicable in Oosterwold and that can be found within the catalogue

Storage & Treatment

primary

secondary & tertiary



Exploring essential service provision on different levels of autonomy

In this chapter a research by design approach is used to further explore essential service systems on different levels of autonomy and understand their differences. In sub-chapter Based on the analyses in previous chapters, three different scenarios are formulated using scenario planning in sub-chapter 8.1. The scenarios are based on three different levels of autonomy: household level, street level and neighbourhood level. This answers the fifth research question:

Q5: What are relevant scenarios for the level of autonomy of future essential service provision in Oosterwold?

Subsequently, three different maximization studies are done based on the three scenarios and explained in sub-chapter 8.2. This establishes nine designs in total. In sub-chapter 8.3, the general trends in land-use, environmental impact and environmental risks between the scenarios are explored. This answers the last sub-question:

Q6: What are the land-use intensity, environmental impact and environmental risks of essential service provision in Oosterwold based on different scenarios?

8.1 Scenario Development

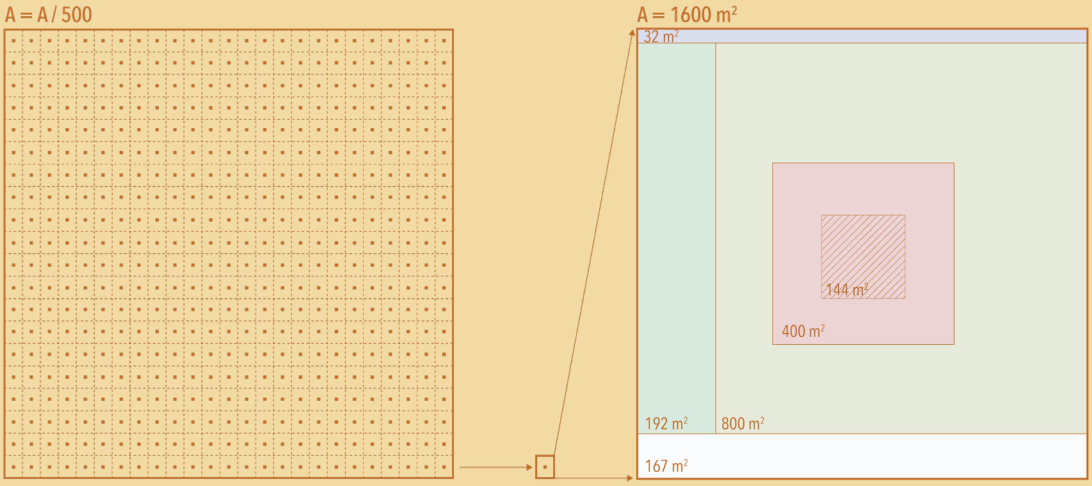
The goal of the scenario development is to generate a set of scenarios that are relevant for the future integration of essential services in Oosterwold. With the future we refer to the second phase of the development (see figure 1.). From the analysis we can conclude that there is ambiguity surrounding the choice for the particular scale on which to apply essential service systems, or in other words, on which level of autonomy. For wastewater, the challenges with individual treatment have led to a reconsideration of the level of autonomy. For energy, if self-sufficiency is to be achieved in the future, the level of autonomy will be an important point of discussion and inhabitants are already interested in the possibilities for shared storage. Paragraph 8.1.1 shortly explains the different scenarios while 8.1.2 explains the spatial model as a consequence of these scenarios.

8.1.1 Levels of Autonomy

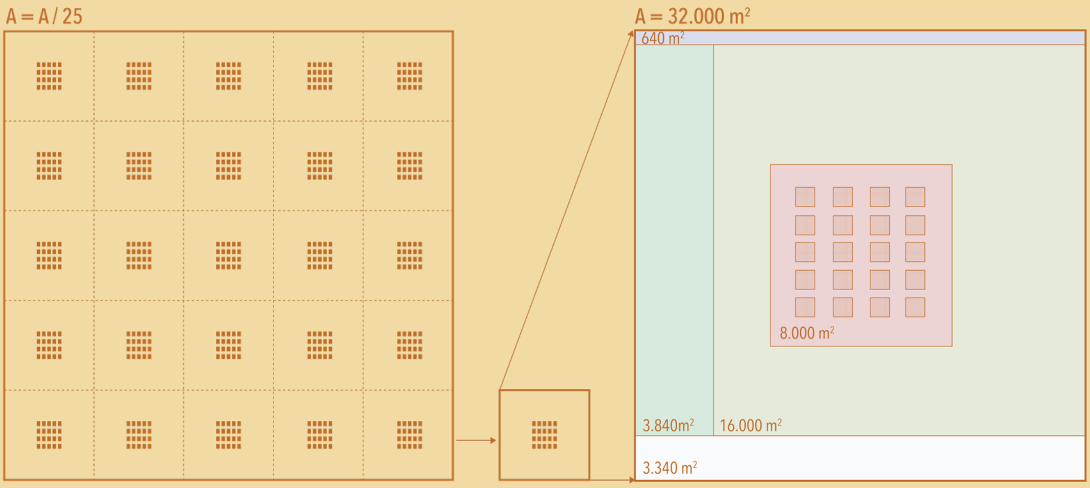
Three different scenarios were developed based on three possible levels of autonomy: Household level, street level and neighbourhood level. These different levels are mainly based upon the levels of autonomy that have been developed in the first phase for wastewater (household and neighbourhood level) and assumptions of the possible level of autonomy in the second phase (neighbourhood level). In all scenarios, full autonomy is assumed (no connection to the grid) as we assume energy autonomy is still something the neighbourhood will strive for in the future.

A. Household level

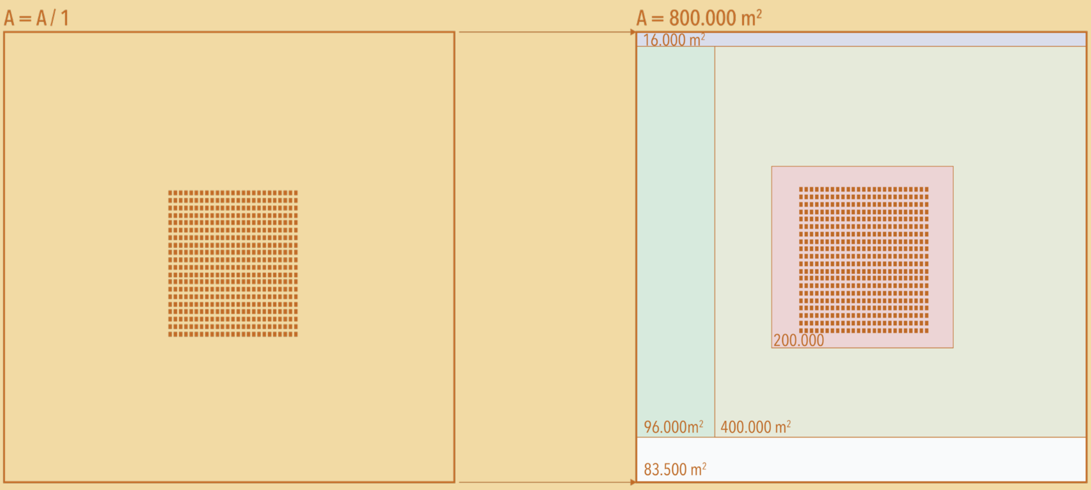
In this scenario the organization of essential services is confined to one single household within the confinement of its own plot. The household level is the most common level of providing essential services in Oosterwold for both wastewater treatment (80%) and energy production (100%) and



19. Spatial division and land-use pattern of scenario A



20. Spatial division and land-use pattern of scenario B



21. Spatial division and land-use pattern of scenario C

therefore seen as a relevant scenario (see 6.4 & 7.4).

B. Street level

In this scenario essential service provision is confined to a group of 20 households. This is mainly based on the average size of communal wastewater treatment in phase 1 of Oosterwold which comprises 20% of wastewater treatment. For energy production there is no account of shared production or storage, however, this might change in the future due to the decrease in payment for electricity shared with the grid and the willingness to install a shared place for storage.

C. Neighbourhood level

In this scenario, essential services are provided on a neighbourhood level with a total of 500 households. This level of autonomy is not yet present in Oosterwold but there are signs this might be present in the future. In the future the area team has proclaimed an interest in large-scale collective wastewater treatment, possibly managed by the waterboard. Since the number of households has increased with around 500 households per year, this number is taken as a starting point for this last scenario.

8.1.2 Spatial model based on the scenarios

Based on the three different scenarios, a model is created in order to provide a base for the maximization studies in 8.2. In order to easily compare the different scenarios and provide conclusions on the basis of their differences, the total spatial boundary and consumption patterns in every scenario remain constant. The spatial boundaries are based upon an estimation of the average plot size of 1600 m2. This leads to a total area of 800.000 m2 for a total of 500 households. The consumption pattern is matched to the average water and energy consumption of a newly built home according to the newest regulations of an average household composition of 2,5 people (see Appendix 5.). What changes in every model is how the space and consumption are divided: into 500 single households, 25 streets or one large neighbourhood. Combined with the prescribed spatial division of plots in Oosterwold (see Appendix 5. Figure 3.), this leads to the following models with housing (red), agriculture (light-green), nature (green), roads (grey) and water (blue).

8.2 Maximizations

Apart from their dependence on the choice for a certain level of autonomy, the land-use intensity, environmental impact and environmental risk associated with essential service provision differentiate based upon the choice for a certain set of techniques. Through the maximization method, three different strategies for the provision of essential services are tested on the three different scenarios creating nine different designs (see Figure 8.4). This enables us to spot trends between the different designs in 8.3. The choice for a certain set of techniques was aided by the catalogue of solutions for wastewater treatment and energy production and based upon the following strategies: exploring the most common techniques in Oosterwold, the techniques with the highest land-use intensity, and the techniques which are easiest to integrate into the agricultural landscape of Oosterwold. Every scenario is ‘maximized’ which means we always look for the most efficient way of implementing essential service systems according to the consumption patterns and within the spatial boundaries. The three different maximizations based on the three different scenarios lead to 9 designs.

1. Current

The first system iteration is based upon the most-used techniques found in Oosterwold based on observations. For some reason inhabitants have chosen these techniques and we can assume that future inhabitants will choose similar techniques.

Essential service techniques used

Based on the analyses and observations in Oosterwold the following systems were chosen:

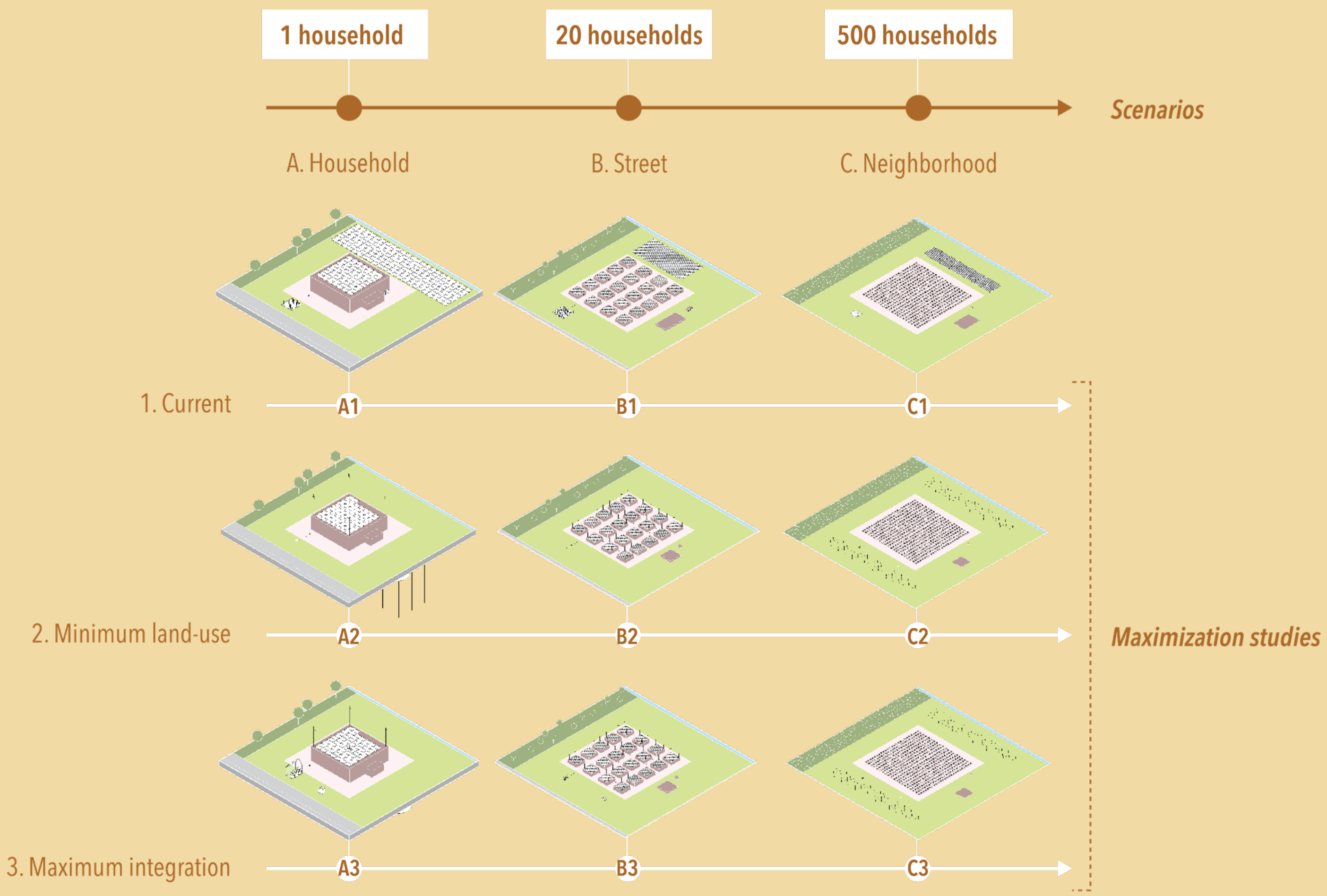
W2 Septic tank
W4 Wetland
W7 Cistern flush toilet

E1 Photovoltaics
E7 Lithium-ion battery
E5 Thermal energy from air

The combination of the septic tank as primary wastewater treatment and a wetland as secondary and tertiary wastewater treatment, results in a complete wastewater treatment system for a combination of all wastewater (black and grey). This is an often-used technique in Oosterwold and visible throughout the neighbourhood. For electricity production, photovoltaic panels are used in combination with electricity storage which is achieved through lithium batteries. There is currently no sign of wind turbines in Oosterwold which is the only other option for electricity production. Therefore, electricity production relies solely on photovoltaics. The lithium-ion batteries have not visibly been detected as these are either found inside homes or cars, however, in order to provide a form of energy autonomy, electricity storage is needed and therefore a technique was chosen. This became the lithium-ion battery as this is the most commonly used electricity battery on the market. For heat production the air heat pump is an often-used device in Oosterwold. To produce sufficient heat around one third of heat production relies on electricity. It is not certain these techniques are all truly the most common techniques in Oosterwold as it happens that these techniques are also relatively visible compared to underground techniques or techniques found within homes.

2. Minimal land-use

As was mentioned in the problem field (see chapter 2.), land-use is often a barrier when it comes to the implementation of local essential service provision. Especially renewable energy resources can claim a large percentage of land. In Oosterwold this is less of a problem since the availability of land is higher than in other parts of the Netherlands. Even so, essential service provision can obstruct other important functions, such as agriculture or living. Furthermore, more land also means a higher



22. Nine different designs based on three different maximization studies based on three different scenarios

investment, and this is becoming a larger issue with rising land prices. This maximization therefore focuses on the minimization of land-use. By analysing the different techniques and their land-use intensity as well the different fluctuations in land-use intensity, a combination of techniques was found and implemented through the use of a design-based approach. Based upon the essential service techniques that were analysed, the techniques with the lowest land-use were chosen as follows:

W2 *Septic tank*
W6 *Mechanical treatment*
W7 *Cistern flush toilet*

E1 *Photovoltaic panels*
E3 *Wind energy*
E4 *Geothermal energy*
E7 *Lithium-ion battery*
E10 *Seasonal thermal energy storage (STES)*

A septic tank provides primary wastewater treatment and a mechanical treatment system provides secondary and tertiary treatment. Both techniques function underground and have a high land-use intensity. For electricity production both wind energy and photovoltaics are used. By utilizing both techniques the fluctuations in solar arrays can be supported by the fluctuations in wind energy (and vice versa). This greatly decreases the total land-use intensity. Additionally, a geothermal energy system needs less electricity in general and the STES (Seasonal Thermal Energy Storage) significantly reduces electricity demand in winter. The geothermal energy system and STES are both situated underground and have a low land-use. The lithium-ion battery was also used in this scenario due to its high storage density compared to other batteries. The combination of these techniques allows for a minimal land-use.

3. Maximum spatial integration

The third scenario is based upon the techniques that are easiest to integrate into the landscape of Oosterwold. What this means is that techniques form synergies with the primary functions of Oosterwold such as agriculture. This strategy is chosen to provide a boundary condition for the implementation of local essential service techniques to avoid undesired impact on spatial quality. By morphing essential service techniques into the landscape and looking for synergies, essential service provision can possibly add to the quality of an area instead of degrading it. This is also a likely strategy applied by spatial planners or inhabitants. Focus is thereby towards integration with agricultural activities as this covers 50% of land in Oosterwold (see image G.).

W1	*Composting chamber*
W2	*Septic tank*
W5	*Living machine*
W8	*Dry toilet*

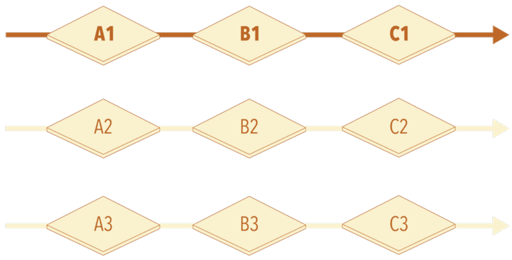
E1	*Photovoltaic panels*
E2	*Thermal solar energy*
E3	*Wind energy*
E7	*Lithium-ion battery*
E10	*Seasonal thermal energy storage (STES)*

The composting chamber, together with a urine collector, functions as a primary, secondary and tertiary treatment for faeces and urine (black water without the water). The end-product, compost, can eventually be used for the growth of crops which creates added value and is the reason for implementing this technique. The septic tank provides primary treatment while the living machine provides secondary and tertiary treatment in order to treat grey water. Where the septic tanks is solely used as a necessity, the living machine can produce crops and grow fish and is therefore an added value for the agricultural character of Oosterwold. For electricity production there is nothing that changes compared to the last scenario. This is mainly due to the limited options for the production of electricity. Photovoltaic panels are in this case combined with thermal panels which create PVT panels. These do not necessarily combine well with agriculture, as there are no heating techniques that combine well with agriculture but integrate well with households. For the storage of thermal energy there is also only one option which is again applied in this scenario. The lithium-ion battery is also used since this battery could potentially be used as car battery storage which is important in the neighbourhood due to its low-density and distance from amenities resulting in high car-ownership.

8.3 Consequences of the designs

Combining the three scenarios of levels of autonomy and the three maximizations create nine designs (see Figure 8.9). The different levels of autonomy are shown on the x-axes. The different maximization studies are shown on the y-axes. In this sub-chapter we analyse the trends that emerge based on the land-use intensity, environmental impact and risks of the different designs. First, we describe the trends found as a result of the three maximization studies which are accompanied by different recommendations for spatial planning in Oosterwold. In a conclusion we reflect upon the general trends found for the different scenarios.

8.3.1 Maximization of the current situation (A1, B1 and C1)



Land-use intensity

The land-use intensity does not change significantly from household to neighbourhood level. Only within wastewater treatment we see a significant change from street to neighbourhood level. This is due to the increase in land-use intensity for wetlands and septic tanks. This increase is in both cases a result of the averaging effect in water consumption. On top of that, for septic tanks there is also an increase in height with larger tanks (not with wetlands due to their maximum height of 60 cm). This directly results in a higher land-use intensity. For the photovoltaics, air heat pumps and lithium batteries the land-use intensity remains the same. This is mainly because the averaging effect could not be calculated for energy provision but also because the techniques do not increase in height when they grow larger. The land-use intensity mainly affects the total land used for the provision of essential services. Even though there is an increase in land-use intensity with wastewater treatment, the total land-use of techniques is not greatly affected because of wastewater only. This is because wastewater only constitutes around 3% of the total area used for the provision of essential services. In this case, the total land-use is most affected by the provision of heat which covers 64% of the total area used for essential service provision. This is due to the relatively low land-use intensity as a result of only using photovoltaics which have a low land-use intensity in winter. At the same time the air heat pumps are in need of a high amount of electricity in winter to fulfil the consumption of heat. Since there is no seasonal heat storage available, air heat pumps completely rely on the production of electricity by photovoltaics in winter. The low production of electricity by photovoltaics in winter and the relatively high need for electricity by air heat pumps in winter therefore require a large area of land.

1. *The land-use for wetlands and septic tanks decreases when wastewater is collectively treated*
Recommendation: To reduce the land-use of wastewater treatment, collective wastewater treatment with septic tanks and wetlands should be considered

2. *The land-use for the provision of energy, as well as the total land-use for the provision of essential services, is greatly affected by the imbalance in fluctuations between air heat pumps, photovoltaics and heating demand*
Recommendation: To reduce the land-use of energy production (which has a large impact on the total land-use for essential service provision) it is important to consider and mitigate fluctuations of energy production in comparison to fluctuations in energy consumption

	A1	B1	C1
Wastewater treatment (m3 wastewater treatment per m2)	6	6	10
Electricity production (kWh energy production per m2)	21	21	21
Heat production (kWh energy production per m2)	47	47	47

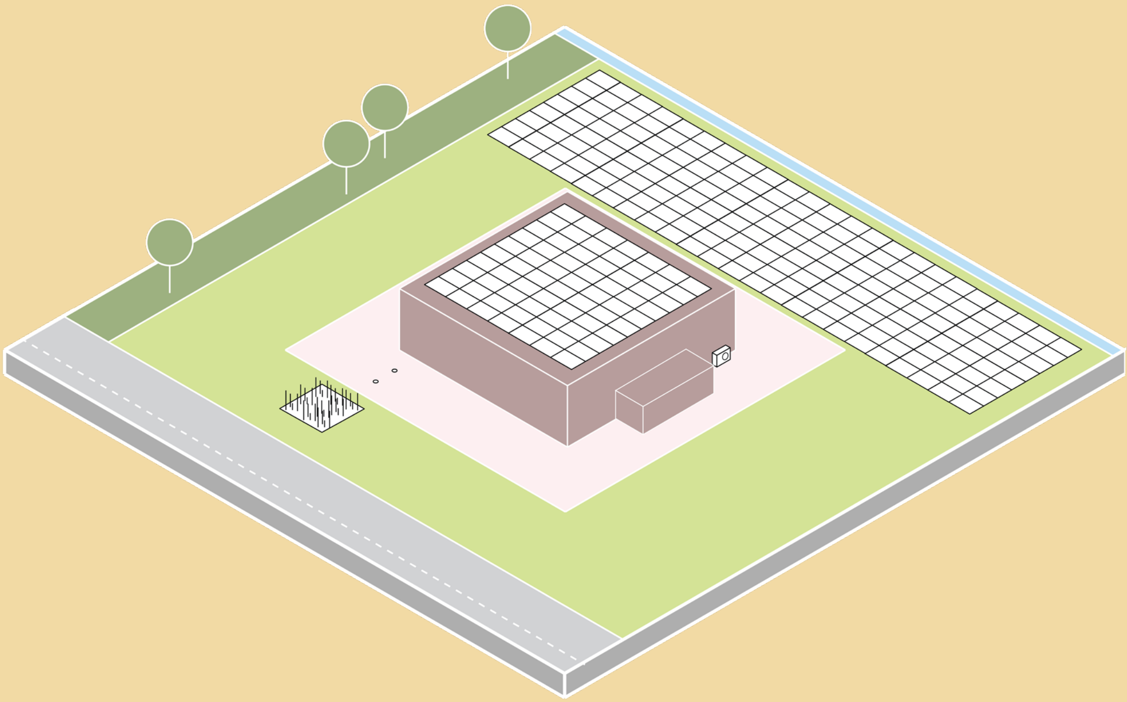
23. Land-use intensity of wastewater treatment and energy production per scenario (A1, B1, C1)

	A1	B1	C1
Wastewater treatment (m3 wastewater treatment per m2)	141386	140747	140640
Electricity production (kWh energy production per m2)	71150	70991	70983
Heat production (kWh energy production per m2)	7375	7050	4035
Total	**219911**	**218797**	**215676**
Percentage for essential service provision of total area	**27 %**	**27 %**	**27 %**

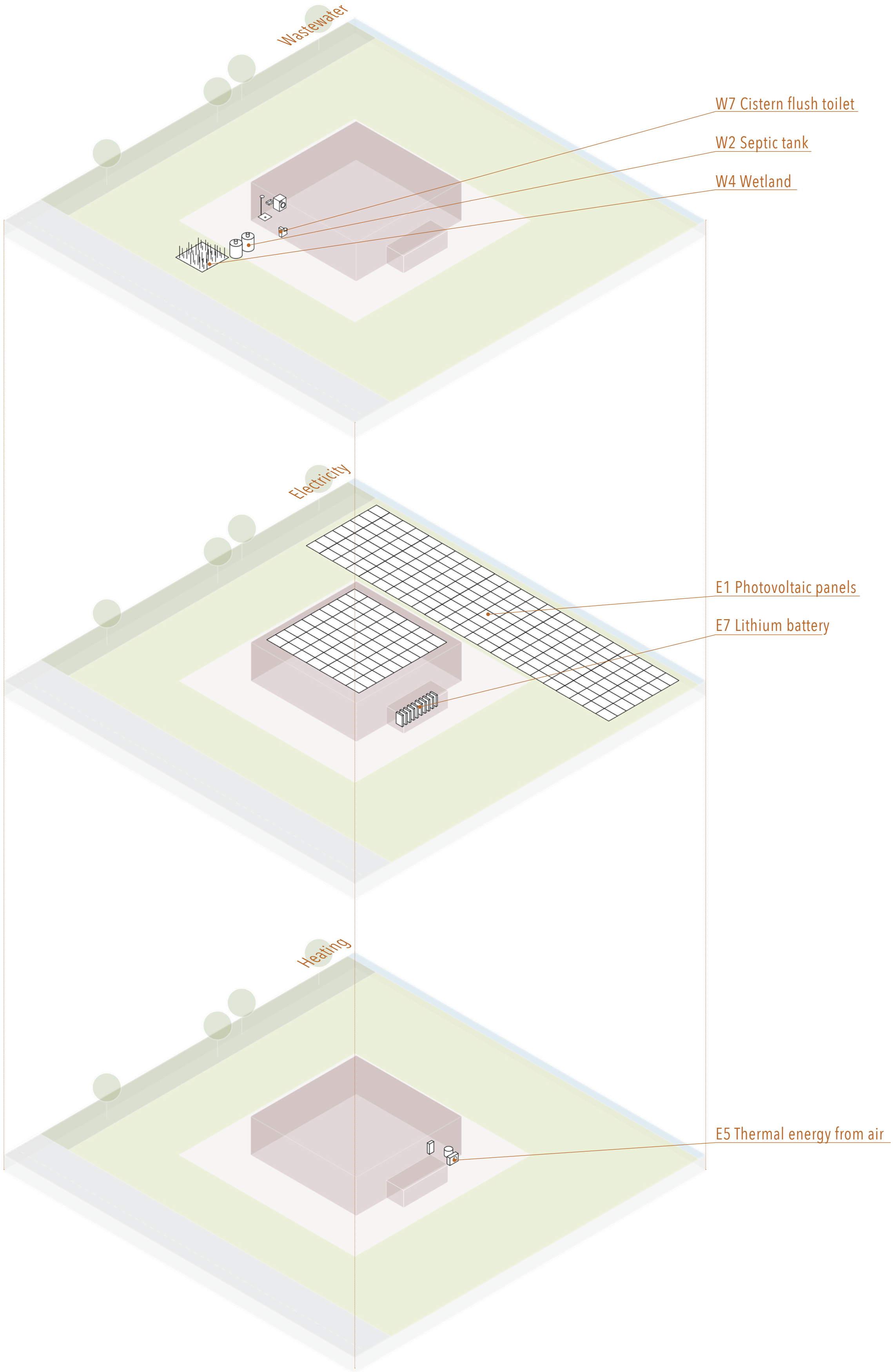
24. Land-use for essential services as a result of land-use intensity (A1, B1, C1)

Environmental impact
The environmental impact of essential service provision only changes with the use of air heat pumps on a street or neighbourhood level (B1 and C1). Where air heat pumps at a smaller scale produce relatively minimal noise, air heat pumps in combination can produce a stronger noise. On top of that, the visibility of energy production (air heat pumps, lithium batteries and photovoltaics) increases from household to neighbourhood scale. This is due to the concentration of techniques in one point instead of dispersed among households and the fact that these techniques cannot be integrated in households. For wastewater treatment this is not a problem as wetlands and septic tanks do not have a (large) visible impact. Septic tanks can, however, produce odour which increases with larger quantities

A_1

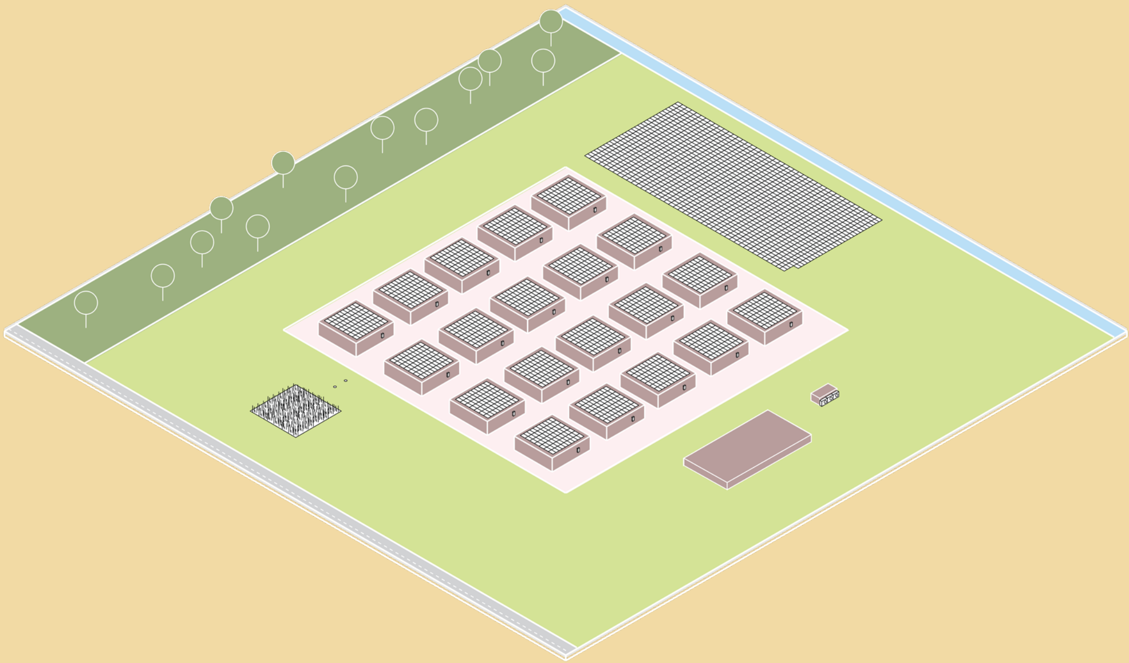


29. Implementation of the most common essential service systems on scenario A

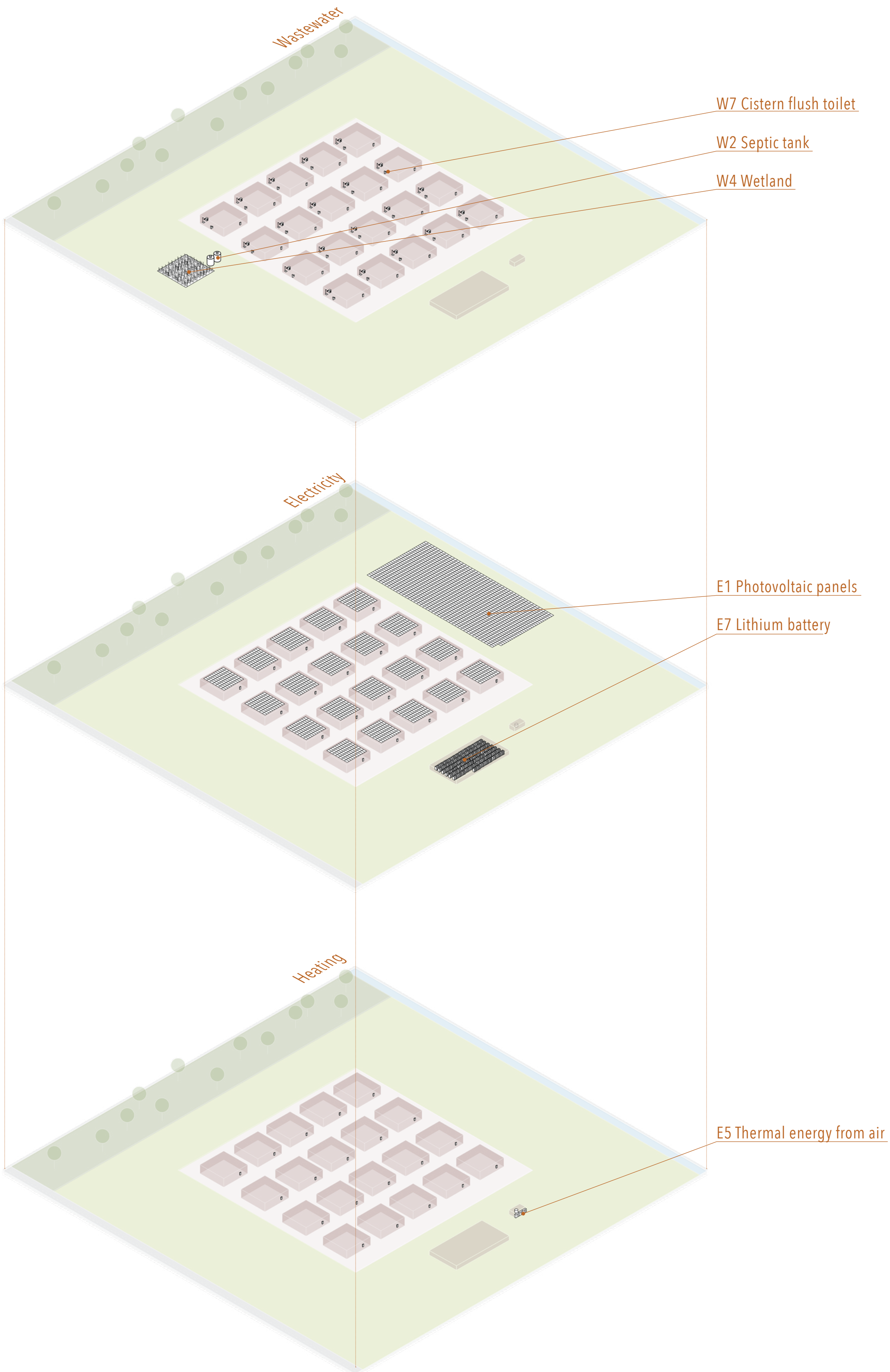


30. The three different maximized layers - wastewater, electiricut and heating - of scenario A1

B_1

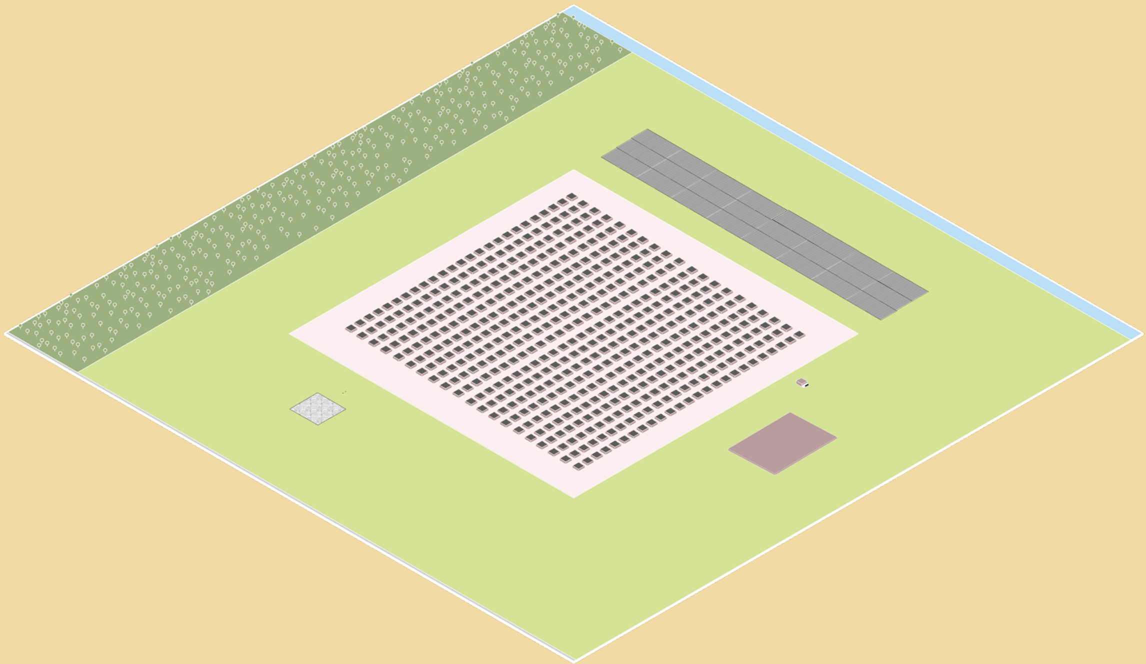


31. Implementation of the most common essential service systems on scenario B

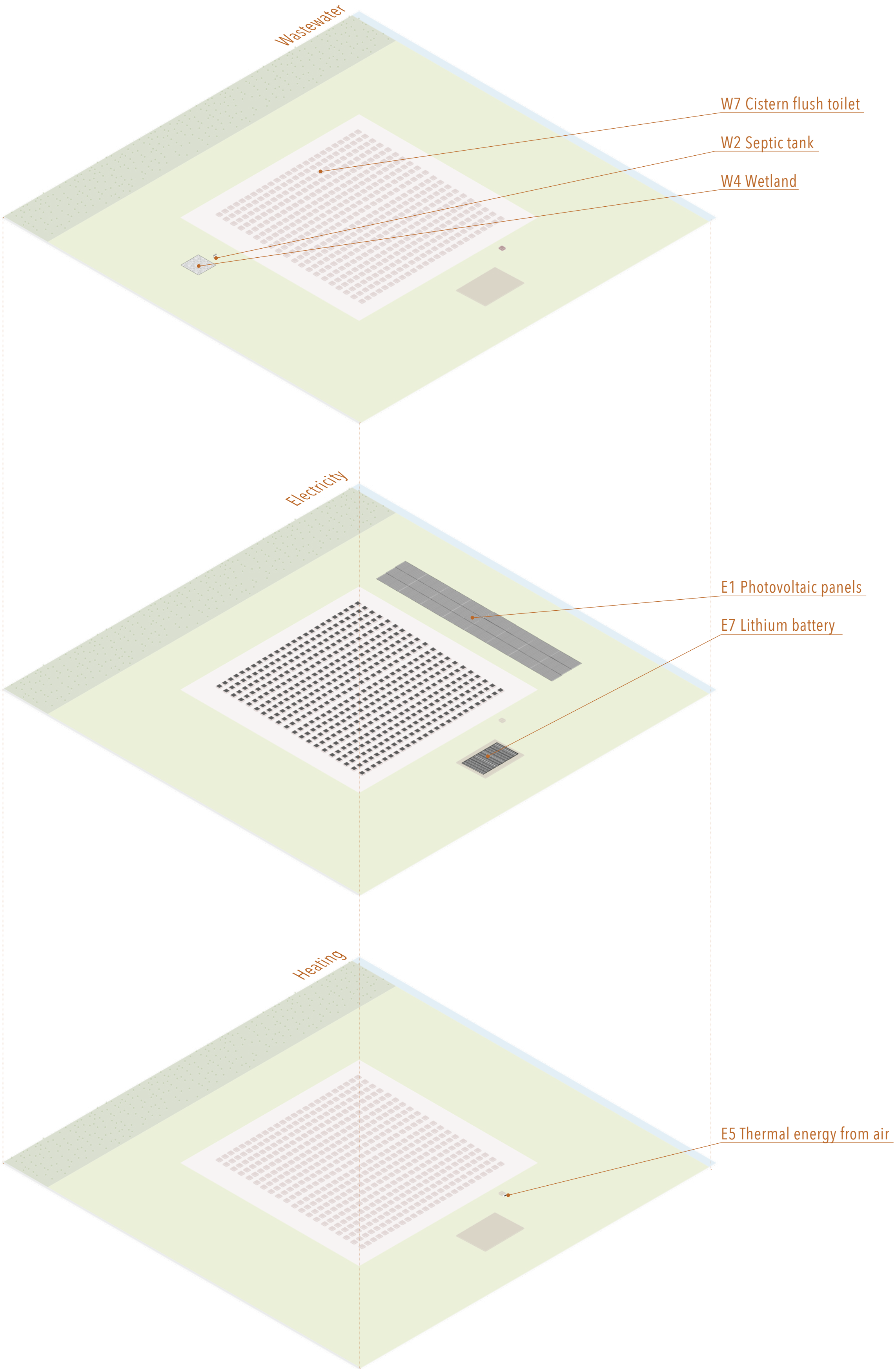


32. The three different maximized layers - wastewater, electiricut and heating - of scenario B1

C_1



33. Implementation of the most common essential service systems on scenario C



34. The three different maximized layers - wastewater, electiricut and heating - of scenario C1

of wastewater.

1. *The noise nuance of air heat pumps increases when these pumps are combined*
Recommendation: To mitigate noise nuance from air heat pumps they can be placed at a larger distance or insulation can be applied

2. *The visibility of air heat pumps, lithium batteries and photovoltaics increase when these techniques are concentrated in public space*
Recommendation: To mitigate the visibility of energy production (air heat pumps, lithium batteries, photovoltaics) these techniques can be integrated into public buildings or structures

3. *Odour of septic tanks can increase with larger quantities of wastewater*
Recommendation: To mitigate possible nuance from odour release from septic tanks it is best to implement septic tanks at a distance from households

Risks

The risks associated with the production of essential services remain constant or increase for the production of energy and decrease for the treatment of wastewater even though the potential hazard increases. The increase in risks associated with energy production are mainly a result of the increase in hazard potential and risks of lithium batteries. Where the probability of one standard lithium battery exploding is low, the probability increases for larger systems. The risks surrounding air heat pumps and photovoltaics remain constant through different levels of autonomy. For wastewater treatment the risk of failure decreases due to the more constant inflow of wastewater as a result of the averaging effect. At the same time the potential hazard increases: if there is a system failure a large quantity of wastewater or contaminated effluent can be exposed to the environment. Still wastewater treatment with wetlands proves to be more stable on a larger local scale then on household scale.

1. *The risks associated with energy production increase from household to neighbourhood level due to the coupling of lithium-ion batteries*
Recommendation: To mitigate the risk of explosion, especially on neighbourhood level, compartmentalization of lithium-ion batteries and their placement at a distance should be considered as well as constructing coverage with insulation

Recommendation: Preventing the full decharging or charging of lithium batteries can mitigate the risk of explosion

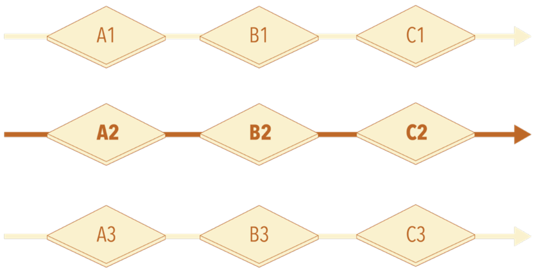
2. *The risks associated with wastewater treatment decrease from household to neighbourhood level*
Recommendation: To decrease risks associated with wastewater treatment, collective wastewater treatment can be considered

Conclusion

The land-use and risks of wastewater treatment in this scenario decrease when the level of autonomy increases while the environmental impact remains constant. Based on these conclusions we can state that if land-use (e.g. due to a scarce amount of available land) or risks (e.g. due to strict water quality regulations) are important, collective wastewater treatment can be considered.

For energy production the land-use remains constant for all techniques while the environmental impact of air heat pumps and the risks associated with lithium-ion batteries increase. Based on these conclusions we can state that air heat pumps are easiest to integrate on a household level and lithium ion batteries, on street or neighbourhood level, should be compartmentalized and distanced from homes.

8.3.2 Maximization towards minimal land-use (A2, B2 and C2)



Land-use intensity

As suspected the land-use is relatively lower than the previous maximizations. This is due to the mitigation of fluctuations in heat demand and supply as well as electricity production. In heat production fluctuations were mitigated due to the addition of seasonal thermal energy storage (STES). In electricity the fluctuations were mitigated by combining photovoltaics and wind turbines. As a result of this mitigation of fluctuations and increase in land-use intensity, the total land-use has decreased significantly. This is visible in the relatively low land-use percentages for essential service provision (9%, 8% and 7%). The differences between the land-use intensities of the scenarios (A2, B2, C2) are also significant for wastewater and heating. The land-use intensity for electricity remains constant. There is a slight increase in land-use for wind turbines from street to neighbourhood level, but this is insignificant compared to other techniques. The change in land-use intensity for wastewater is a result of the decrease in (relative) size for both septic tanks and mechanical treatment. The change in land-use intensity for heat production is mainly due to the decrease in size for seasonal storage. The land-use intensity for seasonal storage increases due to the increase in height (similar to septic tanks) which leads to only a slight increase in land-use compared to a large increase in volume. On a neighbourhood level (C2) the maximum height of 27 meters is reached. Evidently this results in a relatively smaller reduction in land-use intensity from B2 to C2.

1. *The land-use for mechanical treatment and septic tanks decreases when wastewater is collectively treated*

Recommendation: To reduce the land-use of wastewater treatment, apply collective wastewater treatment with septic tanks and mechanical treatment can be considered

2. *The land-use for seasonal thermal storage decreases when heat is collectively stored*

Recommendation: To reduce the land-use for energy production, collective seasonal heat storage is vital

	A1	B1	C1
Wastewater treatment (m3 wastewater treatment per m2)	10	17	21
Electricity production (kWh energy production per m2)	129	129	129
Heat production (kWh energy production per m2)	118	141	149

25. Land-use intensity of wastewater treatment and energy production per scenario (A2, B2, C2)

	A1	B1	C1
Wastewater treatment (m3 wastewater treatment per m2)	4263	2430	1987
Electricity production (kWh energy production per m2)	11685	11625	11625
Heat production (kWh energy production per m2)	55644	46854	44347
Total	**71591**	**60981**	**57959**
Percentage for essential service provision of total area	**9 %**	**8 %**	**7 %**

26. Land-use for essential services as a result of land-use intensity (A2, B2, C2)

Environmental impact

The environmental impact does not increase greatly for wastewater treatment, however, both septic tanks and mechanical treatment can increase in odour due to the larger quantities of wastewater that are collected in one point. The environmental impact for electricity production does not increase for photovoltaics but this does increase for lithium batteries and wind energy. For wind energy the visibility specifically increases from street to neighbourhood level when wind turbines are placed on ground level instead of up on the roof. Apart from the visibility, there is also an increase in shadow formation. For heating the environmental impact remains constant.

1. *The visibility of energy production increases when lithium batteries are concentrated and placed in public space*

Recommendation: To mitigate the visibility of lithium batteries, these techniques can be integrated into public buildings or structures or arrangements can be found to place them in private homes

2. *The visibility and shadow formation of wind turbines increases from street to neighbourhood level if turbines are placed on a ground level*

Recommendations: To reduce the visibility of wind turbines, wind turbines can be placed at a distance from households

Regulation: To mitigate the risk of shadow formation with (larger) wind turbines they should be placed at a further distance from households or the placement of windows has to be adjusted

3. *Odour of septic tanks and mechanical treatment can increase with larger quantities of wastewater*

Recommendation: To mitigate possible nuance from odour release from septic tanks or mechanical treatment systems, it is best to implement these at a distance from households

Risks

The risks associated with wastewater treatment decrease for similar reasons as the first set of maximizations. However, the risks in scenario A2 are larger than the risks in scenario A1. This is due to the usage of mechanical treatment which is generally more prone to fluctuations. For energy production the risks of photovoltaics remain constant. The risks for lithium batteries increase for similar reasons as the first set of maximizations, however, due to the decreased amount of lithium batteries in this maximization the risks are not as substantial as in the first set of scenarios. For wind turbines the risks increase from street to neighbourhood level when the size of the wind turbines changes. This change in size increases the risks of ice formation.

1. *The risks associated with energy production increase from household to neighbourhood level due to the coupling of lithium-ion batteries*

Recommendation: To mitigate the risk of explosion, especially on neighbourhood level, compartmentalization of lithium-ion batteries and their placement at a distance should be considered as well as constructing coverage with insulation

Recommendation: Preventing the full decharging or charging of lithium batteries can mitigate the risk of explosion

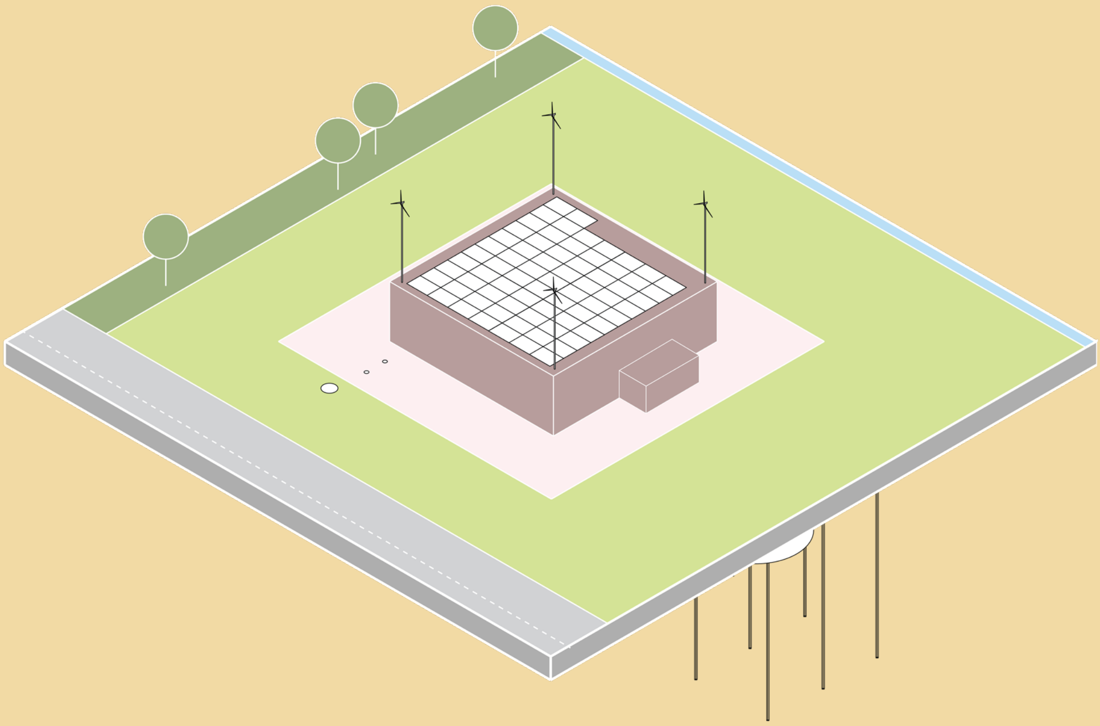
2. *The risks associated with energy production increase from street to neighbourhood level due to an increase in wind turbine size*

Regulation: To mitigate the risks associated with ice formation on (larger) wind turbines they should be placed at a further distance from households

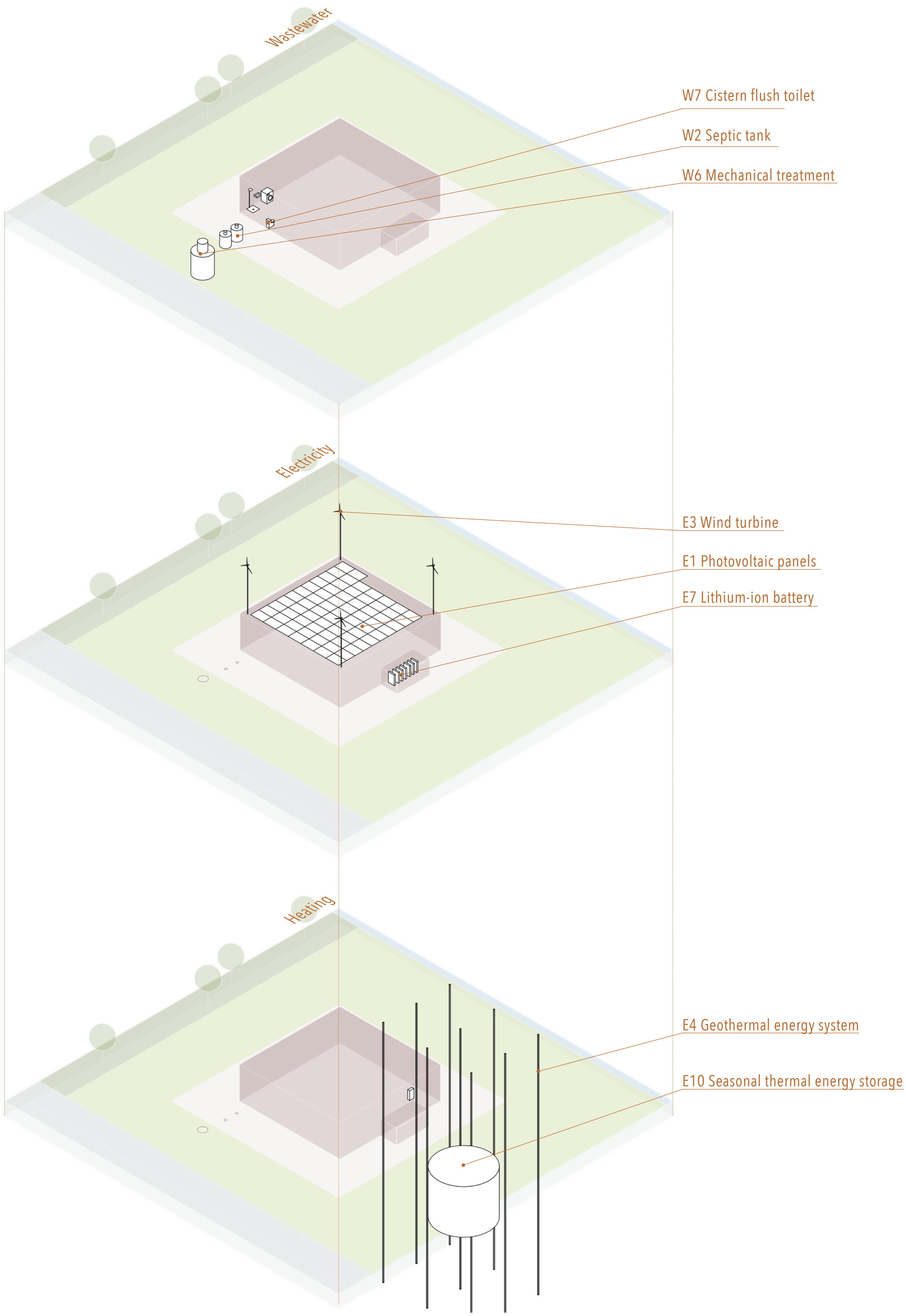
3. *The risks associated with wastewater treatment decrease from household to neighbourhood level*

Recommendation: To decrease risks associated with wastewater treatment, collective wastewater treatment can be considered

A_2

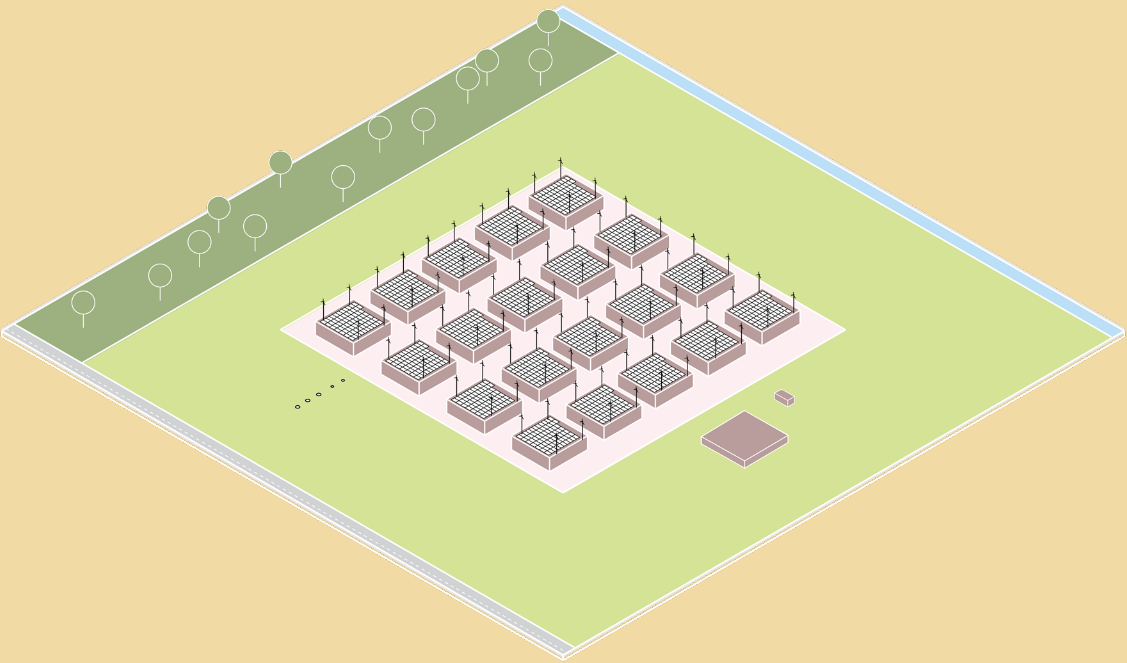


35. Implementation of the essential service systems with the lowest land-use on scenario A

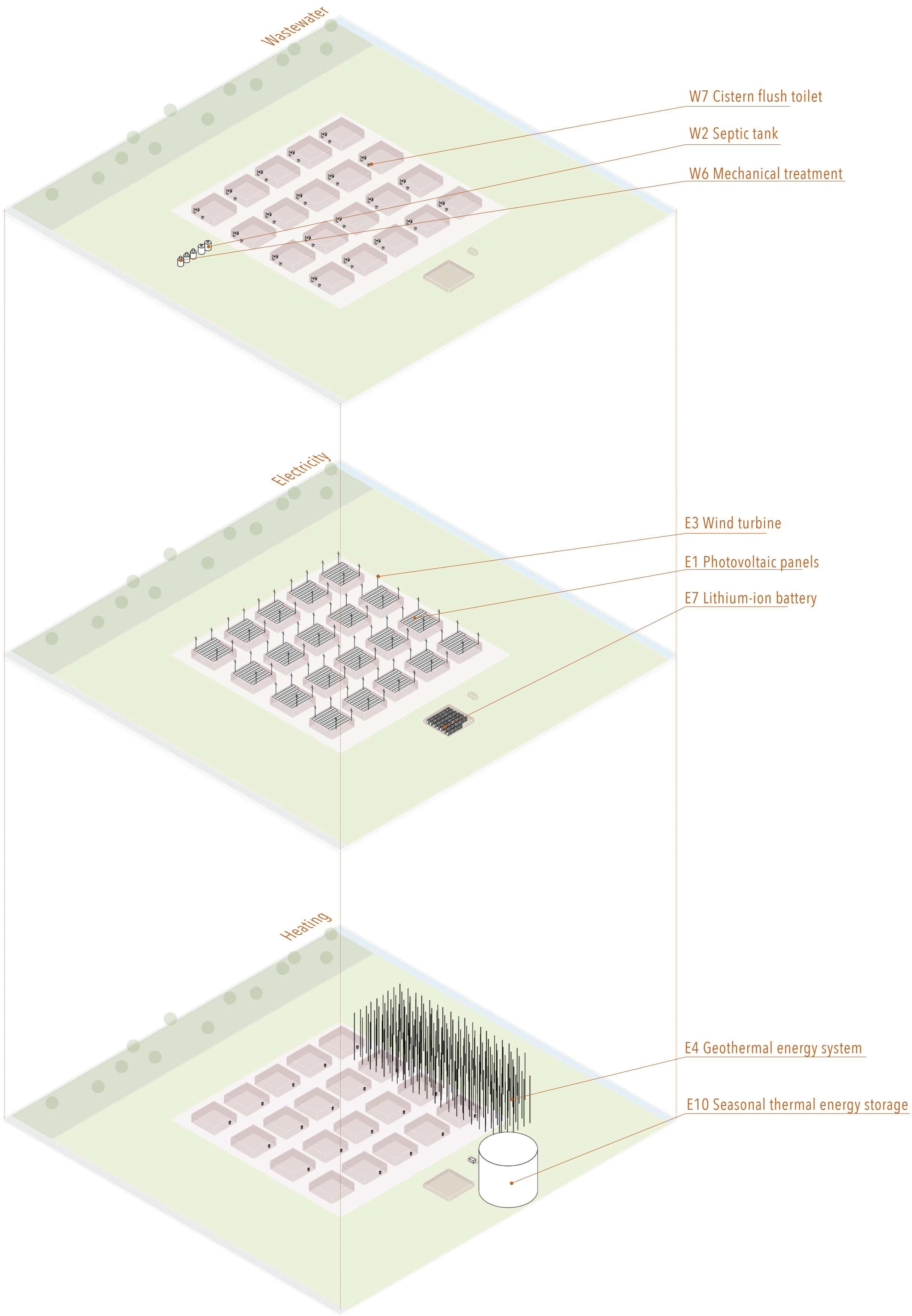


36. The three different maximized layers - wastewater, electiricut and heating - of scenario A2

B_2

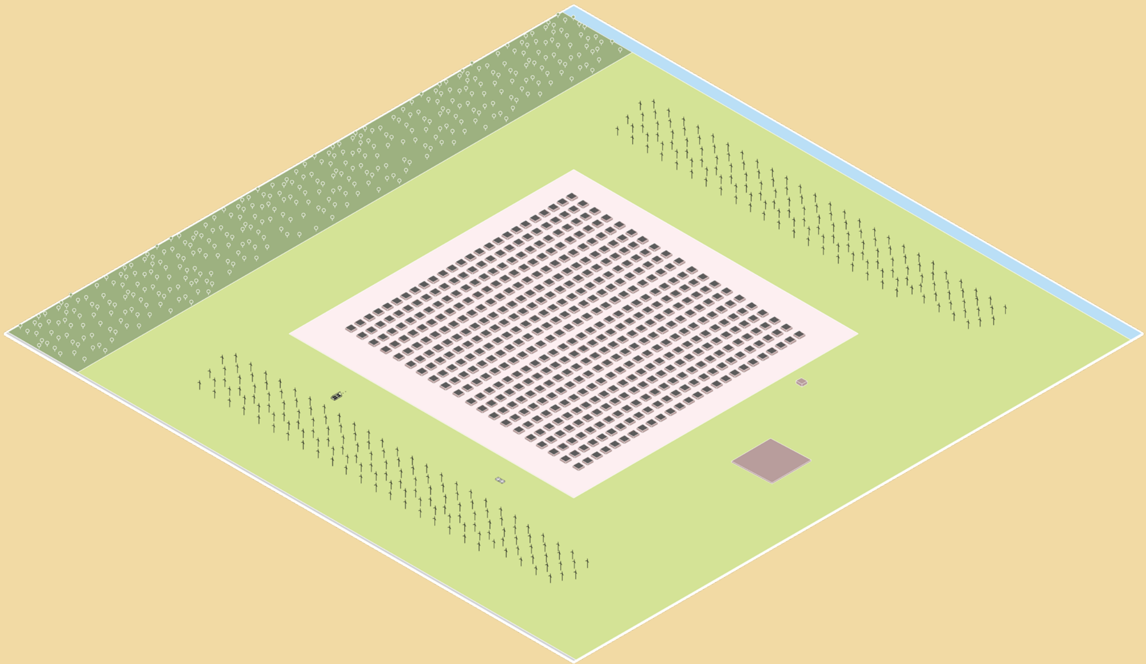


37. Implementation of the essential service systems with the lowest land-use on scenario B

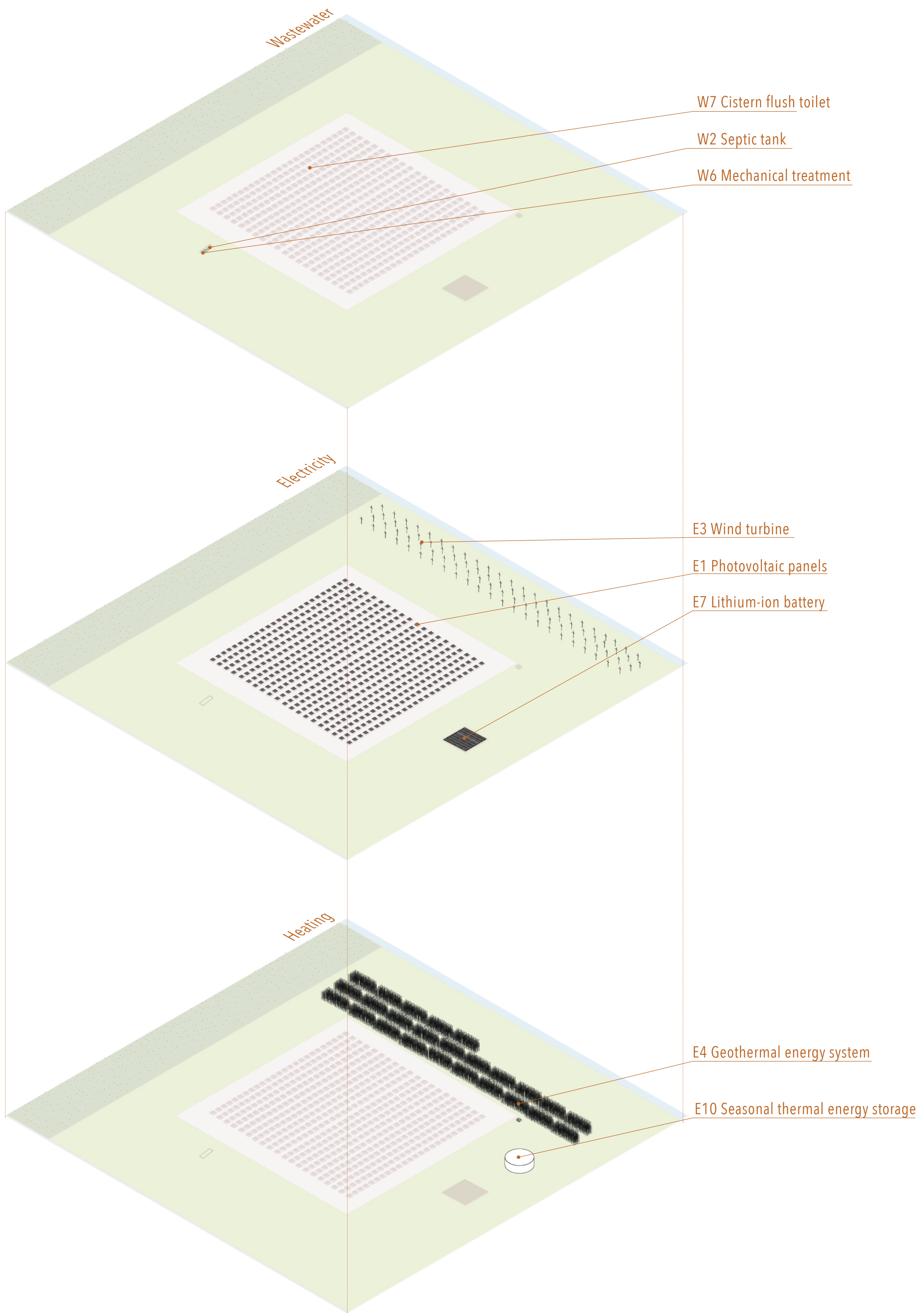


38. The three different maximized layers - wastewater, electiricut and heating - of scenario B2

C_2



39. Implementation of the essential service systems with the lowest land-use on scenario C



40. The three different maximized layers - wastewater, electiricut and heating - of scenario C2

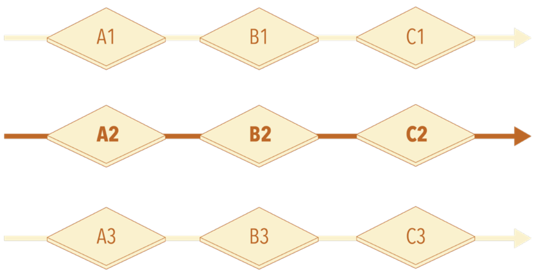
Conclusion

The land-use and risks of wastewater treatment decrease when the level of autonomy increases while the environmental impact remains constant. Based on these conclusions we can state that if land-use (e.g. due to a scarce amount of available land) or risks (e.g. due to strict water quality regulations) are important, collective wastewater treatment can be considered. This is more important than the previous maximizations as mechanical treatment is generally less robust due to a higher incapability of dealing with (strong) fluctuations.

For energy production there is a significant decrease in land-use, a slight increase in environmental impact and an increase in risks. The significant reduction in land-use can mainly be attributed to the usage of seasonal heat storage. It is therefore recommended to consider the implementation of seasonal heat storage (in whatever form) in order to reduce land-use intensity. Collective heat storage will in this case create the largest reduction in land-use. There is no added benefit of implementing wind energy or solar collectively and therefore these techniques are best applied on a household level. Lithium-ion batteries are easiest to place in homes due to the associated risks, however, a connection between the batteries can increase flexibility between inhabitants if individual batteries are collectively shared.

8.3.3 Maximization of spatial integration (A3, B3 and C3)

In this maximization the land-use intensity is less while the environmental impact and risks have increased, mainly due to the addition of a composting chamber.



Land-use intensity

The land-use intensity for wastewater treatment and energy production all increase. For wastewater this decrease is due to the decrease in land-use for septic tanks (again), living machine and in particular for composting. For the living machine this decrease is mainly due to the similar averaging effect which is also present here. For the septic tanks and especially the compost pile this decrease in land-use intensity is also due to the increase in height and therefore direct increase in land-use intensity. For energy production the land-use intensity has increased for STES for similar reasons as the previous set of maximizations. The land-use intensity of photovoltaics and solar thermal panels has remained constant. The land-use intensity for wind energy has increased slightly from street to neighbourhood level due to the implementation of larger wind turbines but this is again irrelevant compared to the total land-use intensity.

1. *The land-use for septic tanks, living machines and compost piles decreases when wastewater is collectively treated*

Recommendation: To reduce the land-use of wastewater treatment, collective wastewater treatment with septic tanks, living machines or compost piles can be considered

2. *The land-use for seasonal thermal storage decreases when heat is collectively stored*

Recommendation: To reduce the land-use for energy production, collective seasonal heat storage can be considered

	A1	B1	C1
Wastewater treatment (m3 wastewater treatment per m2)	7	19	25
Electricity production (kWh energy production per m2)	40	40	40
Heat production (kWh energy production per m2)	78	88	91

27. Land-use intensity of wastewater treatment and energy production per scenario (A2, B2, C2)

	A1	B1	C1
Wastewater treatment (m3 wastewater treatment per m2)	4963	1877	1432
Electricity production (kWh energy production per m2)	38195	37967	37961
Heat production (kWh energy production per m2)	84813	74882	72353
Total	**186101**	**114726**	**111746**
Percentage for essential service provision of total area	**14 %**	**13 %**	**13 %**

28. Land-use for essential services as a result of land-use intensity (A2, B2, C2)

Environmental impact

The environmental impact increases for wastewater treatment due to an increase in environmental impact from adopting compost piles and septic tanks. Generally, the odour increases when the pile of compost grows or with the growth of septic tanks. For energy production, there is an increase in shadow formation and visibility from wind turbines from household to neighbourhood level as well as an increase in the visibility of lithium batteries. This is similar to the previous set of maximizations.

1. *There is an increase in odour when the pile of compost grows*

Recommendation: To decrease the odour that originates from the compost, the compost pile should be placed at sufficient distance from households

2. *Odour of septic tanks can increase with larger quantities of wastewater*

Recommendation: To mitigate possible nuance from odour release from septic tanks or mechanical treatment systems, it is best to implement these at a distance from households

3. *The visibility of energy production increases when lithium batteries are concentrated and placed in public space*

Recommendation: To mitigate the visibility of lithium batteries, these techniques can be integrated into public buildings or homes

4. *The visibility and shadow formation of wind turbines increases from street to neighbourhood level if turbines are placed on a ground level*

Recommendations: To reduce the visibility of wind turbines, wind turbines can be placed at a sufficient distance from households

Regulation: To mitigate the risk of shadow formation with (larger) wind turbines they should be placed at a further distance from households or the placement of windows has to be adjusted

Environmental risks

The risks associated with the production of essential services remain constant or increase for the production of energy and decrease for the treatment of wastewater even though the potential hazard increases. The increase in risks associated with energy production are mainly a result of the increase in hazard potential and risks of lithium batteries. This increase is similar to the previous maximization. The risk surrounding photovoltaics and solar thermal panels remains constant through different levels of autonomy. For wastewater, risks from composting increase with an increase in scale. The larger quantities of compost pose a larger threat to the environment when leachate seeps into groundwater or the compost is not properly treated. For the septic tanks and living machine there is less risk as most harmful substances are present within the compost (due to the separation of black and grey water).

1. *The risks associated with energy production increase from household to neighbourhood level due to the coupling of lithium-ion batteries*

Recommendation: To mitigate the risk of explosion, especially on neighbourhood level, compartmentalization of lithium-ion batteries and their placement at a distance should be considered as well as constructing coverage with insulation

Recommendation: Preventing the full discharging or overcharging of lithium batteries mitigates the risk of explosion

2. *The risks associated with wastewater treatment increase for treatment of wastewater in compost piles*

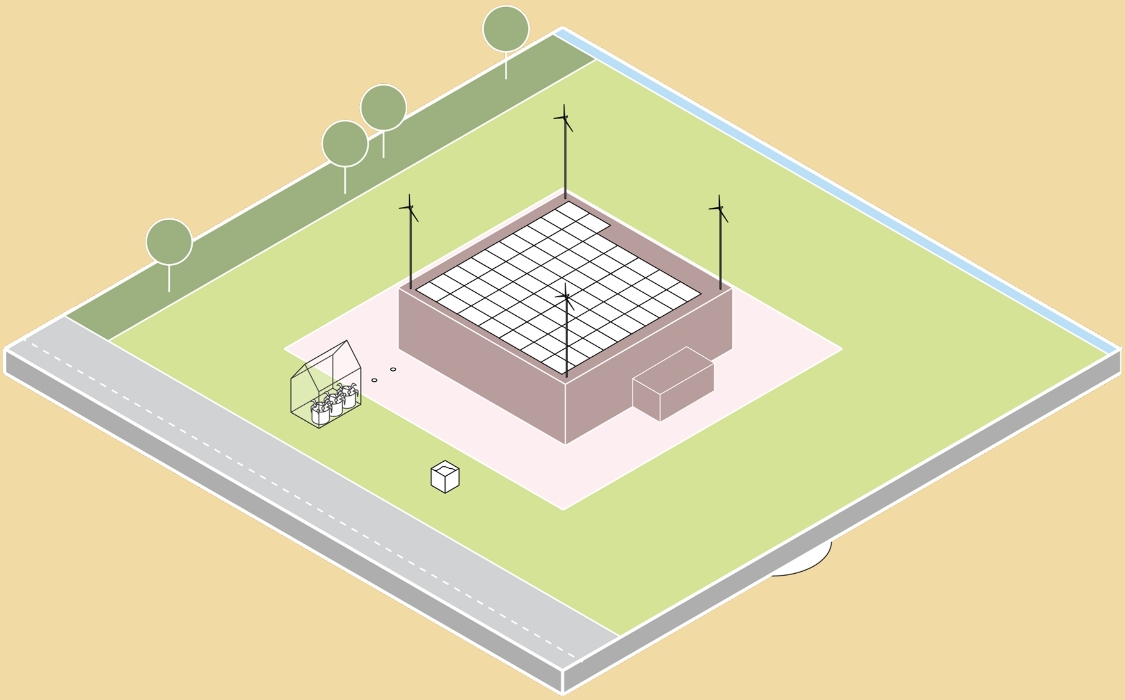
Recommendation: To decrease the risks associated with composting, the application of this technique is best done at a household level

Conclusion

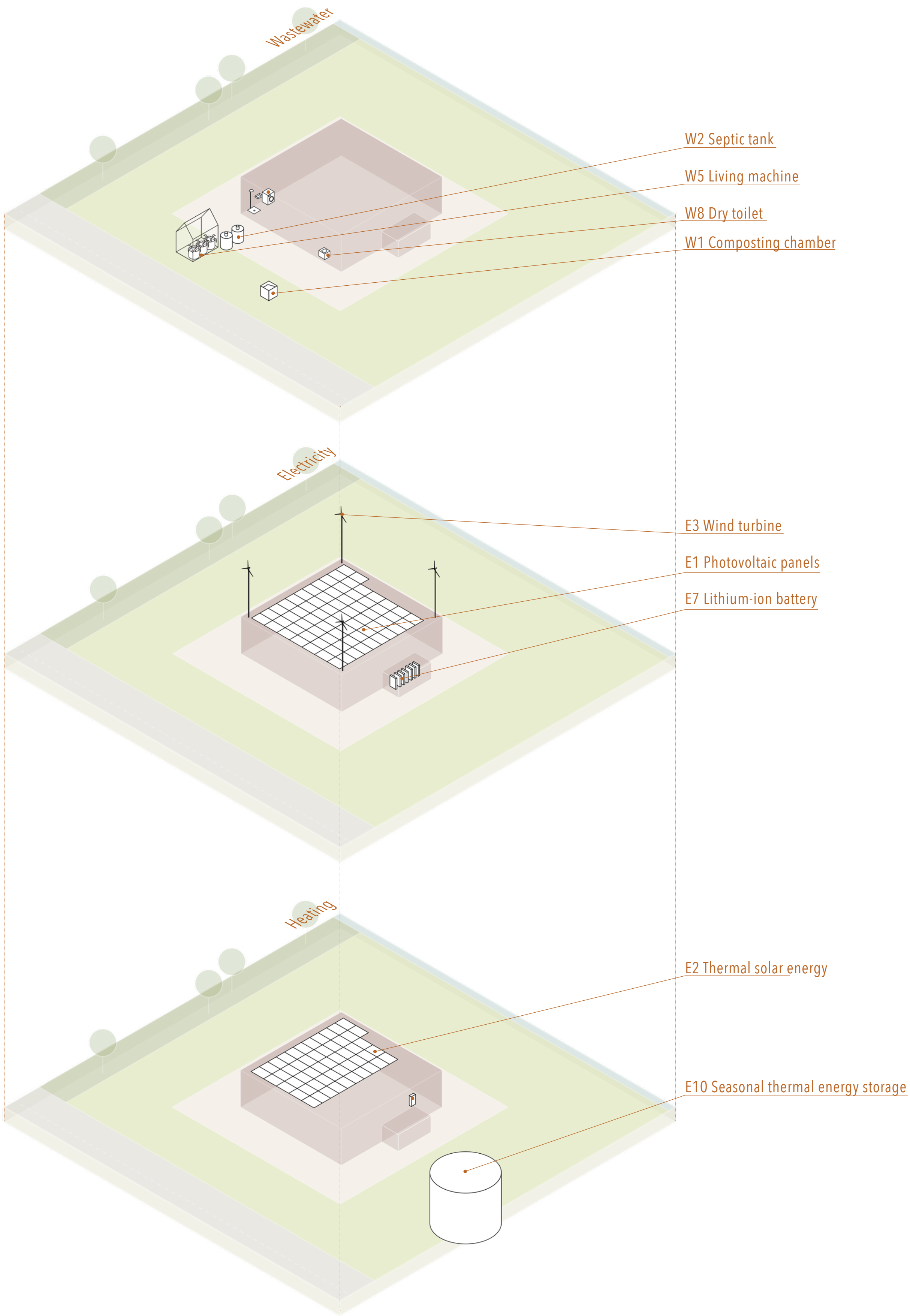
There is a general increase in risks and environmental impact in wastewater while land-use drops. This is mainly due to the use of the composting chamber. Since land-use is not a large issue in wastewater treatment compared to energy production, composting might be more interesting technique to apply at household level.

For energy similar trends apply to this scenario as the previous maximization.

A_3

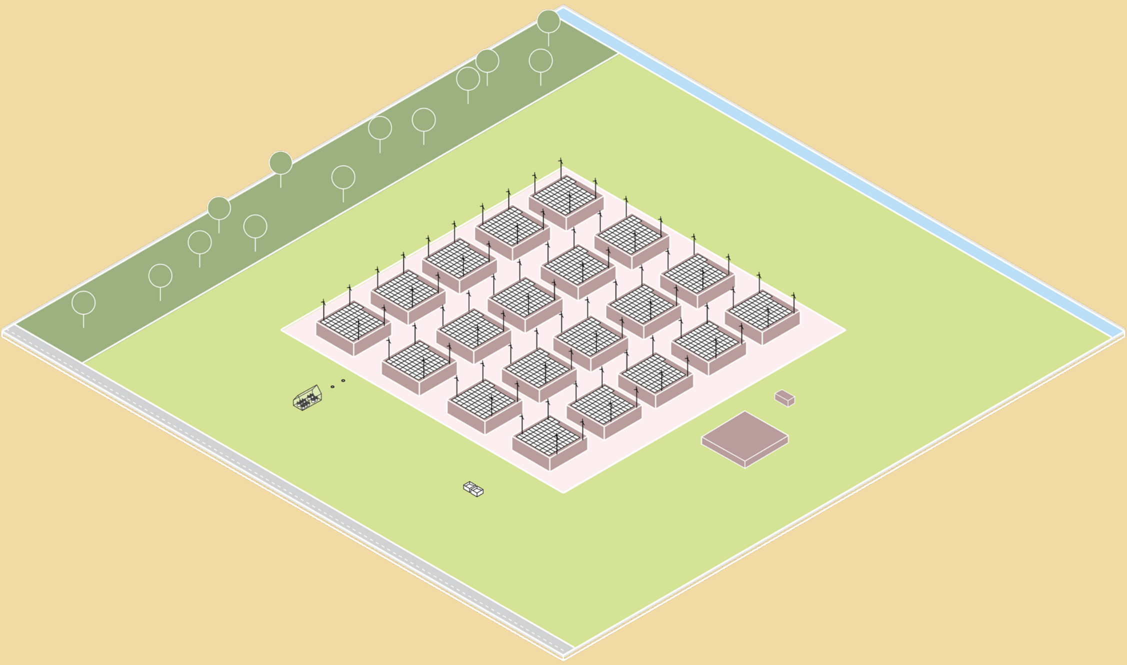


41. Implementation of the essential service systems with the highest spatial integration on scenario A

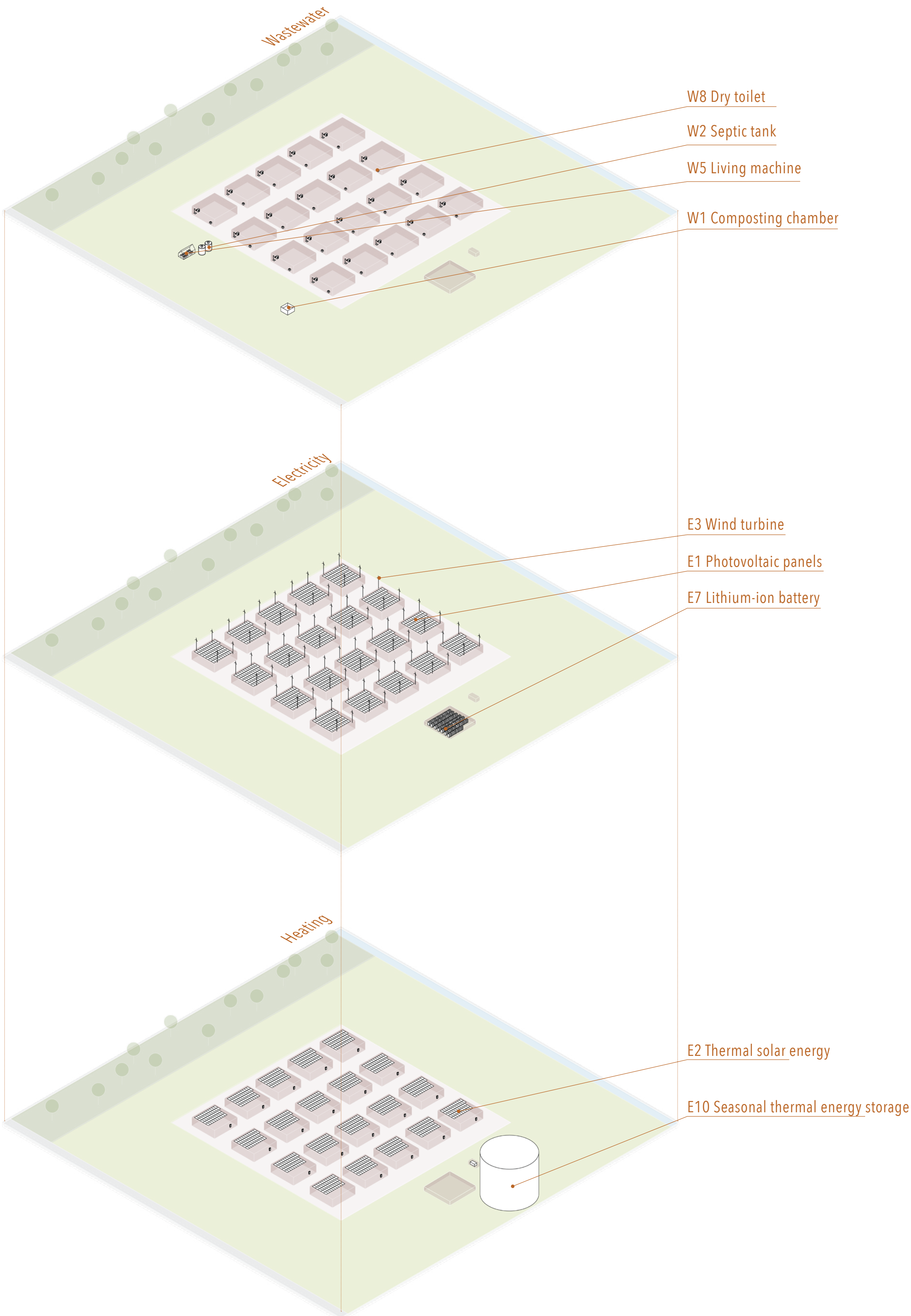


42. The three different maximized layers - wastewater, electiricut and heating - of scenario A3

B_3

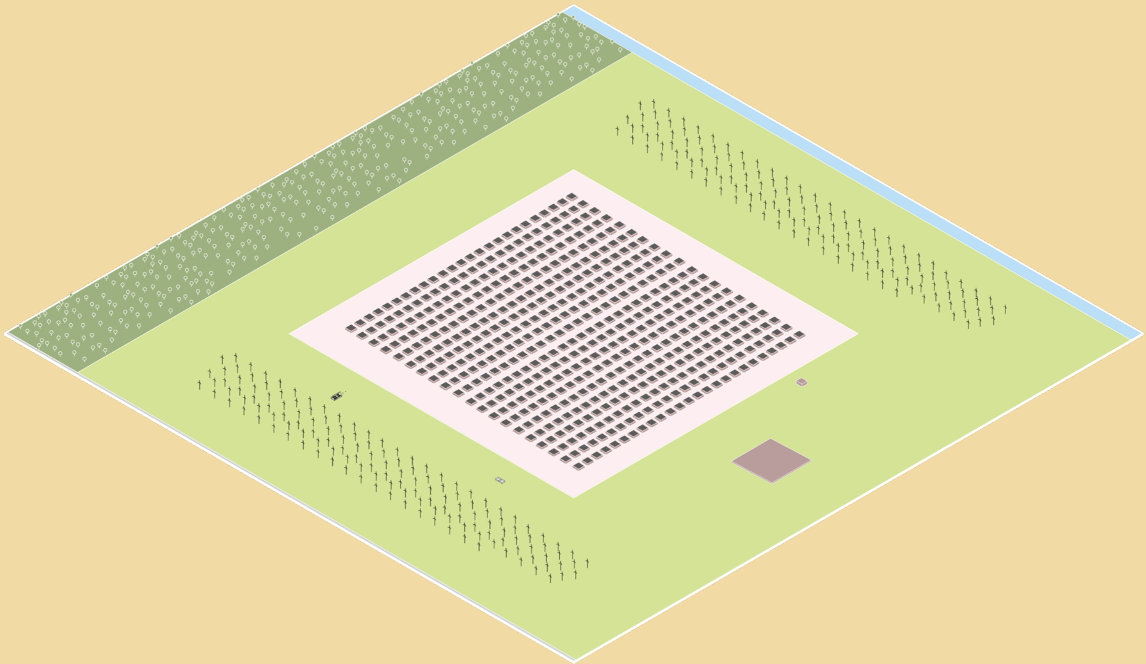


43. Implementation of the essential service systems with the highest spatial integration on scenario B

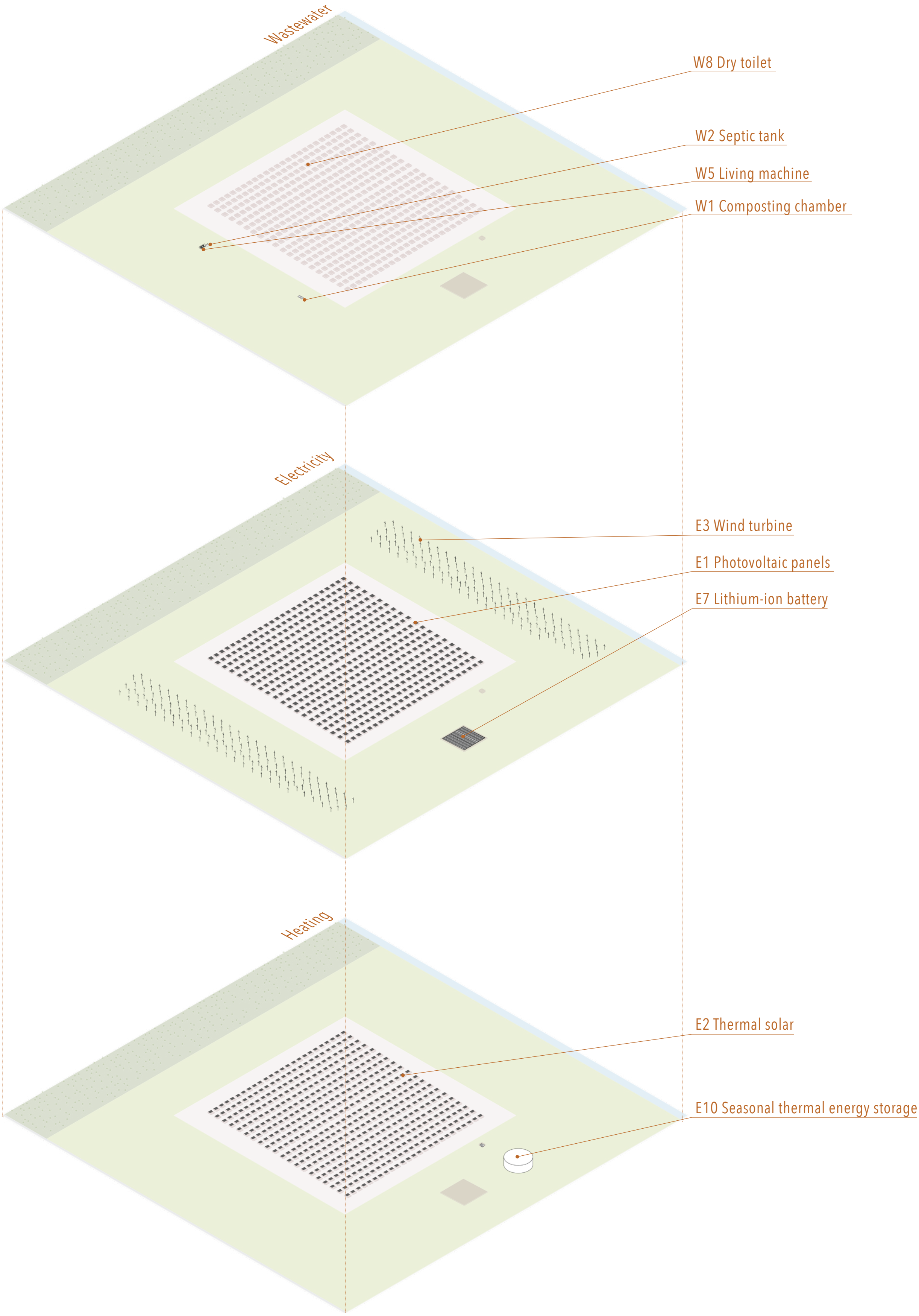


44. The three different maximized layers - wastewater, electiricut and heating - of scenario B3

C_3



45. Implementation of the essential service systems with the highest spatial integration on scenario C



46. The three different maximized layers - wastewater, electiricut and heating - of scenario C3

8.3.4 General conclusions and trends

In all maximizations the land-use for wastewater treatment and seasonal heat storage decreases if a higher level of autonomy is applied. For wastewater treatment this is due to the increase in the averaging effect and the increase in height which lead to a decrease in land-use. For heat and electricity storage the averaging effect could not be taken into account due to a lack of data. If this would be possible this could lead to a higher increase in land-use intensity for these techniques. We can conclude that a higher level of autonomy fosters a decrease in land-use. However, due to the choice of systems in the different maximizations, there is a stark difference between the first maximization and the second and third maximization. In the first maximization the seasonal fluctuation in energy consumption and production were not mitigated which led to a large increase in land-use. In the other two maximizations, seasonal heat storage was applied which resulted in the mitigation of fluctuations leading towards a general decrease in land-use which was larger compared to the decrease in land-use as an effect of a higher level of autonomy.

The environmental impact highly depends on the type of system used and it is difficult to spot trends. For energy the designs show that the noise can increase on a higher level of autonomy, however, many systems, such as solar and geothermal, have little environmental impact in general. Wind energy had the largest environmental impact due to noise and interference in visibility. For wastewater, the odour from composting, septic tanks and mechanical treatment can increase with higher levels of autonomy. In general, we can conclude that the implementation of essential services on household level has less environmental impact than the implementation on a neighbourhood level.

In general, the environmental risks associated with wastewater treatment decrease if systems are designed on a higher level of autonomy due to the decrease in fluctuations of wastewater influent. For energy provision the environmental risks increase for the implementation of wind turbines and lithium ion batteries, other systems remain constant.

	Land-use	*Environmental impact*	*Environmental risks*
1. Current	▼ Wastewater treatment *Note: The total land-use is greatly effected by energy fluctuations due to seasonal weather changes*	▲ Noise thermal air heat pumps ▲ Odour septic tanks	▼ Wastewater treatment ▲ Risk of fire from lithium-ion batteries
2. Minimal land-use	▼ Wastewater treatment ▼ Seasonal thermal heat storage	▲ Odour septic tanks and mechanical treatment ▲ Increased shadow formation of wind turbines	▼ Wastewater treatment ▲ Risk of fire from lithium-ion batteries ▲ Increased risks of wind turbines
3. Maximum spatial integrations	▼ Wastewater treatment ▼ Seasonal thermal heat storage	▲ Odour septic tanks and compost pile ▲ Increased shadow formation of wind turbines	▼ Wastewater treatment ▲ Risk of fire from lithium-ion batteries ▲ Increased risks of wind turbines ▲ Increased risks of composting

▲ *Increase from household to neighborhood level*

▼ *Decrease from household to neighborhood level*

47. Overview of the most important change in land-use, environmental impact and environmental risk per maximization between the different levels of autonomy

Essential service systems and their preferred level of autonomy

There is a lack of research considering the implementation of local essential service systems and the effect on the built-environment and its citizens, however, this information is crucial for spatial planners looking to embed essential service systems within a neighbourhood and decide on their scale level of implementation. Through an explorative approach using a case study and research by design methodology, this study gained insight into aspects as land-use, environmental impact and environmental risks associated with essential service provision, and how these changes due to different levels of autonomy. These outcomes should support sustainable spatial planning for future projects.

The main research question is: **What are the land-use intensity, environmental impact and environmental risks associated with the provision of local essential services on different levels of autonomy in Oosterwold, and what recommendations follow from these insights for spatial planning?** This research question was further broken down into 6 different sub-questions. The answers to these six questions are summarized below whilst mentioning their limitations. Together they form the conclusion to this research. Specific recommendations for spatial planning in general and in Oosterwold are explored in chapter 10.

Q1: What are the advantages and disadvantages of providing local essential services compared to the common centralized essential service provision in the Netherlands?
Through a semi-structured literature study looking at world-wide urban planning and asset management or system engineering, research was conducted to understand the advantages and disadvantages of decentralizing essential service provision viz-a-viz a centralized system. Both for local energy production (Chapter 6.) and local wastewater treatment (Chapter 7.) the efficiency can improve due to a decrease in transport. Reclamation and reuse become easier, an increase in flexibility and adaptability of systems occurs, and local decision-making improves ownership and social capital. Negative side-effects are increased fluctuations (less averaging) and higher land-use. The literature study was hampered by positive bias of most of the sources towards decentralization. Due to this bias more disadvantages may become apparent when research into the topic increases or when more case studies become available.

Q2: What is the impact of local essential service provision on land-use intensity, environmental impact and environmental risks?
Based on the advantages and disadvantages of local essential service provision and further supported by literature, the effect on land-use, environmental impact and environmental risks was determined. Both for local wastewater treatment and local energy production, land-use will most likely increase compared to large scale systems due to a lack of 'economies of scale' and the increasing use of nature-based or renewable systems causing an upward pressure on land-use. For wastewater the environmental impact will most-likely consist of odour nuisance, whilst for energy production this is an important factor to consider, though very dependent on the system chosen. An important environmental risk of wastewater is the pollution of the environment and jeopardy of public health. For energy production, small-scale systems are relatively novel, and risks have yet to be determined.

The results of both literature studies are limited as literature is scarce on this topic, and in-depth knowledge considering the land-use, environmental impact and environmental risks is not available. This could be due to the fact that these aspects are often associated with a particular technology such as solar panels, wind turbines or wetlands opposed to wastewater treatment or energy production as a whole.

Q3: How are essential services provided in Oosterwold and what patterns have emerged?
The patterns or levels of autonomy within energy production and wastewater treatment in Oosterwold were mapped based on interviews and site visits. This showed that energy is always produced individually given the connection to the grid as a fallback, while wastewater is largely handled individually due to the organic urban development. In some cases (when a level of mutual trust existed) a communal development took place, to reduce fluctuations and improve system outcomes, capturing economies of scale. The study provides a good impression of the development of essential services in Oosterwold. However due to the fact the neighbourhood continues to change and grow, these findings cannot be seen as a complete impression of neighbourhood in .

Q4: What are the possible systems for the provision of essential services in Oosterwold?
Possible techniques for the production of energy and treatment of wastewater were summarized in two catalogues. A diverse pallet of land-use patterns, environmental impacts and environmental risks were found, suggesting that these aspects and the eventual spatial implications are very dependent on the essential service system chosen. The research considering the different systems was generally sufficient and valid, however, little research was found how the land-use, environmental impacts and environmental risks change on different scales. Also, legislation with respect to the spatial implications of these aspects is currently lacking in the Netherlands.

Q5: What are relevant scenarios for the level of autonomy of future essential service provision in Oosterwold?
The patterns in energy production and wastewater treatment in Oosterwold were used to create three scenarios by adopting scenario planning. These three scenarios were based upon three different levels of autonomy: household level, street level and neighbourhood level. Household level is the most common level of autonomy in Oosterwold and street level is only adopted in wastewater treatment. A neighbourhood level of cooperation is currently lacking but is seen as a possibility for future wastewater treatment and energy storage. For energy production these scenarios are potentially less relevant as there were no different patterns found in Oosterwold for energy production and there are little signs this will change in the future. However, these scenarios are still theoretically relevant for the implementation of local energy systems elsewhere.

Q6: What are the land-use intensity, environmental impact and environmental risks of essential service provision in Oosterwold based on different scenarios?
Using the maximization method, the three scenarios were explored, and different essential service systems were applied. Three different maximizations were carried out resulting in nine different

designs. The differences between the designs showed a number of trends. Land-used declined with a higher scalefor wastewater treatment systems and thermal energy storage systems but remained equal for other systems. The environmental impact is highly dependent on the type of system. For energy production there is little environmental impact in general but there is an increase in impact with wind turbines. Wastewater treatment systems can locally increase odour generation when applied on a larger scale. The environmental risks for wastewater treatment decrease when the scale of application increases with the exception of composting. The environmental risk of energy production only increases for wind turbines and lithium-ion electricity storage, while other systems remain constant. These general trends show that there are economies and diseconomies of scale to be taken into consideration during spatial planning, which ultimately will enhance sustainable development. However, these conclusions are limited as more detailed calculations and data will be needed, in order to provide more valid and specified conclusions. Furthermore, using land-use, environmental impact and environmental risks as design parameters will be facilitated when legislation or further research around spatial planning of dispersed systems will mature.

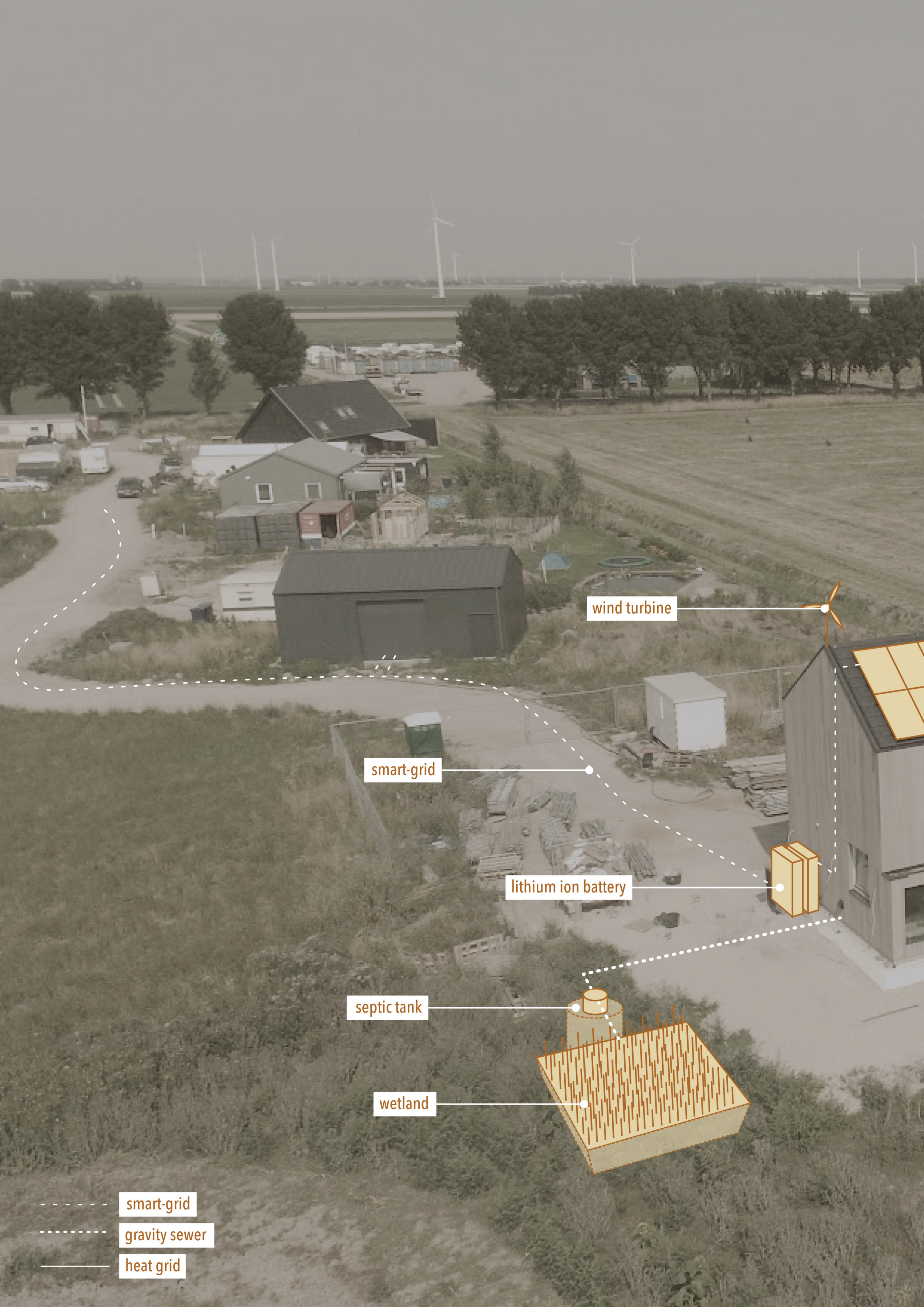
The future of implementing local essential service systems

This research showcases that systems for wastewater treatment and energy provision and their level of autonomy can have an effect on the land-use, environmental impact and environmental risks. These indicators are important to consider to prevent pollution, enhance efficiency or reduce nuisances to ultimately ensure sustainable urban development. Sustainability often goes beyond the individual and beyond the present generation and therefore needs some form of spatial planning or consideration shaping local essential service provision. Essential service systems and the level of autonomy is therefore important to consider early in a design process as this forms the base for other aspects such as occupancy, governance or metabolism. In Oosterwold the philosophy of shaping the built environment came before the consideration of essential service systems in accordance with the social, technical and environmental aspects of the area. This has led to unsustainable situations with wastewater treatment (the potential pollution of ground water) and energy provision (the lack of self-sufficiency) due to the lack of time, money, cooperation or possibilities for inhabitants. With the increase in local essential service systems, integrated spatial planning considering all facets of the build environment without neglecting their connectedness, is increasingly relevant. It is therefore important to continue the line of inquiry in this research, applying other indicators and understanding the consequences of essential service systems and levels of autonomy for spatial planning. This research is a first step in this this inquiry. On the basis of this research recommendations can be given for future spatial planning (paragraph 10.1) and more specific for spatial planning in Oosterworld (paragraph 10.2).

10.1 Recommendations for spatial planning in general

The following remarks deliver a comprehensive summary of the more detailed considerations for spatial planners when working with local essential service systems on the basis of land-use, environmental impact and environmental risks.

For wastewater, we recommend communal wastewater treatment to limit land-use and exposure to pollution, with the exception of composting where the environmental impact and risks can increase with a larger scale. If only wastewater treatment on household scale is possible, risks can be mitigated by implementing a monitoring system that can measure the quality of all individual effluents, thereby preventing long-term pollution. In any case inhabitants need to be educated on the risks of working with compost. The environmental impact of other techniques for wastewater treatment does not increase substantially as most of the treatment takes place underground. However, outlets for monitoring or effluent need to be placed at a safe distance from households to prevent any nuisance due to odour. Further research is necessary on the quantification of odour nuisance due to local wastewater, the risks associated with fluctuations in the scale of wastewater treatment and the exact impact of composting, to implement local wastewater treatment systems in a safe and sustainable way.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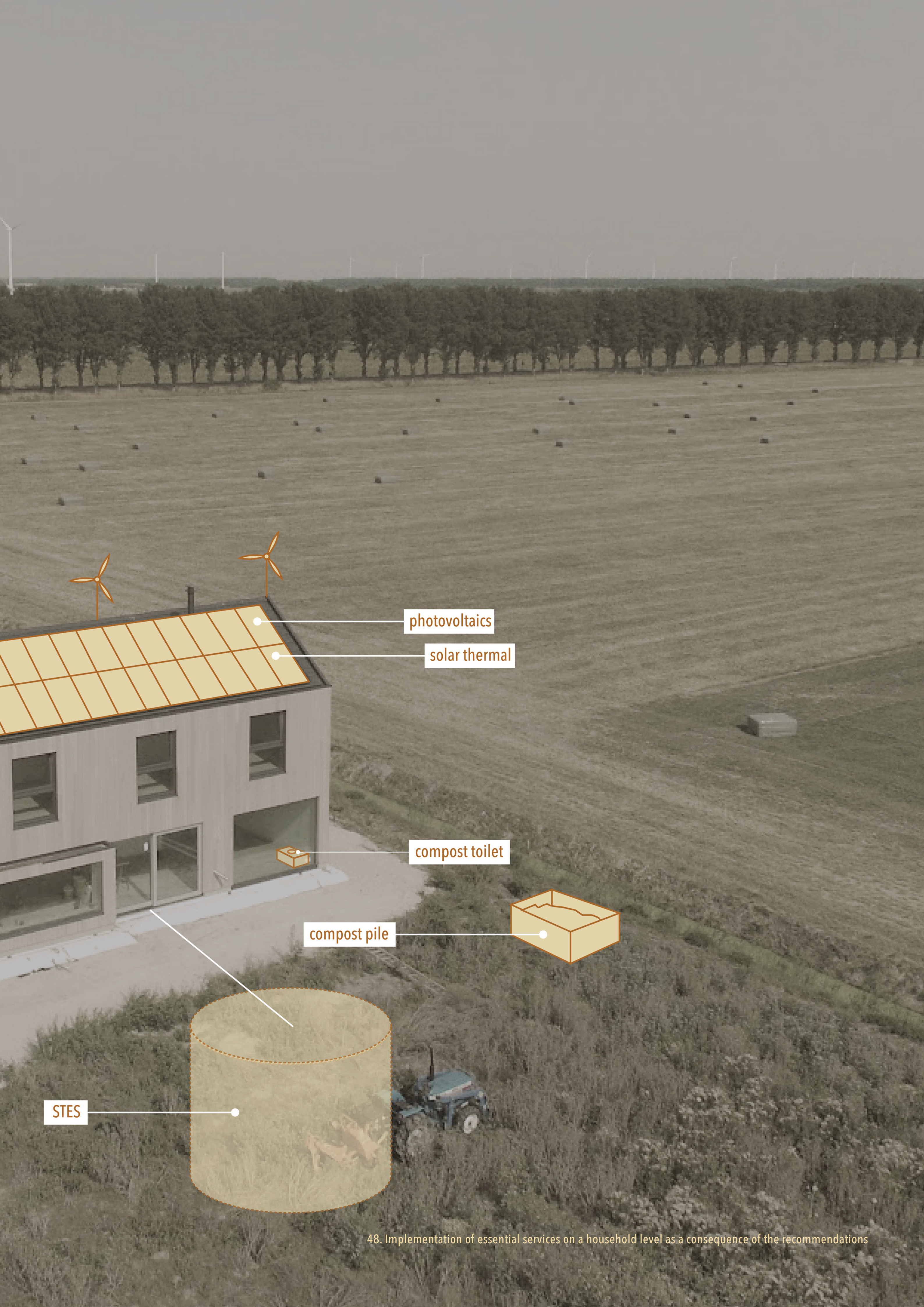

48. Implementation of essential services on a household level as a consequence of the recommendations

For energy production, the implementation of solar energy and geothermal energy can be done on household, street and neighbourhood scale without increasing land-use, or having more environmental impact and risks. The technique chosen should consider opportunities for landscape integration. For wind energy a higher scale will change the impact as there is a stark difference between large wind turbines and small-scale wind turbines on roofs. If there is limited land-use, only small-scale wind energy is possible due to the associated environmental impact and risks of (medium-scale) wind energy on land. To increase the efficiency of the energy system and decrease the amount of land-use it is best to apply communal (seasonal) heat storage as the environmental impact and risks are not present. Care needs to be taken when implementing lithium-ion batteries within the environment as coupling of these batteries can increase the risk of explosion, while the land-use and environmental impact remain constant. This can be mitigated by de-coupling lithium-ion batteries or applying insulation and keeping a safe distance of clusters from households. Another option would be to install lithium-ion batteries on a household scale but implement a smart-grid which facilitates electricity sharing or replace the lithium-ion battery with a newer type of battery (such as the redox-flow battery) which needs more land but has no environmental risks. Further research is needed into the averaging effect in small scale heat and electricity grids to determine the possible increase in efficiency and in the creation of spatial policies on the implementation of large groups of lithium-ion batteries.

10.2 Recommendations for future spatial planning and essential service provision in Oosterwold

Freedom for inhabitants to design their houses, plots and streets is the most important principle in Oosterwold. This has attracted many inhabitants to purchase a piece of land in order to develop their dreams. As we have seen, most of these inhabitants enter the neighbourhood as a single household while some decide to combine forces and establish a community. This has also fostered a mainly individual development of essential service systems. However, within this research we can conclude there are important system additions and economies of scale that should be regarded for the future provision of essential services within phase 2 of Oosterwold and possibly as addition to phase 1, on the basis of land-use, environmental impact and environmental risks. These will be discussed in the following two paragraphs for energy provision and wastewater treatment. These recommendations are elaborated in the last paragraph using three different perspectives of urban development in Oosterwold and how these are combined with essential service provision. The recommendations and possibilities can be utilized by the area team as a base for decision making to cater sustainable and safe essential service provision alongside the core (organic) urban planning principles of Oosterwold (see chapter 5.3).

10.2.1 Future energy provision in Oosterwold

Currently there is no cooperation between inhabitants when it comes to energy provision as all households are still connected to the national grid and therefore there is little incentive to combine forces. The grid connection obliterates the need for sufficient energy production or energy storage (whether heat or electricity) as the grid can provide an infinite amount of energy. The existing production and storage in the neighbourhood are therefore a product of motivation rather than a product of necessity. As a result, most inhabitants are not self-sufficient or autonomous when it comes to energy provision and any energy production that takes place is produced individually. The existing situation therefore opposes the vision of Oosterwold which dictates a sustainable and self-sufficient form of energy provision, possibly even surpassing the need of inhabitants and delivering energy to neighbour communities.

In order to improve energy self-sufficiency in the future as well as the resiliency and redundancy of energy provision, a number of steps can be taken by the area team in cooperation with energy stakeholders (such as Liander) and inhabitants. First of all, it is important to increase energy production in Oosterwold. This can be done by creating policies regarding a minimum percentage of electricity production (as heat production is often a result of electricity production) in cooperation with Liander. This electricity can be exchanged between inhabitants through the grid if intelligent operating systems are added to the grid evolving into a 'smart-grid'. The addition of electricity storage to the grid can further decrease costs and land-use for electricity production. This research has shown that electricity storage is preferably added communally or with the possibility for communal exchange of storage capacity to increase the efficiency through an increase in averaging effect and decrease in land-use. Extra care should be taken for the placement and casing of multiple lithium-ion batteries considering the associated environmental risks. It is advised to create policies in advance to prevent potential hazards or consider other types of electricity storage. Liander also benefits from electricity storage as the grid can be decreased in size as electricity is directly used within households and is therefore an important stakeholder for the implementation or incentivization of electricity storage. The application of a smart grid alongside electricity storage will demand further research considering the governance and potential business case.

The application of wind energy is also important to balance seasonal fluctuations in solar energy and increase the efficiency of electricity production and direct use of electricity within the neighbourhood (which decreases the need for transport and netting). At the moment only wind energy on top of household is possible, but wind energy on land is also possible for larger communities if the environmental impact and risks are taken into account. Here an expansion of rules prohibiting land-based wind energy is recommended. Furthermore, on the basis of this research we can conclude that seasonal energy storage greatly improves the efficiency of the entire energy system by decreasing the necessary electricity for heating and therefore decreasing the necessary land-use, number of systems and eventually costs. Seasonal heat storage can be applied individually but is best applied communally to decrease land-use, increase efficiency and potentially decrease costs. Communal heat storage does require the implementation of a heat-grid which demands further research considering the

wetland
STES
septic tank
wind turbine
smart-grid
gravity sewer
heat grid

49. Implementation of essential services on a street level as a consequence of the recommendations

governance and business case.

To conclude, the area team can develop or improve policies when it comes to energy self-sufficiency, the implementation of land-based wind energy and the implementation of electricity storage to improve energy provision and increase a sustainable and safe implementation of essential services. Furthermore, the area team can take an active role in the development of a smart grid and communal electricity storage in cooperation with inhabitants and Liander, as well as cater knowledge or information on the application of (individual) electricity storage or seasonal thermal heat storage (with or without heat grid) within the area.

10.2.2 The future of wastewater treatment in Oosterwold

Currently around 80% of inhabitants individually treat their wastewater while 20% of inhabitants choose to communally treat their wastewater mostly through the use of wetlands. Since there is no sewer system in Oosterwold, all inhabitants are self-sufficient when it comes to wastewater treatment. The individual approach towards wastewater treatment has had consequences for the quality of effluent. This has led to problems with the quality of effluent as communal wastewater treatment systems generally function better than individual wastewater treatment. A similar conclusion was made within this research as communal wastewater treatment has a lower environmental risk compared to individual wastewater treatment. Furthermore, communal wastewater treatment has a decrease in land-use compared to individual treatment which is a direct consequence of the increase in efficiency and can therefore also lead to a decrease in costs. The land-use in general is of little influence however since there is enough space to develop wastewater treatment systems. As Y. Sikking explained (see Appendix 1.1), and as is visible in the ongoing discussion between the regional waterboard, area team and inhabitants, these important advantages of communal wastewater treatment over individual wastewater treatment are not neglected. Since the groundwater under the neighbourhood is an important source of potable water for the Amsterdam Metropolitan Area, an optimal quality of wastewater effluent is crucial.

In order to improve the situation considering wastewater treatment and adopt a more sustainable approach which safeguards potable water quality and public health, this research shows that a number of measures can be taken. Individual treatment of black wastewater on a household level should be prohibited with the exception of composting. Black wastewater contains most of the potentially polluting substances and therefore poses the highest risk of pollution. The capacity of wetlands and mechanical treatment to treat black wastewater on an individual level, is not enough to sustain a lasting high-quality effluent posing risks for the environment and public health. In order to create specific policies, it is advised to research the minimum number of inhabitants that should be connected to a wetland or mechanical treatment for a stable and safe treatment of wastewater. The composting of black water (without the water in the case of composting) is possible if the process is safely separated from the ground water or soil. After two years the compost can be used for agricultural purposes if inhabitants have enough land to distribute compost. Policies should regard a safe composting process (both for public health and ecological reasons), a maximum usage of compost depending on the total available land for agriculture and number of inhabitants, as well as the placement of composting areas to prevent odour nuisance for neighbours. The area team will also need to take a more active role when it comes to educating inhabitants on the safe handling of compost to prevent pathogen release and secure public health. The residual grey water can be treated using wetlands.

Wetlands or mechanical treatment for black water is still safe and possible within a community. The area team is already incentivising inhabitants to cooperate when it comes to wastewater treatment. Information on the amount of communal land necessary, providing knowledge on the governmental aspect of communal wastewater treatment and connecting plot buyers to each other are approaches that can further stimulate communal wastewater treatment even if inhabitants decide to individually develop their plot. It is also possible to transfer the responsibility of wastewater treatment from inhabitants back to the municipality and regional waterboard. This is against the core philosophy of Oosterwold but seen as a preferred option according to the waterboard (Omroep Flevoland, 2019). To reconcile a top-down approach with a bottom-up urban development, phase 2 could be separated into multiple sections. According to the area team, this separation into sections using roads is already planned for phase 2 of Oosterwold to make the communal development of streets easier. This can be combined with the implementation of one government operated wastewater treatment system for every section. An additional option to decrease the cost of sewer systems (as distances are large in Oosterwold and sewer systems are difficult to implement due to settlement issues) and increase the flexibility of such a system would be to implement solid-free sewer and leaving primary treatment using septic tanks as a responsibility of inhabitants. Before inhabitants are attached to a sewer systems they can make use of a composting toilet, possibly with collection of the product if treatment on their plot is not desired or possible.

To conclude, the area team can prohibit individual wastewater treatment with the exception of composting. New policies and instructions should be generated to guarantee the safe treatment of compost. Furthermore, communal treatment can be further incentivised by supporting households wanting to work together for communal treatment by providing information and connecting inhabitants. If top-down treatment is further considered in the future this could be done in combination with the separation of phase two, taking a phased approach (first composting and later sewer attachment) and considering a solid-free sewer leaving the responsibility for primary treatment in the hands of citizens. In these ways the sustainability of essential service provision in Oosterwold can be increased without limiting the process of organic urban planning.


solid free sewer
wetland
wind turbine
lithium ion battery
smart-grid
solid free sewer
heat grid

50. Implementation of essential services on a neighborhood level as a consequence of the recommendations

Exploratory research and essential service provision

Within this chapter we reflect on the connection of the research with the wider context (11.1), successes and failures in the use of the methodological framework (11.2), the scientific (11.3) and practical (11.4) relevance and any ethical dilemmas that were encountered (11.5).

11.1 Connection with the wider context

This research was conducted within the context of the studio Urban Metabolism. In this studio, the urban metabolism – the stocks and flows of resources within an urban context – are examined and form the basis for strategic decision making and design. This research addresses the systems that cater these stocks and flows, essential service system, and their impact on the built environmental. This is important when essential service systems are placed directly within the built environment as is the case with the ongoing trend of decentralization. The topic of this research therein clearly connects to the graduation lab theme and seeks to contribute to the existing body of research within the field of urban metabolism.

The urban metabolism studio is part of the master track Urbanism. According to the TU Delft (2020), urban planning or design is the integration of "social, cultural, economic and political perspectives with the natural and man-made conditions of the site in order to shape and plan for more sustainable development". In other words, through exploring and understanding the effect of society on the landscape, an urban planner can improve upon this relationship through strategy and design. This research ventures to establish that by understanding the planning processes and effect on the environment behind the decentralization of essential service provision, in order to improve sustainable urban planning for local essential services in the future.

In an even wider perspective, the research tries to connect urban planning or planning in general with asset management engineering through its topic and approach. It combines the goal of urban planning – fostering sustainable development – with the goal of asset management engineering: to create safe, effective, efficient and environmentally friendly physical assets as part of public or private infrastructures (which includes essential service systems) (TU Delft, 2020). In doing so, the research attempts to merge knowledge from different domains in order to enable sustainable development and a safe integration of essential service systems within the near future. In this context, sustainability relates to the concepts of asset management engineering: safe, effective, efficient and environmentally friendly. This adheres to the general vision of the MSc Architecture, Urbanism and Building Sciences programme: working in a multi-disciplinary way in order to create integrated and sustainable solution for the built environment (TU Delft, 2020).

11.2 Methodological reflection

The following paragraphs reflect on the methods that were used to explore the research topic.

11.2.1 Literature reviews

In different parts of this research literature reviews were used in order to understand the theories and practices surround local essential service provision in general and in Oosterwold. As expected, the literature sources considering the scale dilemma for the implementation of essential services were scarce. To increase the amount of data considering the scale dilemma an even broader scope could be adopted, possibly including practical documents or resorting to interviews with experts. This would further dilute the scope of the literature research but could bring new valuable information to the table as the scientific data is scarce. Again, a transparent process is key (see 'literature study' in chapter 3.) as this proves the validity of the arguments made.

11.2.2 Site visits

The three site visits gave a good and necessary impression of the neighbourhood. The observations filled a large gap in data on essential service provision in Oosterwold. The limitation of site visits can possibly become biased by the researcher but in this case the data was mainly quantitative (for example the number of shared versus individual wetlands) allowing little bias. There could have been a more transparent documentation of the observations in the appendix afterwards but due to the little bias factor this was not seen as necessary.

11.2.3 Interviews

The semi-structured interviews provided an important insight into the development of essential service systems in Oosterwold. To deepen this insight, additional interviews could have been conducted with developers, the regional waterboard and Liander to further understand the governance of essential service provision in Oosterwold. Since this was not the direct aim of this research these were not conducted to limit the scope of the research. However, in hindsight these parties could have provided valuable information. Due to the limited availability of literature, these stakeholders could have provided valuable insights regarding their preferred scale level for the implementation of essential services and why.

11.2.4 Scenario planning

Scenario planning was used to create three relevant levels of autonomy for the future of essential service provision in Oosterwold. There were two important challenges of using scenario planning: the consistency between scenarios and the plausibility of the scenarios. The models provide a high consistency as the total land-use, total consumption and division of land is fixed for all models. Only the spatial arrangement and consumption patterns are variable. The plausibility of the scenarios is always up for discussion but in this case the analysis provided a solid base for the formation of scenarios. In hindsight, the most important stakeholders considering essential service provision in Oosterwold (inhabitants, area team, water board and Liander) could have been included in the formation of scenarios to further improve the plausibility.

11.2.5 Maximization method

To implement essential service systems based on the different scenarios, the maximization method was applied in chapter 8. In hindsight the maximization method did not prove to be a useful tool to understand the different scenarios. The method can expose the possibilities for (autonomous) essential service provision when dealing with environmental, social or technical constraints as input for decision making and design. In this research the hypothesis was, that the three scale scenarios would entail divergent constraints. This would lead to different energy provision and wastewater treatment solutions and expose the differences between the levels of autonomy leading to input for decision making and design. However, the problem with this hypothesis is that it assumes there are different approaches on different levels of autonomy. When conducting the maximizations, it became apparent there was no difference in approach considering the type of essential service system. In other words, the different constraints in the different scenarios did not lead to different design choice and therefore fail to provide input for decision making and design. This is most likely due to the absence of spatial policies or regulations which were only found for wind energy as well as the relatively little spatial constraints found in Oosterwold due to the abundance of land. The real differences in scale were found in the technological possibilities (such as the ability to treat wastewater), environmental constraints (such as the restriction on drilling in some parts of the neighbourhood) or governmental constraints (the level of expertise, time investments etc.) or costs rather than the spatial constraints. This is also visible in the eventual choice for the main indicators (land-use, environmental impact and risks) which do not just represent spatial aspects but also environmental and technical aspects. As a result, the maximization studies have become a representation of the research rather than a part of the research inquiry. The maximization studies have provided some useful insight into the possibilities for autonomy in Oosterwold within the boundaries of an average plot. For example, the use of biomass could be excluded as it would never be possible to grow enough biomass to produce the amount of energy necessary for heating.

11.3 Scientific relevance as a result of the research approach

As explained in the problem field (chapter 2), essential services are increasingly becoming an integral part of spatial planning due to the decentralization of essential service systems and the focus on sustainability which is benefitted from a multidisciplinary approach. In order to understand essential service systems, the Urban Metabolism framework is used to provide clarity on the resource consumption of urban areas with the goal of improving sustainability. However, the impact of this resource consumption and the systems that cater it are often neglected in UM research (Adil & Ko, 2016; Wolsink, 2018). This knowledge is important in order to make sustainable design decision for spatial planning and the implementations of essential service systems (Longato, Lucertini, Fontana, & Musco, 2019). This research adds to this research gap by exploring the implementation of essential service systems within a local setting through a literature review, observations, scenario planning and the maximization method.

By adopting an explorative approach, this research has provided a quick insight into the future without much prior knowledge. This has certainly aided the research process and the eventual relevance as new insights would fuel different research directions. As an example, this has happened on multiple occasions with the specific concepts used within this research (land-use, environmental impact and environmental risks). Multiple other concepts were explored (such as flexibility, resilience, efficiency, costs, circularity or maintenance) but the final concepts were found important within the planning process. However, there are also drawbacks from this research approach. In this research, the lack of data was frequently filled with either data from practise or logical, but possibly biased, assumptions. Particularly the land-use intensity, environmental impact and environmental risks associated with local essential service systems were generally not described in literature hampering the validity of the results. Additionally, there is a huge lack of knowledge on the differences between the (local) scales of implementation possibly due to the decades of centralized facilities promoting uniformity rather than diversity. Furthermore, the extensiveness of the topic that was explored has periodically led to research paralysis. The defining of a set of indicators (land-use, environmental impact and risks) at a later stage in the research process, has partially solved this as the research became more focussed. However, due to this decision, the research also became more detailed while there was little research (as explained above) to support this level of detail and decreased the validity. Nonetheless, due to the constant switch between a more macro or micro approach has fostered an understanding of the current research gaps which is essentially the goal of exploratory research.

Q. Fully finished homes (photo by author, Oosterwold) ▶

11.4 Practical relevance

In the introduction, the aim was to provide input for the profession of spatial planning with in particular the neighbourhood Oosterwold. However, due to the exploratory nature, findings are not always directly useful for practical decision making as there is only a modest amount of prior research on which conclusions are based. To alleviate this problem and still provide some form of guidance for the situation in Oosterwold, the previous chapter (chapter 10.) provided more extensive information on how the conclusions can be interpreted for the future of the neighbourhood as well as for the general practice of spatial planning. Furthermore, the more generic catalogues of solutions can provide as a good source of information for similar projects.

However, one thing this research has taught us is that the possibilities for certain essential service techniques depends on the area as well as the importance of certain impacts due to these essential service systems. As an example, geothermal drilling was not possible in Oosterwold which limited the options for energy production and changes the total impact of locally providing energy. At the same time, the risks associated with wastewater treatment were important in Oosterwold due to the possibility of polluting a potable water source. These issues might not be present, or other issues might come up in different neighbourhoods resulting in different choices and a different (desired) impact. More generic parts of this research, such as the literature review or the catalogues of essential service solutions, are more easily applicable to other neighbourhoods. On top of that, a similar approach can be adopted deriving a similar set of conclusions but tailored to a different situation.

11.5 Ethical dilemmas

Self-sufficiency, autonomy or the decentralization of resource consumption and production is generally seen as generating more sustainability. Localism in general is preached as the solution towards the challenges we encounter nowadays which are seen as a result of globalization. The vast and complex networks of material flows foster a ‘disconnection’ from the production of resources and associated impacts, leading to overconsumption, neglect or worse indifference. Localism on the other hand, might awake a feeling of connectedness and lead to an increase in awareness and responsibility.

From a social point of view there might be an important truth in self-sufficiency or localism, however, it can also lead to a false sense of sustainability. This was also visible in Oosterwold where residents might feel benevolent to their environment, but their consumption patterns have not necessarily decreased. Many would occupy large plots of land without producing a large amount of food; all inhabitants are completely dependent on cars; their material and building costs might have a much larger footprint than centralized building (especially considering most houses are built independently, detached and are relatively spacious); they still largely depend on the national electricity grid which is mainly fed by coal (instead of heating their homes with gas they practically heat their homes using the more inefficient resource coal); and their wastewater treatment systems could pollute an important source of potable water in the long run.

This false sense of sustainability is not to be taken lightly if we really want to create more sustainable communities. Sadly, self-sufficiency and localism are not direct solutions towards creating more sustainability even though many philosophers and researchers have preached the movement. Rather, the right strategy is one that is tailored to a specific place. Both centralization and decentralization can lead to an increase in sustainability and will therefore remain a dilemma which needs to be addressed in spatial planning. This, however, emphasizes the need for spatial planners as creating or guiding custom solutions for the large diversity of neighbourhoods, cities or countries. Again, we can stipulate that sustainability is to be found in exploring simple solutions for complex challenges rather than applying a generalized solution which falsely presumes landscape, culture or society is also general.

Within this research this ethical dilemma was present from the start and has made it difficult to use the word sustainable alongside concepts like self-sufficiency and autonomy. Moreover, this dilemma has made it difficult to generate 'generalized' solutions or recommendations as this goes against this philosophy of sustainability. Only when specified, is there value in the conclusions made in this research. This requires a level of detail that reaches to at least the techniques in the catalogues of solutions but the limit in time made it difficult to foster this level of detail. Whether the recommendation truly support sustainable development is therefore to be learned in practice. This is also, in a way, the most important philosophy of Oosterwold that can truly lead to more sustainable urban planning in the long run: its ability to explore, fail, reinvent and succeed creating at least an interesting venue for discussion and maybe even generating important insight. Opposing the critiques of Oosterwold earlier, the sense of community, tiny house movement and commitment to nature are equally found in this large neighbourhood. It is up to researchers and spatial planners to aid in this process, provide critical notes and distil the valuable lessons that might be found within this neighbourhood. Hopefully this research, in its exploration, failures or success has contributed to this endeavour in some part.

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Essential service systems, such as energy provision and wastewater treatment, are important elements within spatial planning as they cater the most fundamental needs of the built environment. The recent rise in decentralized or local systems compared to the common centralized approach have left spatial planners with a dilemma: on which scale level should systems be integrated to develop (partial) autonomy? A similar dilemma is visible in the developing neighbourhood Oosterwold near Almere where inhabitants develop their own wastewater treatment and energy provision systems following an unusual form of bottom-up urban planning. At the moment most inhabitants choose to develop these systems individually. Using the land-use, environmental impact and environmental risks associated with these essential service systems, a case is made for the potential of communal wastewater treatment, the exchange of electricity through a communal smart grid and the implementation of seasonal heat storage. The research highlights the importance of integrated spatial planning when working with local essential service provision.