Reviving the Ruhr

Preparing the Peri-urban Ruhr for an uncertain energy & climate future.

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P5 report

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Motivation

The motivation for the topic of this thesis is derived from my lifelong interest in the Ruhr area. Furthermore, I have an interest in the energy transition and foremost in the spatial component of the transition. When reviewing literature and news articles about the Ruhr area, it became clear that this highly urbanised and highly industrialised metropolitan area - with its typical peri-urban structure - had to transform and was experiencing this transformation. Due to the climate crisis, the energy transition was set in motion. This had and continues to have an effect on this area, known for its heavy (coal) industry. This results in an ever complex task for urban designers and planners, where the spatial component of the energy transition has to be implemented alongside the implementation of climate adaptation elements, while facing several barriers.

Since this is the case in several other metropolitan areas, the topic of energy transition with the Ruhr area as context, was chosen.

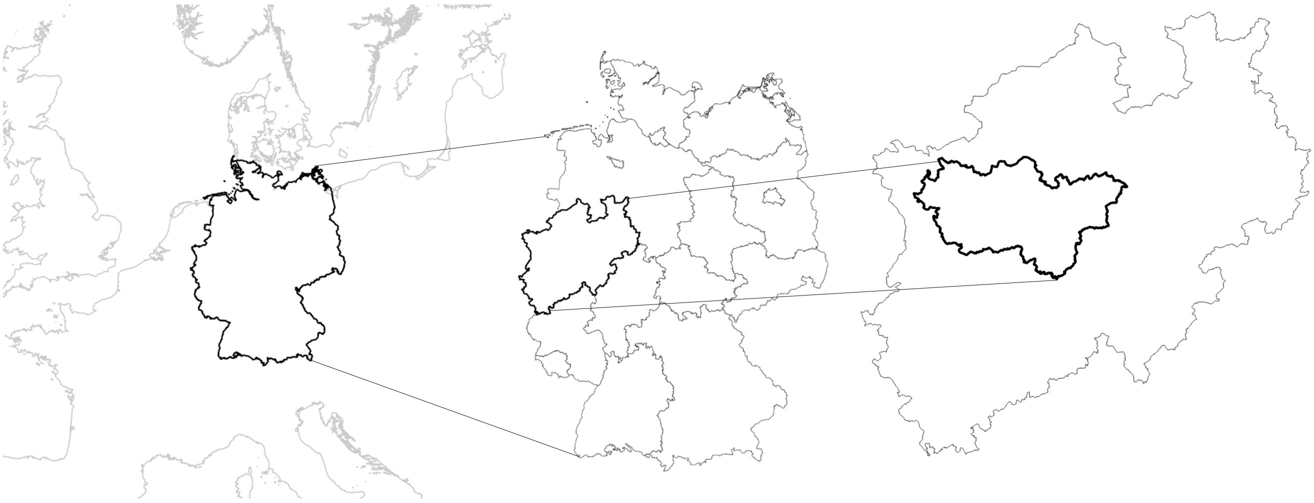

Figure 1: Location of Germany in Europa, North Rhein-Westphalia in Germany and the Ruhr area in North Rhein-Westphalia (author, 2022).

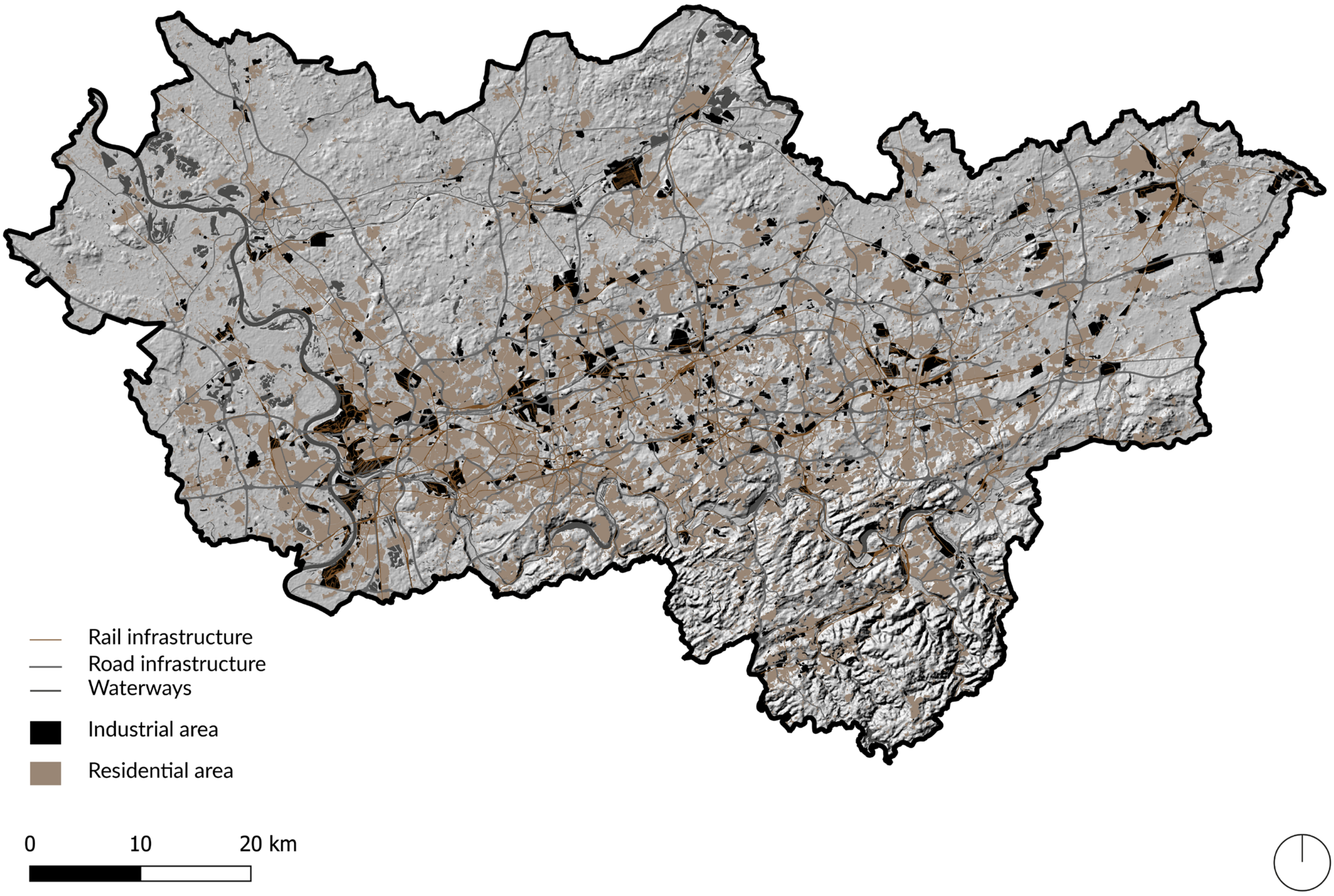

Figure 2: The Ruhr area (author, 2022).

Abstract

With the climate change and energy transition becoming evident and ever so relevant, industrialised regions focussed on fossil fuels need to rethink their socio-economic plan. Furthermore, urban designers are obliged to rethink the energy paradigm. This report combines energy landscape and resilient region theory and applies it on the peri-urban and industrialised polycentric metropolitan region of the Ruhr, Germany. The present structure of the metropolitan region is analysed and linked - using existing literature - to energy consumption and potential energy production. Using scenario building, design exploration is applied to strenghen ecosystem services as a way to adapt to the climate and implement sustainable energy landscapes. These sustainable energy landscapes are the spatial element of the energy transition and the new energy system. Furthermore, these landscapes facilitate climate adaptation. This report is a research-based design experiment, proposing an alternate energy transition strategy, focussing on ecosystem services, while improving the spatial quality of the peri-urban Ruhr area.

Keywords: Energy transition, Energy landscape, Climate adaptation, Peri-urban area, Ruhr metropolitan region

Figure 3: Dortmund-Grevel solar park (UNsere Energiegenossenschaft eG, 2021).

Reading note

This thesis, Reviving the Ruhr, is the end product of my graduation year at the Faculty of Architecture and the Built Environment. This thesis marks the end of my exciting, interesting and fun period at this faculty, obtaining my master's degree for the master AUBS, track Urbanism, Graduation studio Urban Metabolism and Climate.

In this thesis I was able to combine my interest in the energy transition, climate adaptation, environmental technology and design and systemic design, applied on an interesting spatial manifestation; the Peri-urban structure of the Ruhr area, in Germany.

This thesis is structured into three main parts; Introduction, Methods and Research outcome. The first part builds up from a description of the context to a problem statement, resulting in a research aim and question. The second part describes how this research was executed and the last part describes the outcome of this research.

Throughout the third part, I researched the relation between climate adaptation and energy transition (Chapter 07). This relation, ecosystem services, is analysed in chapter 08. The uncertainty the Ruhr area is facing is transformed into scenarios (Chapter 09), on which design exploration is executed (Chapter 10). The outcome of this design exploration is transformed into a strategy in Chapter 11, to implement these solutions in the context of the Ruhr area. This approach is visualized in figure 4.

Throughout this report, you will come across different spatial manifestations of the Ruhr area. At the end of this report, you will have experienced a trip throughout the spatial and temporal solutions for an integrated approach to tackle the energy transition and climate adaptation and have received a brief introduction in the spatial manifestation of the Ruhr area.

Several research and design results can be read in the appendix, which is not included in this document.

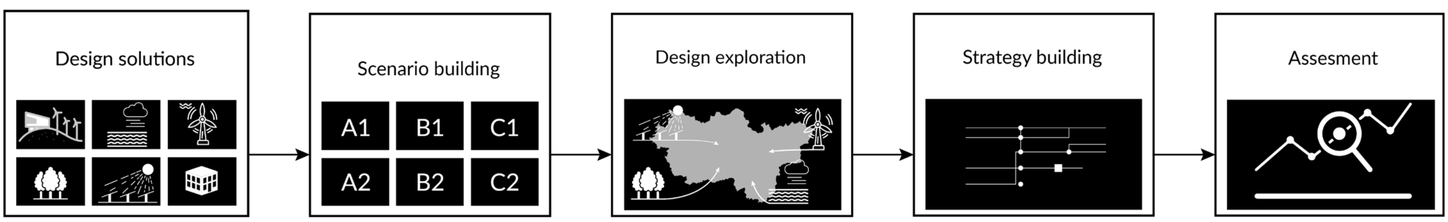

Figure 4: Research approach (author, 2022).

Figure 5: Gladbeck, the Ruhr area (Blossey, 2021).

Acknowledgements

I owe this thesis to the support of many people around me.

Firstly, I would like to thank Alex for the support, productive discussions but mostly fun and interesting meetings. You introduced me to a really interesting topic - peri-urban areas - for which I am really gratefull.

Secondly, thanks to Claudiu for the very interesting meetings we had and a special thanks for your ever detailled observations to indicate how my thesis could be sharpened and enhanced.

Thirdly, a thanks to my fellow students and teachers I had several really interesting meetings with during the incentives in the start of this process. These discussions helped me to figure out how to guide my thesis the way I wanted to.

Thanks to Maarten for the helpfull meetings throughout this year. To have someone with a sharp academic eye raise several key questions at the start of the process was really helpfull.

Thanks to my mum, dad and brother for their support throughout this thesis with your kind words. I really appreciate it.

And finally, Thanks to my friends. Specifically Hibbe, for the nice moments throughout this year and Jin-ah for the support and sessions where we helped each other in our processes. A special thanks to Toke, for your sweet words throughout this year.

Figure 6: The Ruhr Valley (Travel Diaries, 2021).

I. Introduction

Chapter 01. Introduction

i. Climate change
ii. Global energy transition
iii. German energy transition
iv. Energy

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Science

Climate change: IPCC report is 'code red for humanity'

By Matt McGrath
Environment correspondent

9 August | Comments

SPIEGEL International

Brown Coal, Fool's Gold

Can Germany Break Its Lignite Habit?

Can Germany finally turn its back on brown coal? It will have to in order to reach its CO2 reduction pledges. But lignite is a reliable source of cheap energy and provides lots of jobs in economically fragile regions.

Von Benedikt Becker, Frank Dohmen, Gerald Traufetter und Steffen Winter
22.11.2017, 17.48 Uhr

Figure 7: The urgency of climate change and the link to energy (Becker et al., 2017 ; McGrath, 2021).

Code red for humanity sounds disturbing. Unfortunately, this is the reality we - humanity - are facing in the 21 century. Climate change has been a topic scientists, researchers and politicians have been trying to address for several years now (Ourbak, 2017). With the agreement signed at Paris 2015 a major milestone has been set on the climate change horizon (Ourbak, 2017). Unfortunately, several scientist have sounded their fear because of the lack of political ambition in plans regarding climate change (Gavin, 2009). If we keep on addressing climate change on this way, the goals set in the Paris 2015 agreement will not be met (IPCC, 2021).

"Several European Union Member States focus specifically on energy supply and related market-based instruments. Other approaches focus on the demand side, including the expansion of energy efficiency measures in end-use energy applications" (Keles, 2017). Climate change will have an impact on several key elements that we take for granted and that shape the way we live (Steg, 2015). Think of the way we construct cities and buildings (Sijmons, 2014). This process has to change, in order for us to construct green cities and societies. Furthermore, the way we move around in cities, between work and home has to change. This mobility transition will change the way we view transport (Sijmons, 2014). Lastly, the way we consume but foremost the way we produce energy has to change (Sijmons, 2014). This energy transition is related to all the before mentioned aspects and therefore of major importance (Sijmons, 2014).

The energy transition is the most challenging and overarching transition of the consequential transitions from climate change (Sijmons, 2014). Energy cannot be viewed as a single element in the 21st century.

ii. Global energy transition

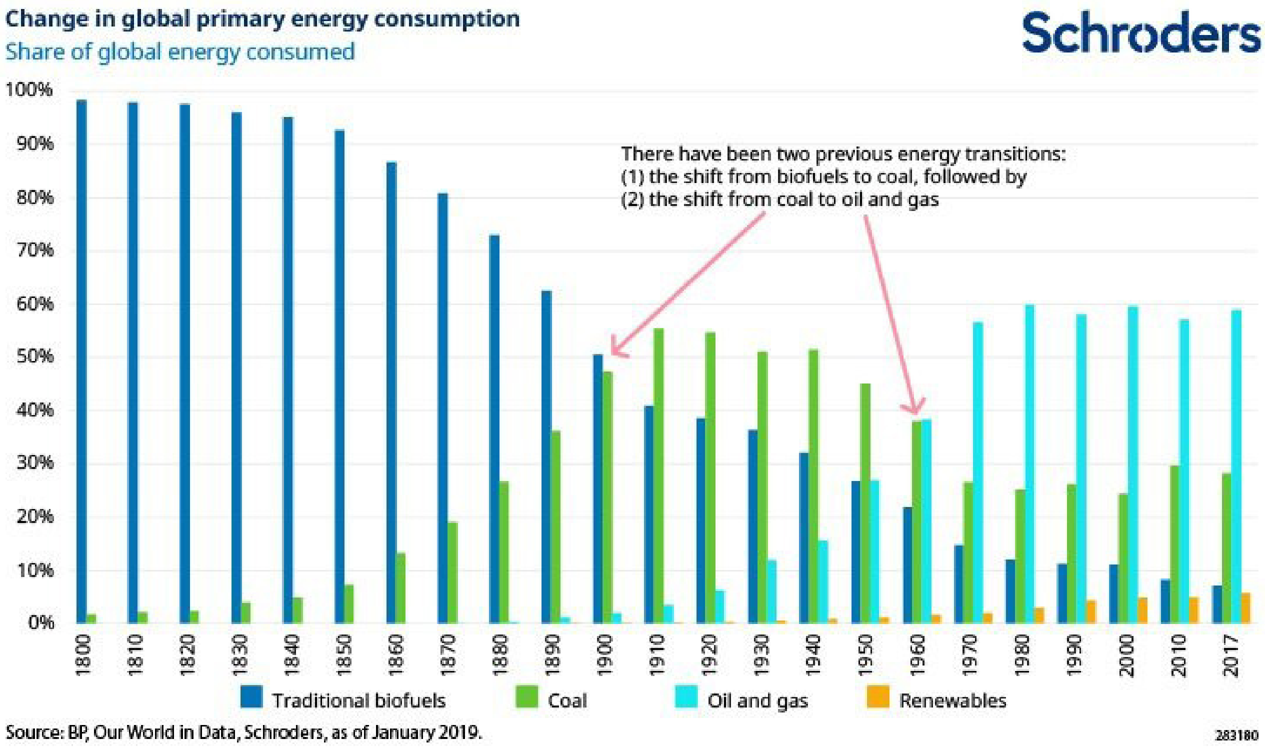


Figure 8: Global energy transition (Lacey, 2019).

Energy is connected to everything we do. The way we move around (fuel), the way we consume products (electricity for the production, fuel for the shipment), the way we live (heating, charching your phone). Because of interconnectedness of energy, this cannot be fixed regionally or nationally but has to be fixed globally (Sijmons, 2014).

Following the most recent COP in Glasgow, a few steps have been taken in the right direction (IPCC, 2021). Since energy is heavily related to urban expansion and industries, the global south as well as China are unwilling to name hard goals, since these goals could minimalize their urban and economic growth (Ourbak, 2017).

Because the global energy transition is a politically sensitive subject, partnerships can be formed or broken during debates about the tackling of the energy transition. This can be seen in Europe, where nations relying on fossil fuels for the national heating and economy are reluctant to face the taxes on emissions (Keles, 2017).

In Europe - where a lot of coal and lignite fields can be found (Osička et al., 2020) - this transition is facing pressure from mainly eastern-European countries. Because the use of this fossil fuels is so imbedded in their nations (economy), it is culturally sensitive and foremost financially heavy for heavy industrialised nations to transition to a more green economy (Osička et al., 2020).

As the largest economy in Europe, Germany is a major player in the EU, the G7 and the UN. This leading role can also be observed in the energy transition, where other countries observe and imitate its example (Guidolin & Guseo, 2016). However, data indicates that the Germany energy transition might not reach its goals by the year of 2050. Germany remains reliant on its coal supply for the production of energy (International Energy Agency, 2020). Major coal fields have been found in the Ruhr area, which were intensively used (Osička et al., 2020). The present of the coal led to economic development, which resulted in a thriving Ruhr area (Brauers et al., 2018). The spatial structure of the Ruhr area was shaped by the intense coal mining and steel production (Zimmermann & Lee, 2021). The consequential spatial structure of the Ruhr area houses multiple potentials, but also several economic and social problems (Vicenzotti, 2017).

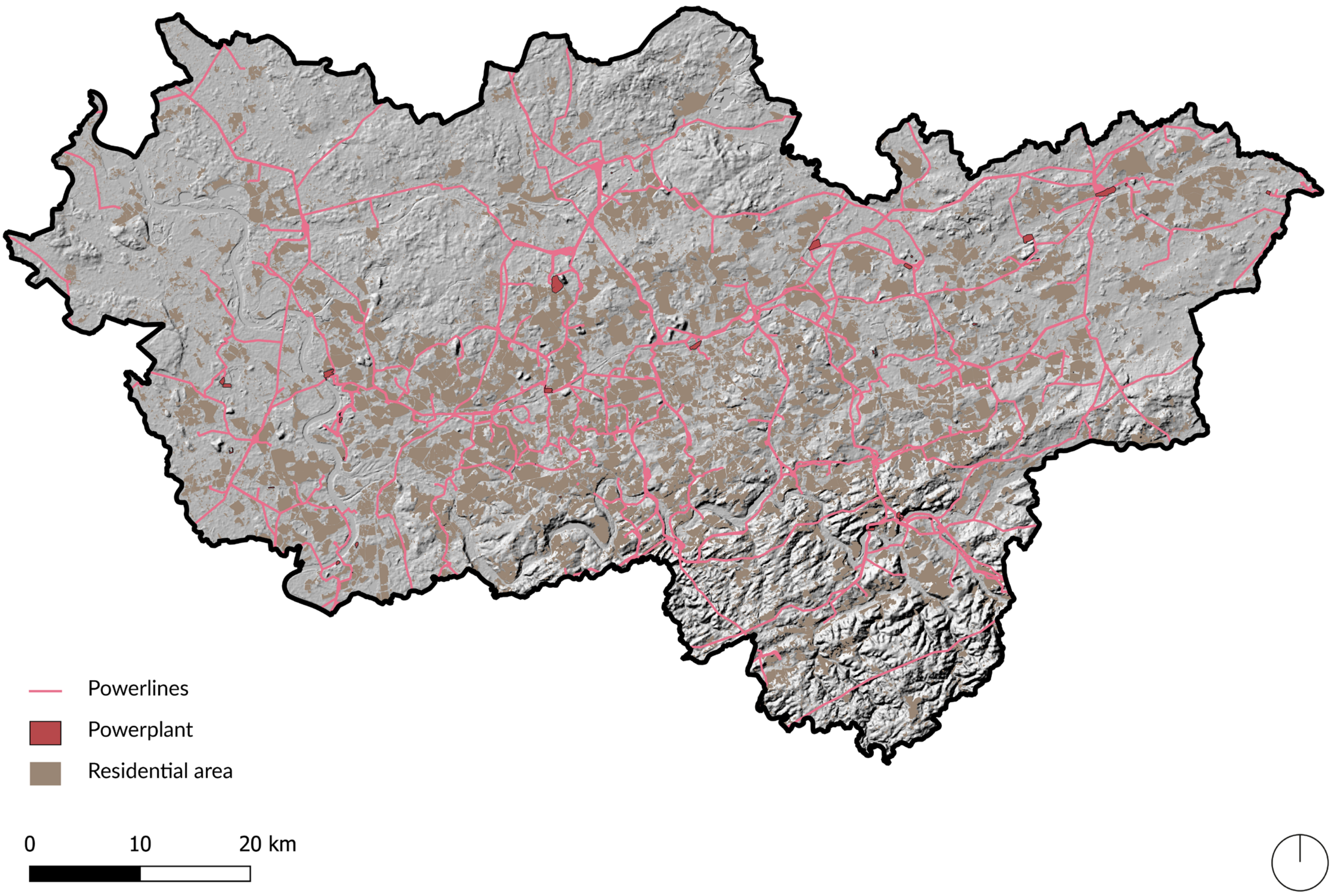


Figure 9: Energy system in the Ruhr area (author, 2022).

iv. Energy

The energy transition has been mentioned, however, the component central in the energy transition, energy, has not been defined yet.
Energy is defined as followed by Falk et al. (1983): ''Energy is a substance-like quantity; it is distributed in and can flow through space.'' Furthermore, the EIA (2021) describe energy as the ability to do work. Because it is possible to change energy from
one form to another, modern civilization is possible to exist. People use energy to light our home, move around by the use of car and factors use energy to manufacture products (EIA, 2021).

The two foremost categories of energy are; potential and kinetic energy (IEA, 2021). Energy can be defined in different forms. These forms are; mass energy, kinetic energy, thermal energy, gravitational energy, potential energy, electrical energy and nuclear energy (Falk et al., 1983).
Furthermore, energy can be carried by different ''substance-like physical quantities which flows while energy is flowing'' according to Falk et al. (1983). Examples of these energy carriers are; coal or oxygen. Energy is not transferred from one form into another, but the energy exchanges its carrier (Falk et al., 1983). The stored chemical energy in coal or natural gas and the kinetic energy of water flowing in rivers can be converted to electrical energy, which in turn can be converted to light and heat (IEA, 2021).

There are many different sources of energy, which can be divided into two basic categories: Energy sources can be categorized as renewable or non-renewable sources.
Renewable energy sources, are sources that can be easily replenished. An example of a renewable energy source, is the wind. However, Non-renewable energy sources are sources that cannot be easily replenished. An example of a non-renewable energy source is coal.
Renewable and non-renewable energy sources can be used as primary energy sources to produce useful energy such as heat, or they can used to produce secondary energy sources such as electricity and hydrogen (IEA, 2021).

Electricity generated from renewable energy sources, such as wind energy from the power of the wind, or thermal energy from the heat of the sun, can rarely provide in the growing demand for energy as these sources do not deliver a steady supply of electricity (IBRAHIM et al., 2008). With the increased usage of decentralized energy production, pressure is added to the network, to ensure proper capability for energy storage. This has led to storage being a crucial element in energy management, allowing energy to be released into the grid during peak hours and being stored during off-peak hours (Ibrahim et al., 2008).

The urban form has major implications for energy demand and energy production (Silva et al., 2017). The form of the urban is a determinant of the level of sustainability of our society, as it influences the private travel behaviour, patterns and modes of energy consumed in everyday activities (Rickwoord et al., 2008).

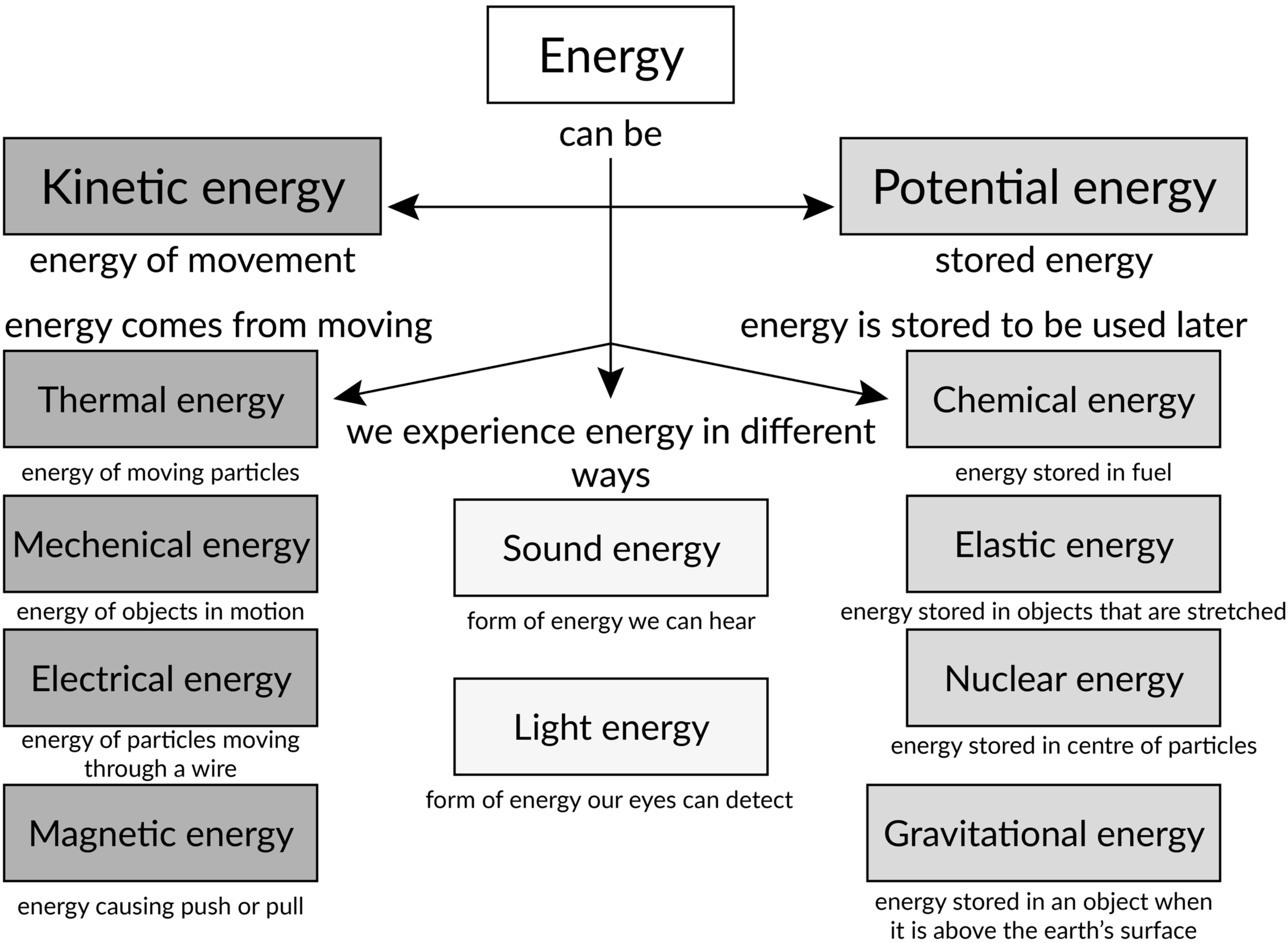


Figure 10: Energy and its shapes (author based on https://mskuksclass.weebly.com/lesson-2-forms-of-energy.html, 2022).

Chapter 02. Problem synopsis

The start of our problem synopsis is located at the typology of the Ruhr area. The Ruhr area is described as a peri-urban area (Sroka et al., 2019). A peri-urban area is described as landscape resulting from natural and human factors that is not fully urban and not fully rural (Spyra et al., 2021).

The dimension of the peri-urban Ruhr area is the result of the common history of coal mining and steel production (Zimmermann & Lee, 2021). Next to that, The Ruhr area is also described as the mother of the Zwischenstadt. This describes the Ruhr area as a new type of suburbia with a city-country continuum (Burdack, 2007). The Zwischenstadt indicates that there are possible potentials in this new urban structure, which are located between the living spaces and the non-places of movement, while also addressing the social and cultural problems (Vicenzotti, 2017).

The peri-urban, an example from the category of sub-urban areas has several consequences (Hesse & Siedentop, 2018). One environmental consequences of suburbanization and the consequential sub-urban areas are more driving (31%) than urban counterparts (Kahn, 2000).

Vicenzotti (2017) described the potential of the peri-urban structure, located between the living spaces and the so called non-places of movement. The map, illustrated in figure 7, indicates

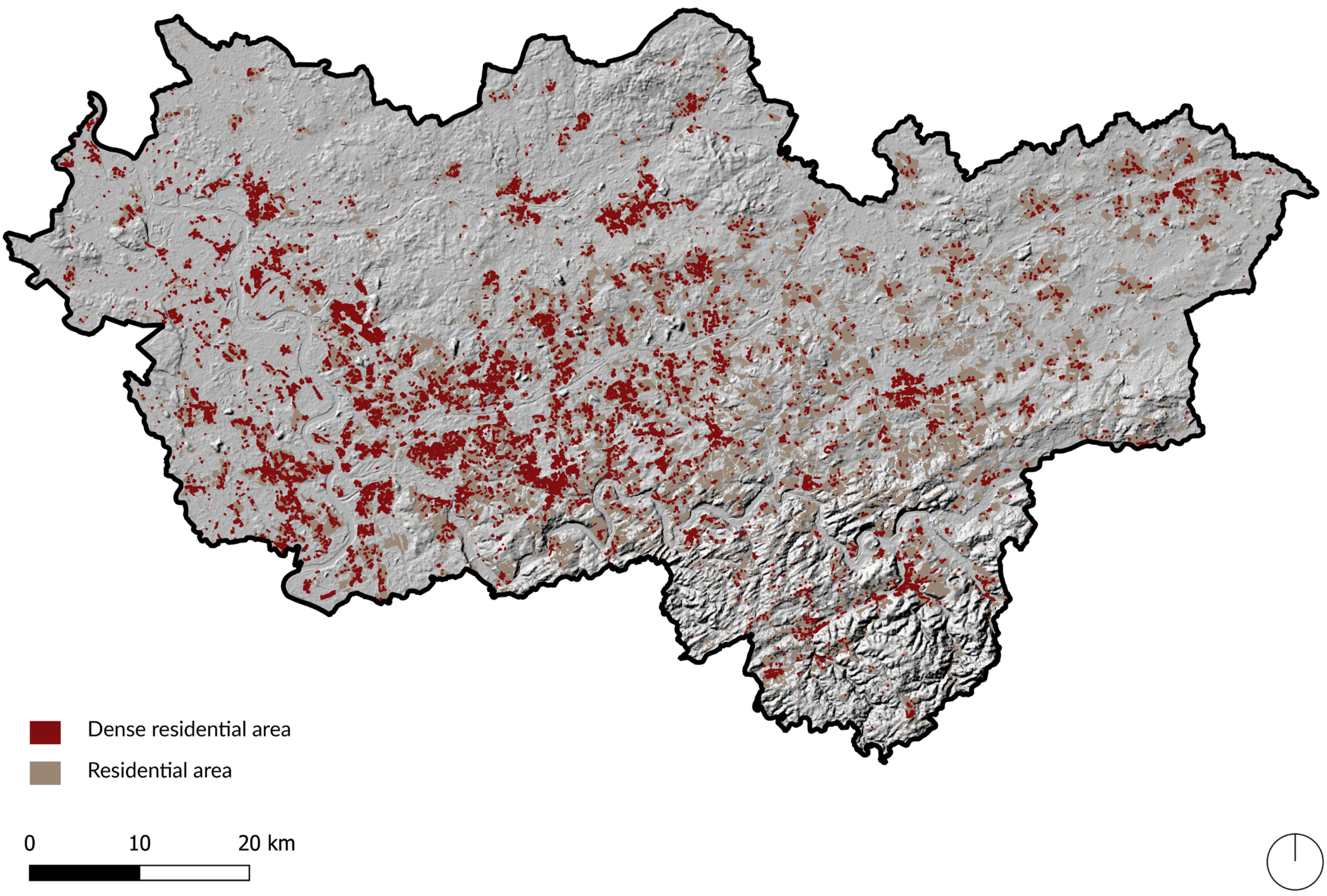


Figure 11: Residential structure of the Ruhr area (author, 2022).

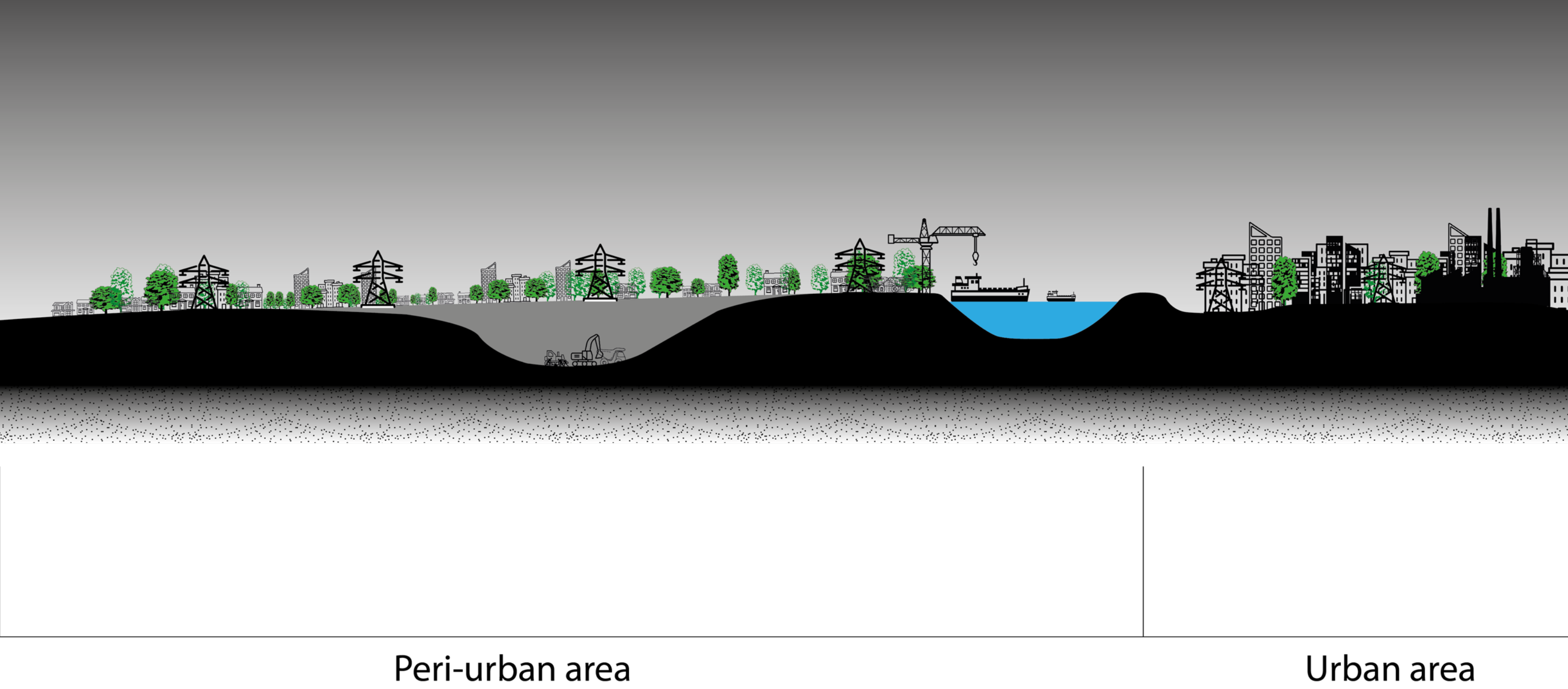


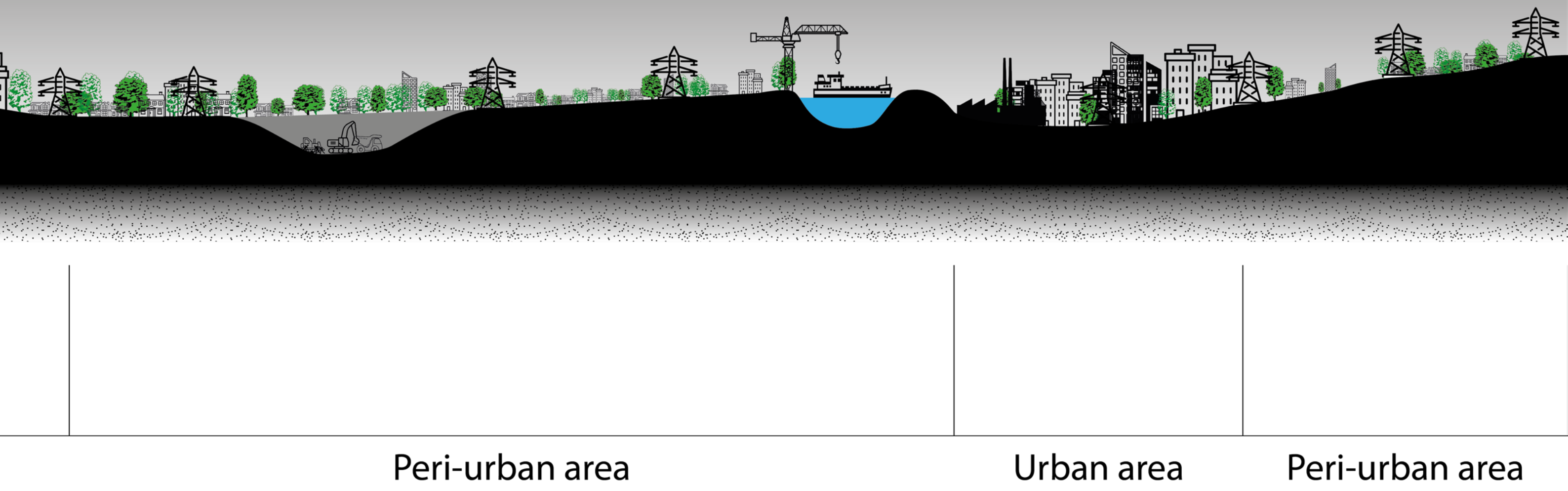
Figure 12: Systemic energy section p

the potential from the structure, and the images, in figure 9, visualizes the potential that this structure entails on the ground level.

Although, this peri-urban area hosts several possibilities, there is no mention of it in regional energy transition policies (International Energy Agency, 2020; Vicenzotti, 2017). This indicates that the potential of the peri-urban structure is not taken into account in the energy transition.

The systemic energy section, shown in figure 8, will be used to indicate the relationship between the several parts of the problem synopsis and how, eventually, this all leads to the problem statement. This first layer, describes the spatial structure of the Ruhr area, and is an abstracted section, focussing on the energy system, from north to south.

As mentioned previously, the urban form has a direct relationship to energy consumption and energy production. The structure of the Ruhr area is a consequence of the mining of coal and lignite from the soil to produce energy (Zimmermann & Lee, 2021). The following paragraph will elaborate on the energy transition that is taking place in the Ruhr area, and eventually describe the (spatial) consequences of this energy transition for the Ruhr area.



eri-urban - urban area (author, 2022).

Figure 13: Peri-urban area in the Ruhr (GeoHilfe.de, 2020).

ii. Insufficient energy transition

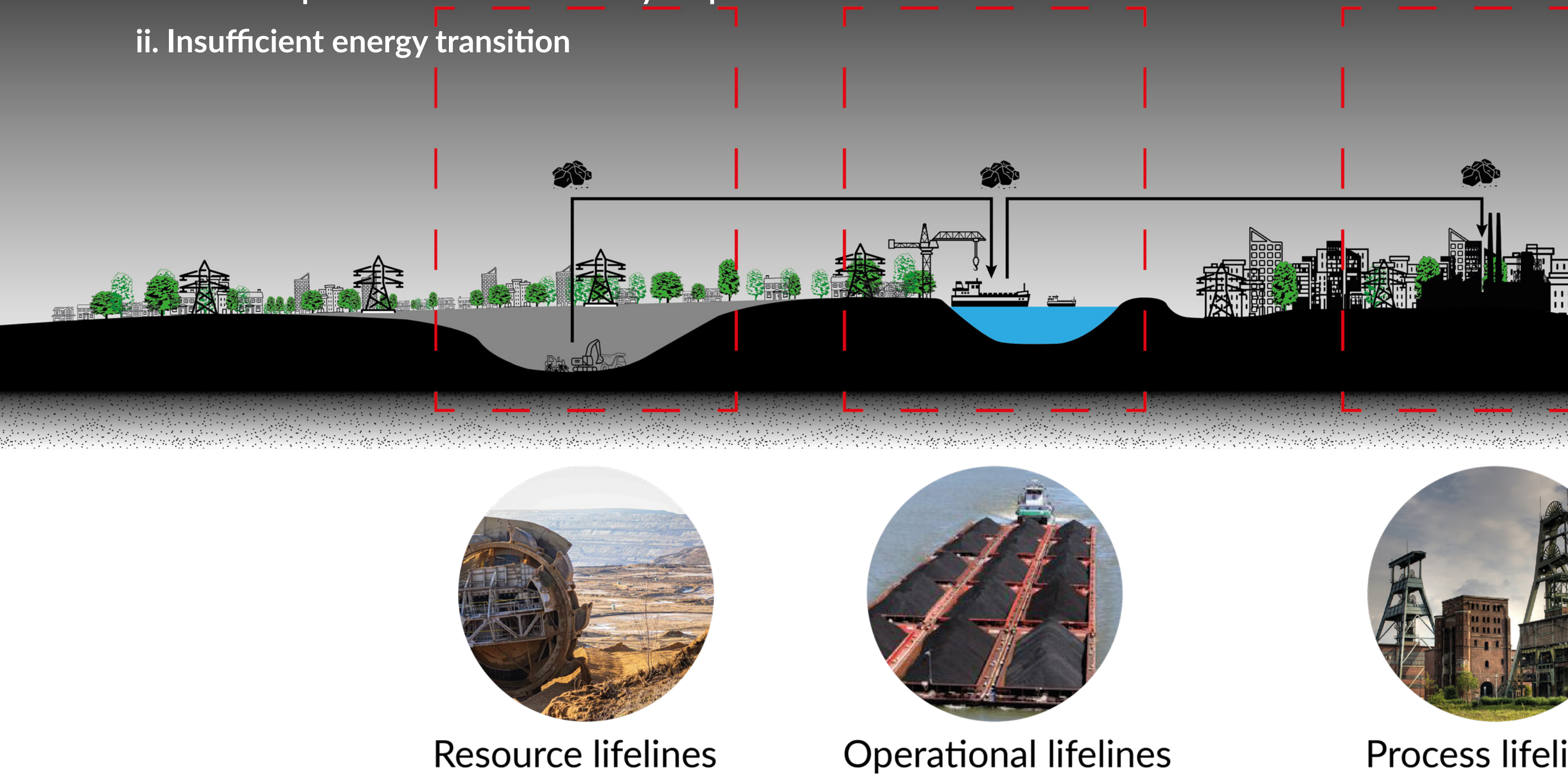


Figure 14: Systemic energy se

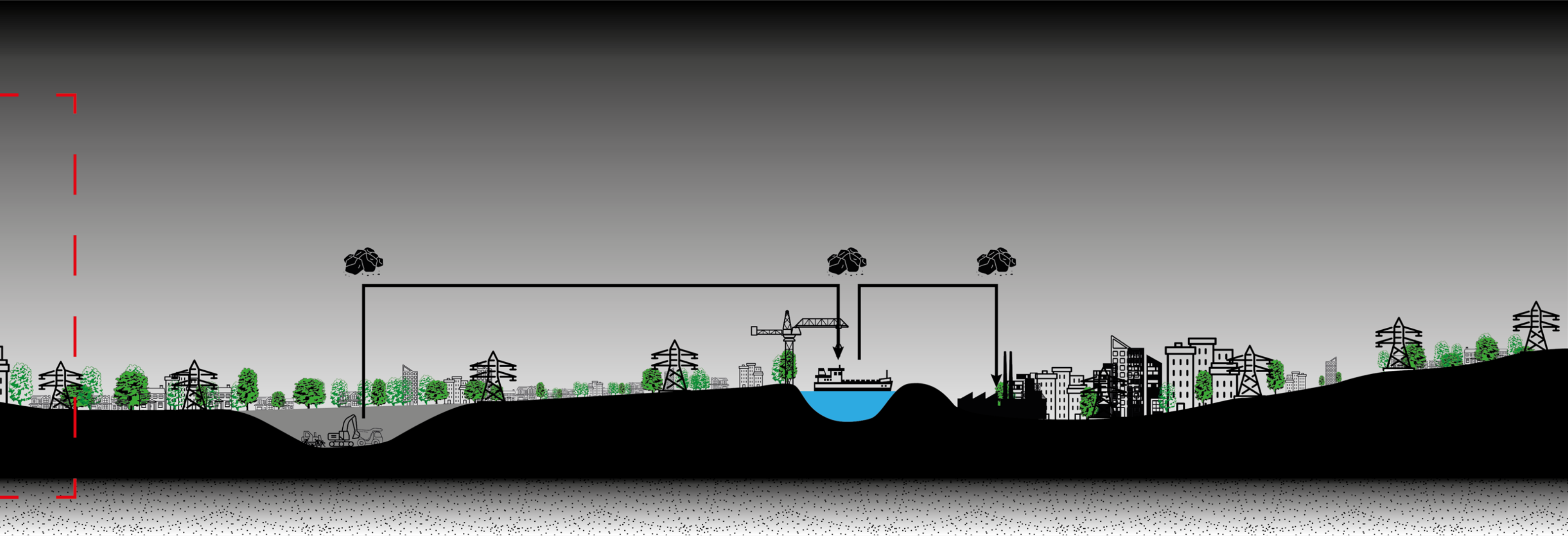
The energy transition is underway in Germany and in the Ruhr area. Although the change from a coal dominance energy system to a more diversified energy system can be clearly seen, coal remains the raw material responsible for 23% of the energy supply in Germany (International Energy Agency, 2020).

Germany has been decreasing its coal use, but in the process, chose to remain using lignite and not decrease the use of that specific fossil fuel (Osička et al., 2020). As of this point Germany remains to use 40.3% of fossil fuels for its electricity production (Osička et al., 2020). Furthermore, 17.000 employees remain to work in German coalmines (Osička et al., 2020).

The trend towards more renewable energy sources, can be clearly recognized in the energy transition strategy of Germany. Nuclear energy will be completely phased out by 2022. However, energy production on the base of coal will be phased out by 2038 (International Energy Agency, 2020).

Although significant progress has been made in the energy transition in Germany and the Ruhr area, with several industrial factories having been shut down or transitioned to a greener approach, modelling regarding the energy transition indicate a significant gap between the results and the emissions reduction target by the year 2050 (International Energy Agency, 2020; IPCC, 2021; Wegener et. Al, 2019).

This energy transition has a major spatial component. The spatial component is a combination of drosscapes, as consequence of the closing of coal mines for example, and the implementation of sustainable energy landscapes (Clark, 2009). The spatial component of transition towards more sustainable energy sources, the sustainable energy landscapes, will be discussed in the following paragraph.



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ection lifelines (author, 2022).

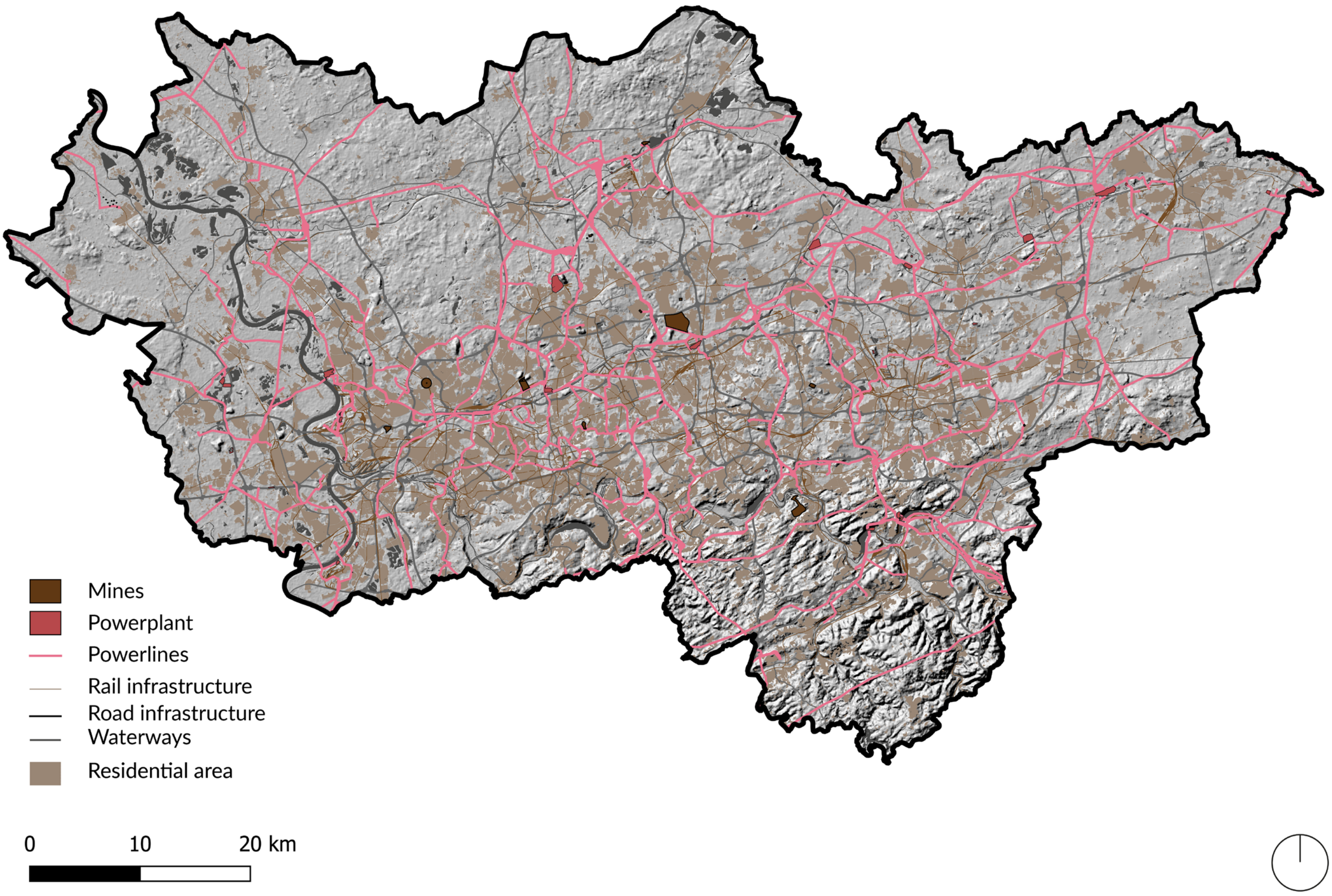


Figure 15: Energy system and lifelines in the Ruhr area (author, 2022).

The systemic energy section, in figure 10, is expanded, with the addition of three lifelines. These three lifelines conceptualize the current energy system. these resource (mining), operational (infrastructure) and process (powerplant) lifelines are mapped in figure 11. These lifelines operationalize the current energy system, from the mining of the resources, through the transportation, using the several types of infrastructure, to the powerplant, where the process is set in motion to create electrical energy from the resources.

The Ruhr area is a polycentric metropolitan area, also known as ''der mutter der Zwischenstadt. This area is a heavily industrialised area that has become a highly urbanised agglomeration as a consequence of the presence of these industries (Burdack, 2007; Zimmermann & Lee, 2021).

A large part of the industries focused on coal and lignite mining and production of metals or energy. As a consequence, this area has a lot of operational lifelines for these materials and their products. There are multiple channels that have been dug, highways that have been constructed, railway that have been placed and powerlines that have been erected to support these processes. These elements come together in the process lifelines like mines, or steel producing factories. These process lifelines, with their operational landscapes and operational buildings, have become a part of the identity of the Ruhr area and are highly valued (Götting, (2014).

With the energy transition pushing the Ruhr area away from these heavy industries the question is what will happen to the current energy operational landscapes? Will they remain? Transform? Be removed? Since these landscapes have become a part of the identity of the area and are highly valued, the first idea that comes up is to preserve them. However, which parts, and which values, of these operational landscapes will be preserved? Which will be adapted and how will the operational landscape look like after the transformation?

Furthermore, how will these energy operational landscapes look in the future? Will they remain to be made up out of channels, roads, rail lines and powerlines? Or will new elements be constructed? Can there be a synergy between the former and current energy operational landscapes?

Literature review indicated that energy can be described as space (Sijmons et al., 2014). Furthermore, there a several connections between the urban form and energy production and consumption (Silva et al., 2017). Thus, the energy transition, or the unsufficient energy transition can be described as a spatial problem / a spatial transition. That is why the following paragraph will elaborate on the spatial outcome of the energy transition.

Figure 16: Former powerplant Zeche Zollverein in Essen, now a cultural destination (NRW, 2014).

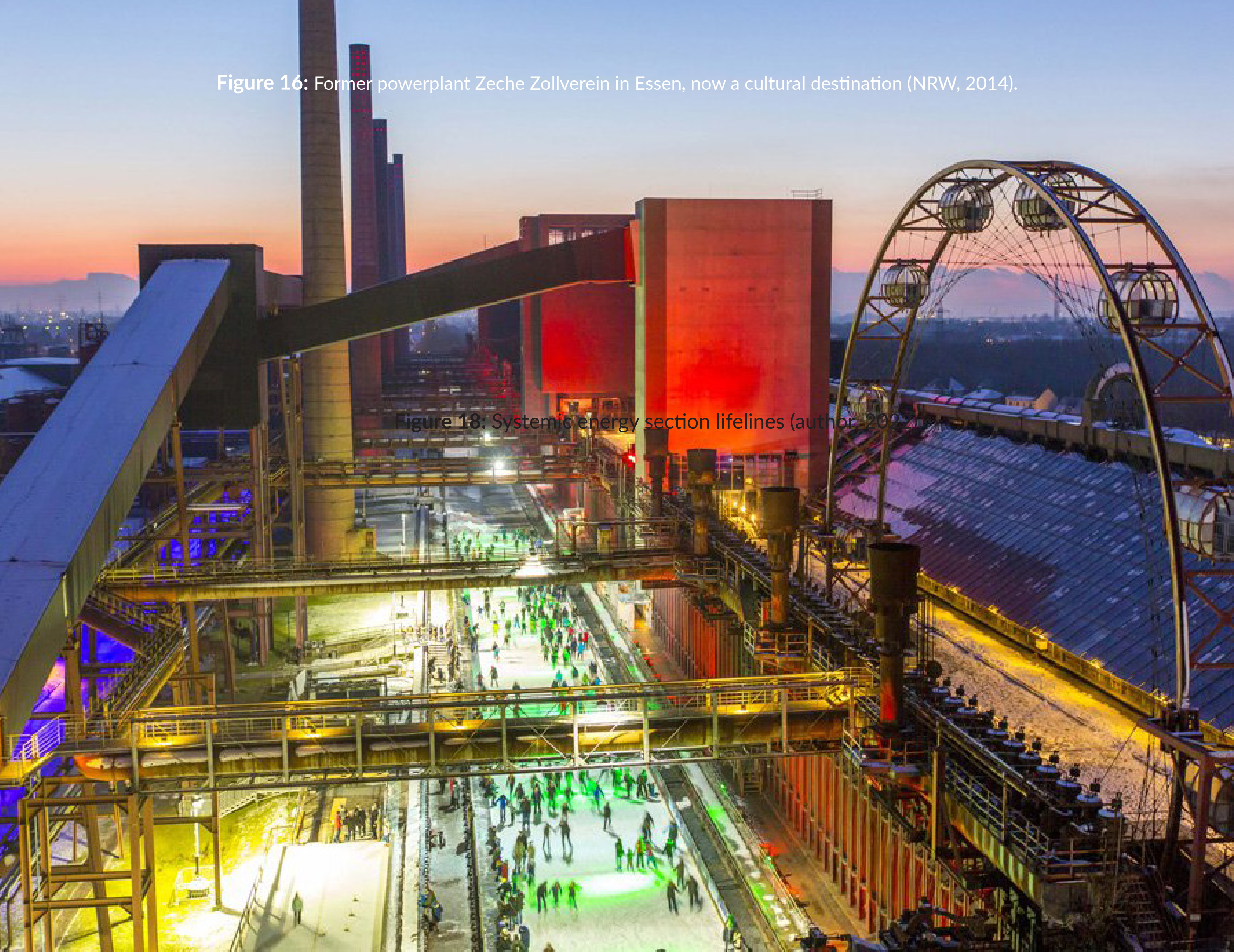


Figure 18: Systemic energy section lifelines (author, 20

Figure 17: RWE - german energy company - coal power plant in Hamm (Wilkes, 2018).

iii. Spatial pressure from energy transition

The energy transition is a systems transition. However, every system has a spatial component. For a comprehensive system such as the energy system, this spatial component is referred to as the energy landscape. Figure 7 gives examples of energy landscapes. Energy landscapes can be described as: "observable landscapes that originate directly from the human development of energy resources'' (De Jong & Stremke, 2020). The implementation of these energy landscapes, through the changing of the contextual landscape, has encountered multiple barriers from surrounding residents (Pasqualetti, 2011).

Energy covers a wide variety of topics such as electricity, heat, fuel and storage (Sijmons, 2014). All these subcategories of energy have a spatial component to their respective system with a different spatial claim for raw material, infrastructure, waste products or extraction area.

The following figures indicate the spatial component of the energy transition, based on Sijmons (2014), applied to characteristics of the Ruhr area (5.3 million residents and 443500 hectare surface area). These figures indicate what the spatial consequence would be if the choice would be made to use only one energy source to cover the energy demand of the Ruhr area. The figures indicate the spatial component of a single energy source's raw material, infrastructure, waste products and extraction area. Furthermore, an example is given to indicate how the energy landscape of that specific source or system looks like.

These figures indicate why the energy transition is much more than a system transition, and more like a transition of the landscape of the Ruhr area as we know it (Pasqualetti, 2011).

Some energy sources are used more than others in the Ruhr area or in Germany (International Energy Agency, 2020). This has to do with availability, although some energy landscapes also encounter different barriers (Pasqualetti, 2011). This will be discussed in the following paragraph.

Figure 19: Examples of Dutch energy landscapes: (a) wind energy landscape; (b) fossil fuel energy landscape; (c) historical wind energy landscape; (d) coal energy landscape (De Jong & Stremke, 2020).

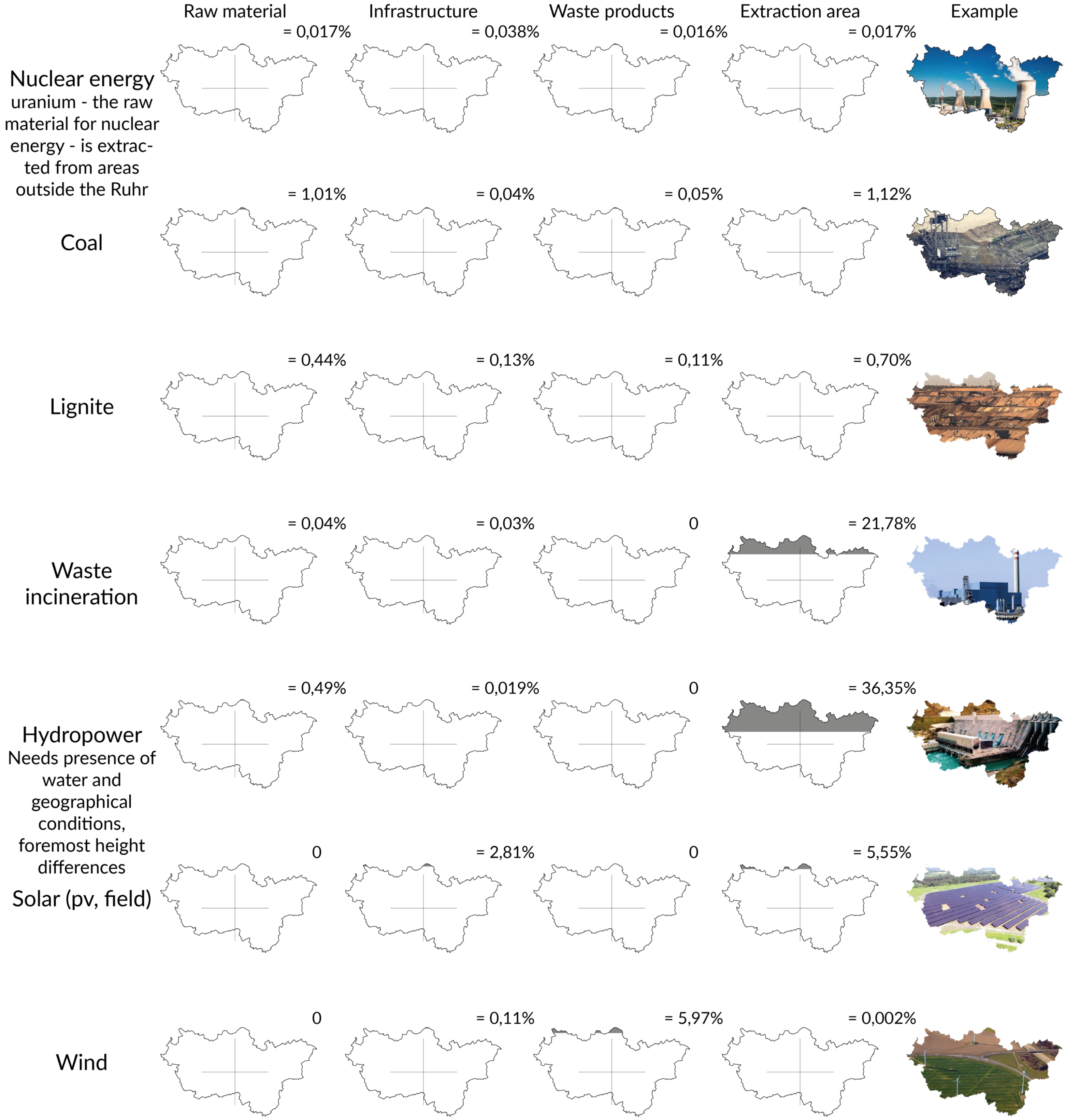


Figure 20: Spatial outcome of electricity demand for the 5.3 million Ruhr residents in percentages of the total surface of the Ruhr area (author, 2022 based on Sijmons, 2014).

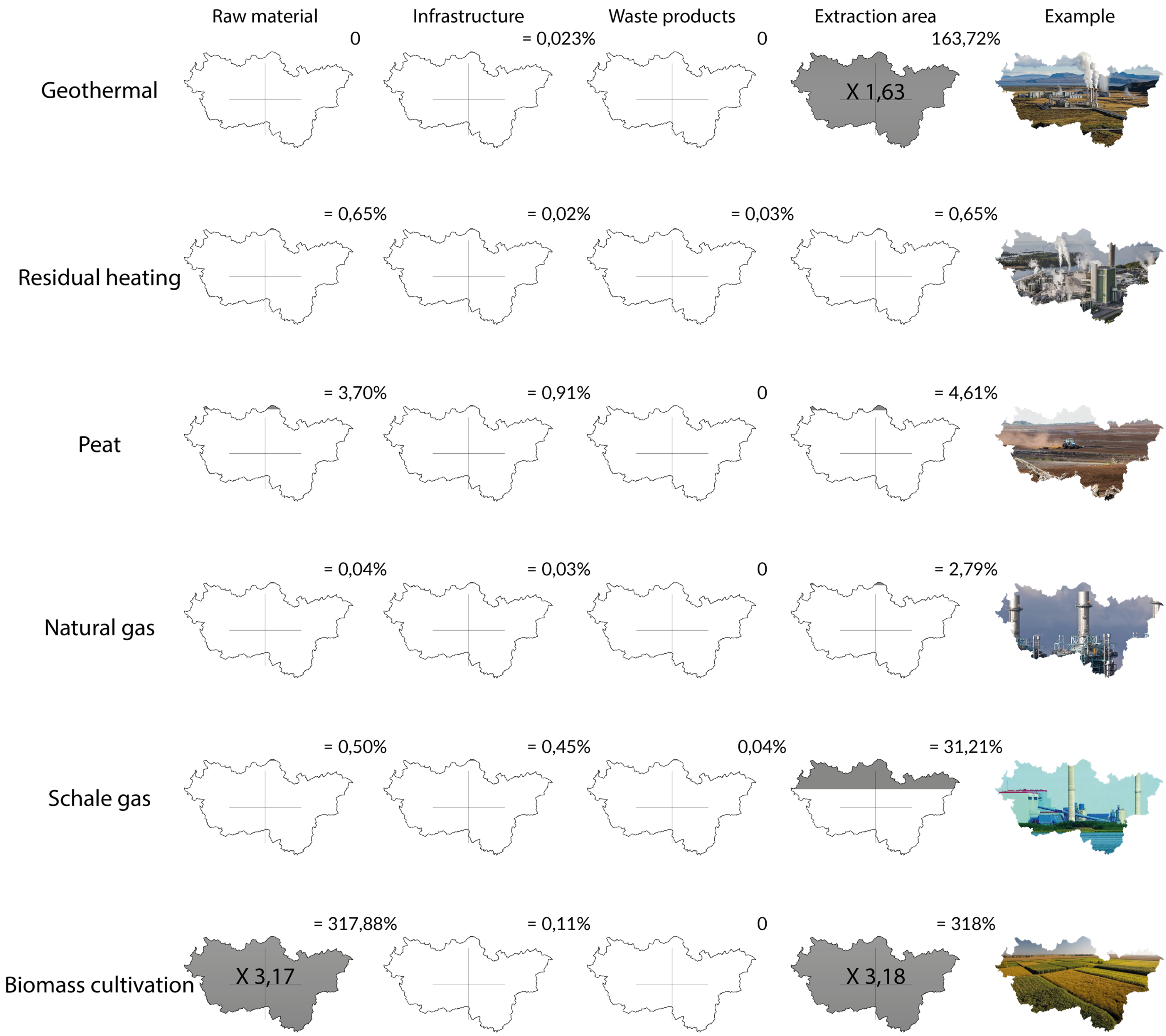


Figure 21: Spatial outcome of heat for the 5.3 million Ruhr residents in percentages of the total surface of the Ruhr area (author, 2022 based on Sijmons, 2014).

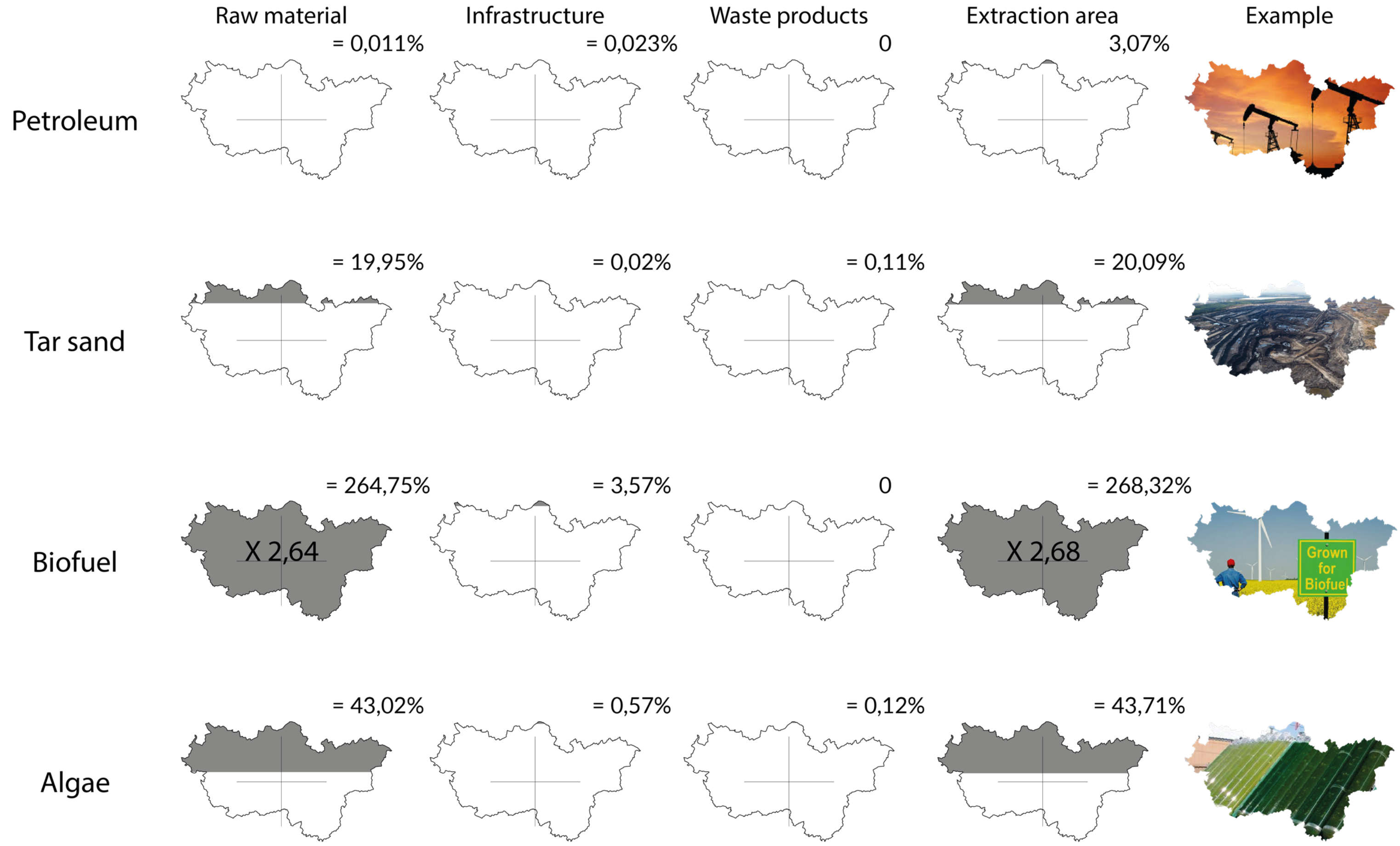


Figure 22: Spatial outcome of fuel for the 5.3 million Ruhr residents in percentages of the total surface of the Ruhr area (author, 2022 based on Sijmons, 2014).

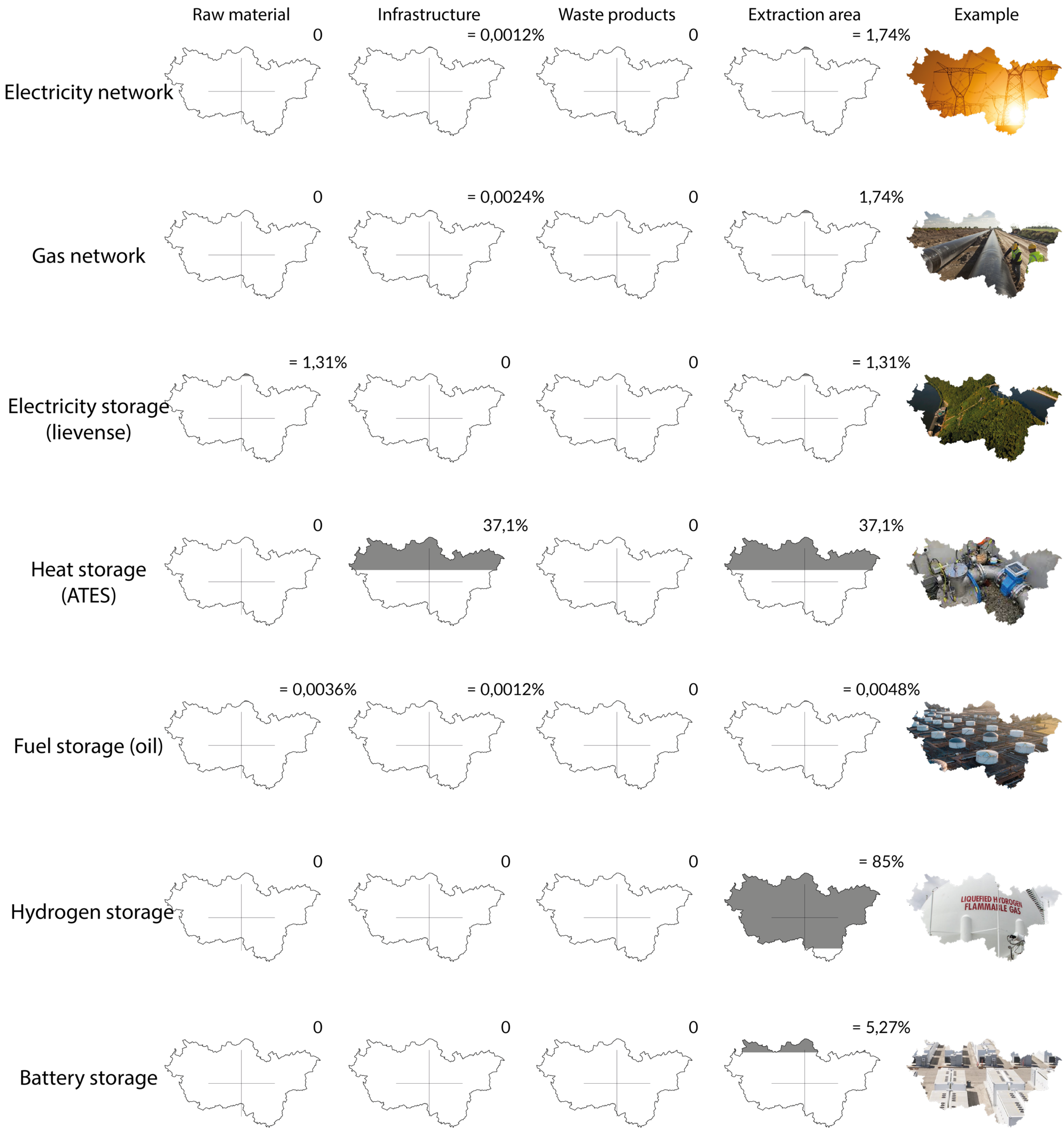


Figure 23: Spatial outcome of systems & storage for the 5.3 million Ruhr residents in percentages of the total surface of the Ruhr area (author, 2022 based on Sijmons, 2014).

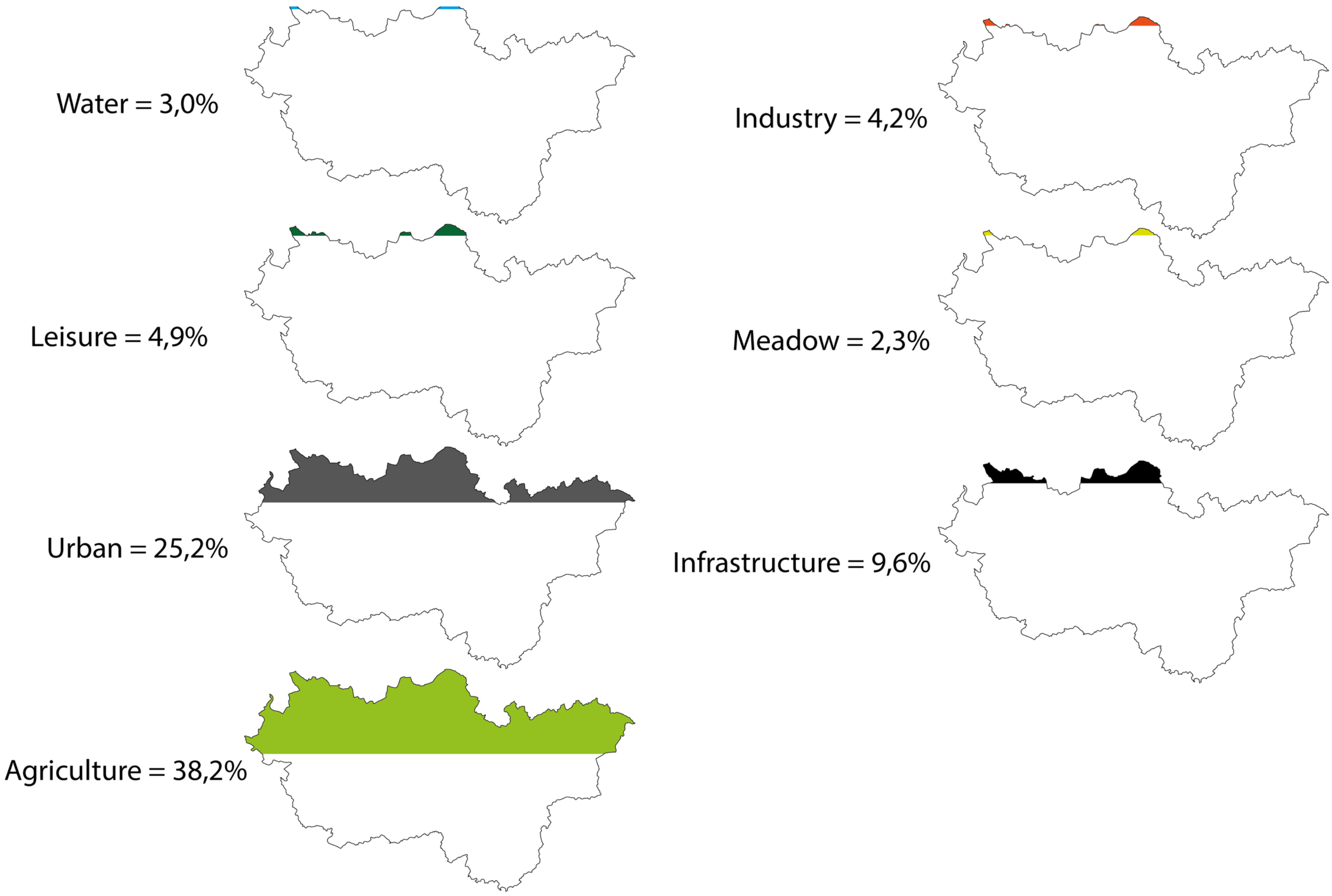


Figure 24: Land use percentages of the Ruhr area (author, 2022 based on Alfken et al., 2019).

Although the potential outcome of the energy transition in the Ruhr area (described in the figures 15-18) might seem abstract, once compared to the current land use of the Ruhr area (figure 12) the spatial component of this energy transition is made clear. For instance, choosing for solar (8, 3%) or wind (6%), to produce the amount of energy demand for the entire Ruhr area results in either 8,3% or 6% of the surface area of the Ruhr area allocated to these energy landscapes. If we compare this to the current spatial manifestation of the Ruhr, we see that by choosing for these energy sources, the result could possibly be a decrease in space for leisure (4, 9%), or water (3, 0%), or almost no infrastructure (9, 6%).

To indicate in what type of way the lack of leisure space, water or infrastructure influences a region, the following relations can be drawn. Research has demonstrated that residents tend to recover better from mental fatigue with the option of leisure in their surroundings. Furthermore, research has also demonstrated that violence can be influenced by altering a neighbourhood - or a city - by greening the area (Bogar & Beyer, 2015). Water bodies (such as rivers) play a key role in drainage systems of regions and cities. If these urban drainage systems were to be taken out of the critical infrastructure, a region could experience economic losses, deteriorated public health and eventually population migration (Möderl et al., 2014).

The solution for the energy transition is defined, although it has a major spatial claim. The question why certain energy landscapes are not there, arises. Which barriers prevent the usage of certain energy landscapes? Or in what way should these landscapes be implemented? This will be discusses in the following paragraph.

iv. Barriers to sustainable energy landscapes

With the potential solutions for the energy transition - sustainable energy landscapes - defined, the implementation of these sustainable energy landscapes should follow. However, within Germany and within the Ruhr area, there are several barriers to energy landscapes.

According to Pasqualetti (2011), it is not the technology but the people that are the problem. The barrier to sustainable energy landscape are local residents. They fear that the implementation of sustainable energy landscapes affect and disrupt the landscape. The consequential changes from an affected landscape, by the implementation of sustainable energy landscapes, changes the established way of life for residents. This must be prevented and that is why residents oppose the implementation of sustainable energy landscapes in their direct surroundings (Pasqualetti, 2011).

Moreover, several low carbon transition proposals have resulted in fierce conflict in Germany. For instance, energy production company RWE is resisting transitioning to the usage of more renewable energy sources as it remains using coal, complicating the proposed phase out of coal by 2038 (Mining journal, 2019). It can be concluded that several stakeholders are resisting change for personal and economic reasons (Weber & Cabras, 2017). Furthermore, several coal oriented nations, such as Poland and the Czech Republic are reluctant to phase out coal or propose low carbon transitions although they are pressured by global organisation (IPCC, 2021; Osička et al., 2020).

Once these barriers have been overcome and the energy transition will be continued, certain heavy industries will decrease or disappear. This will be covered in the following paragraph.

Figure 25: Sustainable energy landscape (Schulz, 2019).

The heavy industry, long present in the Ruhr area has left its mark on the current state of the area. Environmental problems, such as water and soil pollution, have arisen in the Ruhr area (Borel-Saladin & Crankshaw, 2009; Götting, 2014).

Heavy industry originally grew, foremost close to raw materials (Leboutte, 2009). Moreover, the access by water was of major importance, which helped in the economic growth of the Ruhr area (Fernihough & O'Rourke, 2020). The presence of coalfields combined with the access to water, led to the birth of industrial towns. These industrial towns experienced industrialisation, which resulted in the transfer of technology and the migration of labour (Leboutte, 2009). This migration for labour resulted in further urbanization of the Ruhr area. The Ruhr area became a major centre for heavy industry (Fernihough & O'Rourke, 2020).

With the Ruhr area intensively using non-renewable energy resources at that time, the shift towards using renewable energy sources led to de-industrialisation and the rise of the post-industrial society (Leboutte, 2009).

With the de-industrialisation process in affect in the Ruhr area, consequences of the former heavy industry become visible (Leboutte, 2009). This de-industrialisation process will be covered in the following paragraph.

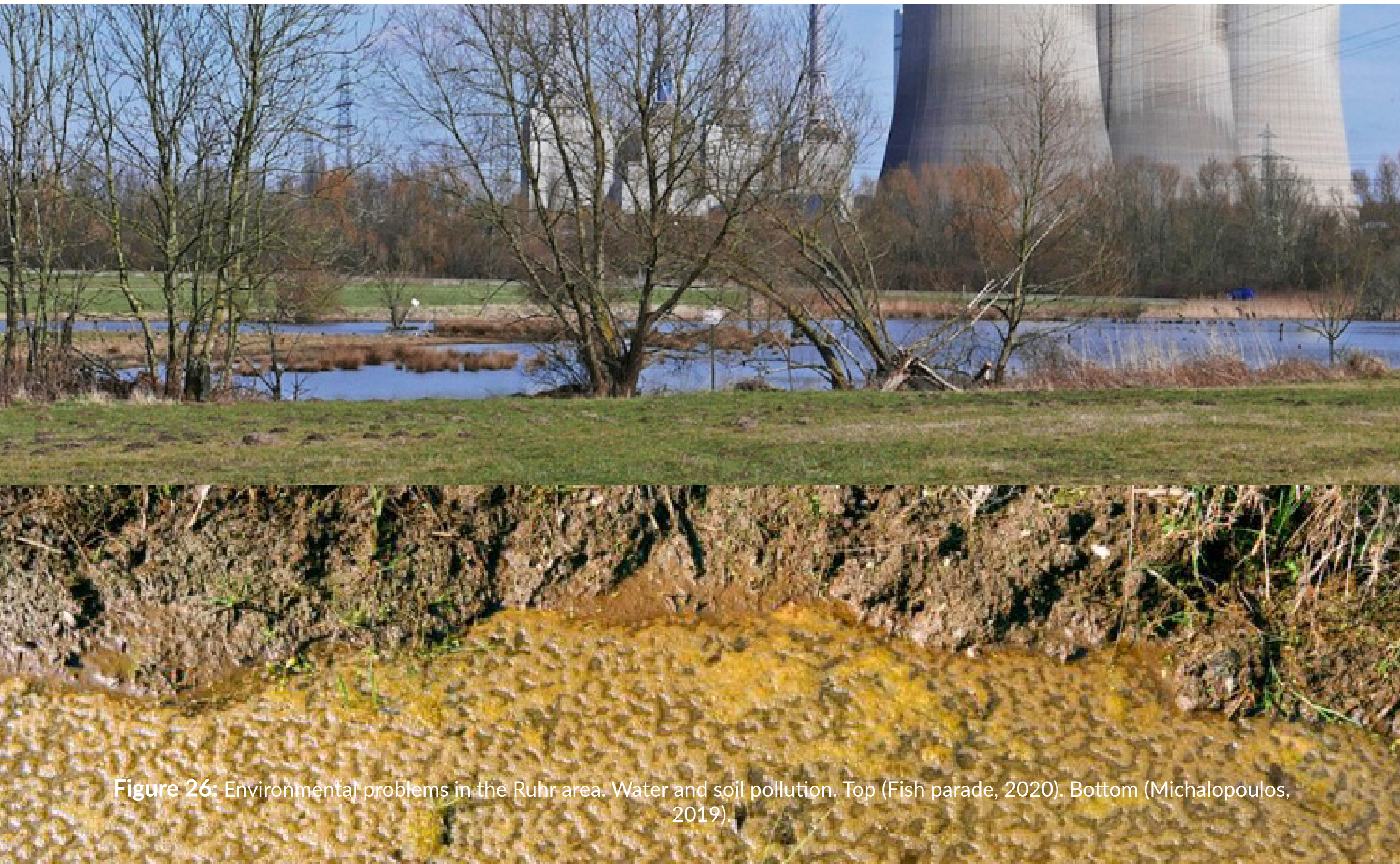


Figure 26: Environmental problems in the Ruhr area. Water and soil pollution. Top (Fish parade, 2020). Bottom (Michalopoulos, 2019).

vi. De-industrialisation

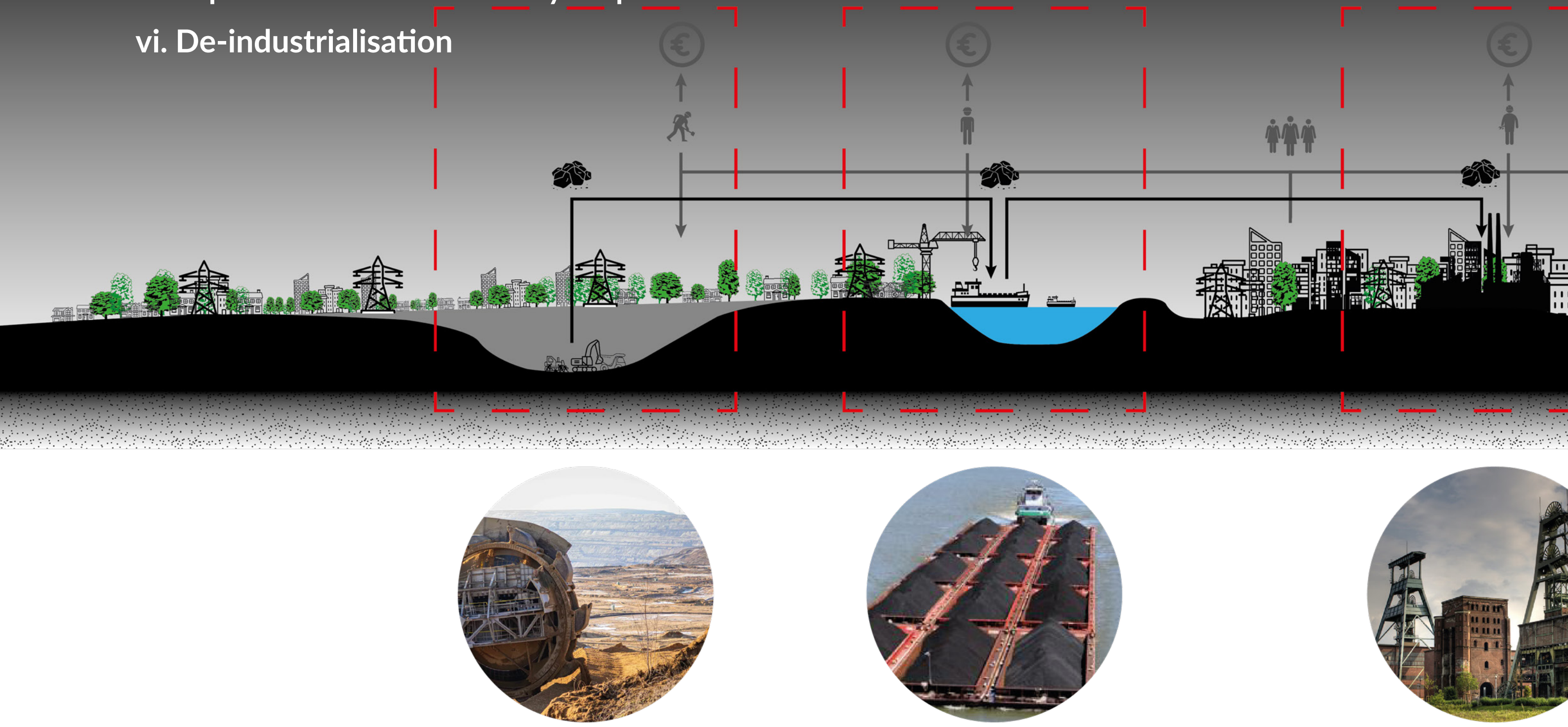
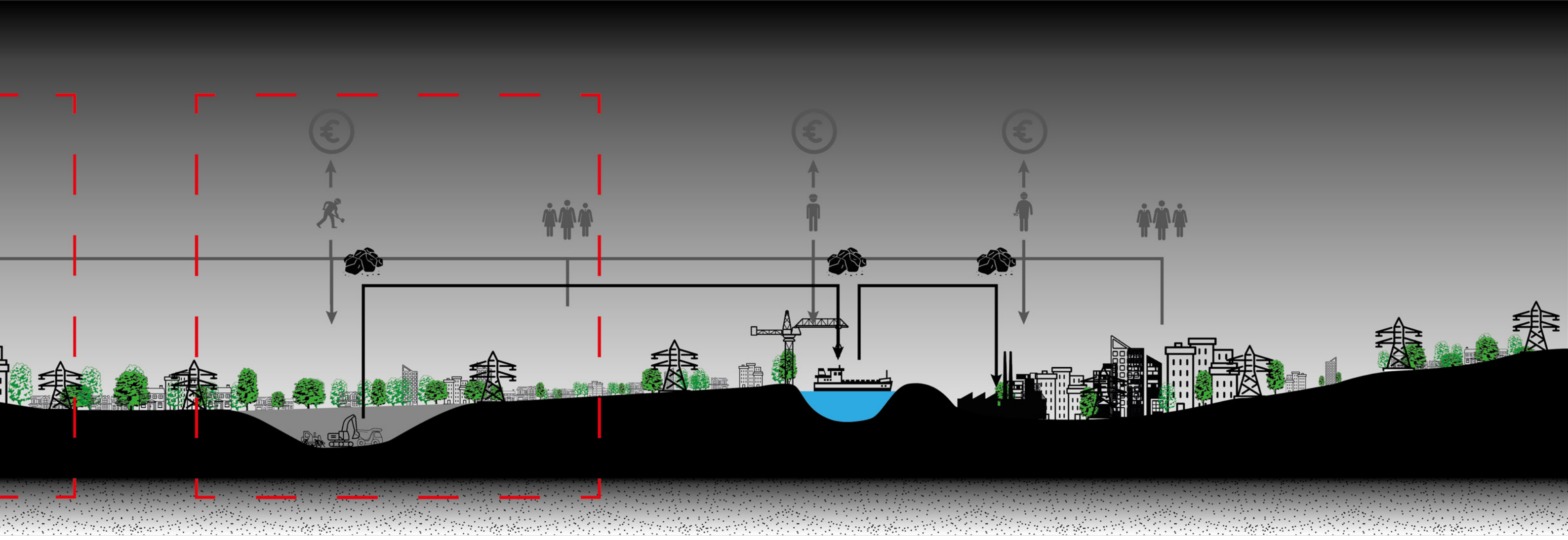


Figure 28: Systemic energy sectic

With the increase of the tertiary sector or the service sector, the de-industrialisation has been set in motion in Europe, Germany and the Ruhr area (Götting, 2014; Leboutte, 2009). This de-industrialisation also revealed the consequences of the heavy industry on the environment of the Ruhr area (Leboutte, 2009).

As a consequence of de-industrialisation, economic problems -such as a rise in unemployment- and societal problems -the polarisation of a region- are occurring (Borel-Saladin & Crankshaw, 2009; Götting, 2014). The socio-economic transition of de-industrialisation and a rise in the service economy, occurring in the Ruhr area, is also partially prevented by the lack of education

Figure 27: Economic problems in the Ruhr area. Decline in heavy industry, lack of education / educated workers. Top (Blossey, 2018) Bottom (Freund & Schrinner, 2015).



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Socio-economic lifelines

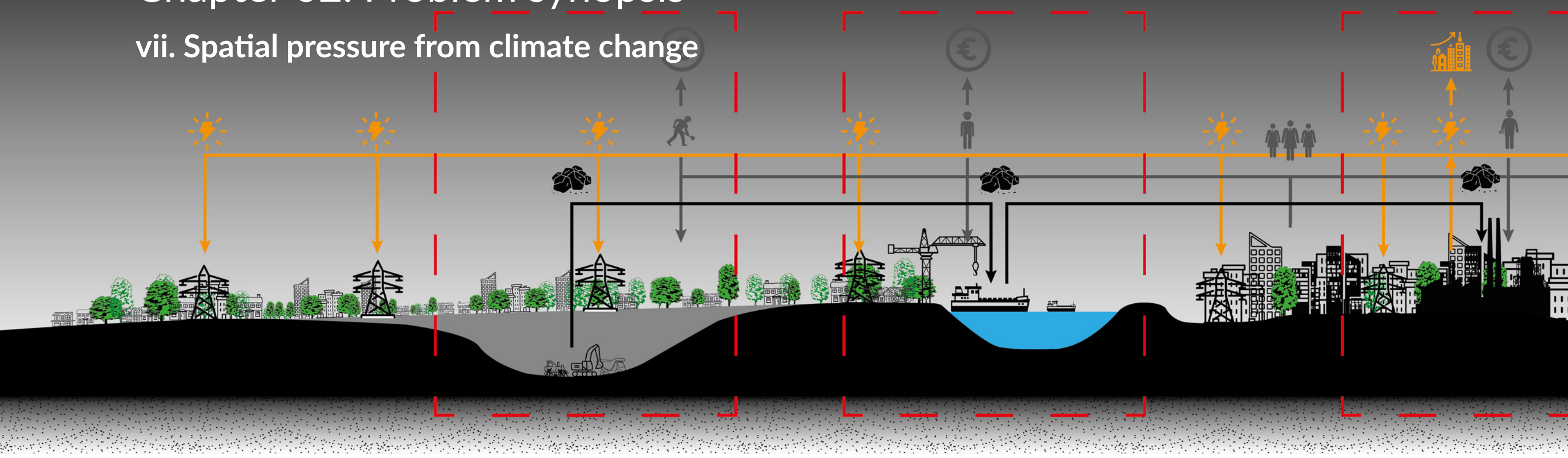
on socio-economic (author, 2022).

and educated workers (Götting, 2014).

Figure 23 indicate the updated systemic energy section. Here the socio-economic lifeline is added. This lifeline defines the socio-economic input and output of the energy sector, with major economic development happening in the past, during the industrialisation, and with a decrease in the socio-economic sector happening currently, as a consequence of de-industrialisation (Götting, 2014; Leboutte, 2009).

Figure 29: High unemployment and social segregation as societal problems in the Ruhr area. Top (AP NEWS, 2021). Bottom (The Economist, 2012).

vii. Spatial pressure from climate change



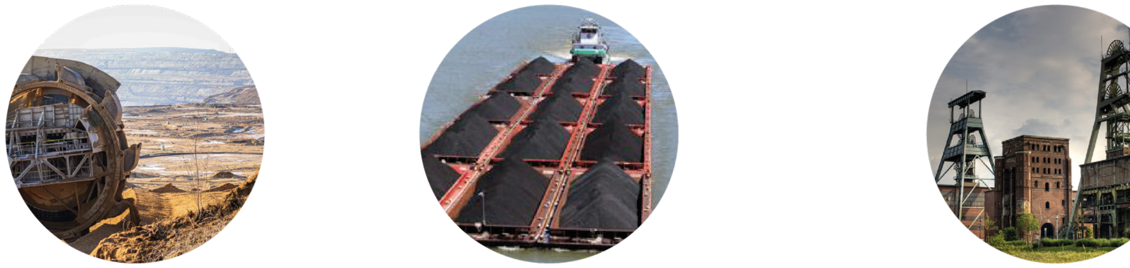


Figure 30: Systemic section c

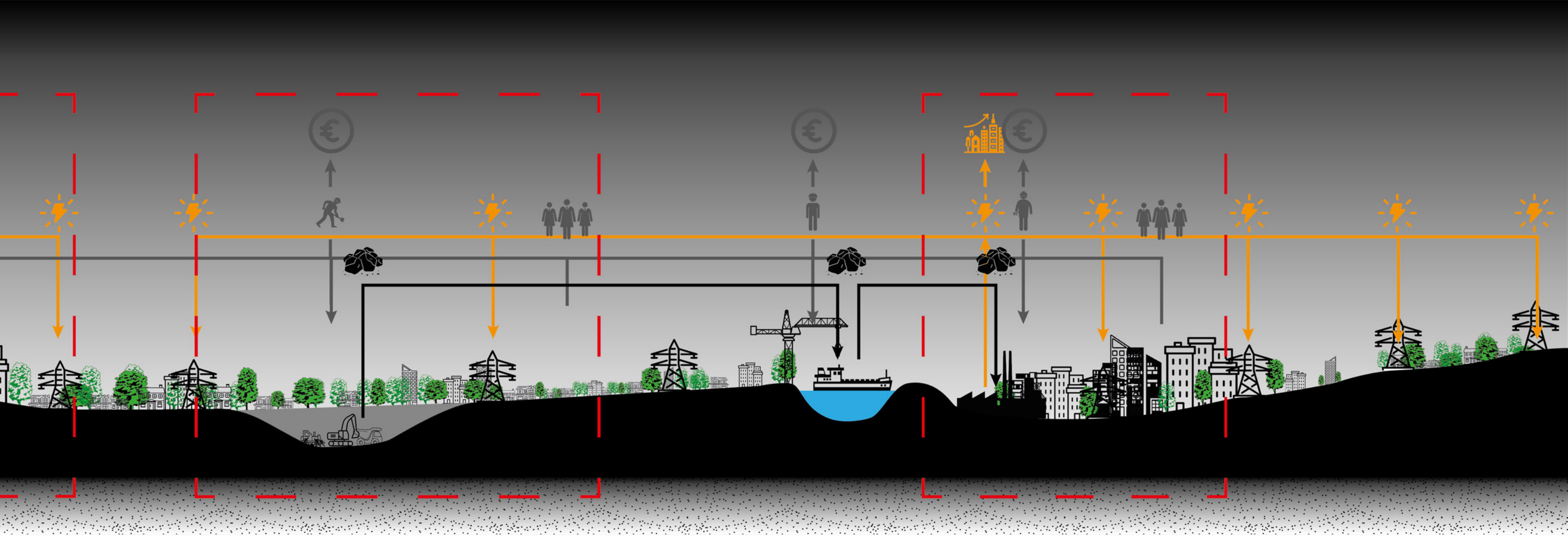
The presence of coal in the soil served as a katalysator for economic development. The industrial basins, such as the Ruhr area, experienced industrialisation, urbanisation and population growth during different periods of time (leboutte, 2009).

The present of the coal led to economic development, which resulted in a thriving Ruhr area where urbanisation focussed around the waterways (Brauers et al., 2018). The spatial structure of the Ruhr area was shaped by the intense coal mining and steel production (Zimmermann & Lee, 2021). With the low ground level elevation, the Ruhr area is experiencing a high flood risk (Zimmermann & Lee, 2021). This is an example of spatial pressure from climate change, with an increase in global temperature rise leading to higher risks of flooding (Apel et al., 2004). The spatial component of climate change manifest itself in two ways; the mitigation of actual climate change and the adaptation of climate change (Zölch et al., 2018).

Figure 25 indicate the updated systemic energy section, indicating the cultural lifeline. This cultural lifeline is the availability of energy as a katalysator for urbanization and population growth, with an increased demand for workers and an increase availability of energy, which result in thriving cities.

Large parts of Germany are strongly polluted. When researching this, the national government mapped 12% of the settlement areas in NRW, including several areas in the Ruhr area, to be extremely polluted. As a direct action against this, the national government proposed a mitigation to reduce the land consumption rate to 30 ha per day, from the current rate of 66 ha per day (Rienow et al., 2022). This results in spatial pressure of functions having to be integrated into the current urban area, without consuming more surface.

Next to the climate mitigation, climate adaption has a major spatial component to it (Zölch et al., 2018). In regards to the uncertainty in climate (Burke et al., 2015), several nature based solutions are proposed (Zölch et al., 2018) as a reaction to possible flood risk of the Ruhr river



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Socio-economic lifelines

Cultural lifelines

ultural lifelines (author, 2022).

Figure 31: The Ruhr valley (London, 2019).

(Apel et al., 2004). Since the exact future climate outcome is not certain, scenarios are used to propose future and base measurements on (Rienow et al., 2022).

Due to the low ground level elevation, which is a long-term effect of intensive land use by coal mining, the risk of floods is high in certain parts of the Ruhr area. Furthermore, the Ruhr area is located in a valley, which increases the risk of floods (Zimmermann & Lee, 2021). With the major population of the Ruhr area inhabitants living close to rivers - including the Ruhr river - future climate adaptation could have a major outcome on the cities of the Ruhr area (Tetzlaff & Wendland, 2007). In fact, climate change and adaptation have been an issue for local governments in the Ruhr region for more than a decade (Zimmermann & Lee, 2021).

With an uncertain future - both in terms of future demand of energy and increase in global temperature rise - , the spatial pressure for climate change and spatial pressure from future energy demand are unclear and need to be taken into account. Future uncertainty as a topic will be covered in the next paragraph.

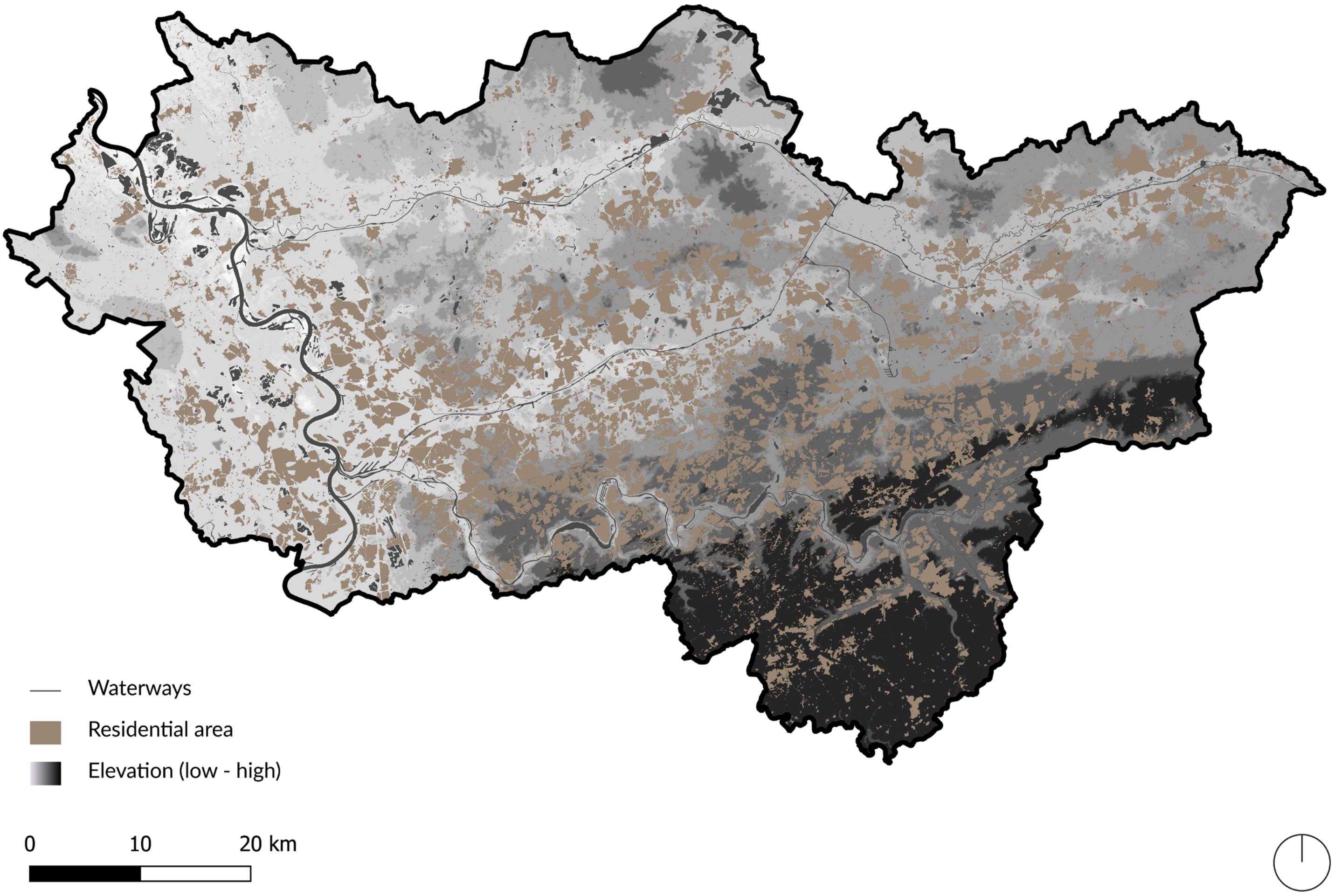


Figure 32: Water and urbanisation Ruhr (Author, 2022).

As stated before, when discussing the future, several uncertainties arise. This uncertainty can be related to numerous topics or system, including the uncertainty in climate and in energy (Burke et al., 2015; Soroudi & Amraee, 2013).

For the uncertainty in relation to energy, economic and technical parameters classify the uncertainty (Soroudi & Amraee, 2013). The increase in energy prices could affect the future usage for instance (Hesse & Siedentop, 2018). For the climate uncertainty, economic and cultural parameters classify that uncertainty (Burke et al., 2015). These parameters can all be qualified and quantified, and their relation to the current situation of both energy and climate is clear (Burke et al., 2015; Soroudi & Amraee, 2013).

To cope with uncertainty scenarios are proposed, based on data that create a vision for the future on which measures can be composed (Rienow et al., 2022). These uncertain future, with their scenarios have different spatial components, as mentioned before. This directly affects the problem statement, which is covered in the following paragraph.

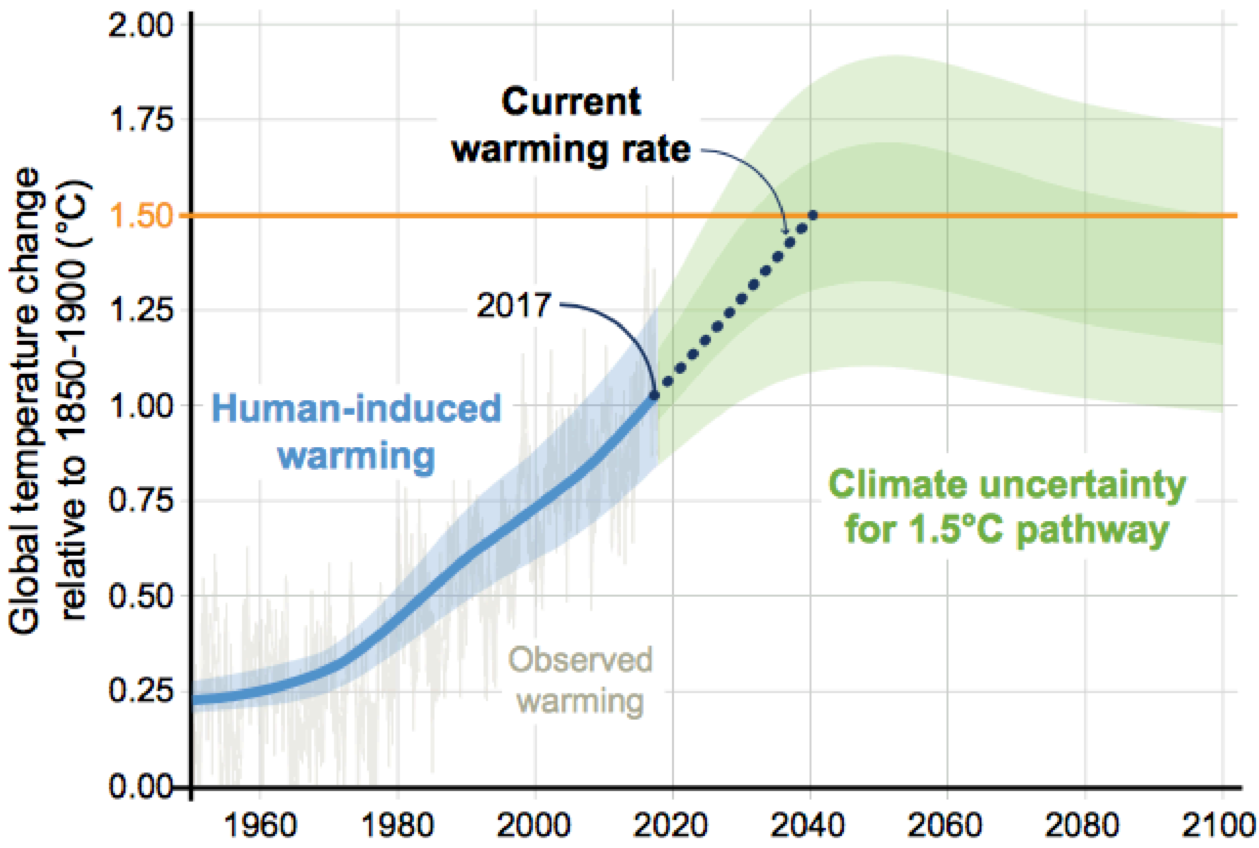


Figure 33: Global temperature change and uncertainty (NASA, 2019).

Chapter 02. Problem synopsis

ix. Problem statement

This problem synopsis leads to the following problem statement:

The Ruhr area, experiencing a socio-economic shift as a consequence of de-industrialisation is undergoing an energy transition - which goals will probably not be met according to modelling - next to the spatial pressure from the energy transition the Ruhr area is facing spatial pressure from climate change. These problems are not tackled in an integrated way, and do not use the specific peri-urban structure potentials of the Ruhr.

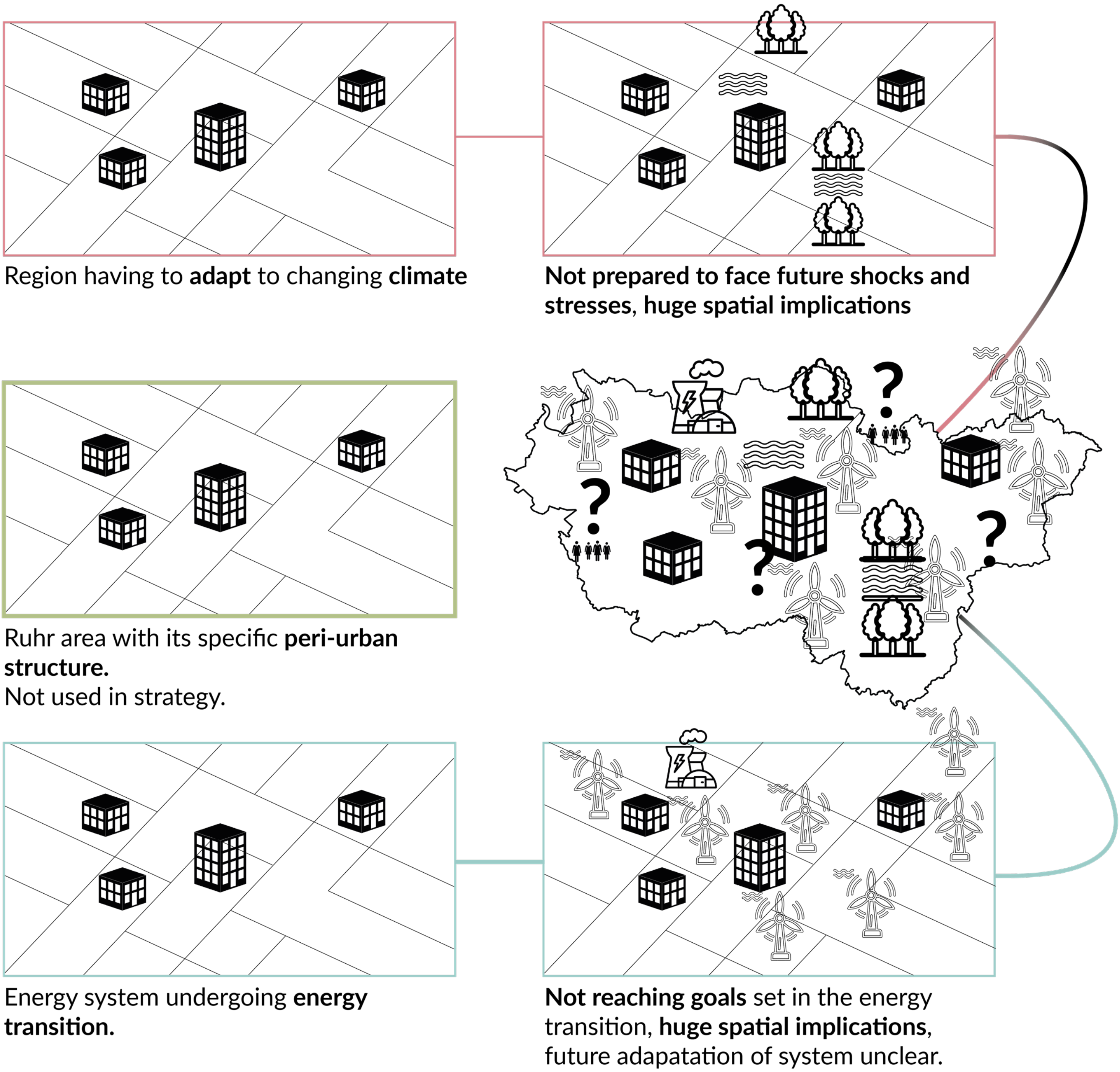


Figure 34: Spatial problem field (author, 2022).

In this thesis, several literature gaps will be addressed. Currently, energy landscapes are defined as mono-functional landscapes. There is a lack in knowledge about the way how to implement multi-functional energy landscapes. In this thesis, energy landscapes, which are the spatial component of the energy system, will be used as a means to fulfil the energy transition goals while developing the region to a climate resilient region. This knowledge can be implemented in other regions that are facing spatial pressures from and the energy transition, and other systems or processes, such as urbanization or climate change.

Furthermore, there is a lack of knowledge about the way to design a peri-urban area maximised for energy production and energy consumption. In this thesis, the peri-urban region will be designed based on the maximisation of energy production and consumption. The gained knowledge can be implemented in ever increasing areas around the world that are turning into peri-urban areas. Because of the energy transition, the way cities are planned should also be addressed in a different way.

Lastly, there is a lack of knowledge on how a transition towards an adaptable energy system can lead to a climate resilient region. During this thesis, it will be researched how a transition towards an adaptable energy system can be combined with a transition to a climate resilient region and how these transitions are positioned to one and other. The knowledge produced in this thesis could possibly be implemented in other regions undergoing the energy transition or tackling climate change.

Energy landscape as a means to meet the goal for the energy transition while facilitating spatial demand for urbanization or climate change

A peri-urban area designed in relation to energy production and consumption, using design principles derived from urban form - energy

A transition towards a climate resilient region implementing a adaptable energy system (for a uncertain future)

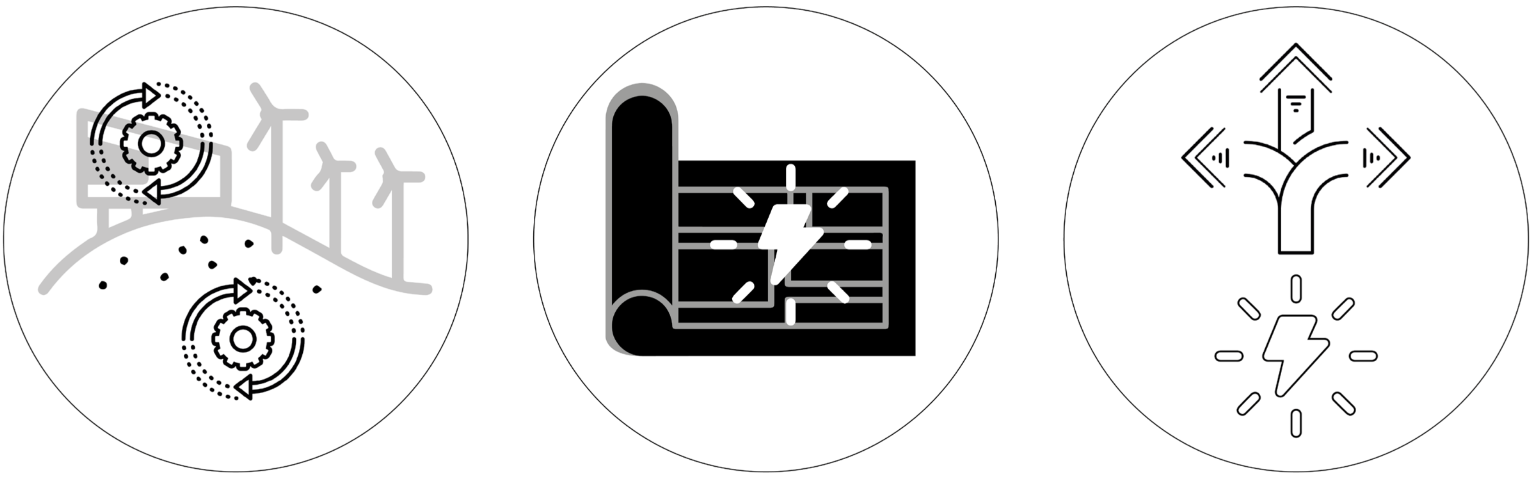


Figure 35: Knowledge gap (author, 2022).

xi. Hypothesis

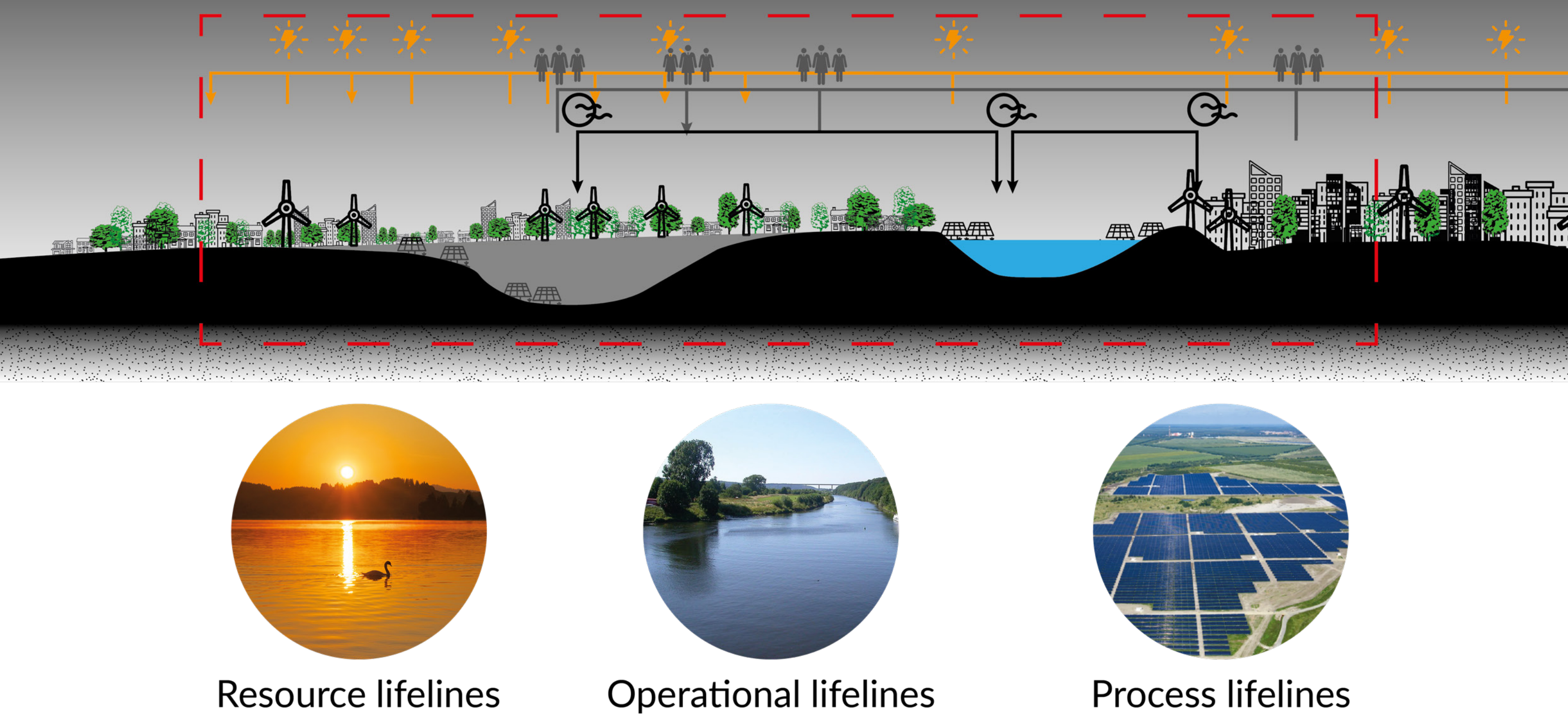


Figure 36: Transitioned systemi

As a consequence of the problem synopsis the following problem statement was formulated;

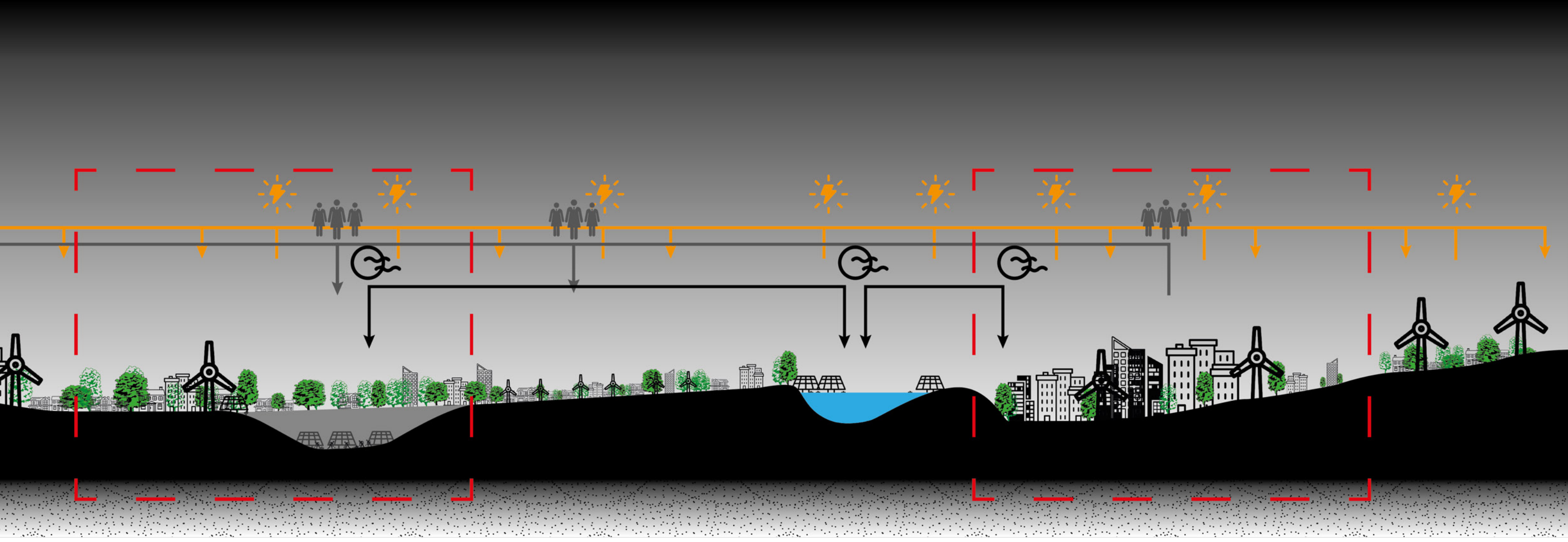
The Ruhr area, experiencing a socio-economic shift as a consequence of de-industrialisation is undergoing an energy transition - which goals will probably not be met according to modelling - next to the spatial pressure from the energy transition the Ruhr area is facing spatial pressure from climate change. These problems are not tackled in an integrated way, and do not use the specific peri-urban structure potentials of the Ruhr.

Underlying this problem statement is the following hypothesis. This hypothesis is based on the potentials of the specific peri-urban structure of the Ruhr area (Vicenzotti, 2017), on the potential of sustainable energy landscape (Sijmons, 2014; Pasqualetti & Stremke, 2018) and on the connection between energy and urban form (Silva et al., 2017; Yang, 2015).
This leads to a hypothesis which is formulated as followed;

By focussing on ecosystem services, the energy transition goals can be met through the implementation of sustainable energy landscapes that facilitate climate adaptation, using the potentials of the specific peri-urban structure of the Ruhr area.

This hypothesis is graphically translated into the adapted systemic energy section in figure 32 and a collage in figure 33. Figure 32 indicates how these different lifelines could potentially look in the transformed energy system. Figure 33 indicates what this transition could possibly mean on an eyelevel of the landscapes of the Ruhr area.

This hypothesis functions as a base for the following part of the thesis, with the conceptual framework and the methodological framework formulated based on this hypothesis.

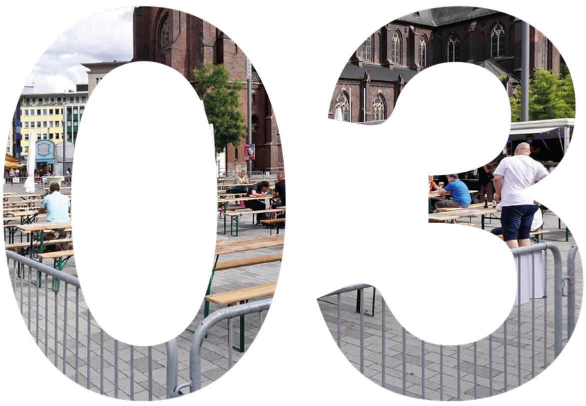


Socio-economic lifelines

Cultural lifelines

c energy section (author, 2022).

Figure 37: Design exploration to an adaptable energy system and climate resileint region (author, 2022).



Chapter 03. Theoretical framework

A literature review was conducted to identify and frame the theories in relation to the energy transition and the peri-urban area. This paragraph will analyse the theories found and eventually lead to a theoretical framework, on which the thesis is based.

Sub-urban areas
The Ruhr area is described as a peri-urban area (Sroka et al., 2019). A peri-urban area is a category of a sub-urban area, a consequence of suburbanization (Hesse & Siedentop, 2018). This peri-urban area is an area that is neither urban nor rural (Wandl et al., 2016). A peri-urban area is an area that has both urban and rural characteristics (Budiyantini & Pratiwi, 2016).

Peri-urbanization, which results in peri-urban areas, is a spatial phenomenon that happens mostly in metropolitan regions, such as the Ruhr area (Budiyantini & Pratiwi, 2016). This process of suburbanization is a consequence of several aspects, such as population size, income and commuting costs (Brueckner & Fansler, 1983). Peri-urban areas can be categorized in a peri-urban area that is predominantly urban, semi-urban and potential urban. However, these areas still remain peri-urban (Budiyantini & Pratiwi, 2016). Peri-urban areas are transition spaces, where the changes in different land uses are incessantly occurring (Mortoja et al., 2020). According to Götting (2014) the peri-urban structure of the Ruhr area is an area of problems but also an area of potentials, to restructure the region.

There are several factors influencing peri-urban growth. Key determinants in generating peri-urban growth are socioeconomic, spatial, and political and policy instruments (Mortoja et al., 2020). There are several approaches on how to demarcate peri-urban areas, all with different outcomes. However, socioeconomic factors are seen as the foremost determinant of peri-urban growth. Furthermore, proximity to major roads and railways play a key role in the structuring of peri-urban areas (Mortoja et al., 2020).

Sub-urban areas can have numerous economical, societal and environmental consequences. Economic consequences of sub-urban areas can be described as the possibility to search for a larger house, in a calmer area. As a consequence of cheap mobility, trips to and from work can be payed for (Hesse & Siedentop, 2018b). However, gentrification is also a possible driver for residents to move away from city centres. This results in a sub-urban area with a lack of social cohesion, that is also prone to demographic shrinkage. (Hesse & Siedentop, 2018b). Furthermore, as a consequence of suburbanization, demographic groups are concentrated in certain areas. This could potentially function as a base for youth to adapt to a criminal lifestyle (Jargowsky & Park, 2008). Environmental consequences of suburbanization and the consequential sub-urban areas are more driving (31%) than urban counterparts. Despite the increased traffic dependence, local air quality is not worse in sprawling areas when related to urban areas (Kahn, 2000).

De-industrialisation
De-industrialisation is a process, described as the decrease of the industrial sector and increase of mostly the service sector (Borel-Saladin & Crankshaw, 2009). This process is currently also underway in the Ruhr area, where a decline in the industrial sector and an increase in the service sector can be recognized (Leboutte, 2009).

The process of de-industrialisation has numerous drivers; improved productivity from labour, trade liberalisation and changed consumption patterns as a consequence of rising income levels and population ageing.

The de-industrialisation has economic and social problems as a consequence (Debande & European Investment Bank, 2006). This can be seen in the Ruhr area, where the unemployment rates are increasing and the decrease in heavy industries is resulting in a region with an unclear economic future (Götting, 2014).

De-industrialisation has changed the composition of employment, through the decline of manufacturing jobs and the simultaneous growth in service-sector employment (Borel-Saladin

Cultural lifelines
- *View on energy*
- *View on the process of using energy*

Socio-economic lifelines
- *Economy and energy*

Process lifelines
- *Operational landscapes*
- *Operational buildings*

Operational lifelines
- *Infrastructure networks*

Resource lifelines
- *raw material*

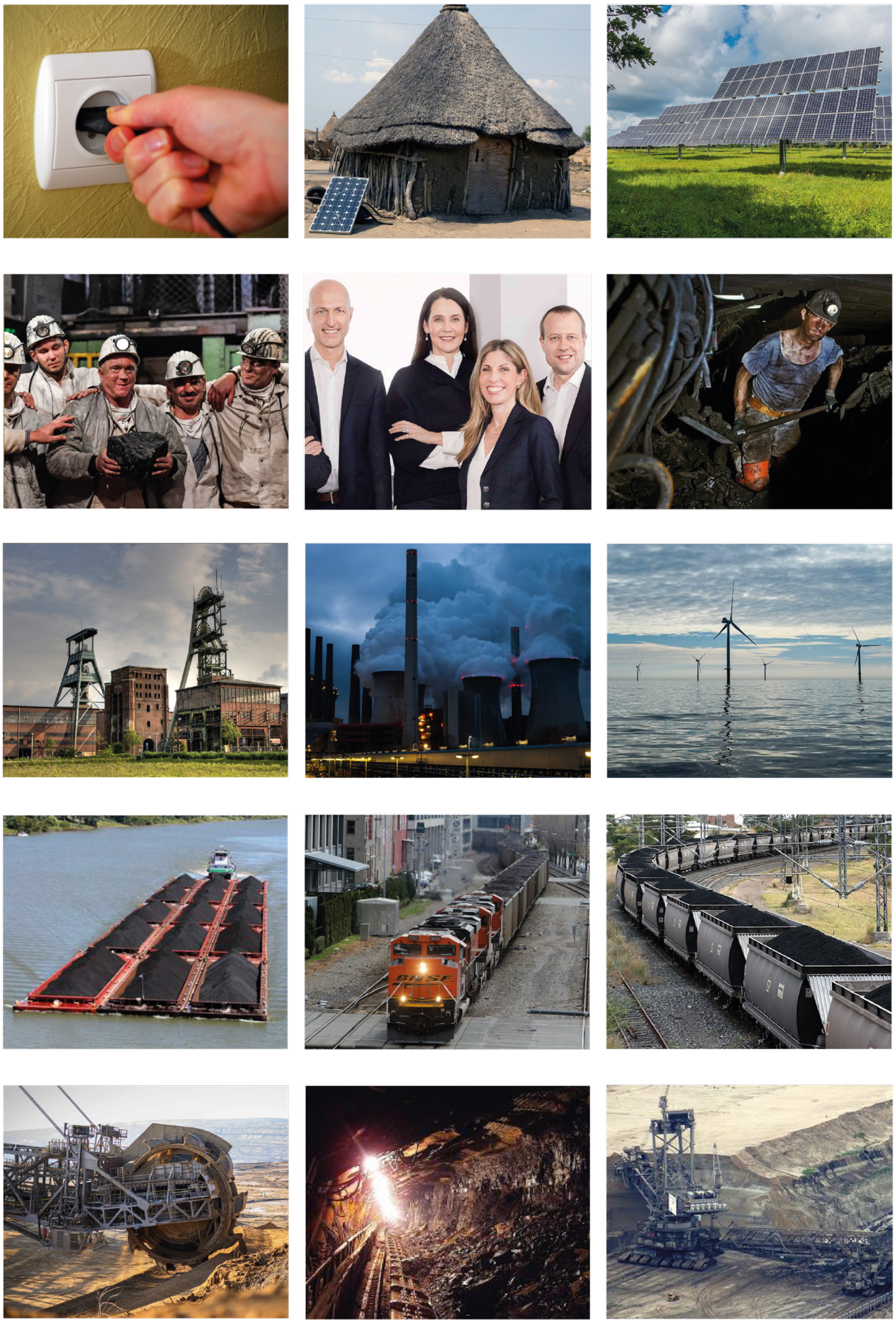


Figure 38: Lifelines composing the panarchy of the energy system (author, 2022).

& Crankshaw, 2009). This is causing a problem in the Ruhr area, where the overall population is not highly educated, since jobs in the coal and other industrial sectors did not rely on educated workers (Götting, 2014).

A major driver for de-industrialization in the Ruhr area is the energy transition (Weber & Cabras, 2017). The Ruhr area is still heavily relying on coal for its energy production (International Energy Agency, 2020). In the past, coal, was a driver for further industrialisation and economic development (Brauers et al., 2018). Although coal served as the backbone for industrial and economic development in Germany, coal has become politically questionable since its facing major climate and environmental concerns (Osička et al., 2020).

With de-industrialisation taking place in Germany, a consequence that can be defined is social polarisation (Borel-Saladin & Crankshaw, 2009). This forms a link between an adaptations in a sector - de-industrialisation - and an adaptation in the social structure of the region - polarisation. If we review this, we can conclude that this adaptation can be placed in a nested hierarchy, which brings us to our next theory, panarchy.

Panarchy

Panarchy theory provides a framework that characterizes and visualizes complex systems of people and nature. This framework is dynamically organized and structured across different scales of space and time (Allen et al., 2014).

During the intensive of projecting urban landscapes, the panarchy visualized in figure 34 was constructed. Following further research into the energy sector the panarchy was edited with the overall result visualized in figure 35. This panarchy places lifelines - found while researching the Ruhr area - in a nested hierarchy. This panarchy, next to the theoretical framework, helped in creating a base for the conceptual framework.

These lifelines, visualized in figure 34, are related to the energy system and visualize the spatial component of the in- and output of the current energy system. The theoretical classification for these lifelines are the adaptive cycles. The lifelines are visualized according to the scale and time, with the smallest scale and smallest time interval placed at the bottom. This lifeline is the resource lifeline, where raw material is mined from adapts quickly. This lifeline can become obsolete and can possibly become a drosscape (Clark, 2009). These resource lifelines are linked to process lifelines, where the actual process of extracting energy from raw material takes place, by the operational lifelines. This lifeline is constructed out of infrastructure networks that serve resource lifelines. These process lifelines are the energy landscapes where the actual energy is extracted from the source. This lifeline, as well as the resource lifeline and the operational lifeline, are operated by workers and owned by companies. These workers move towards these coal industrial regions, such as the Ruhr, to find work and settled down. Factories and companies were formed, to fully make use of the available resource in the region, which resulted in economic growth in the region and further migration of labour (Fernihough & O'Rourke, 2020; (Leboutte, 2009). This socio-economic lifeline, made sure residents could access and use energy, throughout the entire Ruhr area. This view on energy, especially the availability of energy, is the final lifeline. This lifeline is where (urban) society uses the output of this final and last lifeline of the panarchy of the energy system.

Panarchy places adaptive cycles in a nested hierarchy. For the Ruhr area, this is the case when, for example, de-industrialisation or the current energy system is researched. De-industrialisation results in an adaption of, socio-economic lifelines, describing, for instance the polarisation of workers (Borel-Saladin & Crankshaw, 2009). Panarchy is different from typically envisioned hierarchies. In panarchy, control can not only be exerted as a top-down process, but control can also be exerted via bottom-up processes (Allen et al., 2014). A shift in resource lifelines, a possible consequence of the energy transition, where coal is phased out, can, over time influence the cultural lifeline of energy - the way we view energy. These lifelines all revolt and remember in their respected hierarchy. While one lifeline, or a nested adaptive cycle, is adjusted, that cycle can affect those at other scales to influence the overall dynamics of the system (Allen et al., 2014).

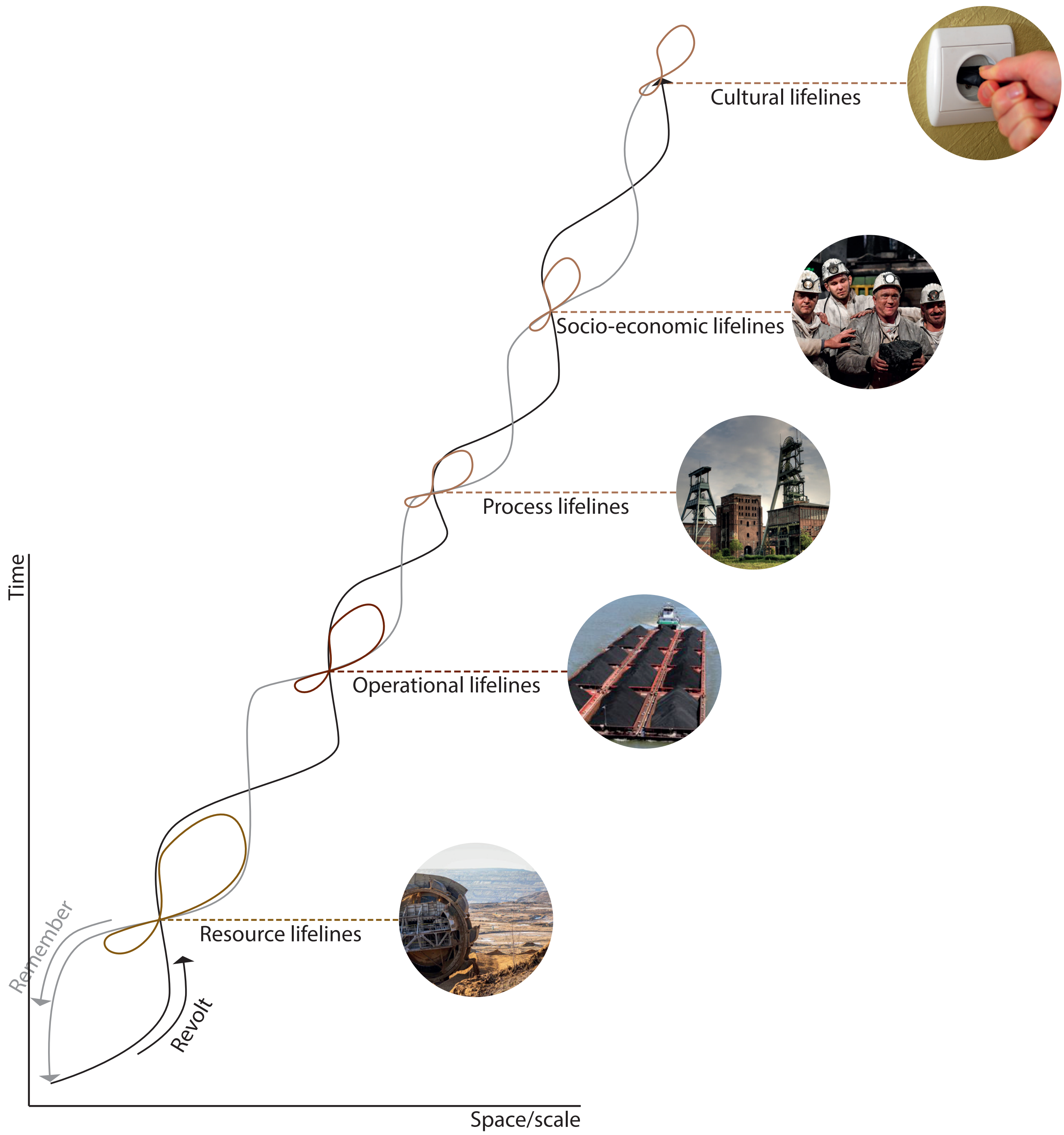


Figure 39: Current panarchy in relation to the energy system (author, 2022).

To conclude, the nested hierarchy of adaptive cycles that has been recognized is that of the de-industrialisation, partially as a consequence of the energy transition. The energy transition has a major spatial component, which also is described as energy = space (Tillie et al., 2012).

Energy = space

The spatial component of energy is immense. Some researchers have therefore decided to describe energy as space (Sijmons et al., 2014). This is a conclusion from the energy transition, where renewable energy sources are woven into the system, which is also visible in the German energy system (International Energy Agency, 2020). These renewable energy sources have a spatial component that will require a lot of land surface (Tillie et al., 2012).

Energy sources can be categorized in non-renewable and renewable energy sources. Since energy is defined as ''a substance-like quantity; it is distributed in and can flow through space'' and energy has the ability to work, the sources of energy are related to the different forms of energy (EIA, 2021; Falk et al., 1983). Because energy has the possibility to change from one form to another, from thermal energy to electrical energy as example, modern civilization is possible to exist, as it exists nowadays. Since energy can change forms and has several different sources, we as society, can light our house, move around by car or heat our rooms (EIA, 2021).

Furthermore, urban form has an impact on energy (Silva et al., 2017). Consider travel patterns as consequence of spatial planning, or thermal comfort in buildings, as a consequence of the design. Next to that, features of the urban environment like density of buildings can be related to lower heating needs in the winter, resulting in a decrease in energy demand (Silva et al., 2017). These urban form attributes, can be categorized in the built environment, with elements like density and green areas and transport networks, with elements like accessibility and hierarchy.

The spatial component of energy can be visualized using energy potential mapping (Broersma et al., 2013). This way of mapping visualizes the energy demand parameters and visualizes the renewable and residual energy potentials. Using energy potential mapping as a base, energy master planning can help regions to fulfil the goals of the energy transition and to improve their climate adaptation (Van den Dobbelsteen et al., 2014). Energy master planning provides a framework of steps on how to tackle the energy transition, aimed at reusing, exchanging, cascading and storing of energy (Van den Dobbelsteen et al., 2014).

This spatial component has to be combined with the spatial component of the climate crisis. Certain solutions can be applied to both of the problems, such as green-blue infrastructure or nature-based solutions (Zölch et al., 2018).

Just as in the panarchy of the current energy system, with a spatial component in process, operational and resource lifelines, there is also a social component to the energy transition, energy democracy (Van Veelen & Van der Horst, 2018).

Energy democracy

The social component of the energy transition can be described as energy democracy.

Energy democracy represents a blue print for an ideal world where energy systems are more decentralised and socially controlled. Access to this energy is equitable and the consequential benefits of this blue print is divided among its users. Foremost, energy democracy describes a system where the energy production and consumptions harm neither people nor the environment

(Van Veelen & Van der Horst, 2018).

There are now several privately owned companies in relation to the energy sector in Germany (International Energy Agency, 2020). In the energy democracy blue print, these companies become privately owned and centralised (Van Veelen & Van der Horst, 2018).

Because of the current control, several stakeholders can resist change, to potentially energy democracy (International Energy Agency, 2020; Van Veelen & Van der Horst, 2018; (Weber & Cabras, 2017). To engage stakeholders to change, to at least partially adapt to energy democracy, or to fully change their control and centralisation, co-creation can be used (Mahmoud & Morello, 2021).
The outcome of the decentralised and socially controlled energy sector contribute to more equitable outcome (Van Veelen & Van der Horst, 2018).

With the social and spatial component of the energy transition described, while using the panarchy and its lifelines, we can now move on.

Resilience, adaptation and adaptability
From the panarchy, where the cycles of adaptability are placed in a nested hierarchy, the theoretical framework builds on, towards resilience.

The resilience of places in response to uncertain, volatile and rapid change has emerged as a focus of academic and policy attention (Pike et al., 2010). With the Ruhr area experiencing uncertain futures in relation to energy and climate, the question about resilience can be raised in the Ruhr area (Burke et al., 2015; Soroudi & Amraee, 2013). Resilience aims at capturing the ability of places to respond to and cope with rapid change as a consequence of uncertainties (Pike et al., 2010).

Resilient design can be applied on several sectors, such as the energy sector. Energy resilience can be realised by changing the urban form (Yang, 2015). Once again, energy is expressed in space, as stated by Sijmons et al. (2014) and Tillie et al. (2012). Urban design can be used as a method to visualize the complex and uncertain future of energy problems in cities or regions (Yang, 2015).

To get a grasp on the uncertainty of the future, scenarios can be proposed. These scenarios take the uncertainty into account, but also create a visualization of the future on which design solutions or measures can be constructed (Rienow et al., 2022). These scenarios can serve as a base to create a strategic vision for the future, while proposing short-term actions and simultaneously construct a development path to structure future actions. This way of working is called dynamic adaptation, and the outcome of this process are dynamic adaptive policy pathways (Haasnoot et al., 2013). When trying to grasp the future, using a scenario for a proposed future named A, the dynamic adaptive policy pathways guide the strategic vision of the future, even though the future is moving more towards the proposed future B (Haasnoot et al., 2013). This dynamic adaptation can create a framework taking into account uncertainties as a consequence of social, cultural, political, technological, and economic and climate change. Since the uncertainty as a consequence of climate and energy have both social, economic, political and technological drivers, this can be applied to guide the future in relation to climate and energy uncertainty (Burke et al., 2015; Soroudi & Amraee, 2013).

Urban climate resilience

From the panarchy, through resilience, adaptation and adaptability, the step can be made to the objective of the thesis, urban climate resilience.

With 70% of the world's population likely to be living in urban areas by 2050 and with climate change making weather and natural resource distributions more volatile, reducing risks and enhancing resilience of vital infrastructures in our increasingly densely populated urban environments is of crucial concern everywhere (Staddon et al., 2018). International concern has been raised on how to address the implications of climate change. This has been for urban areas, particularly in developing countries (Tyler & Moench, 2012). Although, recently this concern has also been raised for non-developing countries and for the Ruhr area (Zimmermann & Lee, 2021). Key indicators for climate resilience are; flexibility and diversity, redundancy and modularity and safe failure (Tyler & Moench, 2012).

Tyler & Moench (2012) describe four key elements for climate resilience; infrastructure systems, ecosystems, agent capacities and institutions. Infrastructure systems relate to flood monitoring for instance, which in the case of the Ruhr area is of major importance due to the low ground level elevation which result in high flood risk in the Ruhr area (Zimmermann & Lee, 2021). Furthermore, institutions should be clearly structured, so human behaviour can be guided and agents can teach (Tyler & Moench, 2012). At this moment, with its complex organisational structure, there is no clear structure of institutions in the Ruhr. Agents can experience this as confusing, which deteriorates their capacity to learn towards climate resilient behaviour or choices (Zimmermann & Lee, 2021). These are elements that need to be addressed if the Ruhr area wants to successfully transition towards a climate resilient region (Zimmermann & Lee, 2021).

The four key indicators for climate resilience can be altered by the use of green-blue infrastructure. Green infrastructure can provide benefits in ecosystem services to improve critical environmental and socio-economic services (Vargas-Hernández & Zdunek-Wielgołaska, 2020). Green infrastruc-ture is understood as the creative combination of natural (green) and artificial (grey) structures intended to achieve specific resilience goals (Staddon et al., 2018).

Furthermore, there is a direct link between regional climate resilience in a region and the energy system. Several studies reveal that there are major limitation in the state-of-the-art energy system, to be able to adapt to changing climate scenarios. The design of the energy system should be revised to be able to integrate adaptation into the design, so these urban energy systems can be able to withstand several extreme climate events (Nik et al., 2020). That is why this thesis – where design elements based on green infrastructure are proposed to tackle urban climate resilience and simultaneously create an adaptable energy system – is so relevant.

ii. Theoretical framework

The theories in context eventually lead up to the theoretical framework. This framework identifies and links the key theories contributing to the theoretical base of this thesis. This framework also indicates what the context of the thesis is - and what specifics theories define this - as well as what the drivers and the overall objective of the thesis is.

This theoretical framework functions as a base for the conceptual framework, research and further design exploration in the thesis.

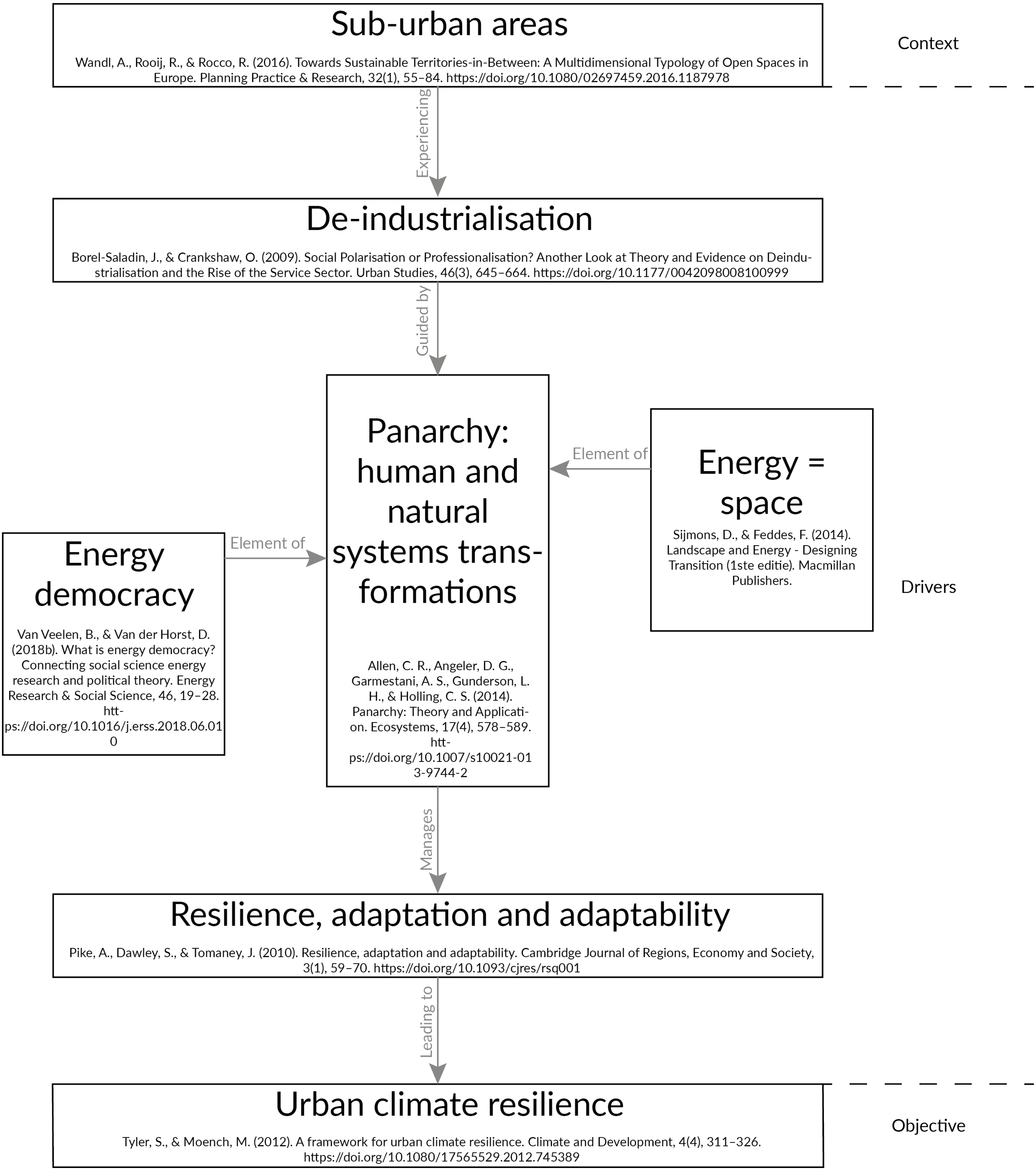


Figure 40: Theoretical framework (author, 2022).

Chapter 04. Conceptual framework

The conceptual framework explains the relation between the problem fields, theoretical framework and identifies the intention of the thesis. Furthermore, the conceptual framework explains how the different parts of the thesis relate to each other and affect each other.

The conceptual framework indicates the different steps required to implement the adaptive energy system and how that can eventually lead to a climate resilient region. The first step is the transformation of the energy system, through systemic design. Because of the future uncertainties in relation to climate change and the energy system, adaptive planning will be required.

How the step from an adaptive energy system to a climate resilient region can be made, will be researched, using design exploration.

Furthermore, the conceptual framework indicates which elements function as a context, driver or an objective.

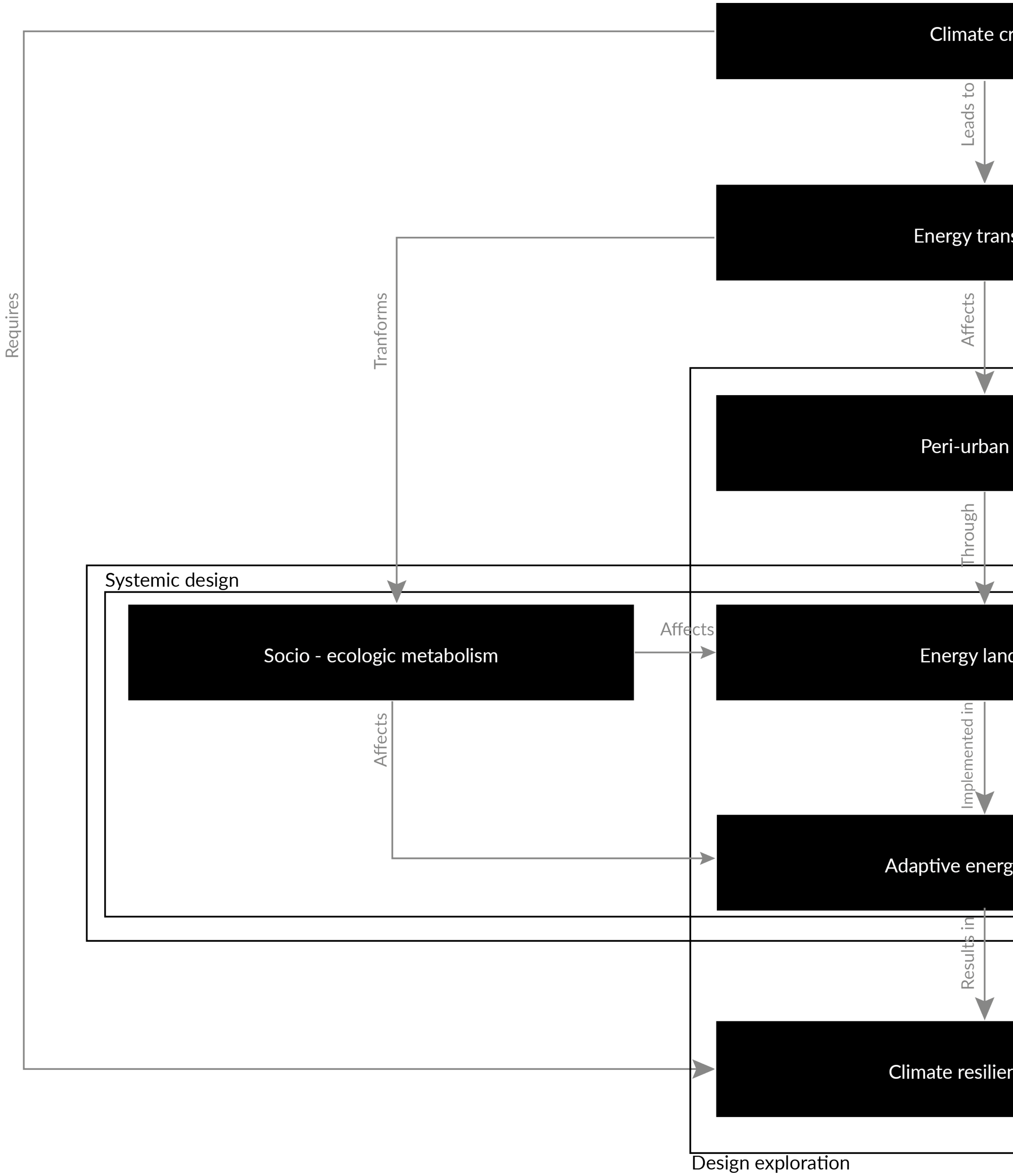
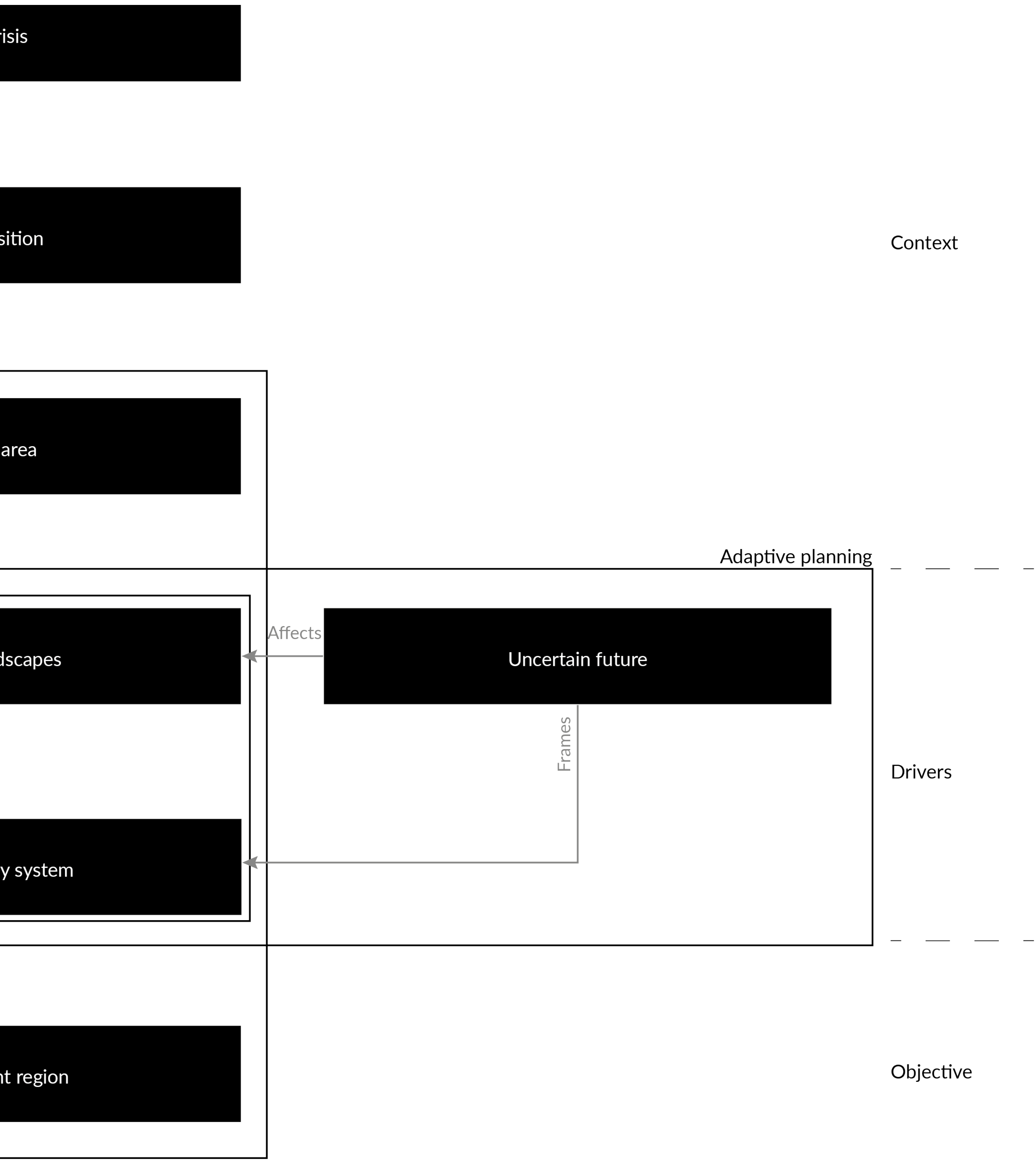


Figure 41: Conceptual fı



ramework (author, 2022).

II. Methods

Chapter 05. Research question & aim

i. Problem statement

Coming from the conceptual framework, the research questions and following research aim will be formulated. Since the research questions and research aim are derived from the problem statement, this will be briefly mentioned here:

The problem statement, based on the current energy transition strategy and the specific peri-urban structure of the Ruhr area is formulated as followed:

The Ruhr area, experiencing a socio-economic shift as a consequence of de-industrialisation is undergoing an energy transition - which goals will probably not be met according to modelling - next to the spatial pressure from the energy transition the Ruhr area is facing spatial pressure from climate change. These problems are not tackled in an integrated way, and do not use the specific peri-urban structure potentials of the Ruhr.

Chapter 05. Research question & aim

ii. Research aim

Following from the problem statement, the research aim for this thesis is formulated as followed:

Research how the construction of a climate resilient region can lead to the fulfilment of the energy transition by the means of sustainable energy landscapes in the context of the peri-urban structure of the Ruhr.

Figure 38 indicates the build-up of research questions. These questions are linked to each other, based on their respective aim. Each question will follow as a base for the next question to be answered.

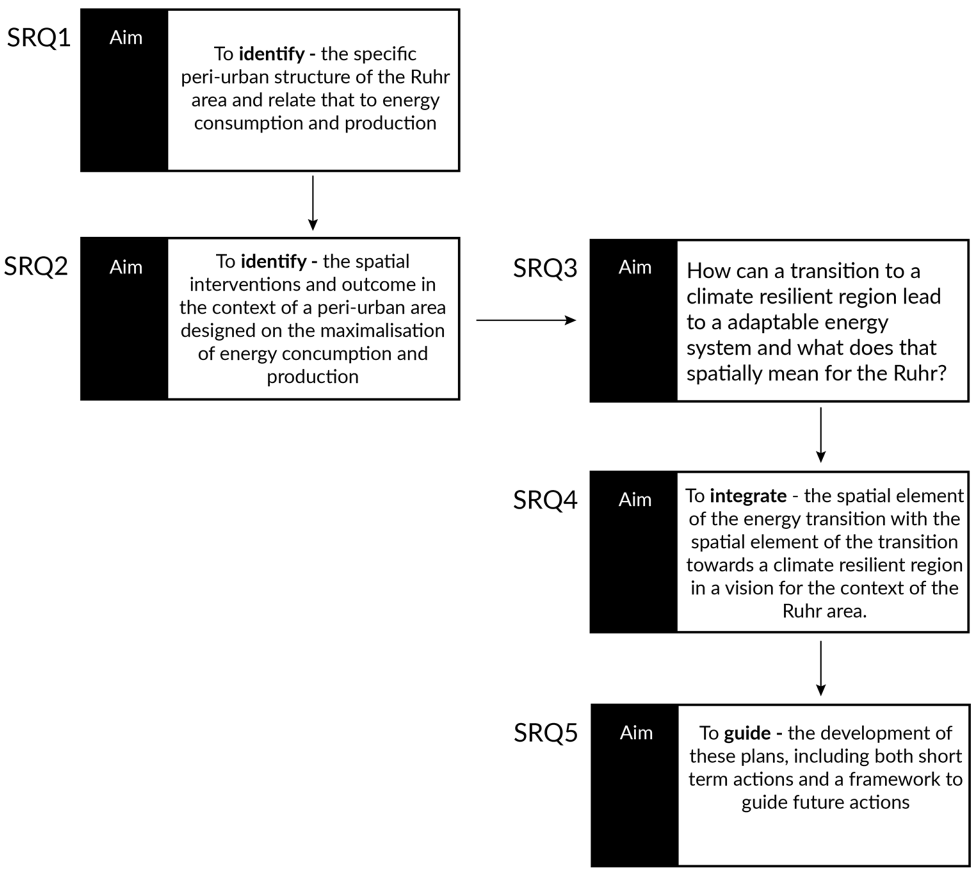


Figure 42: Build up of research questions (author, 2022).

iii. Research questions

The main research question is derived from the problem statement, and is formulated as followed:

How can a spatial development strategy for a climate resilient Ruhr area based on the specific peri-urban condition of the Ruhr lead to fulfillment for the now too limited energy transition?

The sub questions all relate to the main research question in a different way. Each sub research question has a different aim, which is integrated in the research approach in a different way. This will be elaborated in chapter 6, research method.

	Sub-questions		Aim
SRQ1	What is the specific peri-urban structure of the Ruhr and how does that relate to energy (production and consumption)?	→	To identify - the specific peri-urban structure of the Ruhr area and relate that to energy consumption and production
SRQ2	How does an peri-urban area designed on the maximalisation of energy consumption & production looks like and what does that result in when applied to the Ruhr area?	→	To identify - the spatial interventions and outcome in the context of a peri-urban area designed on the maximalisation of energy consumption & production
SRQ3	How can a transition to a climate resilient region lead to a adaptable energy system and what does that spatially mean for the Ruhr?	→	To improve - the current level of adaptability for the region to be able to face future shocks and stresses caused by climate change and create principles for a adaptable energy sytem.
SRQ4	How can sustainable energy landscapes be implemented in a peri-urban area, while facing multiple barriers, and eventualy facilitate the transition to a climate resilient Ruhr?	→	To integrate - the spatial element of the energy transition with the spatial element of the transition towards a climate resilient region in a vision for the context of the Ruhr area.
SRQ5	How can a transition from a heavy industrialised region towards a climate resilient region be succesfully realised while facing an uncertain future?	→	To guide - the development of these plans, including both short term actions and a framework to guide future actions

Figure 43: Sub questions with aim (author, 2022).

Chapter 06. Research method

The research approach of this thesis is structured according to the systemic design framework (Ospina, 2018). Since the energy transition is a transition of a system, which forms the base of the thesis, and the systemic design framework includes design thinking, the choice was made to use this approach to structure the thesis.

By applying this framework, the research (output) can constantly diverge and converge, moving back and forth between different topics. After every two steps of the framework, a conclusion can be drawn, which can serve as a base for the following two steps.

Figure 40 indicates the systemic design framework and how, in a more iterative way, this approach will function as a research approach in this thesis.

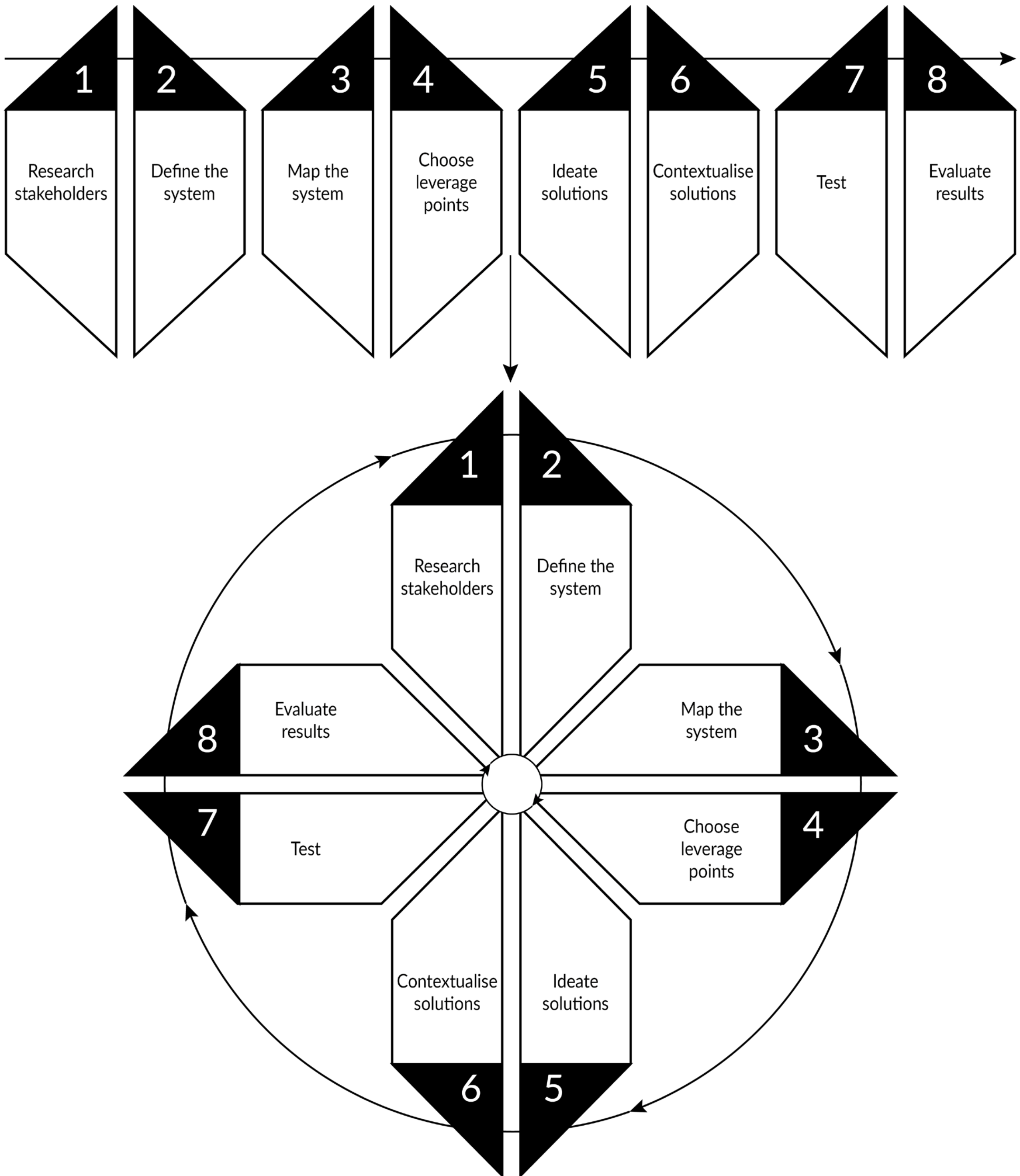


Figure 44: Research approach (author, 2022).

Figure 41 indicates what the relation of the elements in the research approach are, and how they influence each other.

Because in the current energy system, stakeholders are resisting change, the choice has been made to engage the stakeholders, using co-creation. This co-creation will be applied in creating the vision and the strategy. The created vision and strategy will be tested, based on future scenarios, and evaluated.

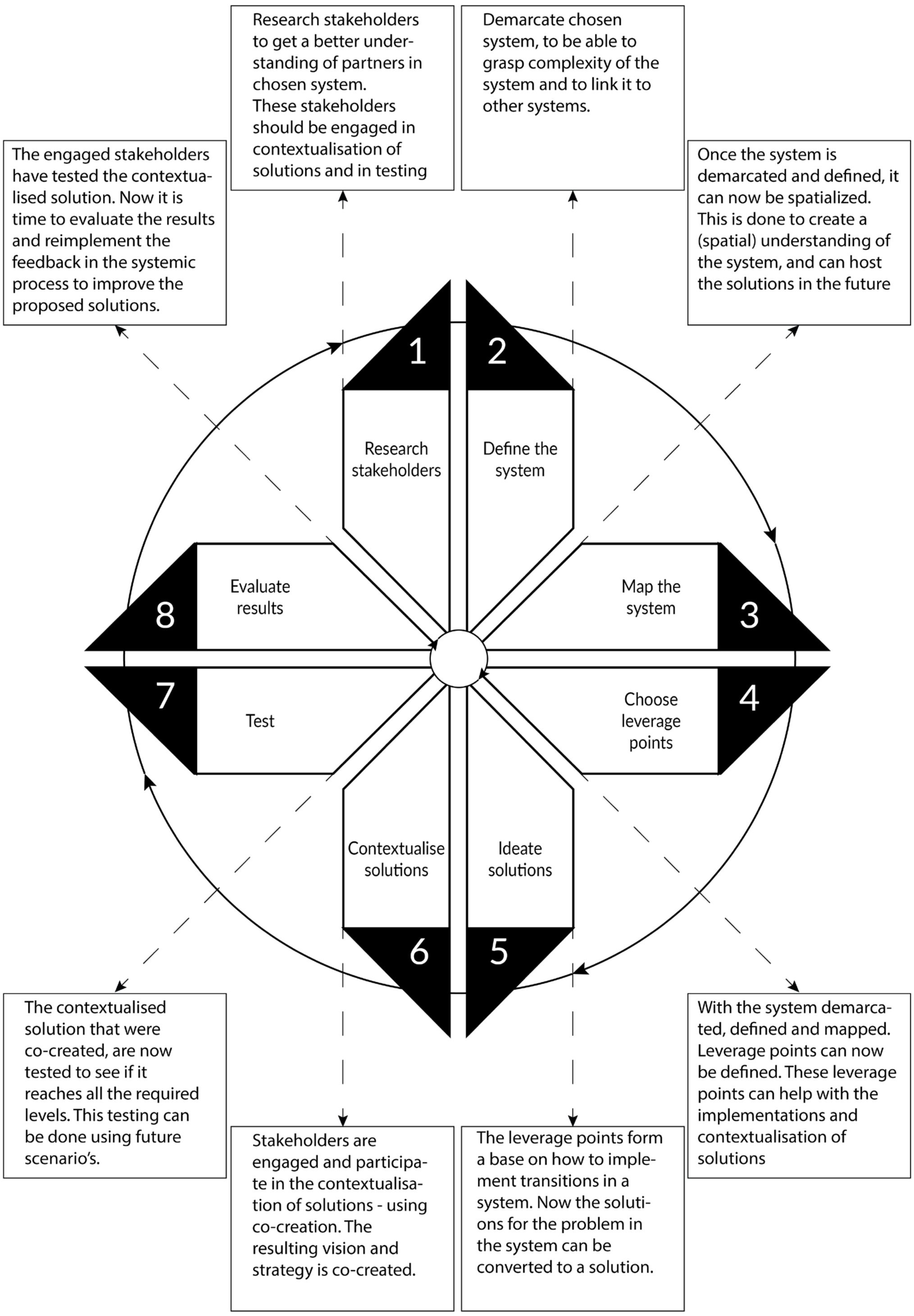


Figure 45: Iterative research approach (author, 2022).

Following the relation of elements in the research approach, the sub-research questions are placed in this approach. With the different aim and approach of each sub- research question, the sub-research questions are placed in different places in the process of this thesis.

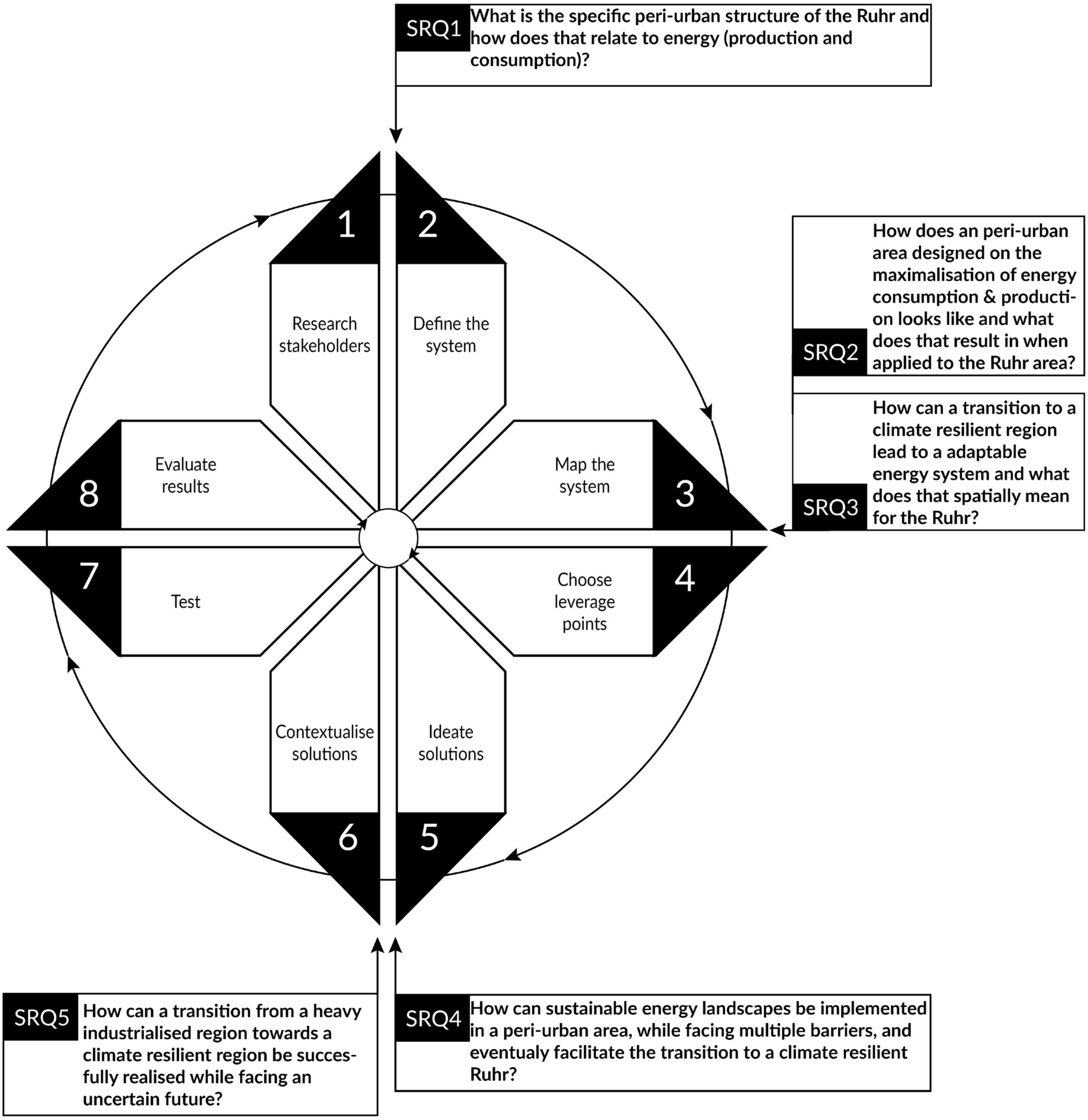


Figure 46: Expanded research approach (author, 2022).

iii. Methodological flowchart

Main research question

How can a spatial development strategy for a climate resilient Ruhr area based on the specific peri-urban condition of the Ruhr lead to fullfillment for the now too limited energy transition?

Approach The main approach of the thesis is based on systemic design thinking. This method structures the thesis and guides the process.

Aim Research how the construction of a resilient region can lead to the fullfillment of the energy transition by the means of sustainable energy landscapes in the context of the peri-urban structure of the Ruhr

Outcome Spatial development strategy

SRQ1 What is the specific peri-u
and how does that relate t
consumption)?

Approach Netzsta

Method Mapping, Energy poten
Morphological analysis, P

Aim To **identify -** the specific p
area and relate that to ene

Outcome Relation between spatia
area and energy consun

SRQ2 How does an peri-urban a
sation of energy consump
and what does that result
area?

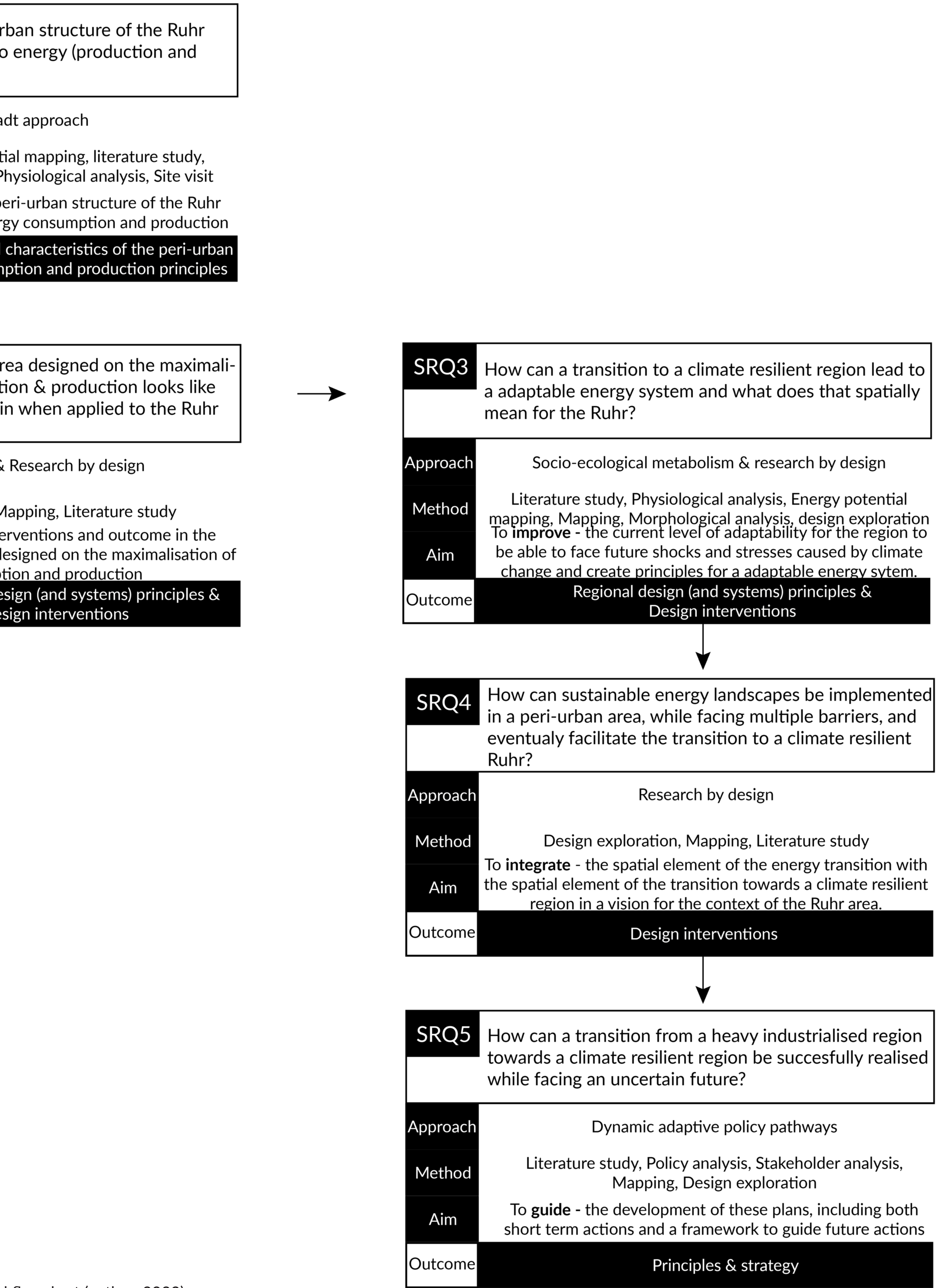
Approach Maximalisation &

Method Design exploration, N

Aim To **identify -** the spatial int
context of a peri-urban area d
energy concump

Outcome Regional and urban de
Urban de

Figure 48: Methodologica



al flowchart (author, 2022).

Chapter 06. Research method

iv. Methodological approaches

Certain approaches will be applied in this thesis. These approaches will be briefly introduced.

- Netzstadt approach (Baccini & Oswald, 2008)
The Netzstadt approach is a strategy to develop understanding of an urban systems. The steps required are;
- describing a perimeter in which the urban system embedded.
- The node in the observation is addressed firstly according to the morphological criteria, followed by physiological analyses.
- The third step is to perform a first assessment of the urban characteristics in the project perimeter on the basis of five criteria of quality.

- Research by design (Roggema, 2016)
Research by design is an academic investigation, through which design is explored as a method of inquiry with the goal to produce new knowledge. The methods that can be used are sketching, mapping and others. This approach creates a strategy with the aim to generate desirable urban perspectives in places where urban development will happen.

- Socio-ecological metabolism (Erb, 2012)
Socio-ecological metabolism approach is an approach that focusses on not only, socioeconomic metabolism, but also on ecological metabolism. This approach is centred on the study of biophysical (material and energy) exchange relationships between societies and their natural environment. This approach is embedded in a concept of socio-ecological systems, which define society as a hybrid form where cultural system and biophysical structures connect.

- Urban energy masterplanning (Van den Dobbelsteen et al., 2018)
Urban energy master planning is an approach used to guide cities to become more resilient cities. Based on the Rotterdam Energy Approach & Planning (REAP) the REAP2 was created. This approach has several principles;
- matching supply and demand directly,
- (inter-)exchanging residual heat and cold,
- cascading waste heat, and
- storing temporal differences in supply and demand.

By applying these principles on different scales, several strategies can be formed, to guide the cities in their way to become more resilient.

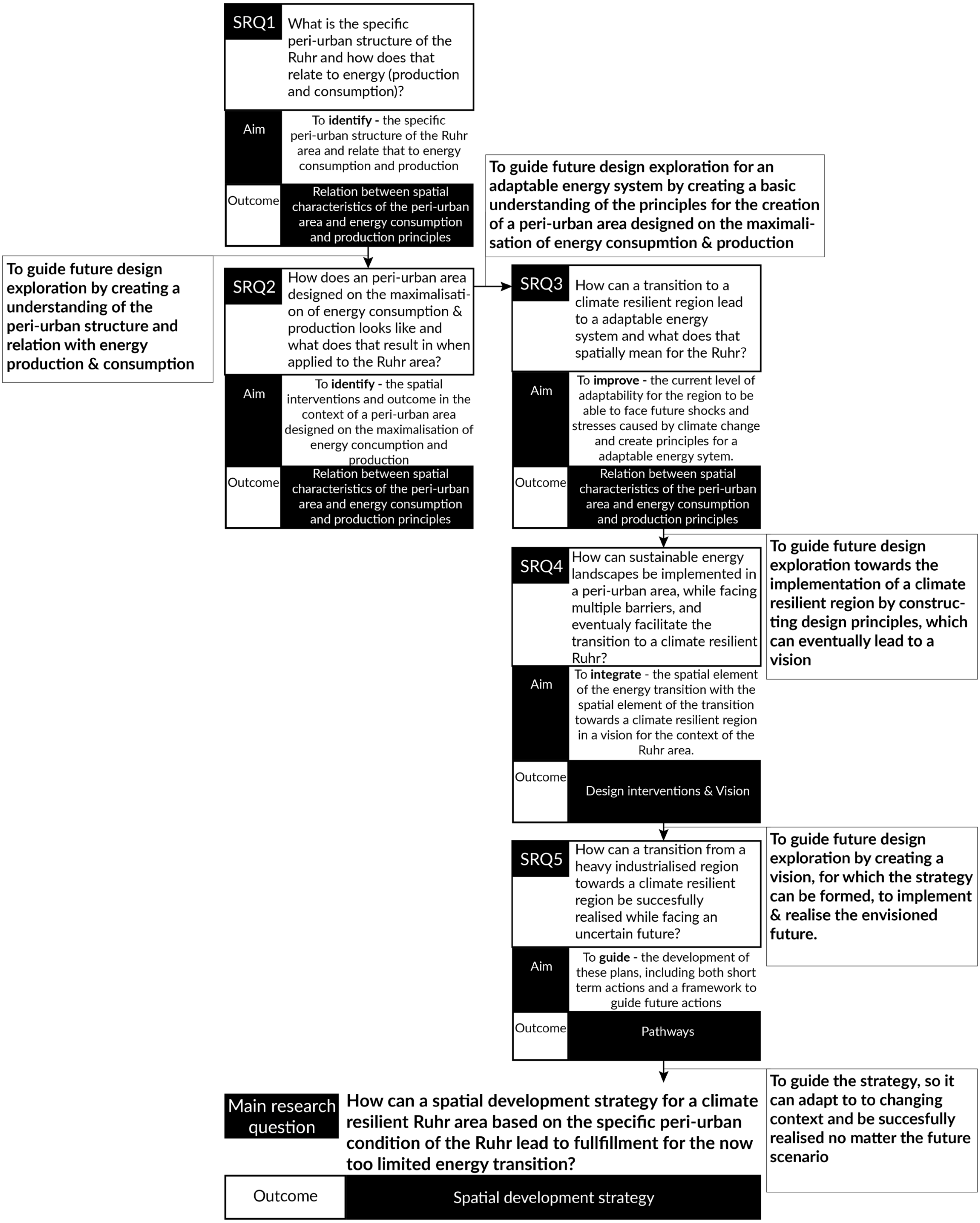


Figure 49: Relation between subquestions (author, 2022).

With the methodological flowchart, and the relation between the different sub research questions made explicit, the methods needed to answer the sub-research questions can now be described. The aim, outcome and process of every method will be listed, alongside the aim per sub question of that method.

Method 1
Literature review

Type:
Mixed

Sub - questions:
1,2,3,4,5,6

Databases:
Google scholar, TU Delft library, Elsevier, Springer.

Aim & outcome:
Read and review scientific papers and reports. The aim, reached by reading and reviewing, is to create a theoretical understanding of the topic chosen in the sub-research questions, to gain an understanding of the energy system in the Ruhr area, to conceptualize climate resilience and to research and quantify certain variables for the region.

Process:
1. Compose selection criteria and a search strategy
2. Select papers and reports according to their relevance. Determine which topic(s) are addressed.
3. Read the abstract, the introduction and the conclusion of the selected papers and reports to assess the suitability. If the selected literature is suitable, read the remaining part of the literature.
4. Compose an own conclusion of the findings. Use the findings in the process of the thesis.
5. Compare and complement the conclusions of several papers and reports. Eventually, conclude and reflect on the outcome.

Aim per sub question:
1. Defining peri-urban area's characteristics. Identifying and qualifying relations between spatial characteristics and energy demand. Identifying and qualifying relations between spatial characteristics and energy production (potential).
2. Identifying and qualifying spatial principles for the maximalisation of energy consumption and production.
3. Identifying the definition of an adaptable energy system, the definition of a climate resilient region and identifying possible transition strategies to a climate resilient region
4. Quantifying the exact goals for the energy transition. Identifying the spatial component of certain energy sources and energy systems.
5. Identifying the definition of sustainable energy landscapes. Identifying possible barriers for implementing sustainable energy landscapes. Research known literature on how sustainable energy landscape can facilitate climate resilience.
6. Identifying the definition of a heavy industrialised region. Research know literature on the composition of scenarios to frame the uncertain future.

Method 2
Policy analysis

Type:
Mixed

Sub - questions:
4,6

Databases:
German national documents, North-Rhein Westphalia provincial documents, Ruhr regional association, Municipal documents.

Aim & outcome:
Collect, compare and review policy documents. The aim is to create an understanding of current and future policies, describing the governance mechanics and shortcomings.

Process:
1. Find key planning and policy document
2. Compose and summarize the important aspect in relation to energy and resilience
3. Research current mechanics and outcomes. Describe limits and potentials for the chosen topic or mechanics.
4. Conclude and reflect on the findings.

Aim per sub question:
4. Identifying existing policy and strategy documents in Germany relevant for the energy transition.
6. Identifying existing policy and strategy documents in the Ruhr relevant for the heavy industry and climate resilience.

Method 3
Stakeholder analysis

Type:
Mixed

Sub - questions:
4,6

Databases:
North-Rhein Westphalia, Ruhr regional association, Municipalities, Research institutes, educational institutes.

Aim & outcome:
Compile a list of stakeholders in the region, with the aim of creating a better understanding of actors in certain sectors or processes. These actors can be engaged, depending on their influence and interest. This will be incorporated in the vision and will lead to certain instruments in the strategy to realize the vision.

Process:
1. Identify stakeholders relevant for the chosen topic and / or involved in the region
2. Compose maps and summary of interest and influence of stakeholders
3. Compose maps and summary of relation between certain stakeholders.
4. Search for synergies and conflict, currently and for the future.
5. Compose engagement strategies for certain stakeholders. This will lead to instruments.
6. Conclude and reflect on the findings.

Aim per sub question:
4. Identifying main governmental bodies, institutions, private developers, civil communities, non-governmental organisations (NGO’s) and residents (groups) related to the energy transition.
6. Identifying main governmental bodies, institutions, private developers, civil communities, NGO’s and residents (groups) related to the transition towards climate resilience.

Method 4
Site visit

Type:
Qualitative

Sub - questions:
1

Databases:
Conclusions from analysis (performed using data from GeoFabrik and Urban Atlas).

Aim & outcome:
Visiting several sites in the Ruhr area to create a feeling of (opinions from residents on) the geographical features. The main aim is to observe, describe and conclude on the geographical characteristics, how they are perceived and how they shape life.

The process can be divided into two approaches, each one for its own aim:
- Sketching, drawing, photographing and verbally describing geographical characteristics.
- Interviews with residents and/or frequent users of the area.

Process Sketching, drawing, photographing verbally describing:
1. Compose a list of interesting locations from previous analysis that have to be personally visited.
2. Formulate questions, way of approaching or required outcomes from the site visit.
3. Plan the site visit.
4. Conduct the site visit.
5. Conclude and reflect on the findings.

Process Interviews:
1. Draw hypothesis or conclusions from previous analysis that have to be personally further researched.
2. Formulate forms to support or oppose hypothesis or conclusions.
3. Initiate contact with stakeholders in order to fill in the forms.
4. Plan the site visit.
5. Conduct the site visit.
6. Conclude and reflect on the outcomes of the forms.

Aim per sub question:
1. To observe and get a basic understanding of the spatial characteristics of the Ruhr area. Furthermore, to get in touch with users or residents of the area and get an understanding of their view on the Ruhr area.

Method 5
Morphological analysis

Type:
Mixed

Sub - questions:
1,3,4

Databases:
GIS, GeoFabrik, Urban Atlas, Opendata NRW, North-Rhein Westphalia, Ruhr regional association, Municipalities, Research institutes, educational institutes.

Aim & outcome:
The aim is to understand characteristics of the landscape that humans have changed, their construction and their functions in their relationship with each other. This must be understand in a historical context. The outcome is a visualization of the hybrid landscape, composed by natural history and cultural history.

Process:
1. Compose base maps, using geodata.
2. Choose which topic has to be analysed.
3. Choose how this topic will be researched (choose from possible attributes; coherence, boundaries, scale, tasks, urban granulation, urban resistance and how these attributes will be researched; contour, field, size, structure, figure, hierarchy)
4. At each stage of analysing, throughout the process, key findings are defined and summarized.
5. Conclude and reflect on the findings.

Aim per sub question:
1. To identify how the specific peri-urban structure was constructed, what the relation of functions are and how the natural landscape has been altered by the peri-urban areas. The connection of cultural history and natural history is researched to find an understanding of characteristics in relation to energy production and consumption.
3. To identify current characteristics that will be affected by the transition to a climate resilient region, relation of functions that will be affected or used for the transition and finally, the visualization of the hybrid landscape to see where the transition to a climate resilient region will have the most (spatial) impact.
4. To understand the current hybrid energy landscape. So it becomes clear where possible synergies can take place in relation to energy production and consumption, to be able to construct the base for design exploration to take place on, to eventually propose the spatially most suitable outcome of the energy transition.

Method 6
Physiological analysis

Type:
Mixed

Sub - questions:
1,3,4

Databases:
GIS, GeoFabrik, Urban Atlas, Opendata NRW, North-Rhein Westphalia, Ruhr regional association, Municipalities, Research institutes, educational institutes.

Aim & outcome:
The aim is to understand the physiological processes (transport and transportations of matter and energy) within the metabolism of the chosen urban system. Furthermore, physiological tools are introduced in order to comprehend physical attributes of urban systems and qualify them.

Proces:
1. Identify flows.
2. Create system border.
3. The desired period of observation must be defined.
4. Compose the metabolism of the chosen system (phenomenology).
5. Compose input and output of chosen system.
6. At each stage of analysing, throughout the process, key findings are defined and summarized.
7. Conclude and reflect on the findings.

Aim per sub question:
1. What are key physiological elements of the energy system and how does that affect the peri-urban area.
3. What are key physiological elements of an adaptable energy system.
4. What are physiological elements of the energy system and how can they be connected, combined, excluded to compose the desired spatial outcome (in relation to a climate resilient region) of the energy transition.

Method 7
Energy potential mapping

Type:
Mixed

Sub - questions:
1,3,4

Databases:
Google scholar, TU Delft library, Elsevier, Springer,

Aim & outcome:
The aim of this method is to visualize the potential of energy production and consumption based on the quantity, quality and location of demand and supply.

Process:
1. Compose desired output (generally consisting of one or more renewable and anthropogenic energy sources, energy demand, transport and storage possibilities of an area, expressed in a pre-defined way).
2. Use Energy Conversion Techniques. For each source or use, the technical limitations of energy techniques, which convert energy source into a useful form of energy, have to be determined.
3. Determine the Spatial Yield. For each type of energy source, the different type of limitations have to be taken into account and quantified.
4. Compose output.
5. Visualize.

Aim per sub question:
1. To identify the influence of the specific peri-urban and geographical characteristics of the Ruhr area on potential energy production.
3. To identify, qualify and quantify the energy potentials of the Ruhr area so it can function as a base for the transition towards a climate resilient region.
4. To identify, qualify and quantify the energy potentials of the Ruhr area and surrounding areas, to identify potential synergies and compose the most desired spatial outcome of the energy transition in relation to the climate resilient region.

Method 8
Mapping

Type:
Mixed

Sub - questions:
1,2,3,4,5,6

Databases:
GIS, GeoFabrik, Urban Atlas, Opendata NRW,

Aim & outcome:
The aim of this method is to visualize certain observations and connect or reflect on them through different scales. This is done by mapping certain topics, spatial structures or proposed design solutions. In the first part of the thesis, mapping will compose a general understanding of the peri-urban structure of the Ruhr and the relation between the spatial structure and the energy system. During the main research phase, mapping supports the spatial relationship between systems and structures on different scales and different (sub)topics. In the last part of the thesis, where solutions will be contextualised, mapping can be used to visualize how solutions, scenarios or designs could be implemented and what the result will be like.

Process:
1. Compose base maps, using geodata.
2. According to the topic and type of analysis required, required morphologies and structures are mapped.
3. At each stage of mapping, throughout the process, key structures and findings are defined and summarized.
4. Conclude and reflect on the findings.

Aim per sub question:
1. To identify, qualify and quantify the specific peri-urban structure, potentials and problems.
2. To identify, qualify and quantify the potentials of the region to be used as a base for the maximalisation of energy production and consumption.
3. To identify, qualify and quantify the potentials for a transition to a climate resilience region.
4. To identify, qualify and quantify the spatial component of the current energy system and where possible expansions / synergies can be informed.
5. To identify, qualify and quantify where possible sustainable energy landscapes can be implemented.
6. To identify, qualify and quantify the possible spatial component of the uncertain future in relation to climate adaptation.

Method 9
Design exploration

Type:
Qualitative

Sub - questions:
2,3,4,5

Databases:
Data on determined context (geographical; GIS, GeoFabrik, Urban Atlas, Opendata NRW and policy; have to be combined with data on the variable context.

Aim & outcome:
This method is about investigating, comparing and reflecting on possibilities in a certain context, on a certain topic. The aim is to create new knowledge, through design. The outcome of this method can be a sketch, a map, a principle or a policy document.

Process:
1. Pre-Design phase. The primary phase of the research by design process is about understanding. Research is carried out before the actual design. This pre-design research is aimed at composing a basic understanding of the question at hand, the investigation of tasks, context, potentials, and values for the actual design exploration.
2. Design Phase. The design phase is the main part of the research by design process. The iterative (and possibly interactive) approach continues and intensifies, where the research output from the pre-design phase is implemented in the design process and design considerations. Design exploration is a reflective and iterative approach with critical assessing, comparing and evaluating taking place moving between problem and solution.
3. Post-Design Phase. The final phase is about synthesising the work and coherently presenting the future, the way that will be realised and the way that will impact our current society, landscape and/or system.

Aim per sub question:
2. To identify and qualify the possible scenarios of implementation of a maximised energy consumption and production on the Ruhr area.
3. To identify and qualify the possible landscapes of the Ruhr and how they can both foster an adaptive energy system and the transition to a climate resilient region.
4. To identify and qualify possible synergies and spatial outcome of the energy transition.
5. To identify and qualify possible implementation of sustainable energy landscapes and the way they can facilitate climate resilience.
6. To identify and qualify the different scenarios of the uncertain future and to identify and qualify the way these scenarios affect the vision and thus shape the strategy.

vii. Expected outcome

With every method defined, the link between the outcomes of every sub-question can be defined.

The outcome of a sub-question relates to the aim of that specific sub-research question and to the role that that sub-research question plays in the overall research.

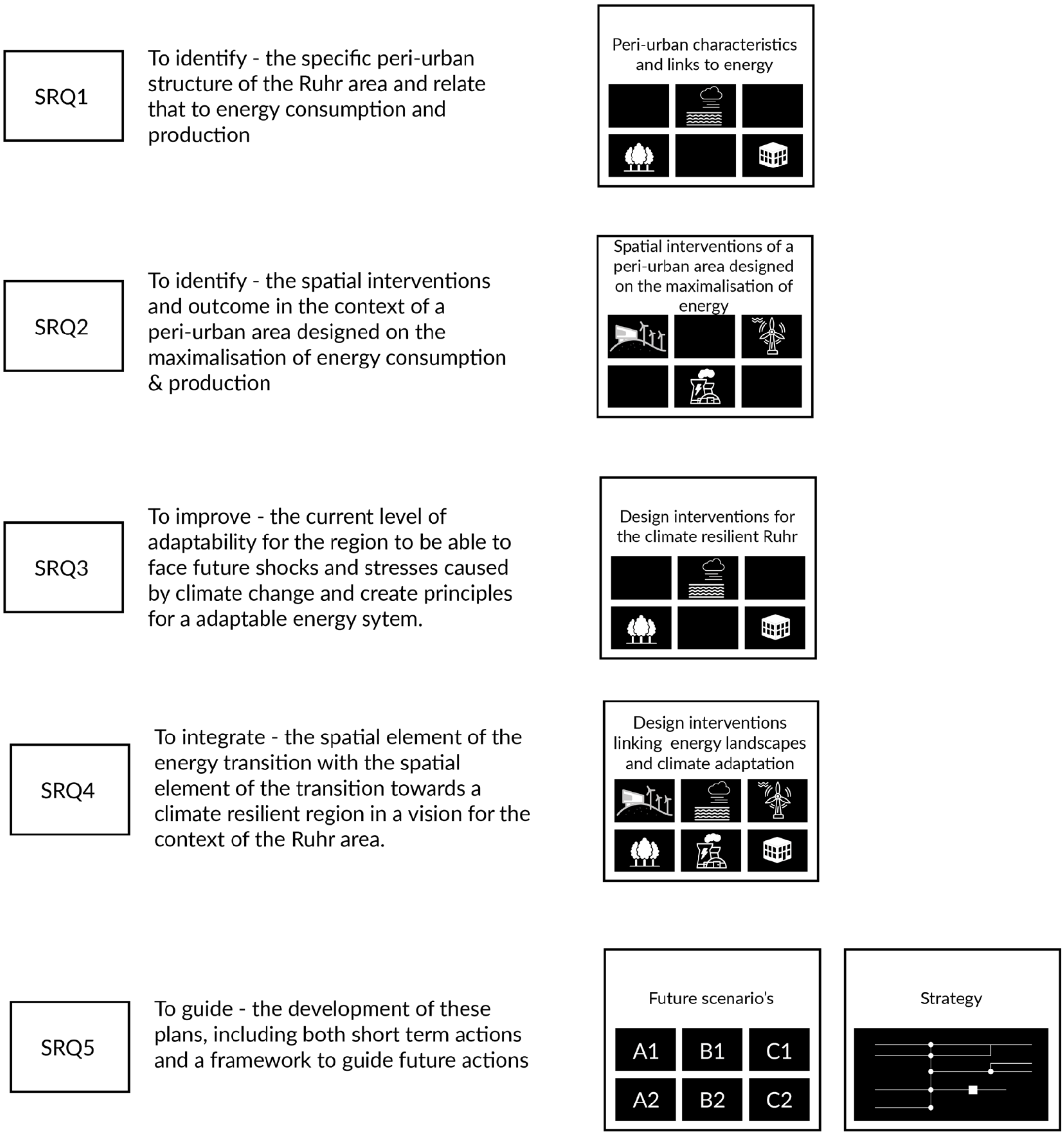


Figure 50: Expected outcome per subquestion (author, 2022).

Furthermore, the expected outcome per sub question relates to the overall research approach and expected outcome of the research.

The scenarios that are presented here are based on the uncertainties in relation to climate change and the energy system, and are a way to grasp and cope with the uncertain future ((Haasnoot et al., 2013).

Co-creation will be applied when construction the vision and strategy, by using pattern languages. By doing so, stakeholders will be engaged that are currently resisting change (Mahmoud & Morello, 2021).

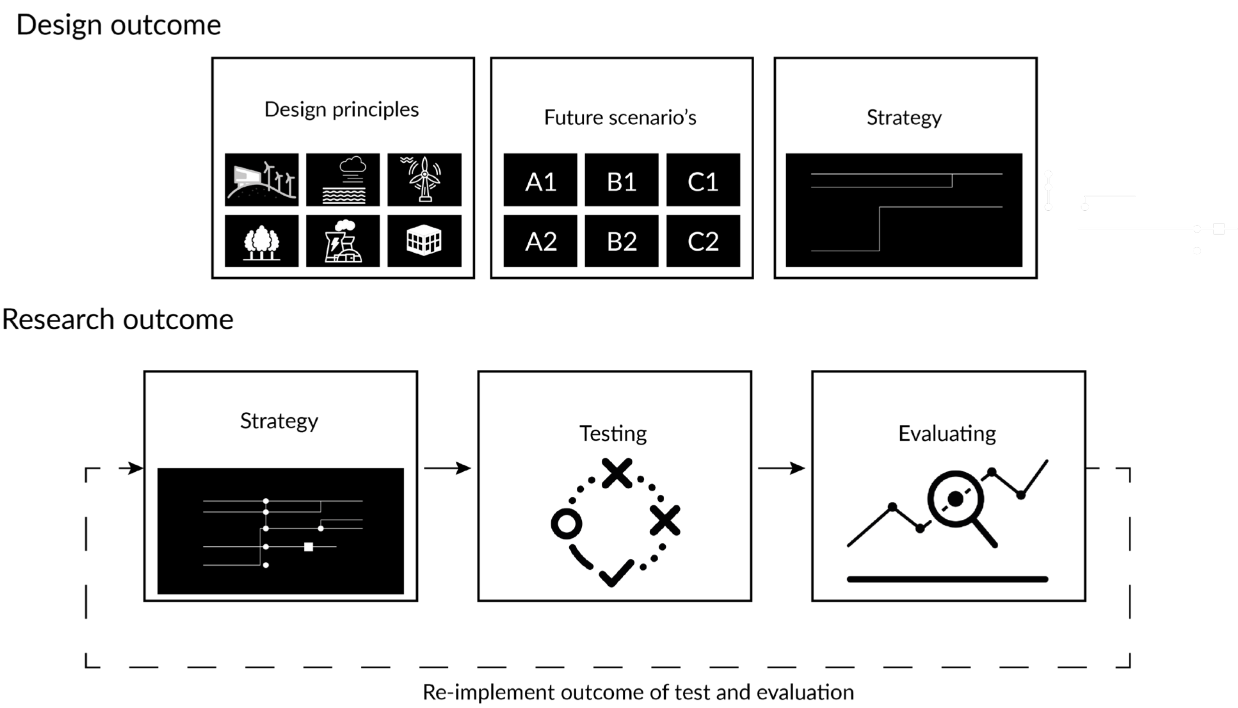
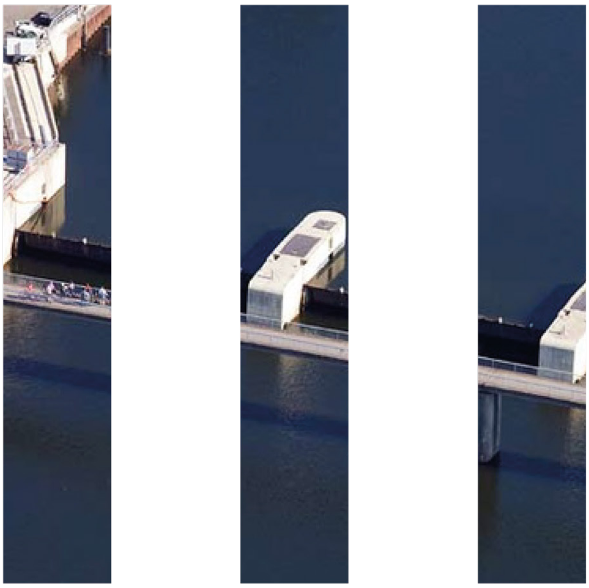


Figure 51: Expected resarch outcome (author, 2022).



III. Research outcome

Chapter 07. Climate adaptation and energy transition as means to prepare the Ruhr
Chapter 08. Analysis
Chapter 09. Uncertainty in gobal warming and energy consumption.
Chapter 10. Design exploration
Chapter 11. Strategy

Chapter 07. Climate adaptation and energy transition to prepare the Ruhr

Chapter 07. Climate adaptation and energy transition to prepare the Ruhr

i. Climate adaptation.

Climate adaptation is the way to operationalize climate resilience. The Ruhr metropolitan area is currently operationalizing climate resilience by focussing decreasing energy-related greenhouse gas emissions (Regionalverband Ruhr, 2017).

Literature review provided several alternative options to enhance climate adaptation (Lee & Kim, 2021). These options are visualized in figure 52. These examples are all green-blue infrastructure, which can be described as the spatial manifestation of ecosystem services (Staddon et al., 2018). An ecosystem can be defined as "a set of inter-acting species and their local, non-biological environment functioning together to sustain life"' Ecosystem services are defined as "the benefits human populations derive, directly or indirectly, from ecosystem functions (Bolund & Hunhammar, 1999).

Design elements climate adaptation

Spatial range	Natural method	Technical method	Functional method
Regional & city River systems/floodplains Regional greenspace systems Transport corridors Riparian systems	River & stream Wetland Forest	Dam & reservoir Artifical wetland	Wind corridor
Neighborhood	Parks & gardens Green streets & urban trees Urban creek & water detention	Urban farming Low impact development Water channels & fountain	Wind corridor (through site plan) Permeable paving
Street Pocket parks Stream daylighting	Pocket park Open green areas		
Building Green courtyards Green rooftops Green walls	Private garden & courtyard Flower pots Design for airflows	Green roofs & rooftop garden Green walls & water walls Vertical farm	Biomimicry Bio-facades Building envelope using phase change materials

Figure 52: Design elements for climatea adaptation (author, 2022. Derived from Lee & Kim, 2021).

ii. Energy landscapes.

Energy landscapes are the spatial component of renewable energy production. These energy landscape develop over time, spatializing what type of energy system, we as society use Pasqualetti, M. J. (2011).

The first recognizable energy landscapes were that of organic economy, using wood as energy source. Then came the mineral economy, using unconventional fossil fuels. Then, the energy system changed to electricity. The current energy landscapes, spatialize the current sustainable economy. All these types of energy landscapes, use one or multiple functions of the ecosystem services, with the energy-conversion of the carrier function being used for the sustainable economy (Stremke, 2013).

Due to the complexity and sheer size of the energy transition, the implementation of energy landscapes is described as; ''the clash between local rights to landscape and the global progress towards a low carbon economy'' (Stremke, 20013). There are multiple social barriers against implementing energy landscapes. Different types of energy landscapes are defined in figure 54.

Design elements energy landscapes

Spatial range	Natural method	Technical method	Functional method
Regional Wind-energy landscapes Solar-energy landscapes Hydro-power landscape Algea-energy landscape Geothermal-energy landscape Residual-energy landscape Biomass cultivation landscape Biofuel-energy landscape Electricity storage Heat storage Fuel storage		(Floating) Floodscape Multilayered elements in; - leisure - floodscape - agriculture - infrastructure - industrial area `- meadow	Wind turbines MIcrogrids Geothermal Solar farms Rooftop solar Wave and Tidal Concentrated solar power (CSP) - mirros to heat a fluid Biomass Nuclear energy Cogeneration (CHP) combined heat and power Microwind Methande digesters In-stream hydro Waste to energy Grid flexibility Energy storage Solar water

Figure 54: Design elements for energy landscapes (author, 2022. Derived from Pasqualetti & Stremke, 2018; Sijmons, 2014).

iii. Relation between climate adaptation and energy transition.

The relation between climate adaptation and energy transition can be summarized by figure 56. Climate change, resulting in global warming, is predominantly a consequence of using fossil fuels to produce energy (Gielen et al., 2019). In the process of producing energy through fossil fuels, carbon dioxide is emitted, which results in climate change.

Furthermore, the adaptation to this process, climate adaptation, as well as the mitigation, the energy transition, have a connection. Climate adaptation can be operationalized as one of the (urban) ecosystem services. The ecosystem services are summarized in figure 55. These green and blue infrastructures play an important role in increasing the capacity to adapt to clime change (Elmqvist et al., 2015). This adaptive capacity is a key notion in climate resilience (Tyler & Moench, 2012). The energy transition, resulting in a changed energy landscape, use the carrier function of ecosystem services. Especially, the energy-conversion facilities, facilities for the conversion of solar, wind and water power into energy, are used (Stremke, 2013). Furthermore, the production function, with the production of biomass as fuel, is used.

The connection between climate adaptation and energy transition is defined. This connection is used as a base to analyse the Ruhr area, which is done in the following chapter.

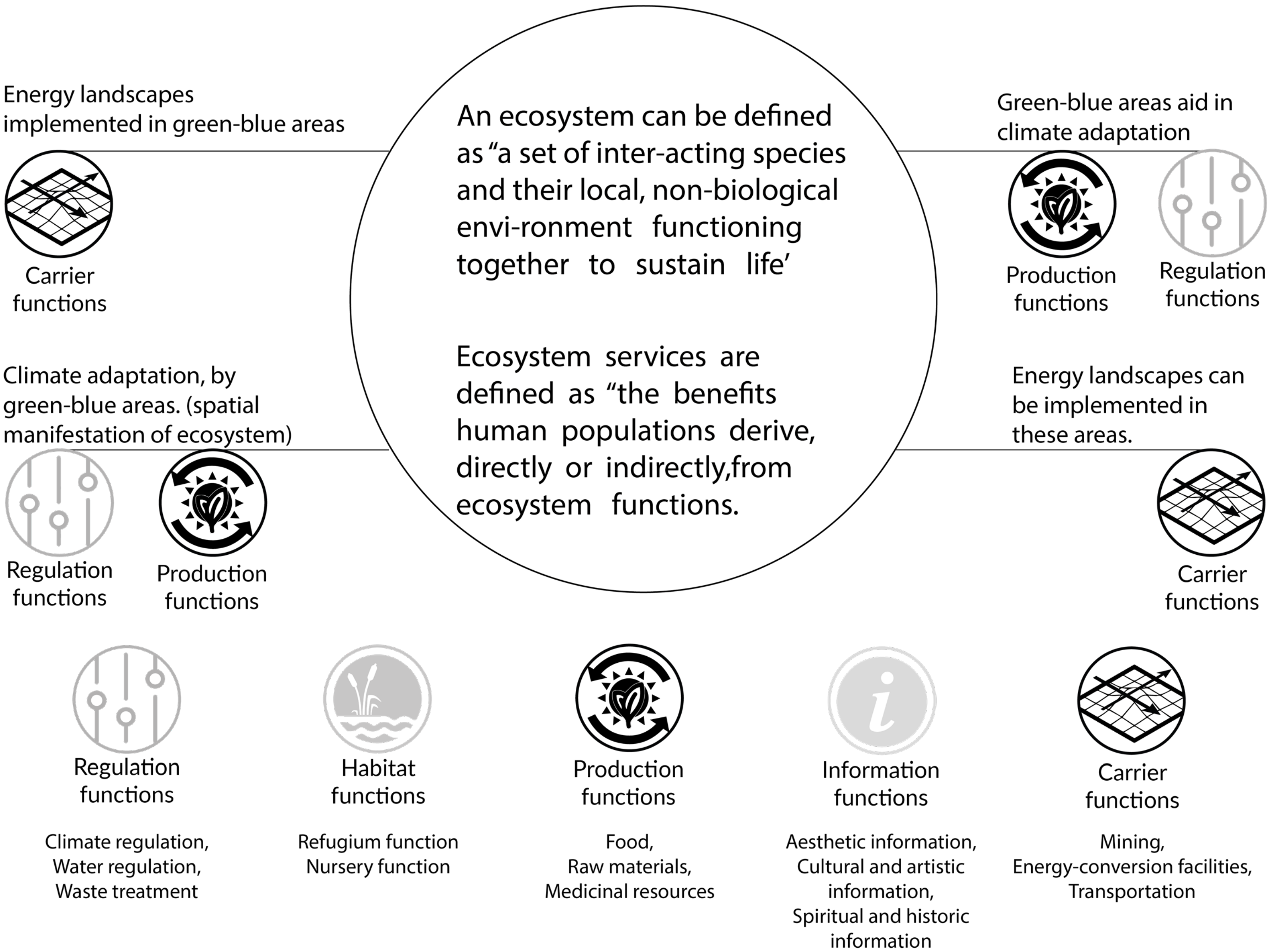


Figure 55: Relation between ecosystem services, climate adaptation and energy landscapes (author, 2022. Derived from Stremke, 2013 and Gielen et al., 2019).

iv. Spatial manifestation of ecosystem services.

The ecosystem has nine different spatial manifestations (Bolund & Hunhammar, 1999) .

These spatial manifestation have to be brought back into the current spatial manifestation of the RUhr, or have to be strenghtened to be able to become climate resistent.

Furthermore, these current spatial manifestation will change in certain occassions - since climate adaptation objectives and sustainable energy landscape components will be added.

These spatial manifestation will be analysed in the following chapter, to be able to conclude on the current spatial manifestation of the ecosystem services in the Ruhr area.

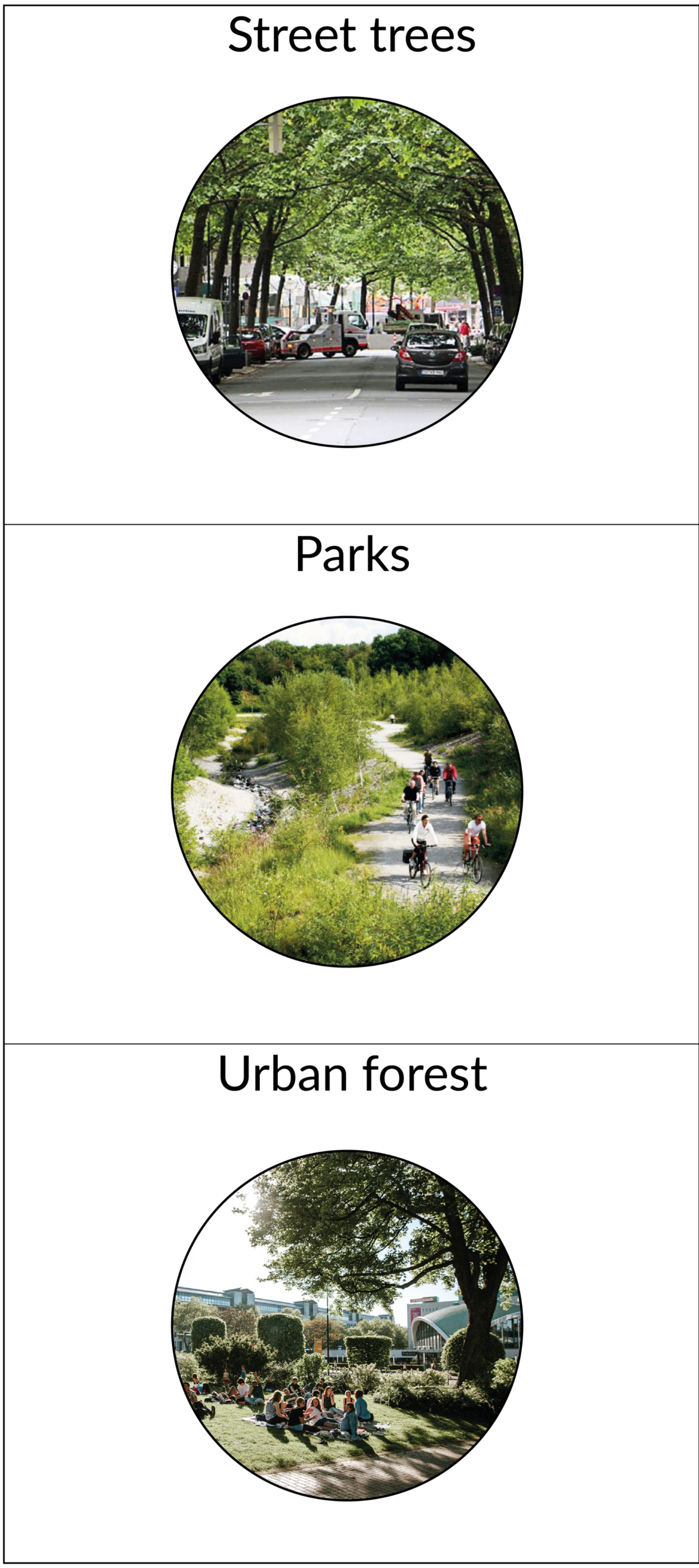


Figure 56: Spatial manifestation of ecosystem
Hunhamm

Lawns	Streams
	
Cultivated land	Lakes
	
Wetlands	Sea
	

services (author, 2022. Derived from Bolund &
nar, 1999).

08

Chapter 08. Analysis

i. Spatial analysis for energy landscapes and climate adaptation.
ii. Spatial analysis of the Ruhr.

With the relation between energy landscape and climate adaptation defined, the Ruhr area can now be analysed on these notions. The green-blue infrastructures, the spatial manifestation of the ecosystem services, will be the base to analyse the Ruhr area on.

This analysis will focus on the current spatial configuration of these characteristics. Literature review indicate several land use types that could be of interest to integrate the transformation to energy landscapes and to implement climate adaptation. These land use types are analysed in the following paragraph.

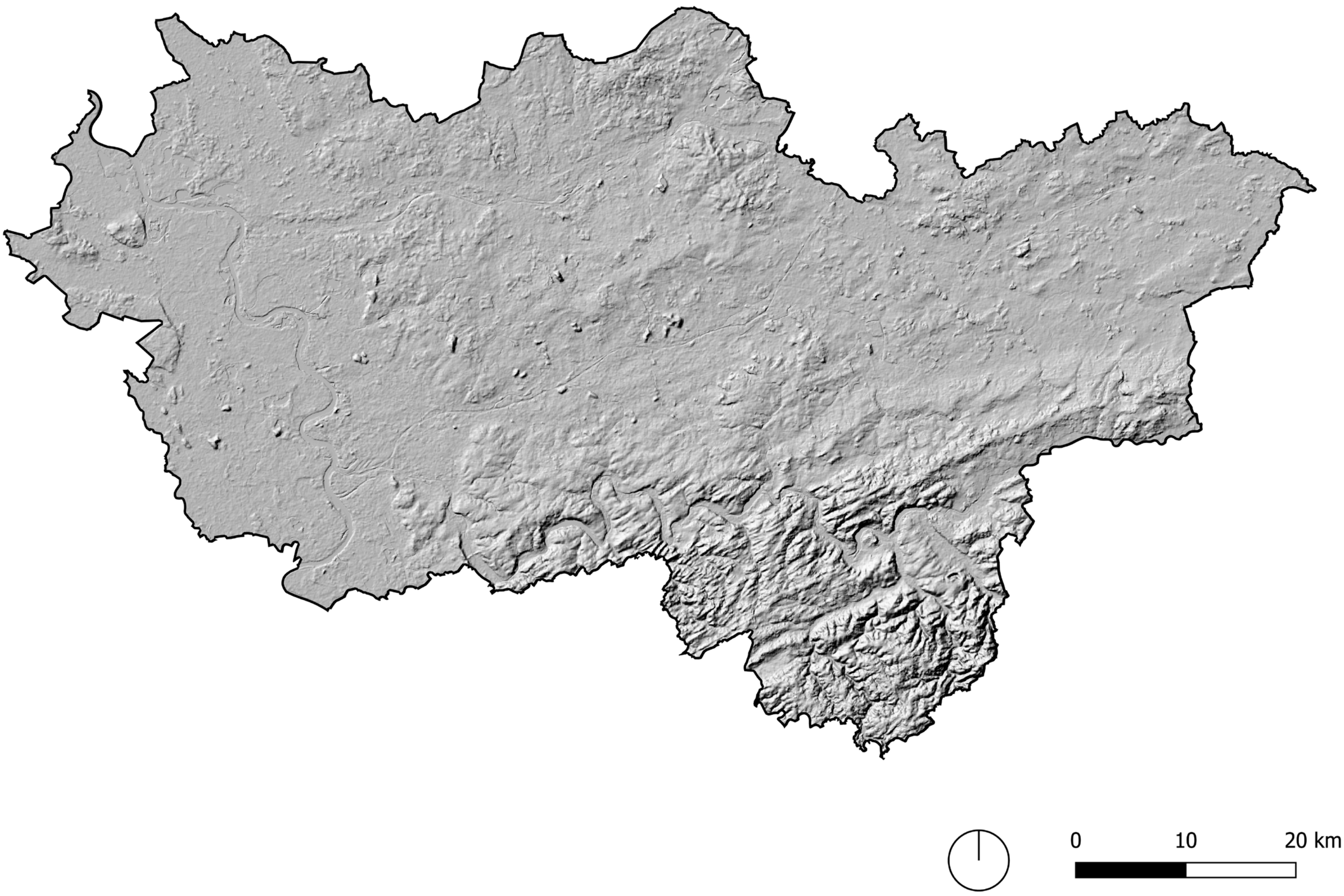


Figure 57: Shaded image of the Ruhr (author, 2022. Derived from Copernicus, 2018).

ii. Spatial analysis of the Ruhr.

The first relation that needs to be analysed is that of the gradation of urbanisation in the Ruhr area. This is important because of distribution of services, availability of and accessibility to green areas and connectivity. In several cities, a ring around this historical city centre can be recognized. This is the expansion of the old historic city centre. Following that ring, the spatial configuration becomes less clear, and harder to recognize. We can recognize the polycentric metropolitan region in the Ruhr, with the several cores, and the surrounding metropolitan region. This is of importance since major since current principles describe that wind turbines have to be placed at least 5 km from urbanised area and within 75 km of an urbanised area (Barrington-Leigh & Ouliaris, 2017)

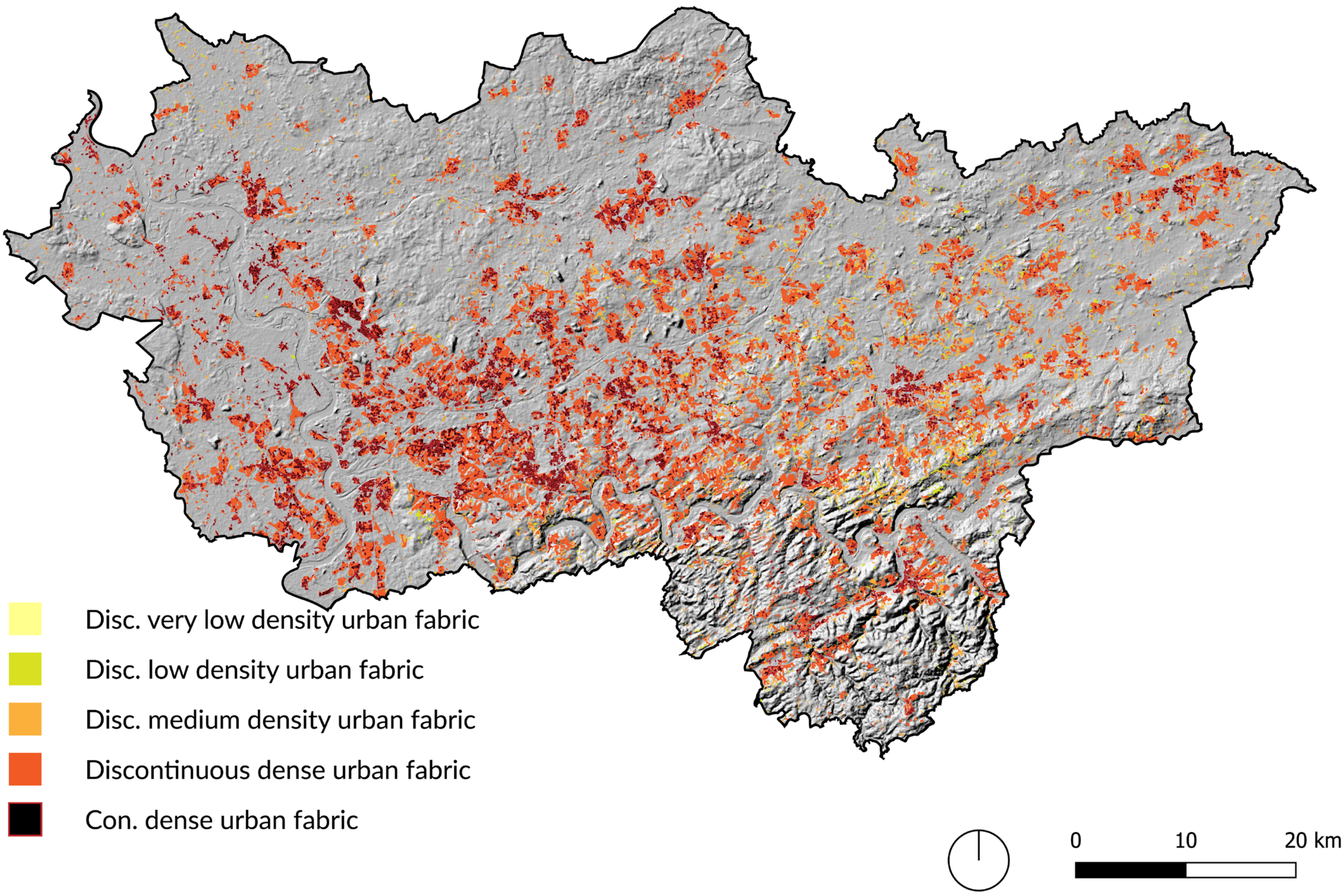


Figure 58: Gradation of urban area (author, 2022. Derived from Copernicus, 2018).

The second topic that needs to be analysed is the current infrastructural network. This is can be linked to the carrier function of the ecosystem services, offering possibilities to implement sustainable energy landscapes. This infrastructure, especially the major water infrastructure, is key for the Ruhr area. This infrastructure network offers the possibility to implement wind turbines or other types of sustainable energy landscapes.

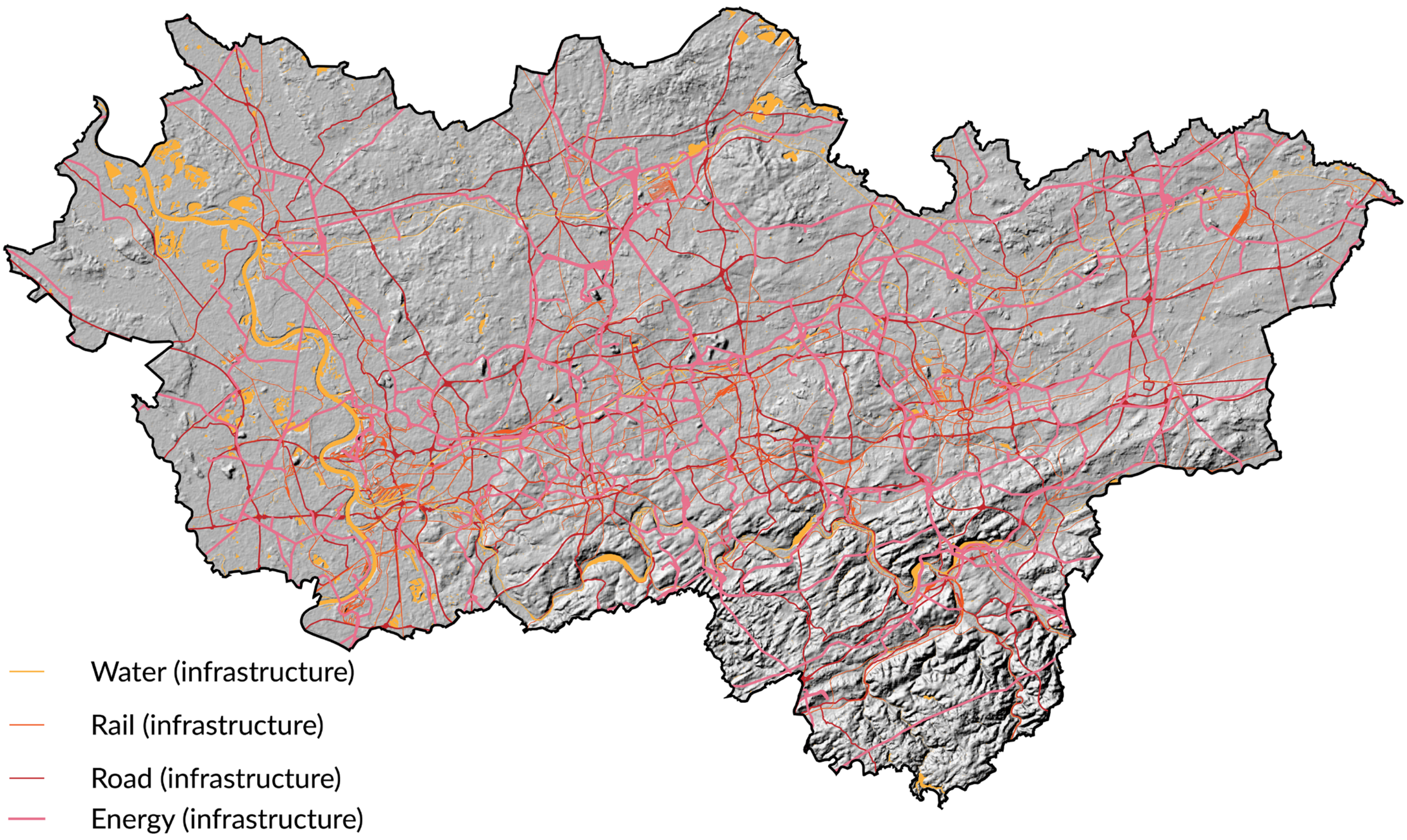


Figure 59: Infrastructure network (author, 2022. Derived from Copernicus, 2018).

The following relation that needs to be analysed is the overlay of these previous two maps. This indicates where the urbanised area and network connect and where there is a lack of connection. The east-west urbanization connects with the majority of the infrastructure network, also placed in an east-west orientation. The link between the current infrastructure network and the consumers - the residential area - is of major importance, since it describes which area is suited for implementation of sustainable energy landscapes, since it has to be well connected (within 75 km of an existing line) and close to a population of consumers (within 75 km) (Barrington-Leigh & Ouliaris, 2017).

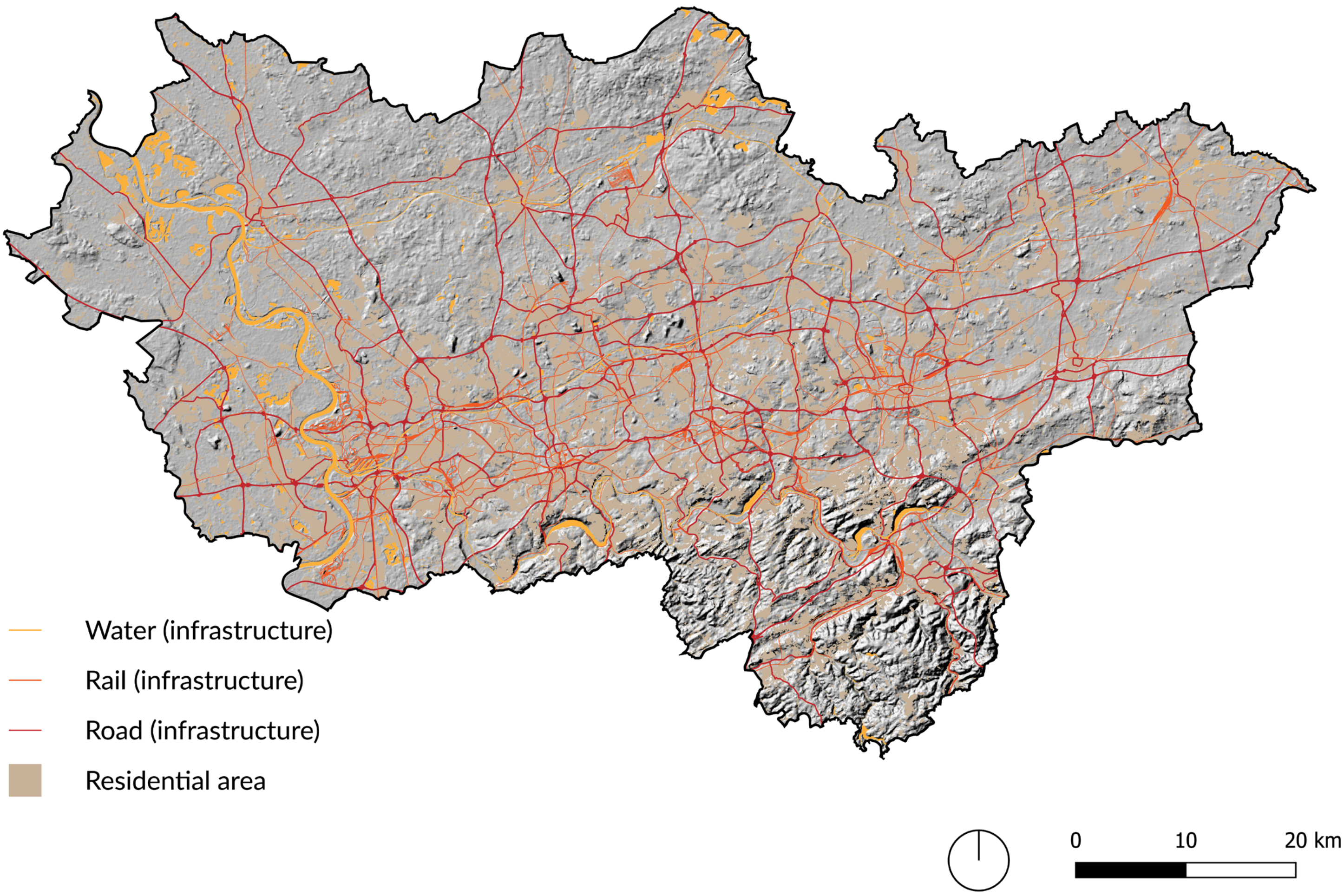


Figure 60: Relation between infrastructure network and residential area (author, 2022. Derived from Copernicus, 2018).

The following relation that needs to be analysed is that of the relation of flooding and residential area. In the north, south and east, we clearly see a relation between the water infrastructures we analysed. Furthermore, several areas with flood risk can be clearly recognized, although it is hard to pinpoint why this happens there. The main conclusion from this map is that the Ruhr area is facing multiple flood risk, especially with the major urbanisation located around these areas.

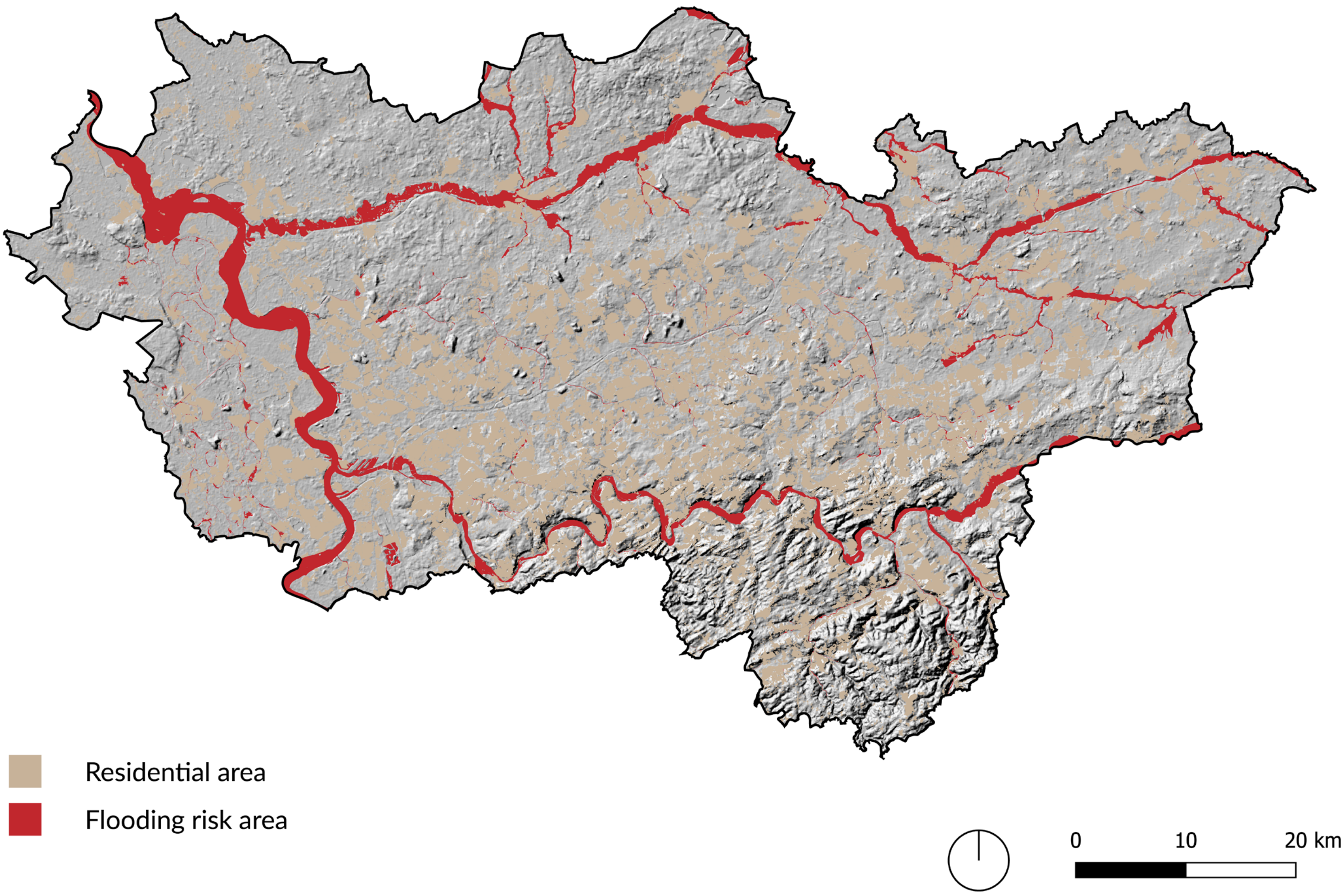


Figure 61: Relation between flood risk areas and residential area (author, 2022. Derived from Copernicus, 2018).

The following relation that needs to be analysed is between the industrial area and residential area. This is partly due to the potential to implement residual heating. Furthermore, this is because of the suitability for implementing solar panels of top of the flat roofs of these industrial buildings. The map indicates that these industrial areas are wedged in between residential areas and placed along major infrastructure networks, such as the water networks.

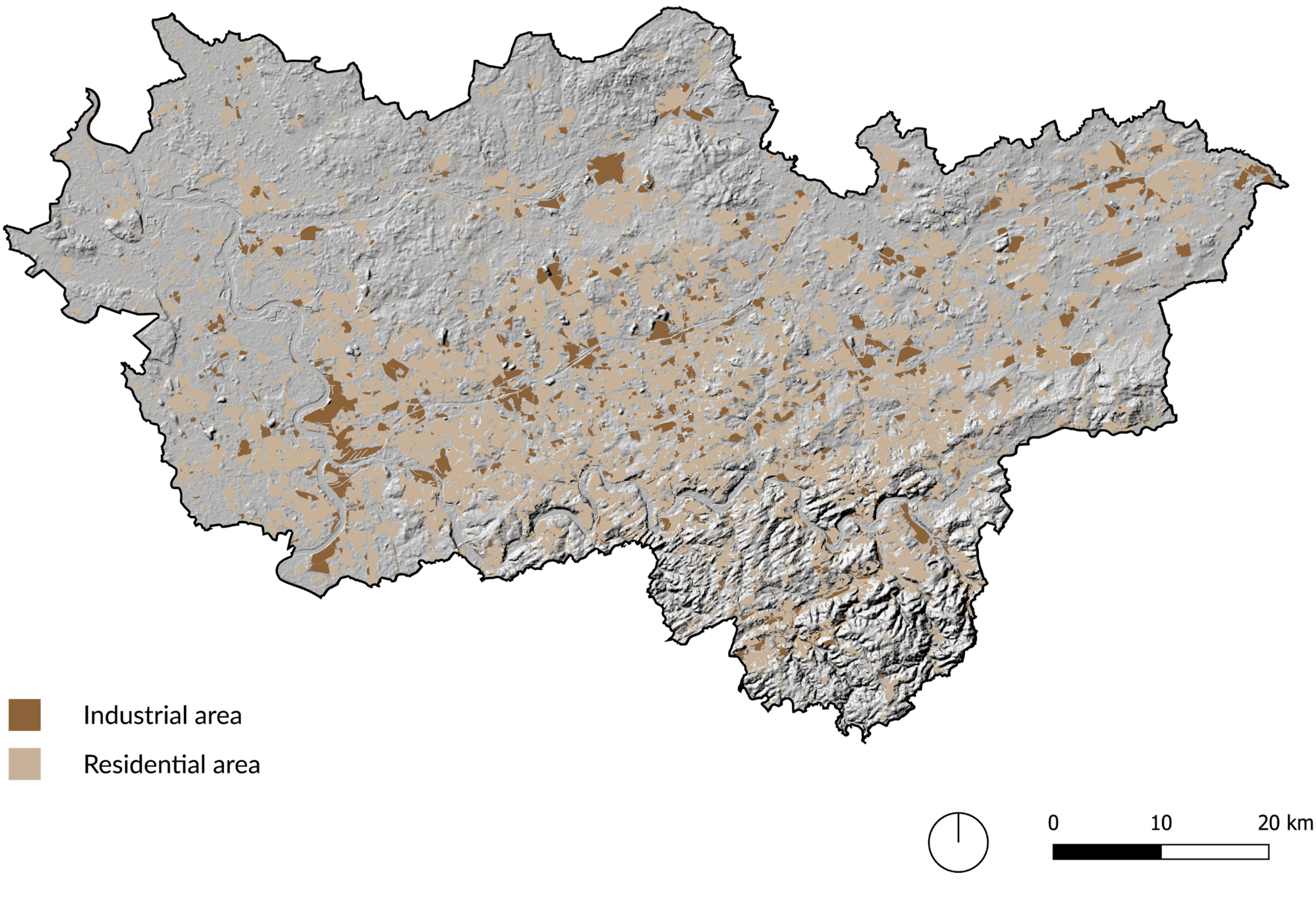


Figure 62: Relation between industrial area and residential area (author, 2022. Derived from Copernicus, 2018).

The following relation that needs to be analysed is between the agricultural area and residential area. This agricultural function is an ecosystem function, to be specific, a production function. This function is concentrated around the east, north and west edge of the Ruhr area. The map furthermore indicates that several residential and urbanised areas are interrupted by agricultural areas, in a north-south orientation.

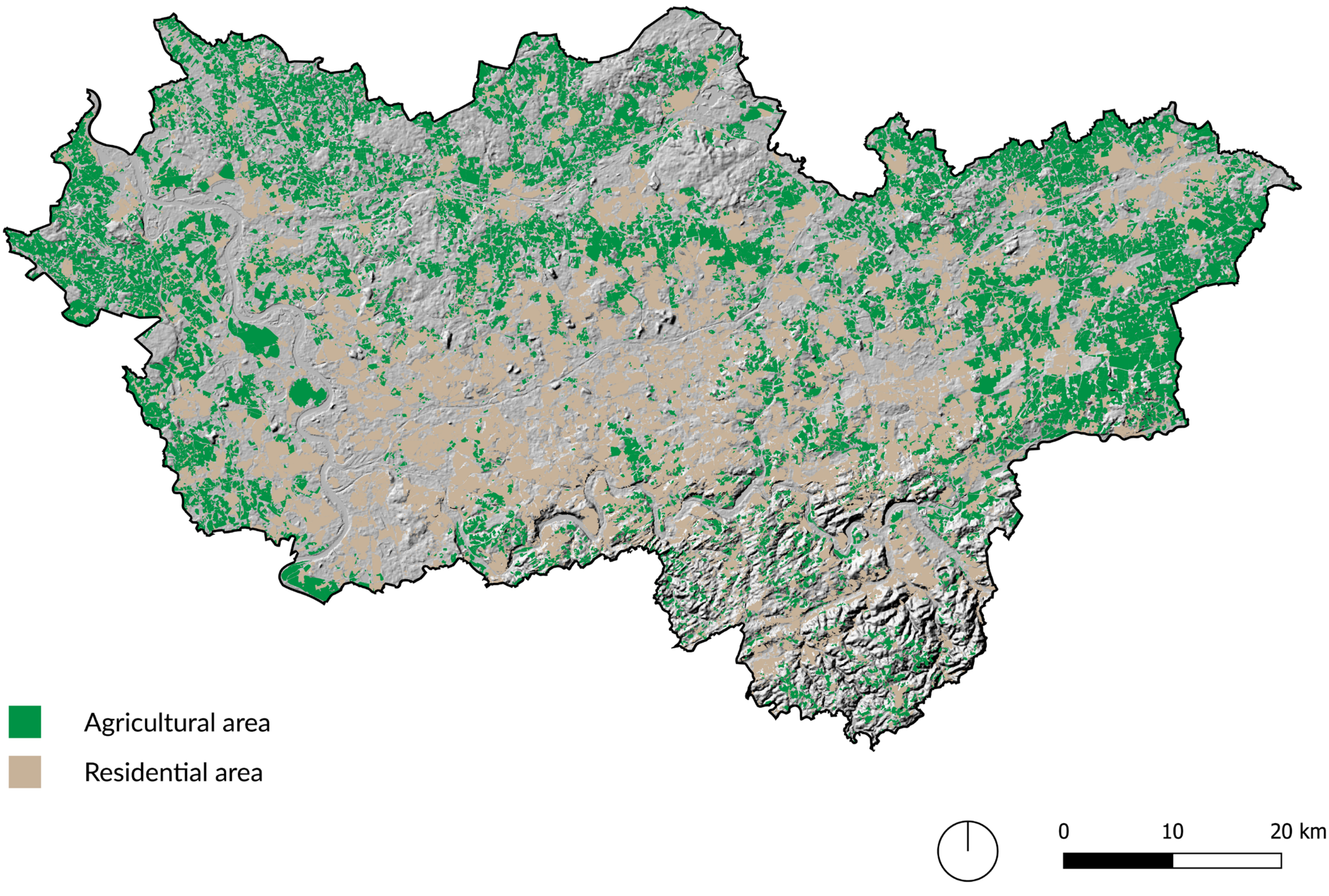


Figure 63: Relation between agricultural area and residential area (author, 2022. Derived from Copernicus, 2018).

The other relation that needs to be analysed is that of green areas and residential areas. This green infrastructure is a key spatial manifestation of the ecosystem services, both for the energy production using renewable energy sources such as solar, wind, water as well as for the climate adaptation. The map indicates the concentration of the green infrastructure on the north and south side and the lower concentration in the residential area.

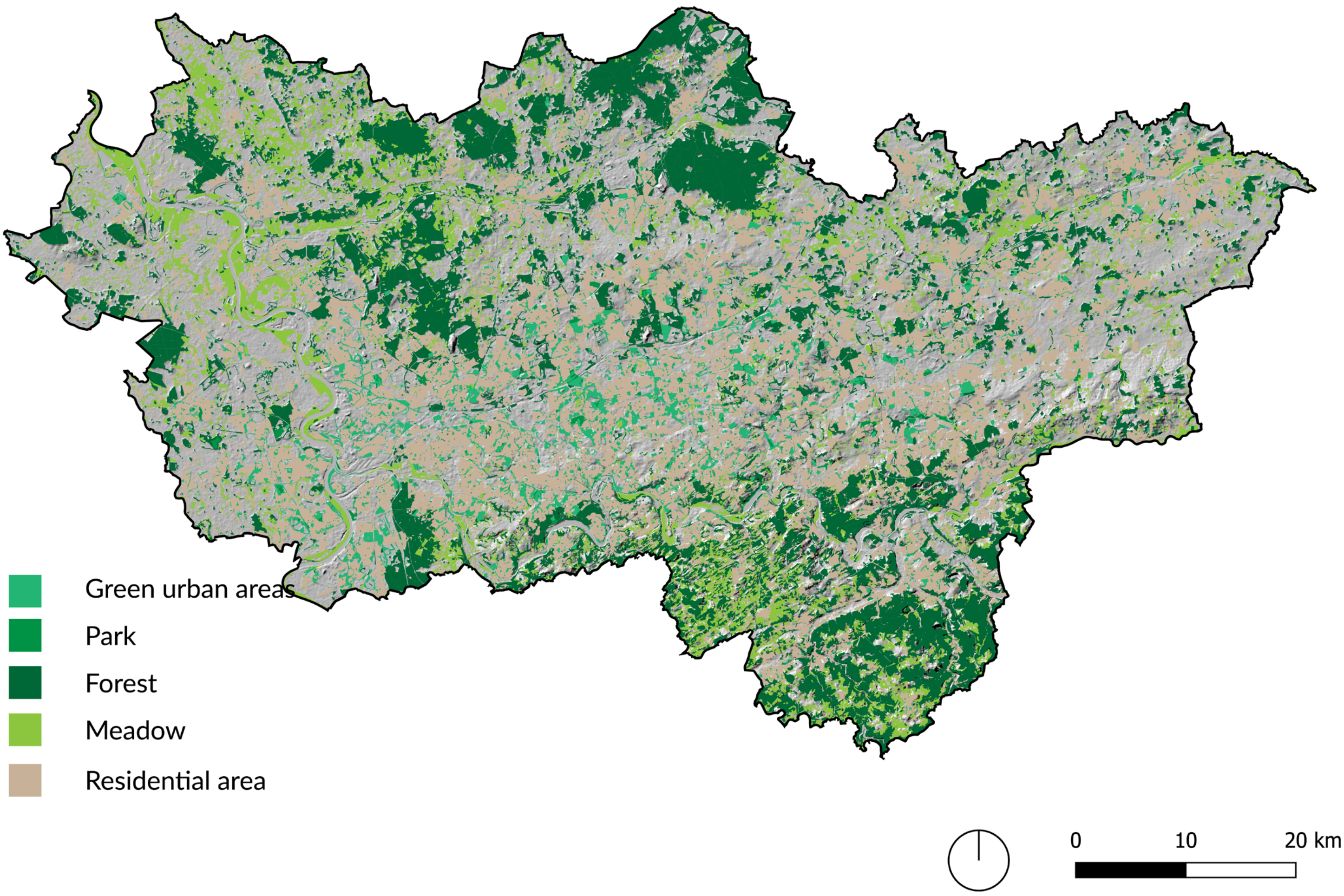


Figure 64: Relation between green infrastructure and residential area (author, 2022. Derived from Copernicus, 2018).

The following topic that needs to be analysed is that of the physiological notion. This is of importance because the current energy infrastructure is the starting point for the energy transition. The current network, together with the output, is of importance to be analysed.

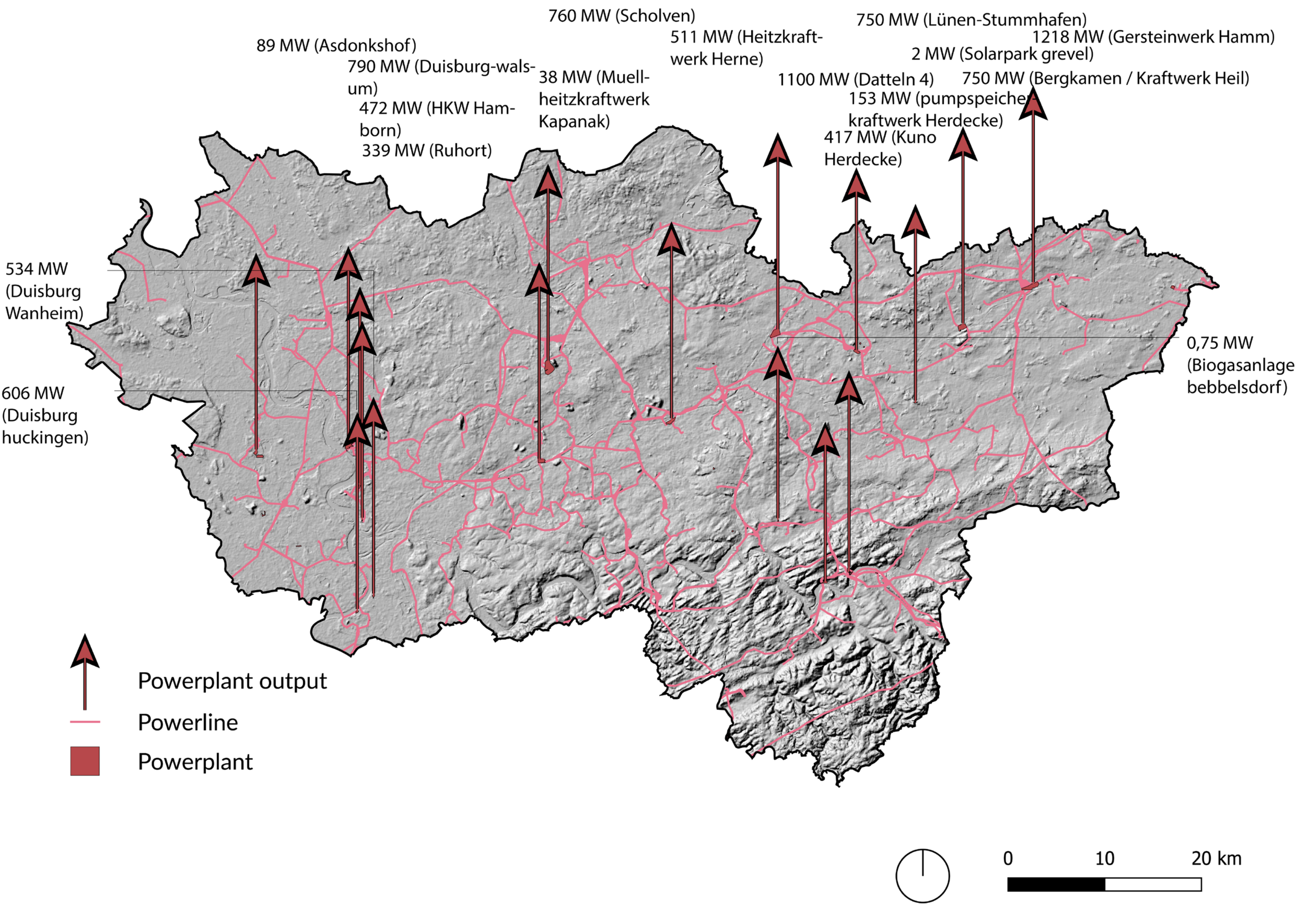


Figure 65: Relation between energy infrastructure and energy output (author, 2022. Derived from Copernicus, 2018).

Before concluding on this analysis, we must research the relation between the current spatial manifestation of ecosystem services and the urbanised landscape of the Ruhr. This map visualizes the current spatial manifestation of ecosystem services in the Ruhr area and relates it to the current residential area.

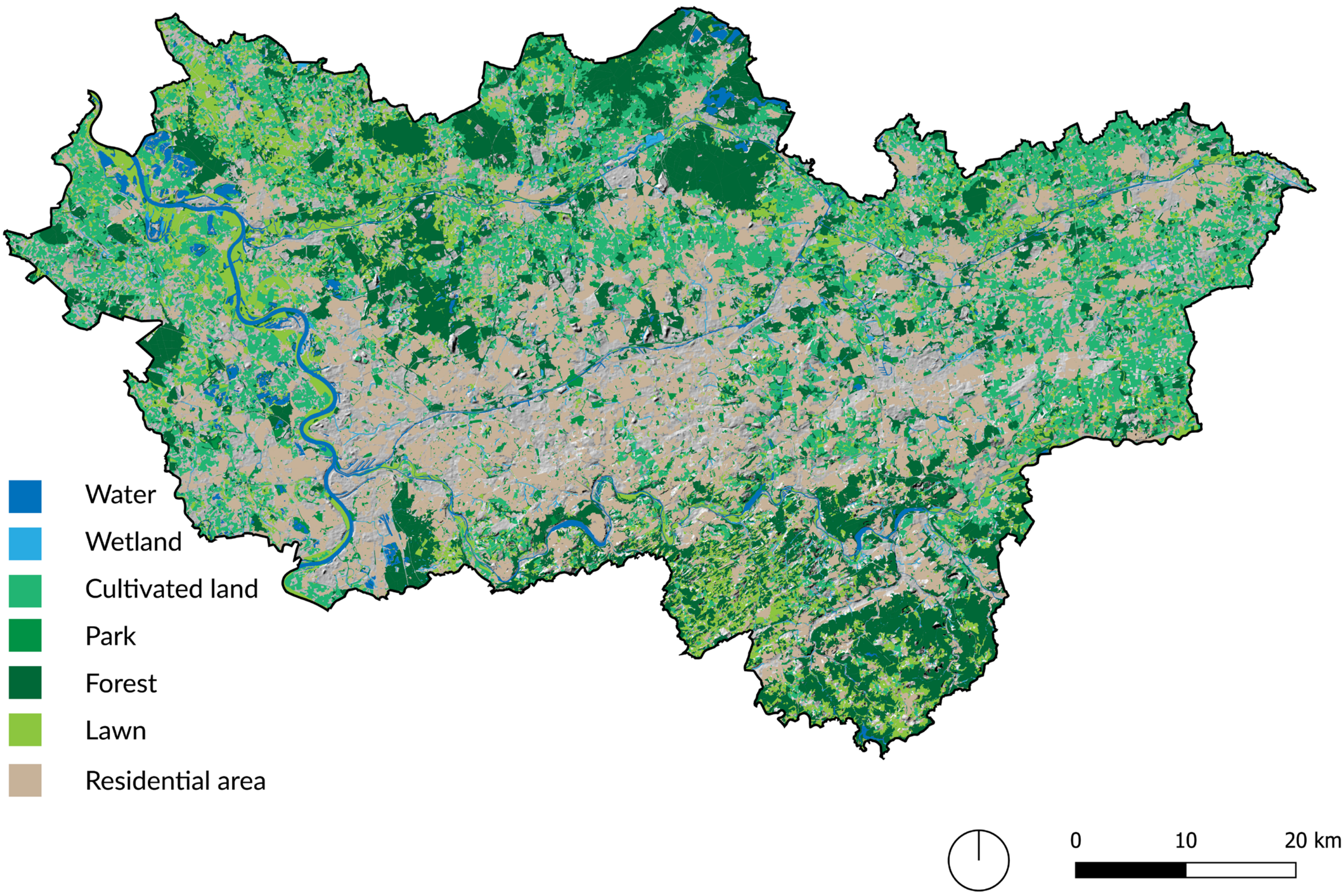


Figure 66: Current spatial manifestation of ecosystem services (author, 2022. Derived from Copernicus, 2018).

When concluding on this analysis, we can describe that there is one urbanised patch, in a east-west direction. This urbanised patch is framed by rivers, as well as framed by several infrastructural networks. There are several parks and forests in the Ruhr. However, these are located around the urbanised patch and not inside it.

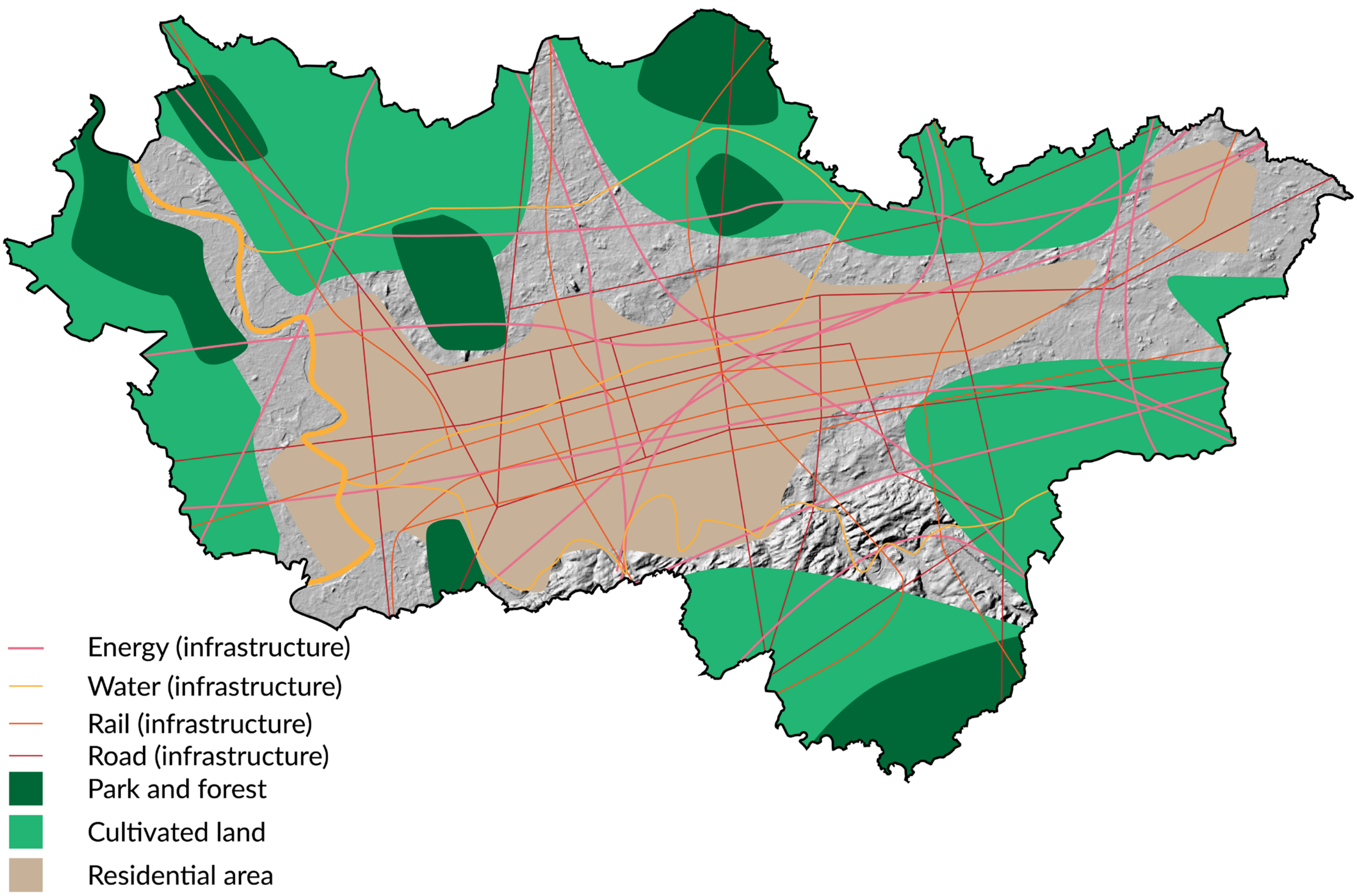


Figure 67: Concluding image of analysis (author, 2022. Derived from Copernicus, 2018).

Chapter 09. Uncertainty in global warming and energy consumption

i. Relation between global warming and energy consumption.
ii. Variables in uncertainty.
iii. Scenarios.
iv. Principles for uncertainty; resilience.

As mentioned before, specifically in chapter 7, paragraph 5, global warming and energy consumption are related. The main component of the relation is carbon dioxide. The emission of carbon dioxide as a consequence of production for energy for the sectors Industry, Residential, Transport and Trade & services and the other sectors makes up two thirds of the overall emission of greenhouse gasses (Gielen et al., 2019).

By executing the energy transition, thus producing energy using renewable energy sources and reducing the primary energy consumption, we can reduce the carbon dioxide emission as a consequence of the energy sector (Gielen et al., 2019).

This mitigating of climate change, has an effect on the amount of global warming we, the Ruhr area and the society, will experience (Gielen et al., 2019). This mitigating is done – partially - by the energy transition. The geopolitical notion on carbon dioxide taxes is excluded from this thesis, due to time constrains.

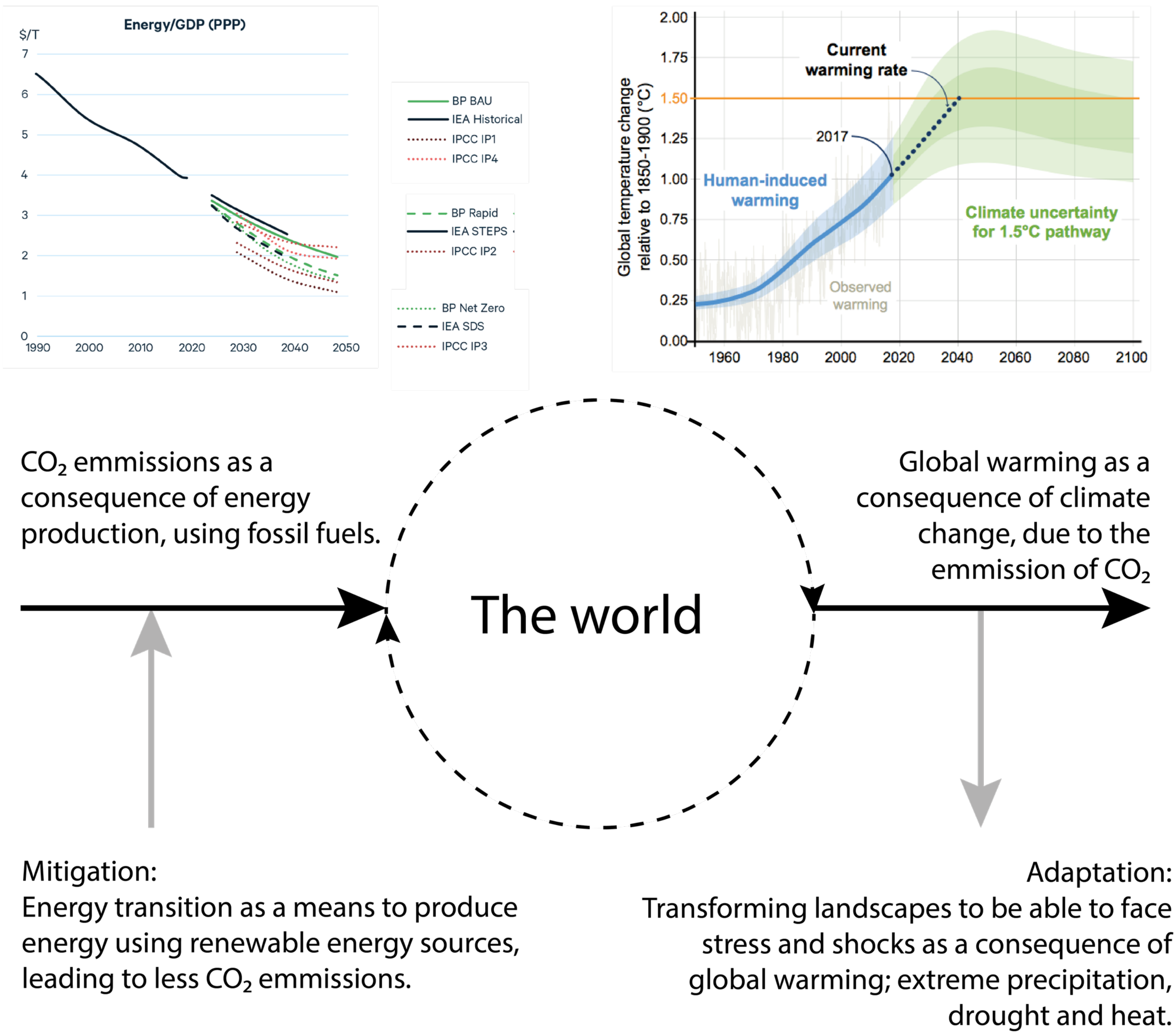


Figure 68: Relation of CO2 emmissions and global warming (author, 2022. Derived from Nasa, 2019 and IPCC, 2021).

ii. Variables in uncertainty.

Certain variables are of key essence to be able to describe the scenarios. Before these scenarios can be described, these variables should be defined. In the scenarios, the two variables on the axis are that of the global warming and primary energy consumption. These variables are directly related to the spatial manifestation of climate adaptation and energy transition. A decrease or increase in primary energy consumption has a spatial component through the increase or decrease in demand to produce energy using renewable energy sources. This changed demand has to be covered by increasing output, by adding windmills or solar panels to the landscape of the Ruhr area. The level of global warming results, among others, in a rising sea-level with an increasing flood risk. Furthermore, extreme precipitation asks for increased buffer capacity to retain the water. These notions all have a spatial component, in adding floodplains, heightening dikes or adding green-blue infrastructure in urbanised area to retain water.

As the IPCC (2022) indicated, we are moving towards global warming of +1.2 °C compared to pre-industrial revolution times. And if we do not act now, we are likely to move towards a +3.0 °C temperature rise compared to pre-industrial revolution times. Furthermore, Wupperstal university expects a decline in primary energy consumption for the Ruhr area, ranging from 0,28 till 0,38 PJ (Regionalverband Ruhr, 2017).

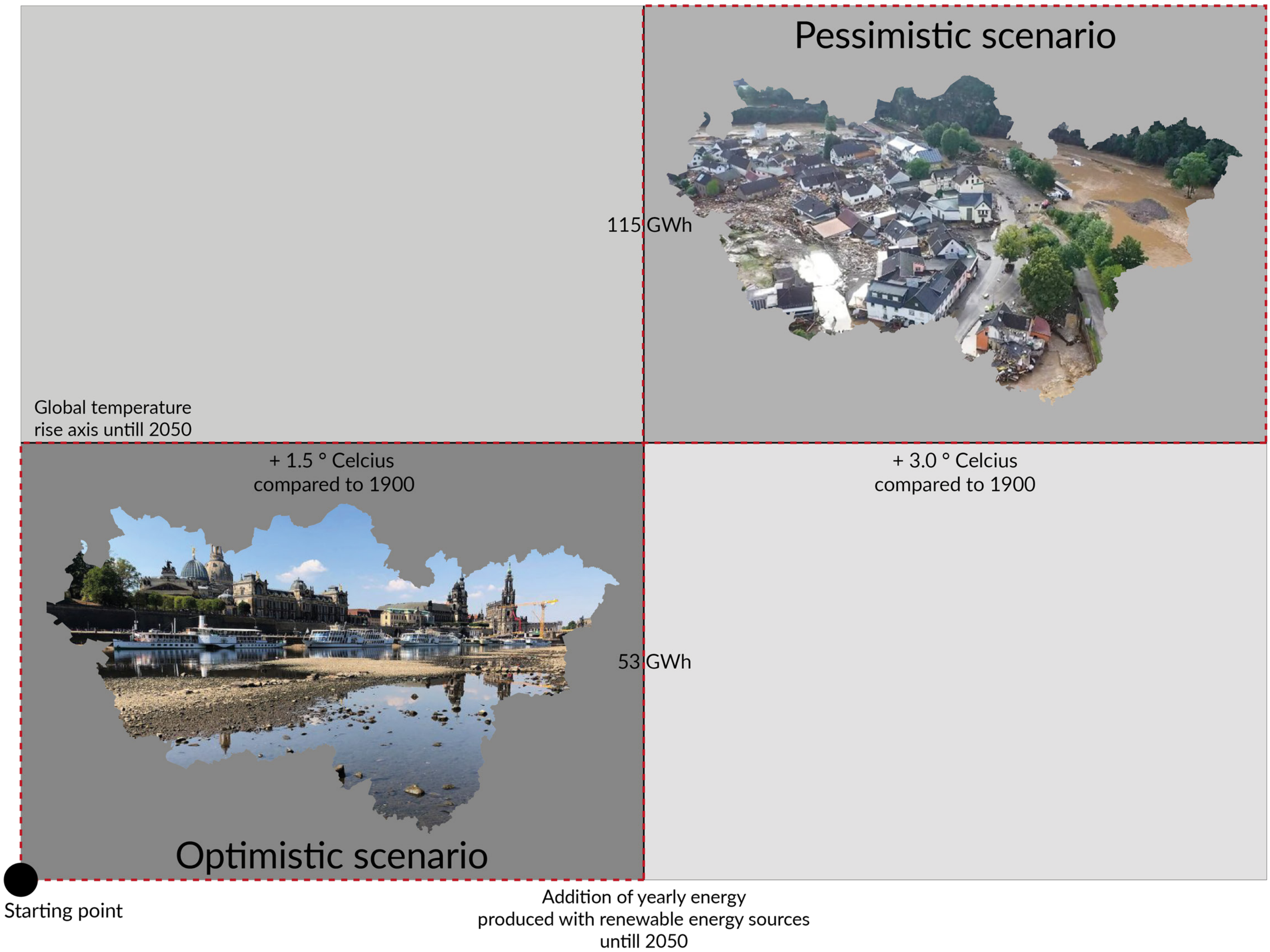


Figure 69: Proposed scenarios (author, 2022).

To be able to create and propose a context for the implementation of design solutions, several scenarios for the future of the Ruhr area, are proposed.

Four different scenarios are proposed, based on literature on the chosen variables. For the sake of this thesis, the optimistic and pessimistic scenario have been chosen to work with, since these are expected to become reality. By focussing on two different scenarios it becomes possible to place these different scenarios in the strategy and see if, and if yes, how these scenarios affect the strategy, and vice versa. Figure 70, possibly, indicates how these scenarios are linked over time.

Based on literature review and several calculations, the different values on the climate axis were composed. The difference on the climate axis is that the global temperature rise will be +1.5°C rise or +3.0°C rise compared to pre-industrial revolution temperatures. The IPCC (2021) indicated that we are currently moving towards a +1.2°C rise but if we do not execute the energy transition, we will move towards a + 2.5°C rise or even towards a +3.0°C rise compared to pre-industrial revolution times.

Based on literature review and a calculation, the different values on the energy axis were composed Regionalverband Ruhr, 2017). The current primary energy consumption, and the amount of energy produced using renewable sources was defined. This created a percentage of current energy production using renewable energy sources. This can be juxtaposed to the goal of percentage of energy production using renewable energy sources as well as the expected primary energy consumption. This resulted in the creation of a scenario where 0,25 PJ was produced using renewable energy sources, which is the goal for 2030. In this scenario, half of the energy is produced using other – non-renewable energy sources- sources, such as fossil fuels. The other scenario, the maximum, defines a demand of 0,5 PJ. This demand is the expected primary energy consumption for the year of 2050. The goal for that year is to only produce energy using renewable energy sources, so no energy is produced using fossil fuels.

Due to time constrains, the decision was made to focus on two different scenarios. These are visualized in figure 69. We define the scenario in the left bottom corner as the optimistic scenario and the scenario in the top right corner as the pessimistic scenario.

The optimistic scenario.
In the optimistic scenario, the Ruhr area has experienced a optimistic temperature rise of +1.5°C compared to pre-industrial revolution times. Furthermore, the Ruhr area is producing 50% of its primary energy consumption using renewable energy sources. This resulted in a optimistic demand of 53 GWh produced by renewable energy sources on a yearly base.
Due to the temperature rise, the climate has changed. The Ruhr area is experiencing higher maximum of precipitation on a daily base, as well as on the maximum of a five day precipitation period. The maximum precipitation on a daily base can increases up to three times as the current maximum precipitation. Furthermore, the maximum temperature can rise up to 6 degrees on top of the current maximum temperature, as a consequence of the climate change. These consequences of the climate change result, for central Europe specifically, in droughts, heatwaves and increased precipitation. This can be described by the intensification of the water cycle, as a consequence of climate change. This intensified water cycle results in intense rainfall and intense drought. The global temperature rise of this scenario, is expected to occur in the coming decades (Jacob et al., 2018).

In the pessimistic scenario.
In the pessimistic scenario, the Ruhr area has experienced a optimistic temperature rise of +3.0°C compared to pre-industrial revolution times. Furthermore, the Ruhr area is producing 100% of its primary energy consumption using renewable energy sources. This resulted in a optimistic demand of 115 GWh produced by renewable energy sources on a yearly base.
The climate change described in the optimistic scenario has further intensified. Extreme events happening once every 20 years, will now happen once every 4 years (Jacob et al., 2018). Furthermore, heat extremes would reach critical thresholds for agriculture and health (IPCC, 2021). Health, agriculture (e.g., crop yields) and tourism are all affected by reductions or increases in water availability (Jacob et al., 2018). Under global warming, a European-wide increase in the frequency of some types of extreme events such as extreme daily or sub daily precipitation and heat waves is expected. the extreme events related to the water cycle are expected to increase the most; heat waves, maximum/optimistic temperature, heavy precipitation etc. (Jacob et al., 2018).

The scenarios are defined as complete as possible. However, especially in regards to global warming consequence, there are still several uncertainties. Extreme events will occur more often and when they occur, will be more extreme than we now know. However, exactly how often and exactly how extreme these events will be are still unclear. This notion is further elaborated in the discussion.

The scenarios are placed on a timeline, since it is possible that the optimistic scenario will be succeeded by the pessimistic scenario. These scenarios formed the base for the next chapter. The following chapter, indicates how the strategy and the scenarios are related and what the consequence of changing scenarios are on the strategy and vice versa. The following chapter indicates how the design solutions will be transformed to a strategy, and which planning instruments are required.

Uncertainty and design do not provide a useful context for design. However, when we review literature on resilience, we can compose several principles for our design, without defining the exact context. This notion of resilience is derived from the literature and proposes several key systemic characteristics. These key systemic characteristics can be applied to the notion of ecosystem, to cover the ecosystem services of climate adaptation and energy transition.

These principles for uncertainty formed the base for the design exploration to propose design solutions, which will be elaborated in the following chapter.

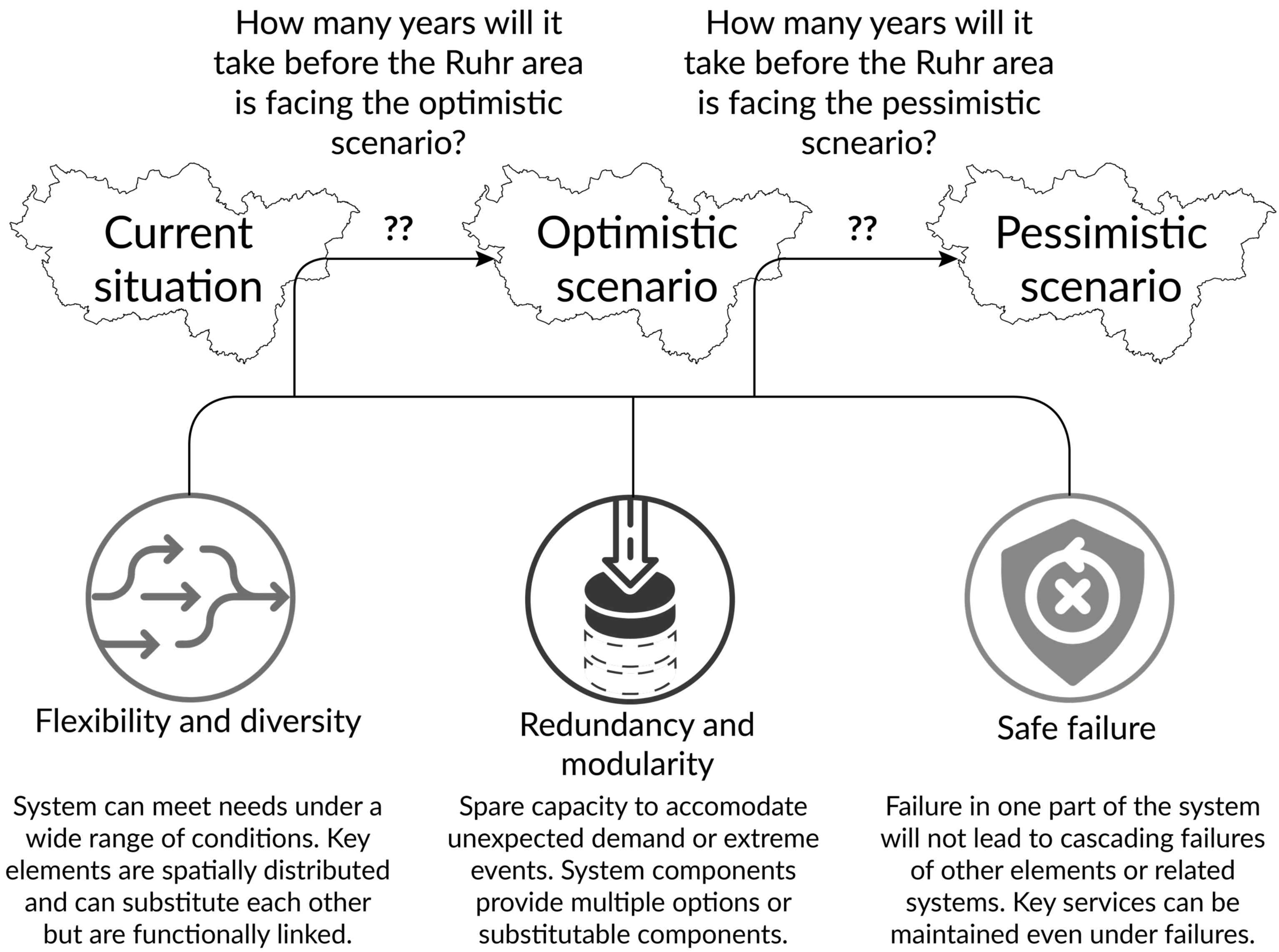


Figure 70: The relation of the current situation and the proposed scenarios, linked with system characteristics for resilience (Author, 2022 based on Tyler, Moench, 2012).

Chapter 10. Design exploration

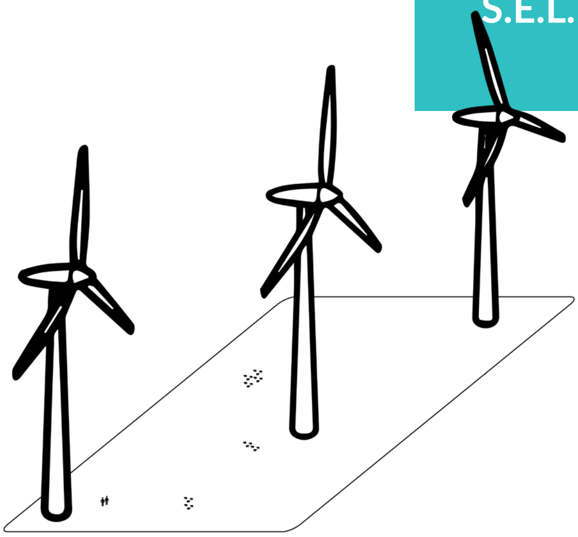
This chapter will focus on creating a framework of design solutions on how to implement climate adaptation and the energy transition in an integrated way, while remaining flexible to the changing context.

The design exploration of this chapter will focus on the construction and implementation of concepts that define solutions for climate adaptation and the energy transition. We start this design exploration with mono-layered design solutions. These mono-layered design solutions are derived from literature (Lee & Kim, 2021; Pasqualetti & Stremke, 2018; Sijmons, 2014). These mono-layered design solutions are proposed both for climate adaptation (c.a.) and for sustainable energy landscapes (s.e.l.). Two examples are shown here, while all the mono-layered design solutions, as well as their evaluation, can be found in the appendix.

These design solutions are first reviewed individually, to see if these mono-layered design solutions can be transformed to multi-layered design solutions, depending on their spatial contextual relation. This transformation, from mono- to multi-layered design solution is executed in the following paragraph.

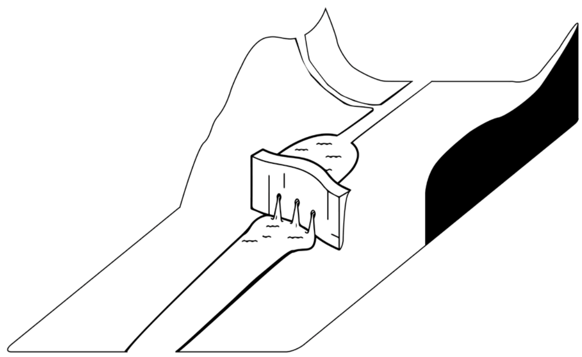
Wind-mill park

S.E.L. 1



Dam & reservoir

C.A. 4



+
possibility to compose multi-layered solutions, since ground level can be used in a different way.

Possibility to use, otherwise uncreachable locations.

-
Huge impact on landscape, destroying morphological structure of current landscape

Certain functions are excluded from being implemented on ground level, due to safety mainly.

+
Can serve as a ecologic node/corridor.

Counter UHI.

Can be covered in solar panels

Can serve as water retention, added to a network.

-
Geographically huge impact on landscape, by changing morphological layout

Figure 71: Mono-layered design solutions (author, 2022).

Chapter 10. Design exploration

ii. Spatial contextual relation.

The goal off this chapter is to create a framework for design solutions, which aid in climate adaptation and the energy transition. For this to happen, the mono-layered design solutions have to be transformed to multi-layered design solutions.

This transformation, from mono-layered to multi-layered, is done analysing the respected spatial contextual relation of these mono-layered design solutions. The spatial contextual relation is described using a framework derived from Dupuy (2008). This is based on the definition of the three levels of network operators, which I describe here as the geographical context, functional context and the network.

This framework was used as to describe the spatial contextual relation of each of the mono-layered design solutions. The description of the spatial contextual relation of each of the mono-layered design solutions can be found in the appendix. These mono-layered design solutions were transformed to multi-layered design solutions, based on similarities in their spatial contextual relation. This is elaborated further in the following paragraph.

Spatial contextual characteristics

Physical (Geographical, topological, morphological) context
open green spaces - missing open green spacces
open grey spaces - missing open grey spaces
height (in relation to surrounding) - missing height (in relation to surrounding)
built environment (urban, peri-urban area)
unbuilt environment (rural area) - missing unbuilt environment

composition, fragmentation/concentration, dimensions, accessibility, orientation.

Function
types of landuse (residential, industrial, leisure, network, public space, commercial, mining, quarry, forest, park, education, meadow, retail, storage, logistics, transportationinfrastructure, river, stream canal)
diversity of landuse - mono-functionality
types of building
function of building
diversity of function - mono-functionality
proximity to certain function - minimum distance to certain function

composition, fragmentation/concentration, dimensions, accessibility, orientation.

Network
corridor of network - missing corridor of network
node of network - missing node of network
network operators (type of operator, consumer/producer)

composition, connectivity, fragmentation/concentration, dimensions, accessibility, orientation.

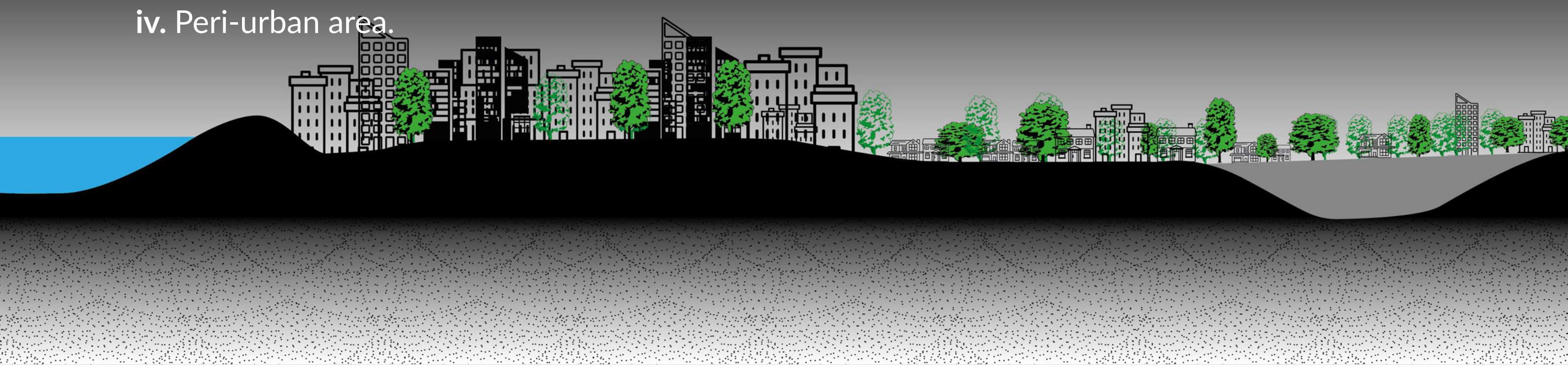
Figure 72: Spatial contextual relation framework (author, 2022. Derived from Dupuy, 2008).

The spatial contextual relation formed the base for the multi-layered design solutions. These multi-layered design solutions are mentioned in figure 73, with their respectively energy producing and climate adapting component mentioned.

These multi-layered design solutions are implemented in five areas of the Ruhr area, to see how this design solutions interact with their surroundings and which conclusions can be drawn based on this implementation. These five areas are defined as patches. According to Vigano (Pisano, 2018), patches are ''elementary units, designed as discrete entities within the territory, characterized by an inherent tendency to the transformation based on the relations between them and with the ecological substrate on which they insist (patch dynamics)''. This notion will be further elaborated in the following paragraph.

Multi-layered design solution	Climate adaptation component	Energy landscape component
Wind corridor + windmill/microwind	Wind corridor	windmill/microwind
Wind corridor + urban creek	Wind corridor + urban creek	urban creek
Low roof (urban farming + solar)	urban farming	solar
High roof (microwind + solar)		High roof (microwind + solar)
Artificial wetland + floating pv panels	Artificial wetland	floating pv panels
Water in urban areas (hydropower)	Water in urban areas (hydropower)	Water in urban areas (hydropower)
Water in urban areas (hydrostorage)	Water in urban areas (hydrostorage)	Water in urban areas (hydrostorage)
Microgrid + green streets + densification (counter mono-functionality)	green streets	Microgrid
Green streets + urban farming	Green streets + urban farming	
Urban farming + park (adding public functions)	Urban farming + park (adding public functions)	
Urban farming + solar + microwind	Urban farming	solar + microwind
New canal / river + hydropower (in case of extreme high tide)	New canal / river	hydropower
New canal / river + solar	New canal / river	solar
New canal / river + wind	New canal / river	wind
Park + urban solar elements	Park	urban solar elements
Park + water retention / urban creek	Park + water retention / urban creek	
Ribbonpark + solar	Ribbonpark	solar
Ribbonpark + microwind	Ribbonpark	microwind
Park + hydropower	Park	hydropower
Park + hydrostorage	Park + hydrostorage	hydrostorage
Connectivity road + solar + wind		solar + wind
Connectivity rail + solar + wind		solar + wind
Expansion wetland + algea	Expansion wetland	algea
Urban creek + algea	Urban creek	algea
Urban farming + biomass	Urban farming + biomass	Urban farming + biomass
Green streets + biomass	Green streets + biomass	biomass
Art & energy. Urban solar elements in park	park	urban solar elements
Art & energy (urban solar elements) in leisure axis		urban solar elements
Urban shading elements, green roof + solar panels	green roof	solar panels

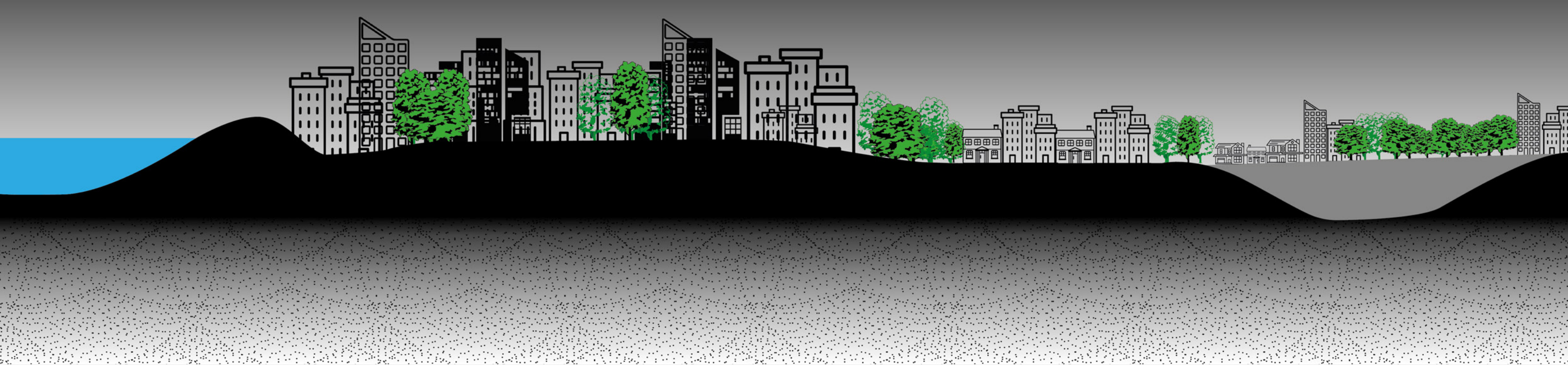
Figure 73: Multi-layered design solutions (author, 2022).



Due to the spatial configuration of the Ruhr area, which can be described as a peri-urban area, this patch, the peri-urban, is analysed separately. Based on literature review (Silva et al., 2017), several characteristics of the peri-urban area are mentioned with their relation to renewable energy production as well as climate adaptation.

The literature reveals several key relations between green areas, compactness, proximity to public transport, proximity to central business districts and energy consumption (Silva et al., 2017). If the optimistic energy consumption is the key design principle, the peri-urban area we now know as the Ruhr area, will change. This change is visualized in figure 75. The outcome of this transformations raises the questions if this proposed peri-urban area can be classified as a peri-urban area. With the majority of the rural spatial characteristics removed, the proposed area can be described as a compact urban area with several green areas in between. Furthermore, the literature raises several notions on the relation between urban networks and energy usage. As described in the theoretical framework however, the peri-urban area can be described as a consequence of sprawl, where the car dominates the spatial manifestation of an area. This, the position of the car, has to change as well. Public transport, as well as accessibility has to be increased in order to minimize energy consumption as a consequence of the spatial configuration of the area.

The second sub-question - How does a peri-urban area designed on the maximalisation of energy consumption & production looks like and what does that result in when applied to the Ruhr area? - can be answered based on this information. A peri-urban area designed for the optimistic energy consumption is an area that is highly accessible, compact, with several green areas surrounded by a dense and diverse urban area. The remaining patches will now be described.



Characteristics of a peri-urban area	Relation to energy consumption and production
Built environment:	
Density	Reduces energy demand by bringing urban activites closer and shoretns travel patterns.
Green areas	Reduces energy demand by offering cooling and shading
Compactness	Reduces energy demand for cooling and heating
Passivity	Reduces energy demand by offering cooling and shading
Shading	Reduces energy demand by offering cooling and shading
Orientation	Orientation towards son could increase or decrease energy demand for cooling
Urban networks:	
Connectivity	Connectivity (spatial configuration of the urban network) reduces energy demand for travel
Accessibility	Accessibility (ease of reaching desired destination) reduces energy demand for travel
Centrality	Centrality to central business district reduces energy demand for travel
Proximity to public transport	Reduces energy demand by offering shared mobility, reducing energy demand for sole user (compared to car)
Design (provision of trees)	Reduces energy demand by offering cooling and shading
Design (shading effect of vegatation)	Reduces energy demand by offering cooling
Design (parking lots provisions)	Reduced green (cooling) on street
Sprawl	Increases energy usage by fuel demand

Figure 74: Spatial characteristics and their relation to energy. Applied to the systemic section of the Ruhr. Top left; current situation. Top right; design based on energy consumption and production (author, 2022. based on Silva et al., 2017).

v. Patches.

The Ruhr area was spatially analysed, focussing on different patches. Based on their presence and relation to climate adaptation and the energy transition, a choice was made to zoom in to five different patches. These patches, as well as their location, are visualized in figure 77.

These five patches visualize different spatial characteristics in the Ruhr area. These differences offer a base for the design exploration, to implement multi-layered design solutions into the area and compose and define design principles and a hierarchy. The remaining patches that were found while spatially analysing the Ruhr area placed in the appendix.

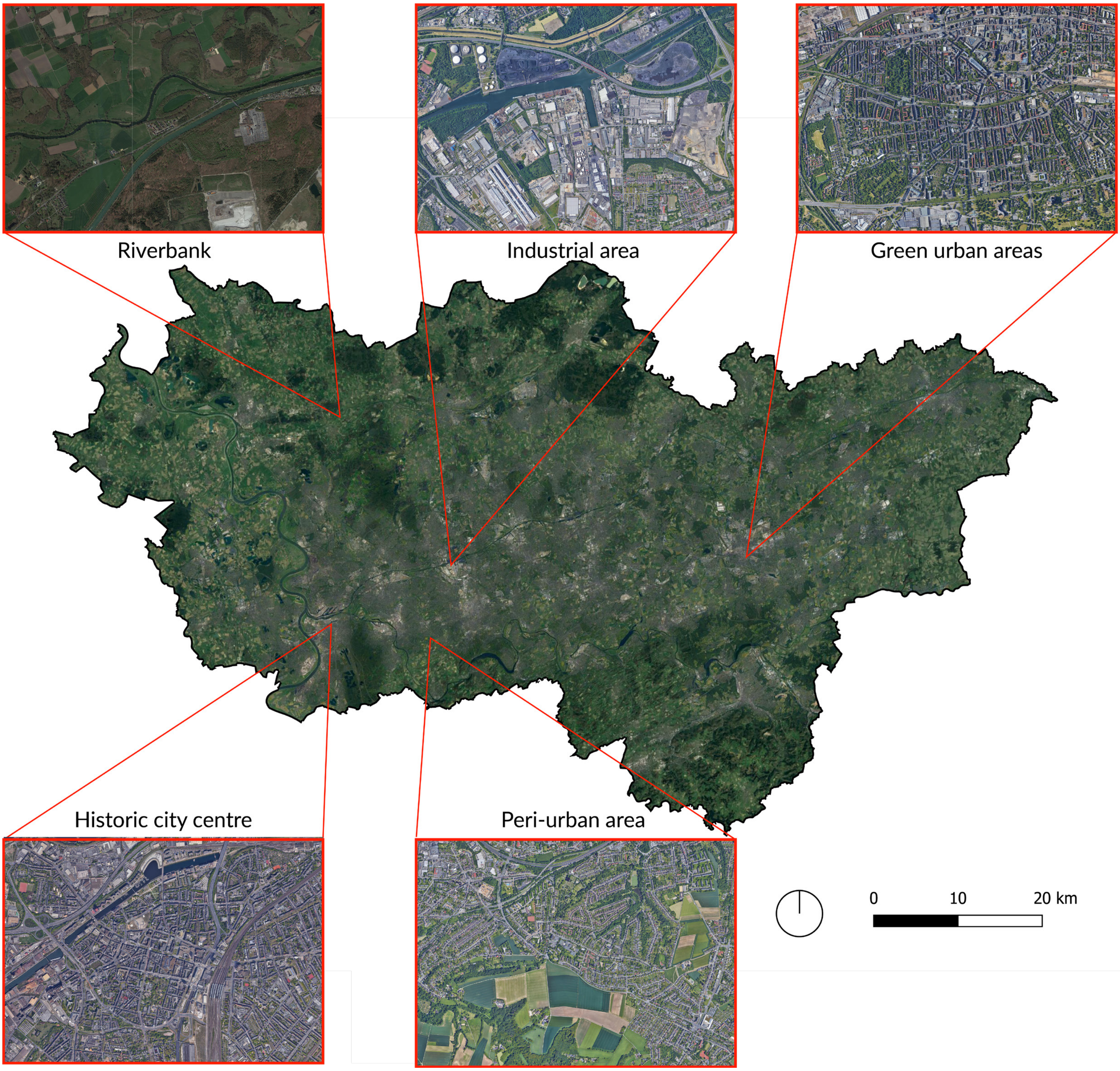


Figure 75: Satellite image of the Ruhr area with the five different patches (author, 2022).

Prior to the actual design exploration, several key design principles were constructed. These principles were derived from literature review, indicating how ecosystem services can be enhanced in urban areas. These principles are: street trees, lawns, parks, urban forests, cultivated land, wetlands, lakes, sea and streams. These principles were derived from Bolund & Hunhammar (1999). Strengthening the ecosystem in these areas, as it forms a base for climate adaptation as well as energy landscapes. The strengthening of ecosystem services is done using green-blue infrastructure (Elmqvist et al., 2015).

The scenarios, proposed in paragraph 9.5, describe the future of the Ruhr area. These scenarios define a context where the design solutions will be implemented in and create several issues, such as a certain energy demand or the presence of extreme weather events. These contextual notions shape the design process and the overall design outcome.

Following the description of the scenarios, it is proposed that extreme weather events will occur more often and, additionally, these events will be more extreme. For the Ruhr area, the extreme weather events will most likely be extreme drought, extreme precipitation and extreme heat. This formed the base for research in design solutions and design principles for extreme drought, precipitation and heat, using literature review and reference studies. Following this research, several design principles were defined. They propose infiltration, evotranspiration, capturing and reusing storm water through permeable pavement or green-blue infrastructure. These principles are visualized in figure 77.

For each patch, a problem map is proposed, indicating what problems this patch is facing. Following this problem map, a design is proposed, that counters the site specific problems and handles consequences from the optimistic or pessimistic scenario. For each

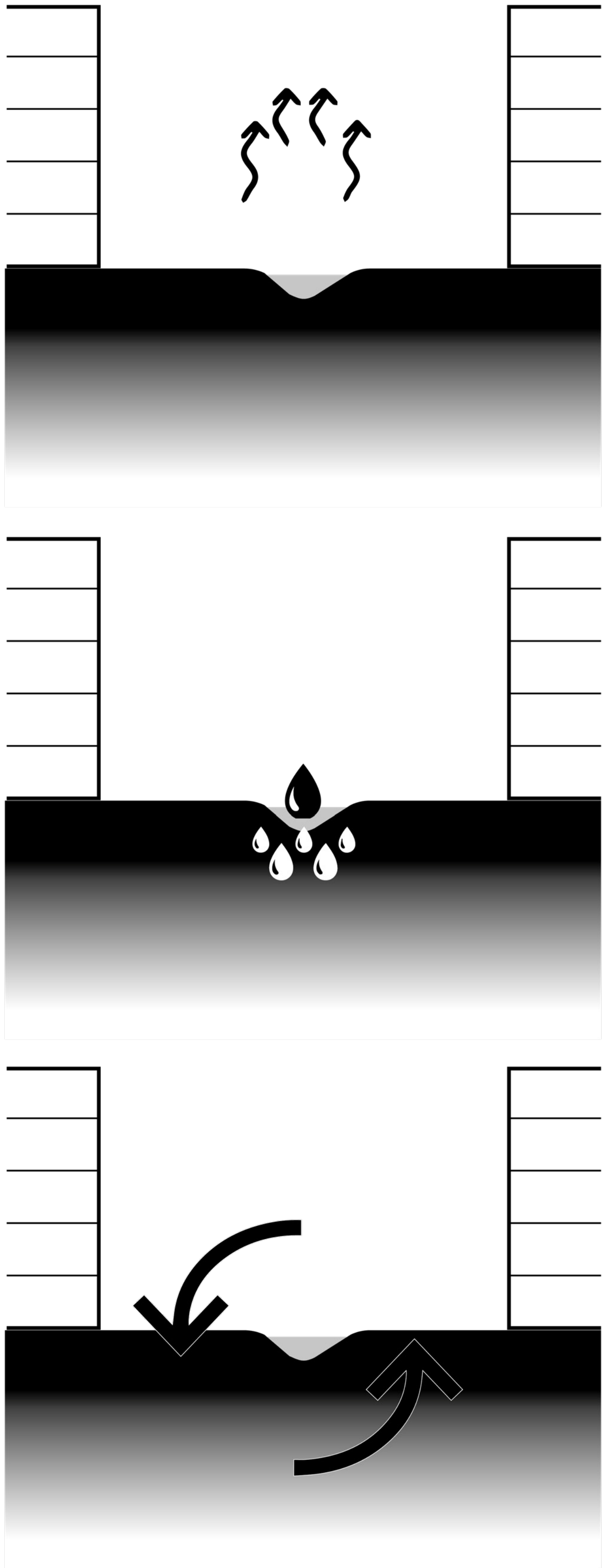


Figure 76: Principles for water sensitive urban design and sponge cities. Top to bottom; Evatransporation, infiltration and capturing and reusing of water (author, 2022. Derived from Coutts et al., 2012 and (Zevenbergen et al., 2018).

patch, the design concepts that I implemented are briefly mentioned. These design concepts will be further elaborated in the following paragraph. Following the problem map, design map for the optimistic and pessimistic scenario, a section and eye-level view is created. The location of these images is visualized on the map. These section and eye-level visualize the current spatial manifestation of the area. The concepts that were implemented in the designs, are now visualized in the zoomed in map, eye-level and section. The overall design principles, at the start of implementation of multi-layered design solutions into the patches, can be concluded as visualized in figure 78. This formed the base for the design exploration.

Other design principles derived from literature are adaptability through modularity and redundancy through flexibility. Adaptability through modularity can be achieved by focussing on ecosystem services as a base. By doing so, design solutions can be implemented throughout the Ruhr area. This results in adaptability - where the system can adapt to changing circumstances - through the implementation of design solutions, that can be implemented throughout the entire Ruhr area.

Concluding from the reviewed literature, the design principles were formulated as followed: adaptability through modularity, redundancy through flexibility and safe failure. These principles were formulated to reach the overall goal; strenghten ecosystem services. These design principles are visualized in figure 77.

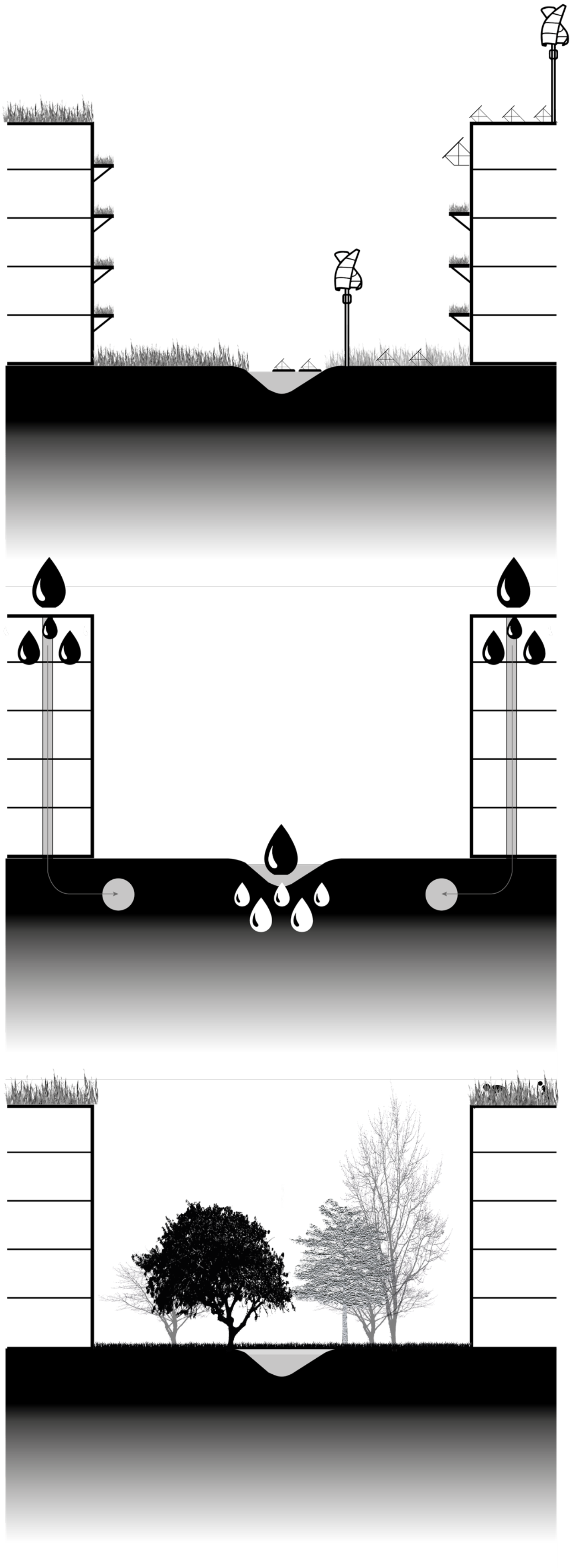


Figure 77: Principles for adaptability through modularity (top), redundancy through flexibility (middle) and ecosystem services (bottom) (author, 2022. Derived from Tyler & Moench, 2012).

The following paragraph shows the design exploration. The overall design approach is excecuted according to figure 78. This design exploration is done for the five patches, as mentioned in figure 75.

For each patch, a analysis is exceccuted to indicate current problems for each patch, and indicate what the proposed solutions are. The analysis is excecuted focussing on the current thermal quality. This is chosen because this can be related to ecosystem services, as one of the functions of ecosystem is the regulating function, regulating the microclimate. Furthermore, the area is anlaysed to see if the patch is defined as a area with a flood risk.

Throughout this design exploration, several design solutions were defined. These design solutions are described as concepts, since they can change according to the changing scenario. The overall system is described using a map, with the chosen design concepts, zoom-ins using a eye-level view and section and a bird eye view is shown to indicate how the new system operates.

Each proposed design solutions per patch is assessed based on the three key functions of ecosystem services. They can be compared to the assesment of the current situation.

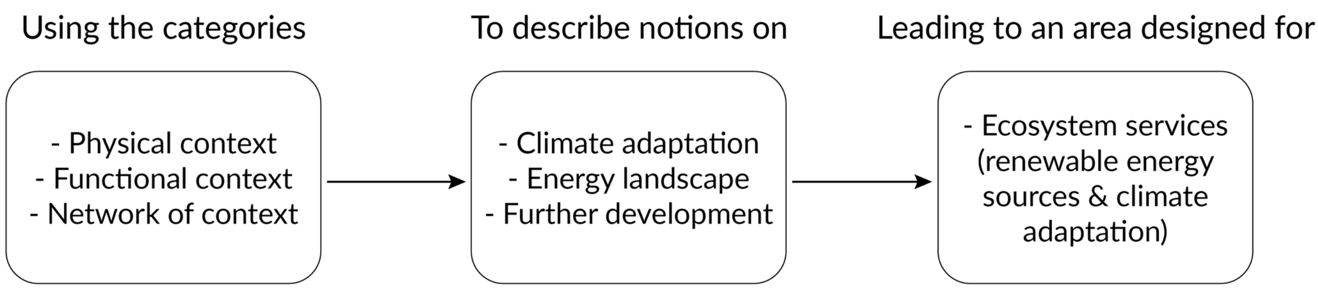


Figure 78: Design approach (author, 2022).

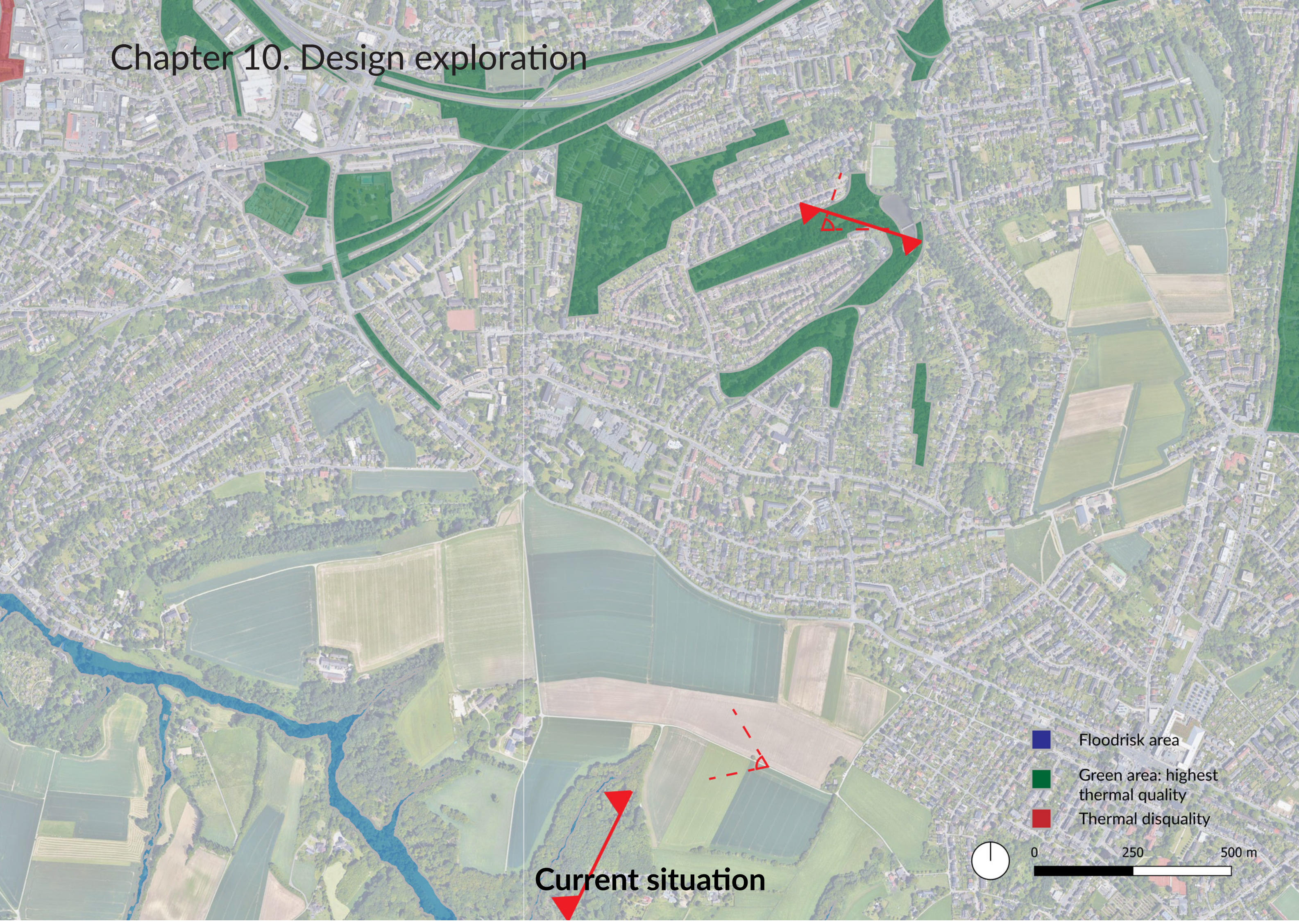
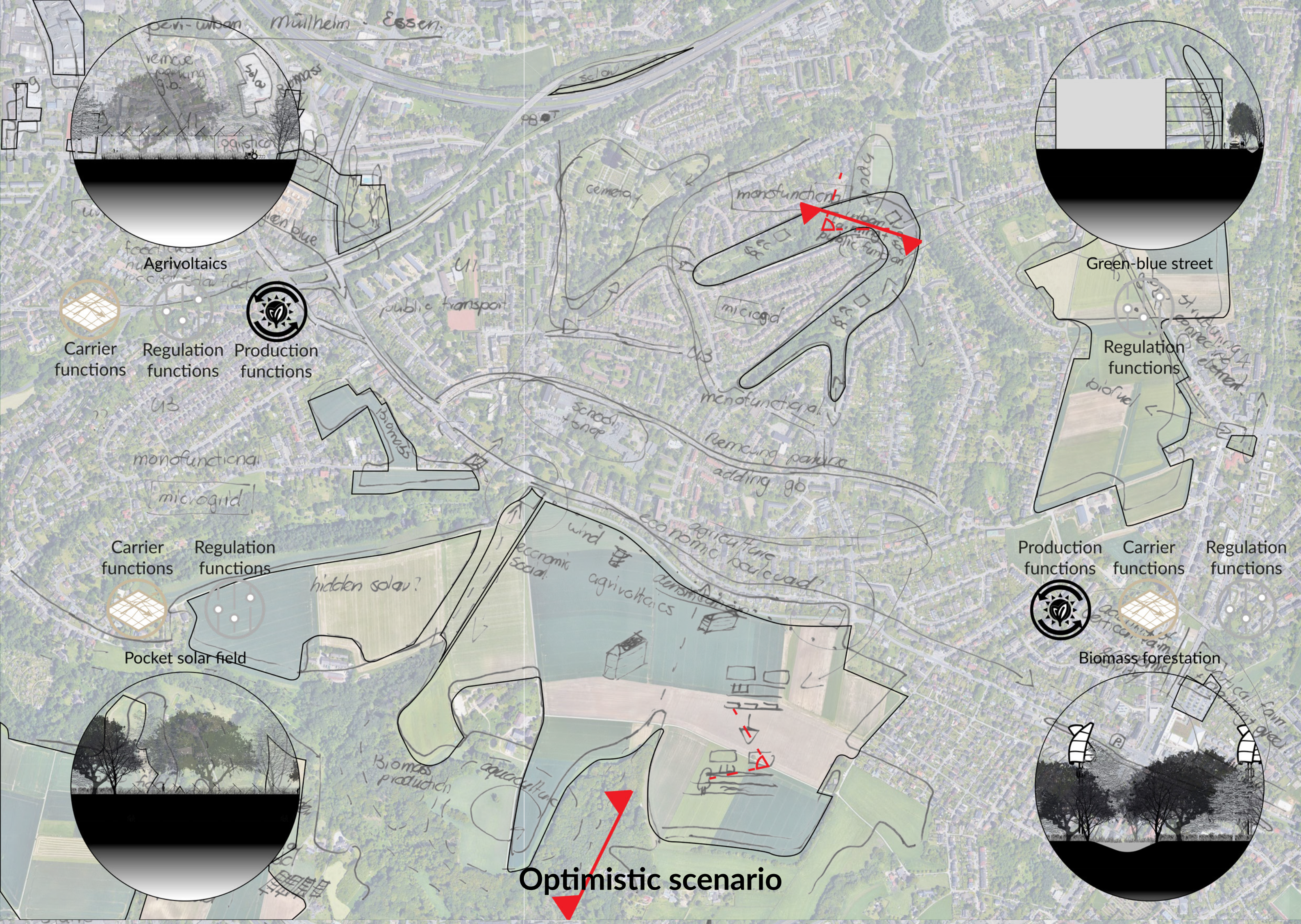


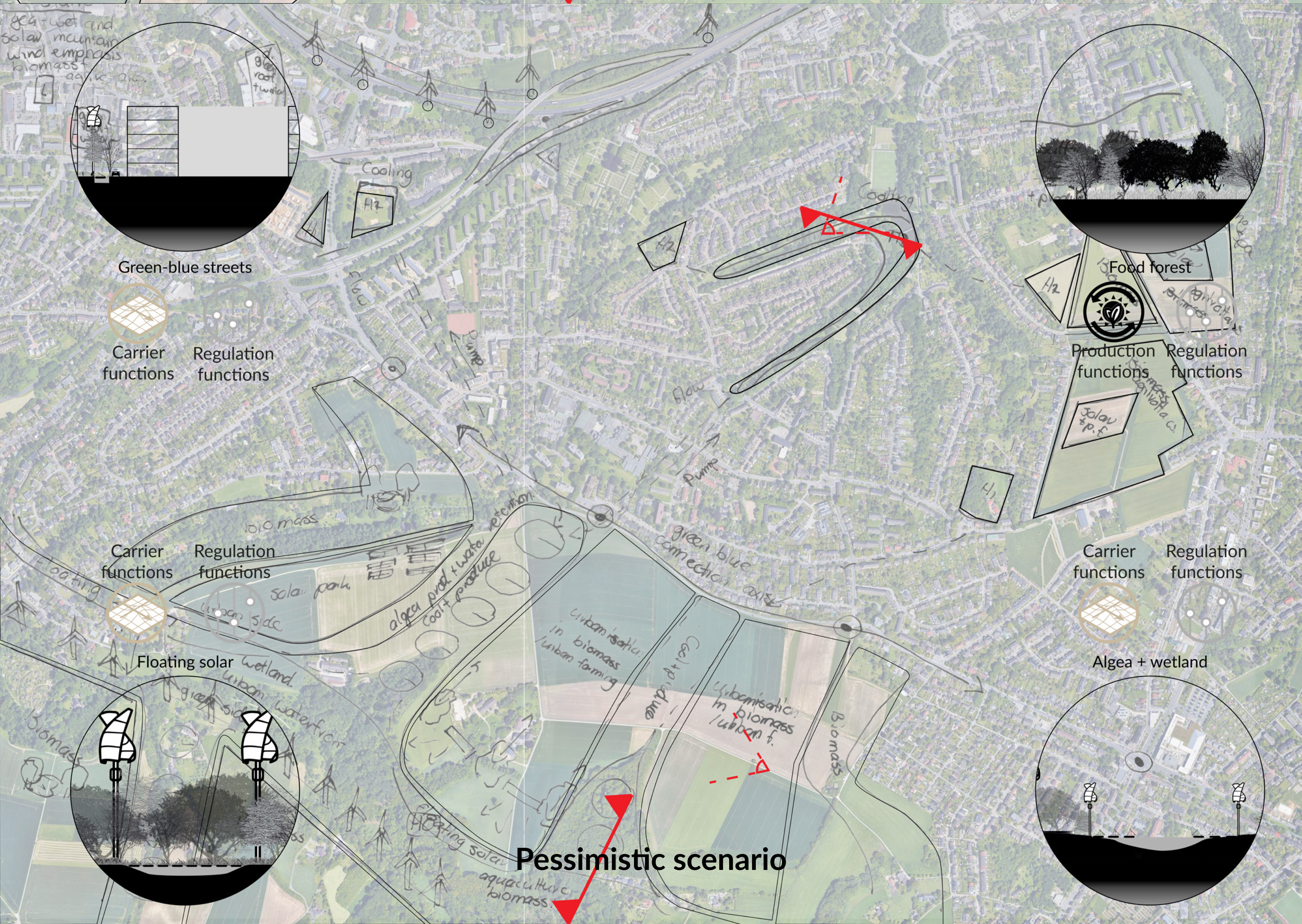
Figure 79: Current situation, optimistic and pessimistic scenario for the peri-urban patch with implemented concepts (author, 2022).

The peri-urban area faces several problems. To start, a clear gradation of urban to rural can be recognized. The urban area, in the north, with public transport as well as a highway slowly fades out into a rural area, in the south, with mono-functional agricultural areas. This agricultural area on the south-side of the area is defined as an area with a flood risk. Furthermore, the residential area of the peri-urban area is a total mono-functional area that is highly car-oriented. The urbanised area on the north-east side is highly urbanised, with a lack of permeable paving, creating an intensified water run-off to the lower agricultural area that is demarcated as a flood risk area.

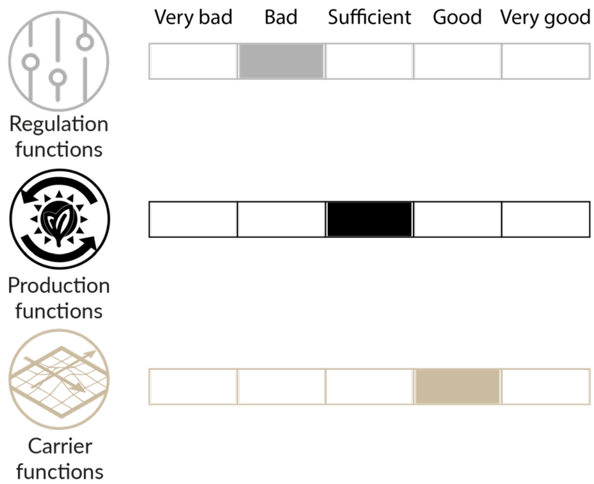
The design, that is visualized on the images on the right, Proposes a shift to a agri-, aquaculture and cultural area in the flood risk area, where the biomass production is intensified for the total area that is defined as a flood risk area. Furthermore, the agricultural area will transform to an agrivoltaics area, with selling points on the edge to the residential area. These selling points will be combined with shared mobility facilities and parking spaces. This frees up space on the streets, to implement green-blue streets, to further implement a green-blue network throughout the area. For the pessimistic scenario, the area defined as a flood risk area becomes an algae production area combined with a wetland area, with floating solar panels and wind emphasis.



Optimistic scenario



Pessimistic scenario

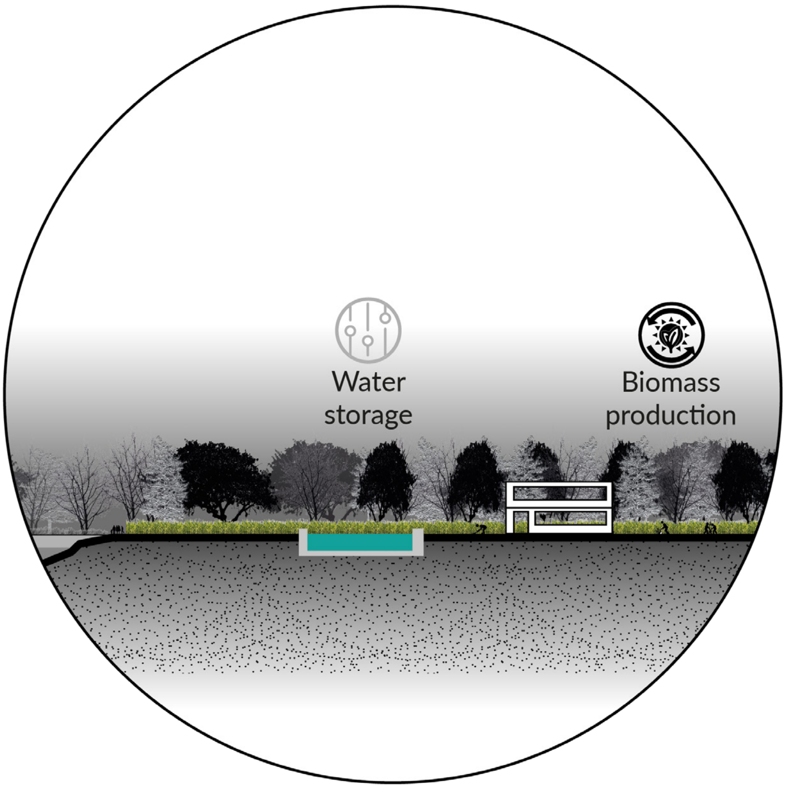


Current situation

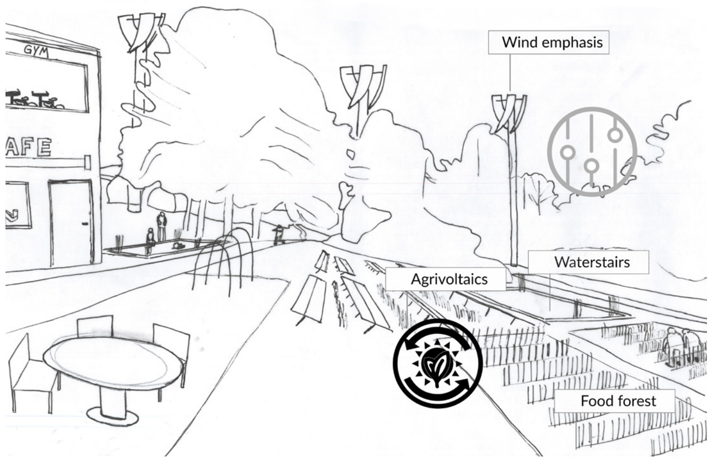
Figure 80: Current situation (above), optimistic (top right) and pessimistic scenario (bottom right) for the higher peri-urban in eye level view, map and in terms of ecosystem services score (author, 2022).

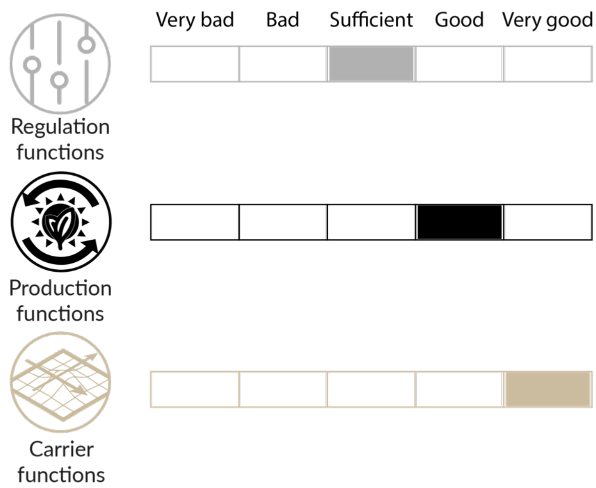
The current peri-urban area is a monofuncitonal residential area. By adding functions, other than residential, the monofunctionality is countered and the area is economically and socially strengthened.

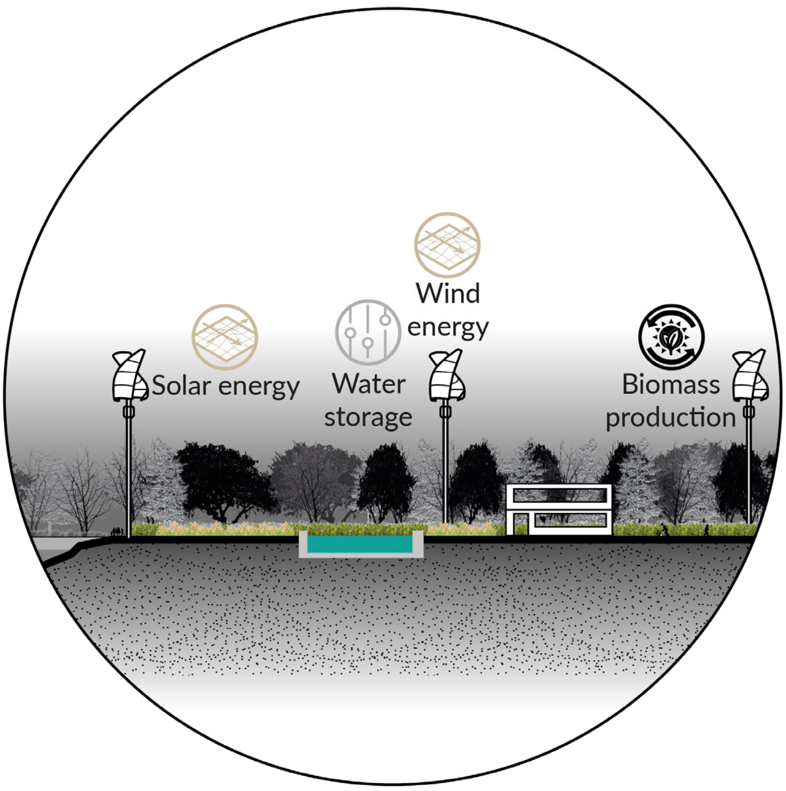
In the pessimistic scenario agrivoltaics and wind emphasis are added.



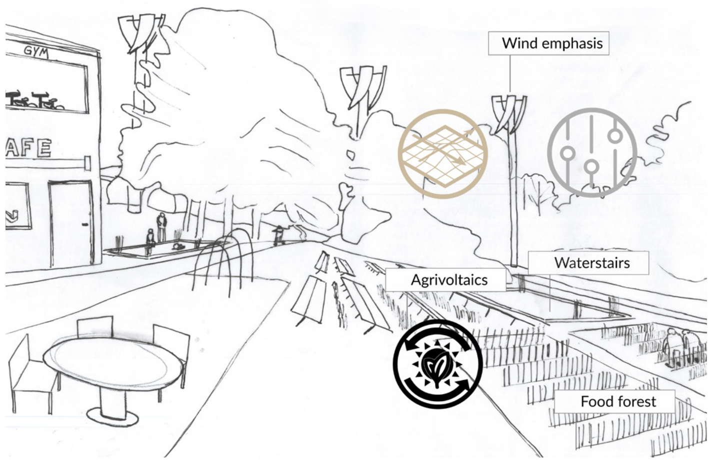
Optimistic scenario

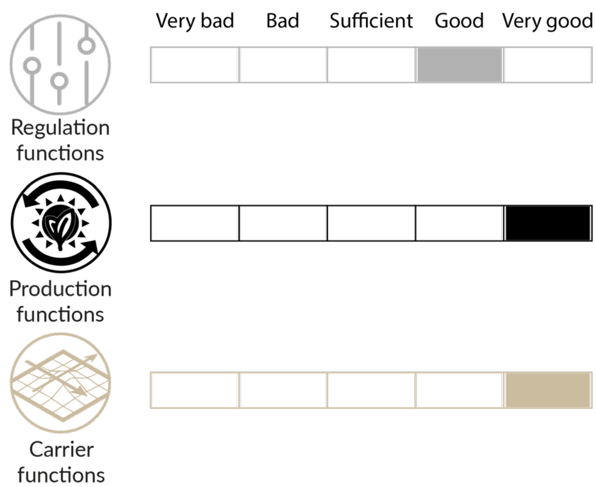






Pessimistic scenario





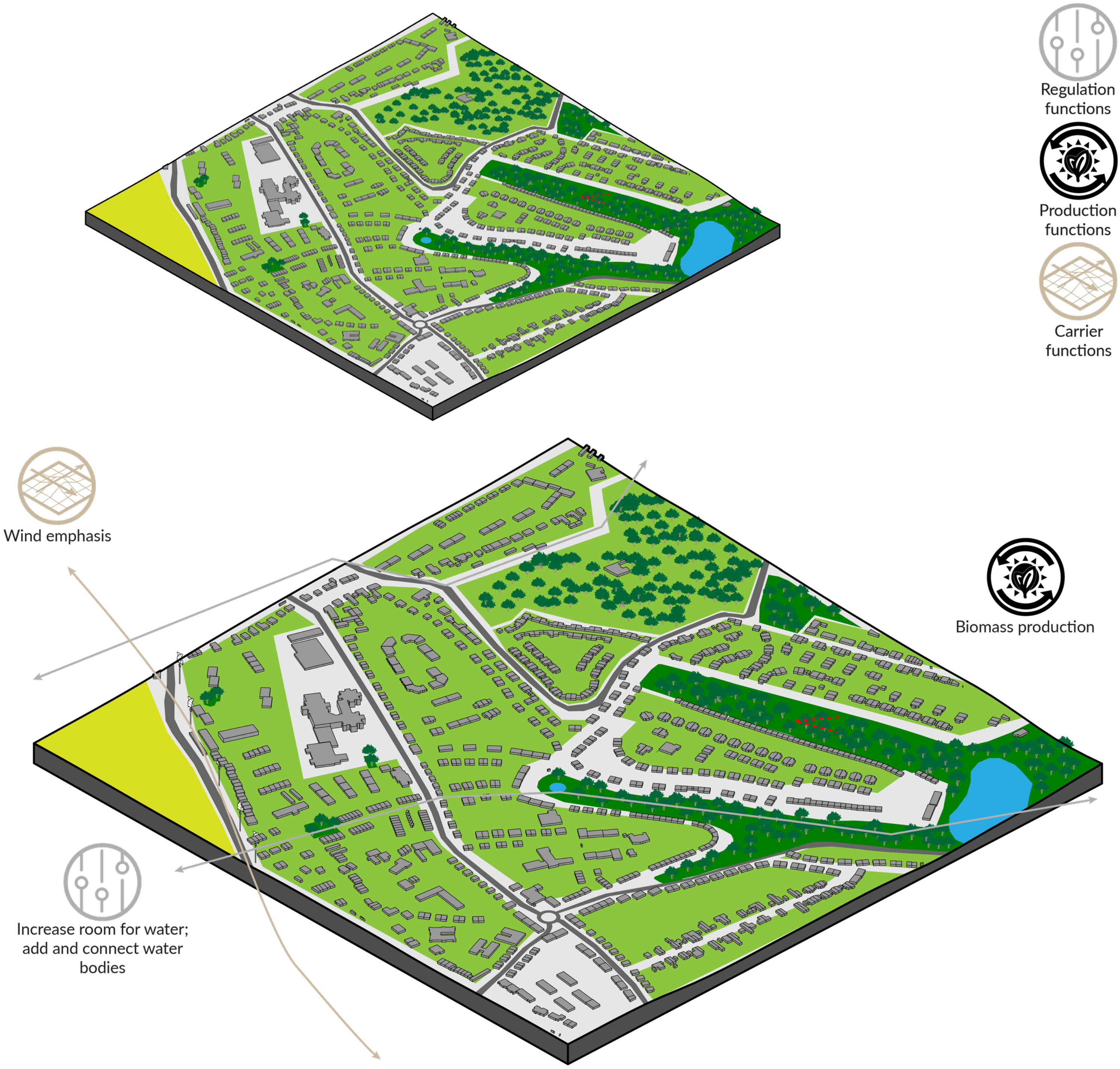
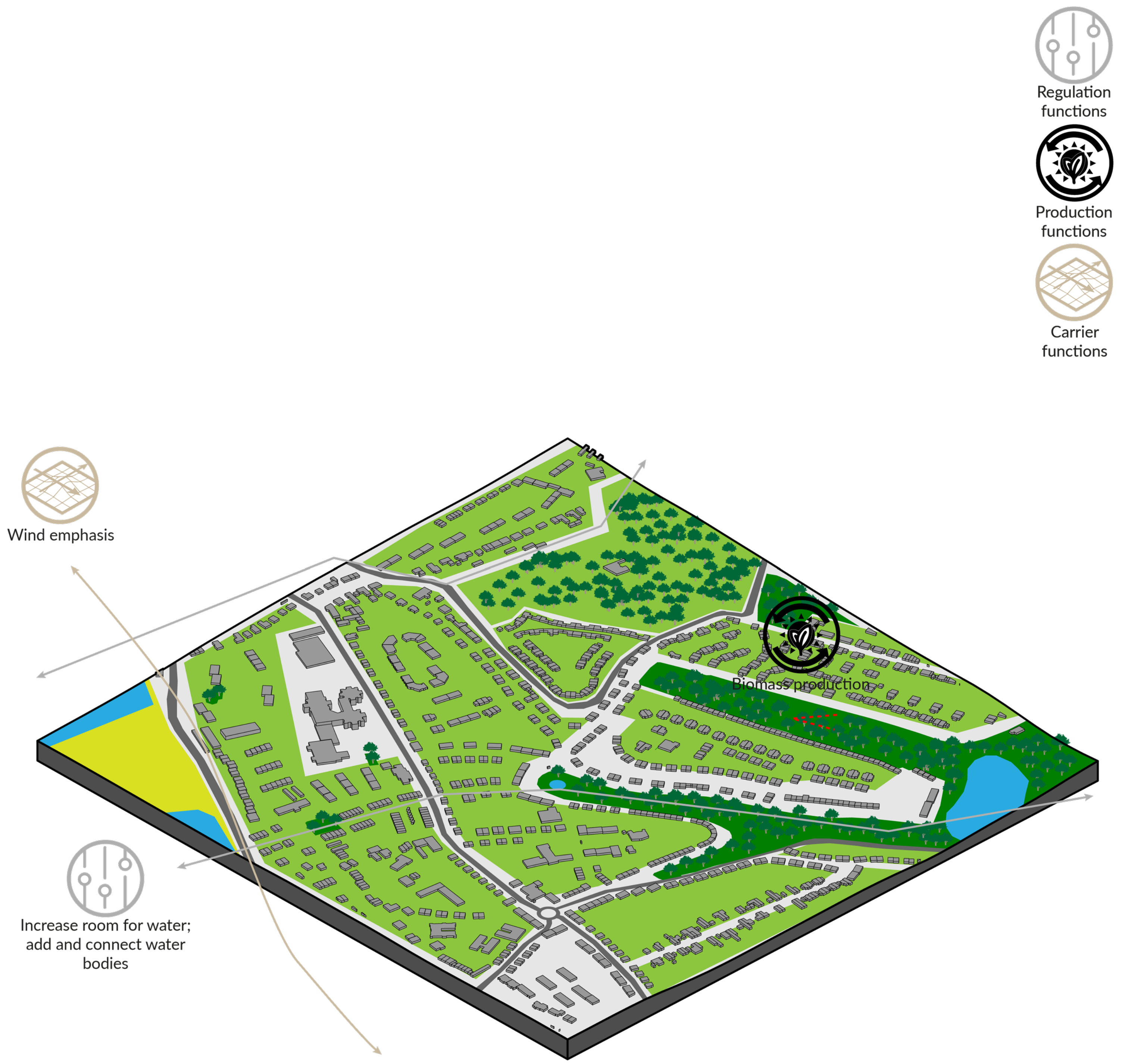


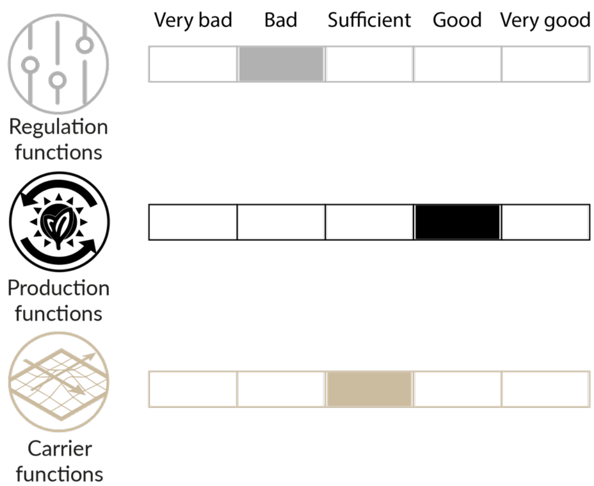
Figure 81: Current situatio
and pessimistic scenario (righ
bird eye view in terms of ecos
202



n (above left), optimistic (left) t) for the higher peri-urban in system services score (author, 22).

Current situation

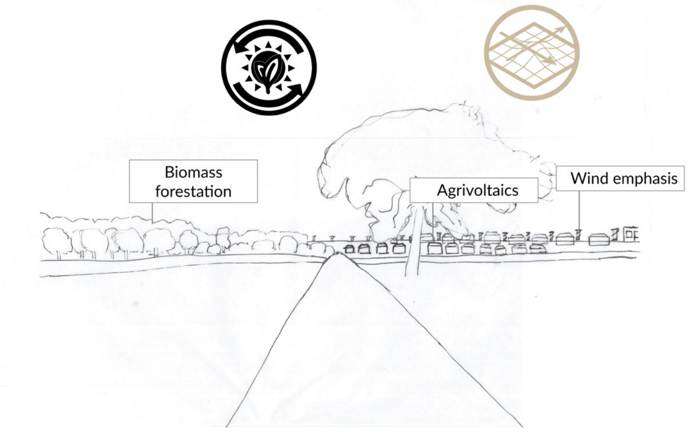
Figure 82: Current situation (above), optimistic (top right) and pessimistic scenario (bottom right) for the lower peri-urban in eye level view, map and in terms of ecosystem services score (author, 2022).

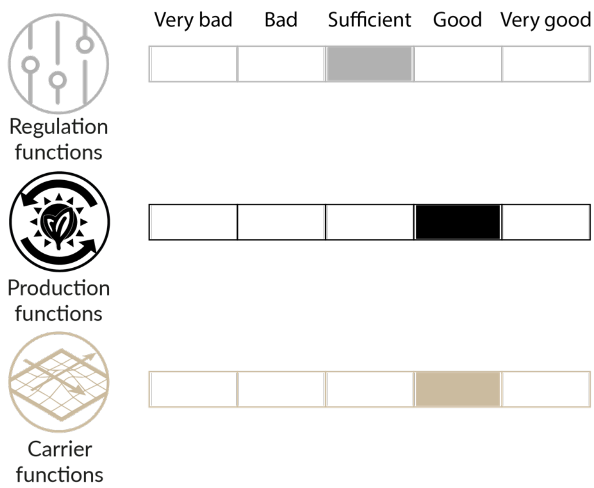


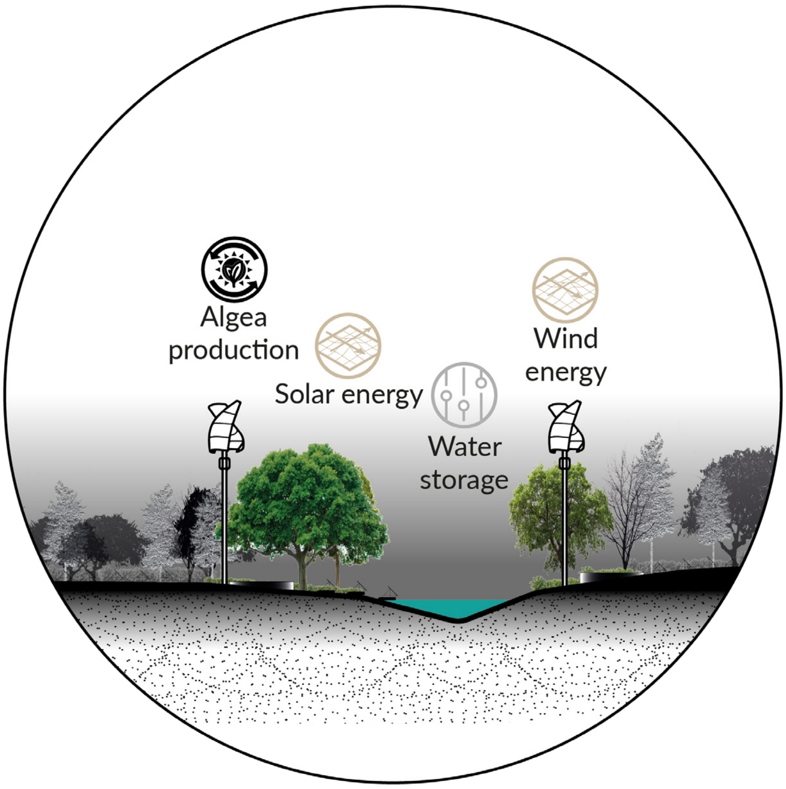
The current flood risk area is transformed to focuss on biomass forestation. The buildings located in the current flood risk area are moved. Furthermore, agrivoltaics are implmented, this increases production and ensures production, even in more arid climates. Next to that, certain lines in the landscape are emphasized using wind emphasis.

In the pessimistic scenario, the wetland is enlarged, to be able to accomodate the increased area defined as floodrisk. In this enlarged area allocated to water storage, algea production and floating solar panels are implemented, to ensure these areas are used, in times of drought but also in times of extreme precipitation.

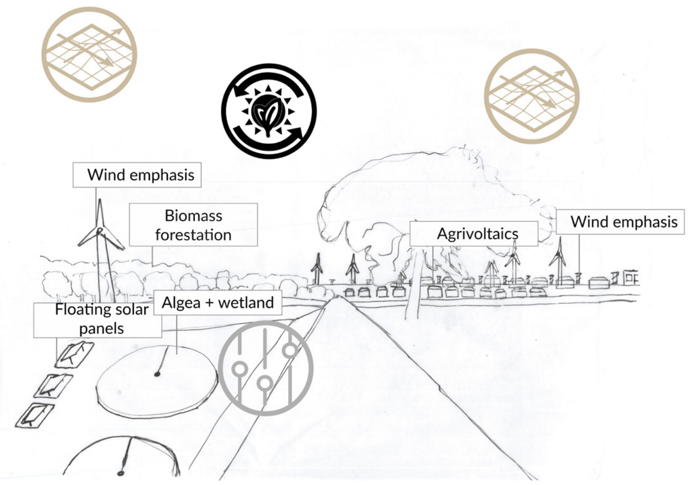
Optimistic scenario

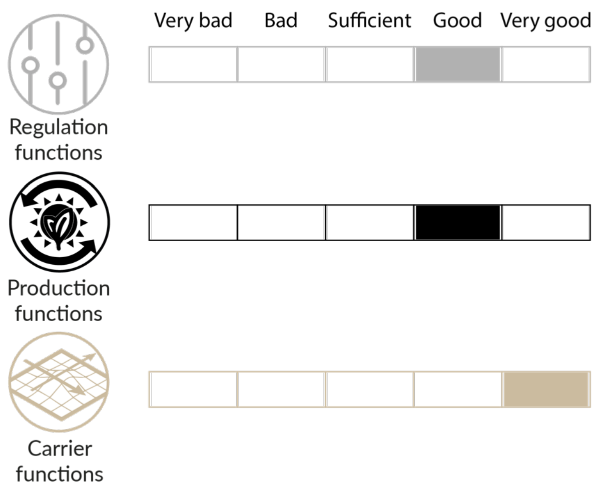






Pessimistic scenario





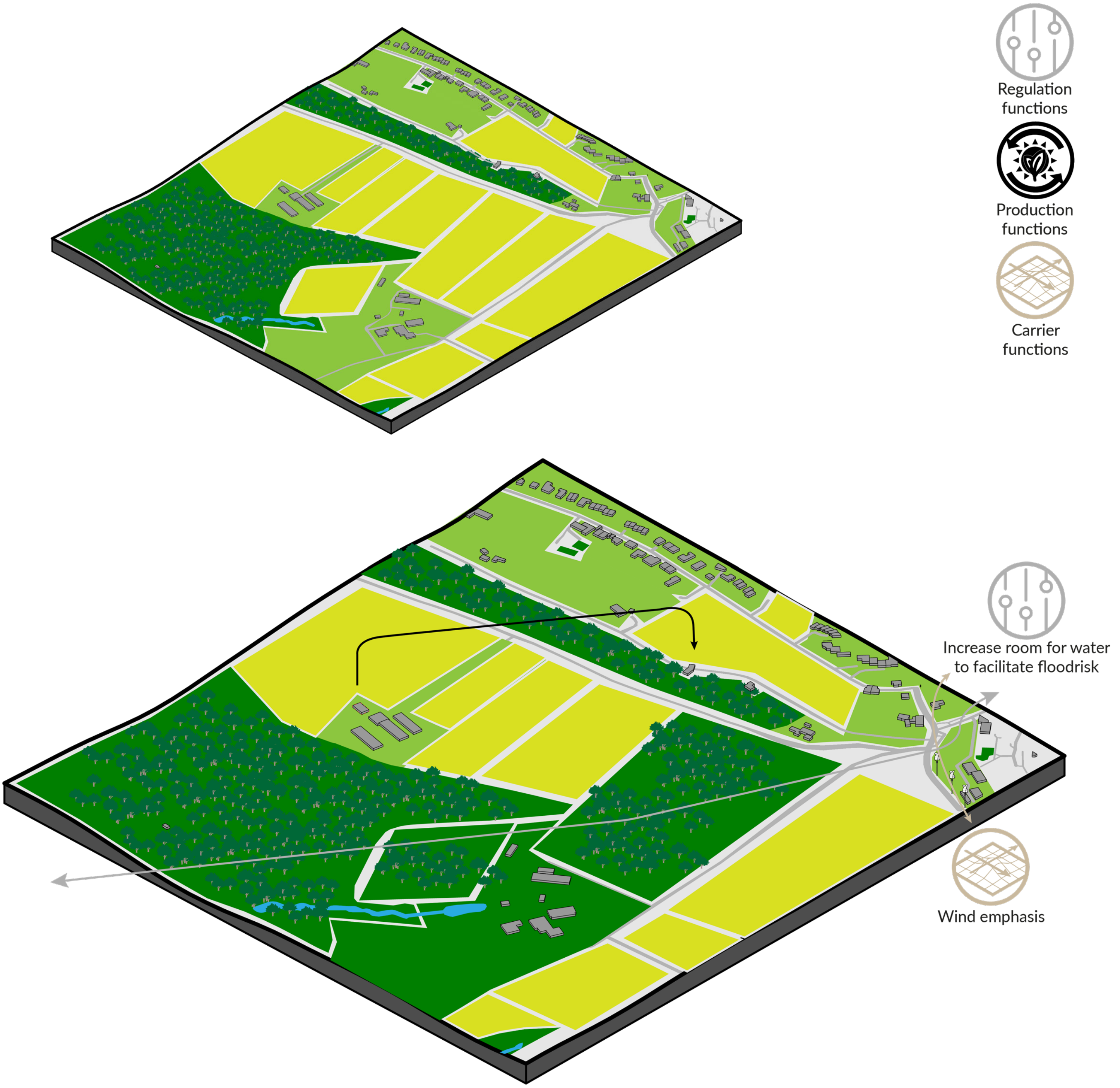


Figure 83: Current situatior
and pessimistic scenario (righ
bird eye view in terms of ecos
202

n (above left), optimistic (left)
nt) for the lower peri-urban in
system services score (author,
22).

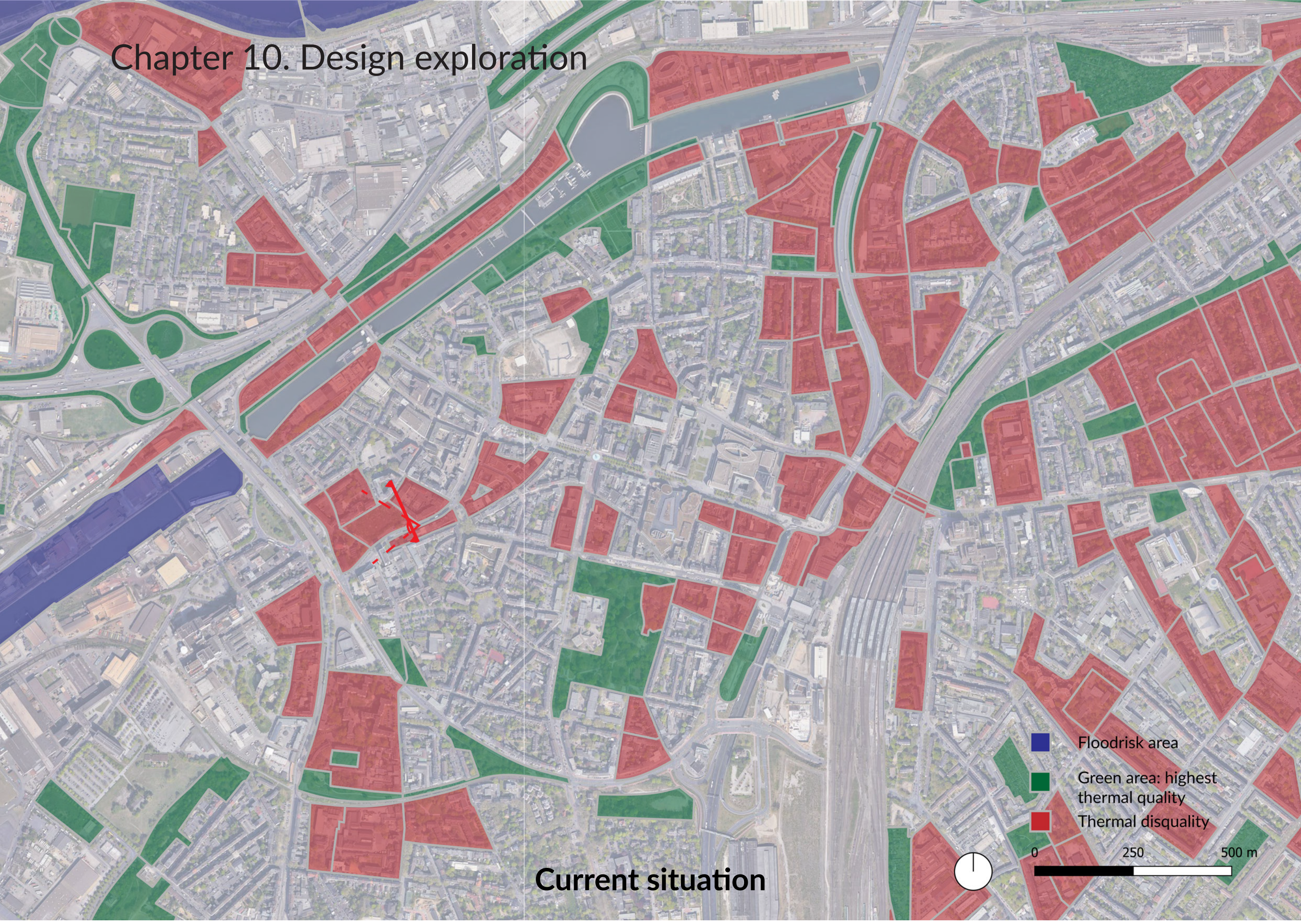
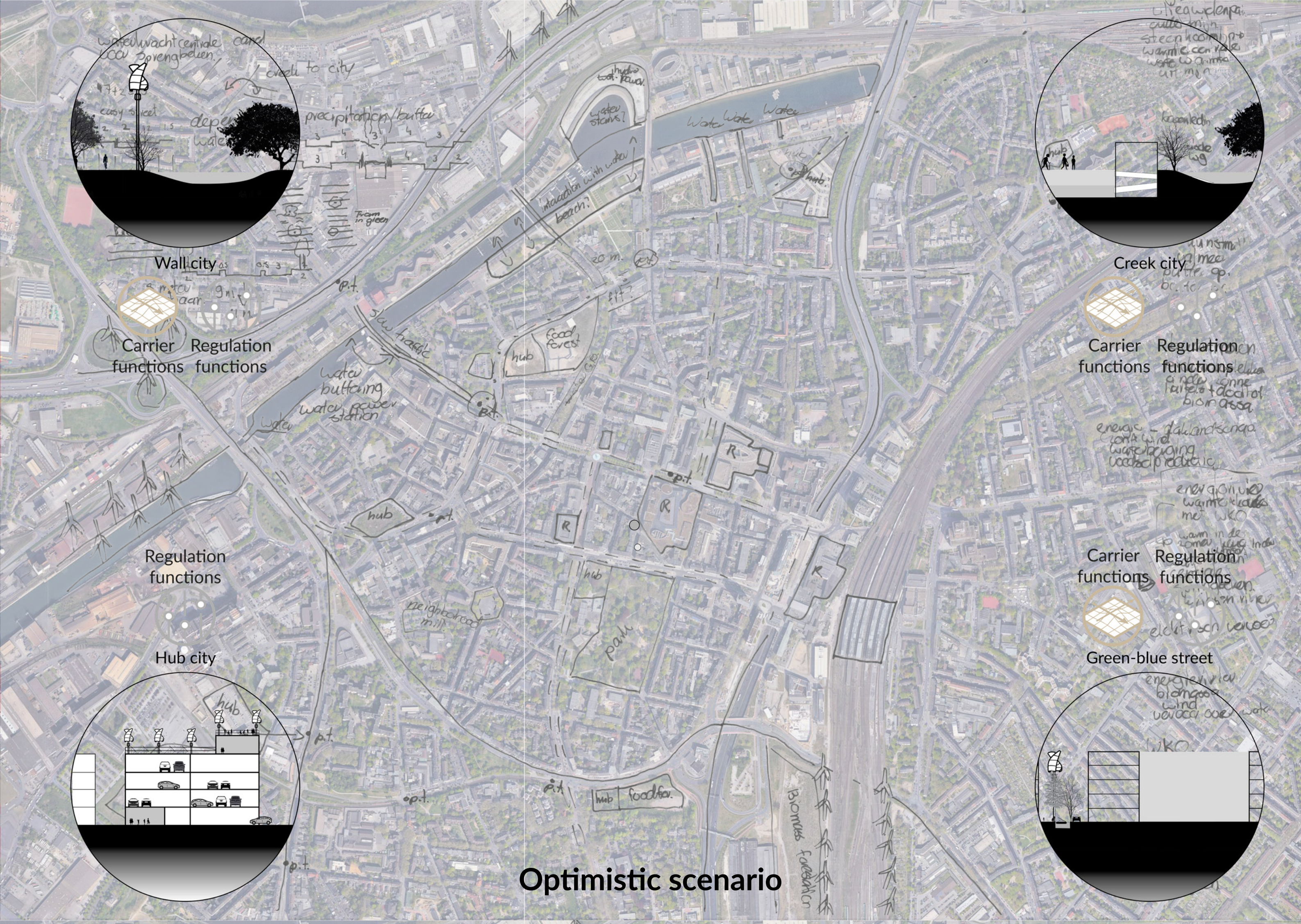


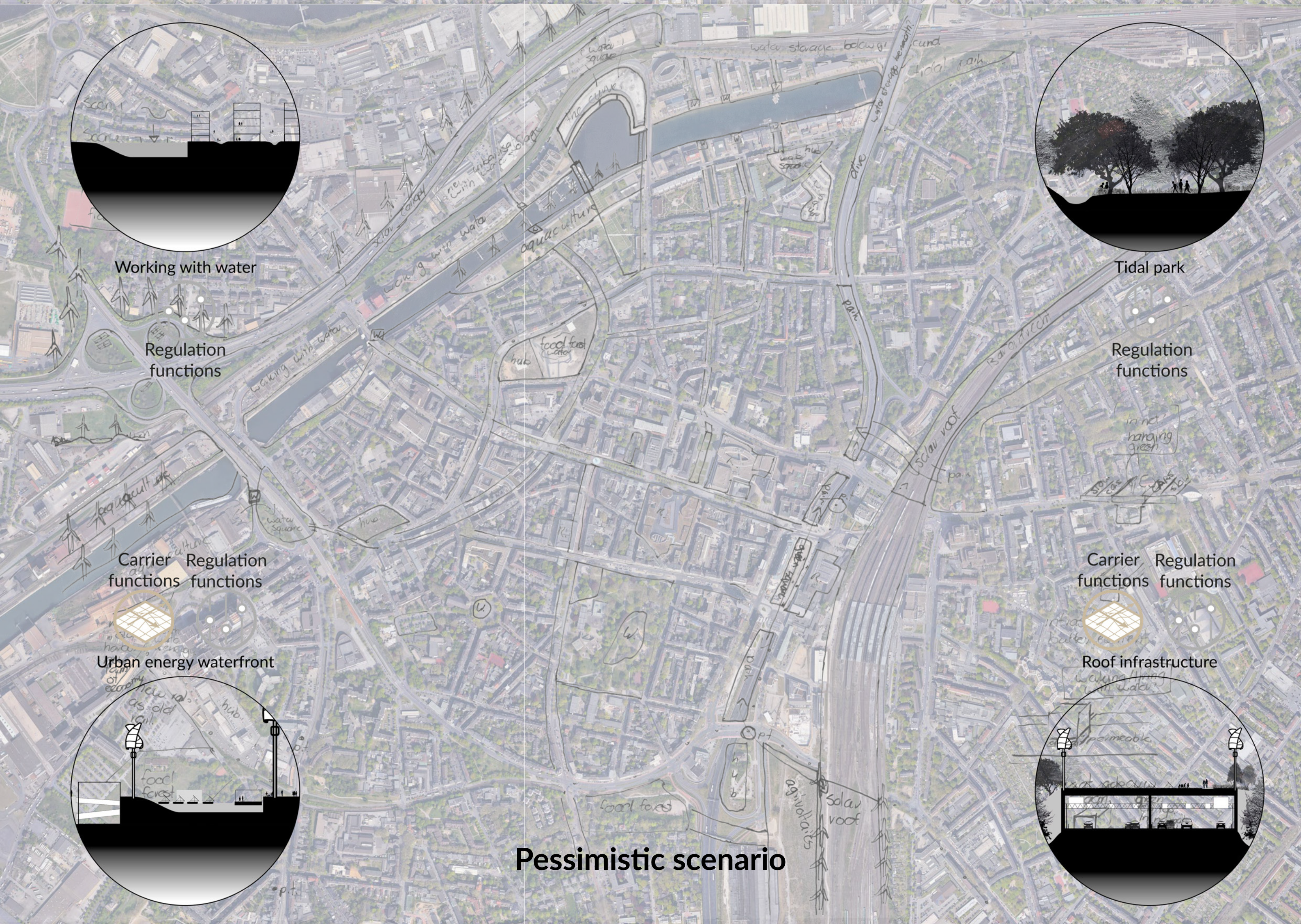
Figure 84: Current situation, optimistic and pessimistic scenario for the historic city centre patch with implemented concepts (author, 2022).

This historic city centre is facing several problems. There are several areas with a bad thermal quality. Furthermore, there are are also several areas defined as flood risk areas. This area is highly car oriented, with lots of pavement and a lack of greening.

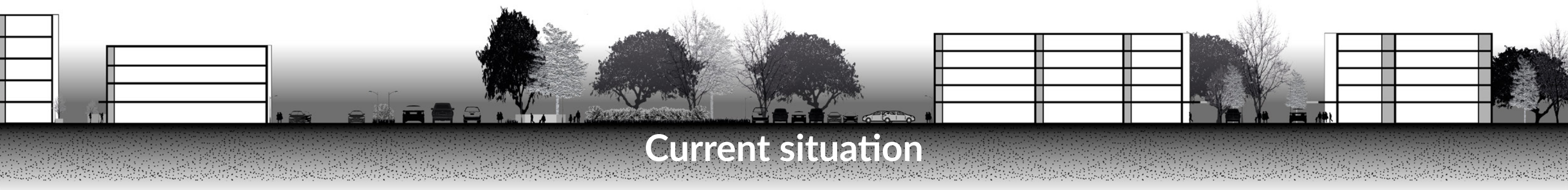
The design, that is visualized on the images on the right, proposes a shift to a more shared and electric transport system. Freeing up space for ecosystem services, in the form of green-blue streets and food forest. Furthermore, water will be integrated in the urban tissue, distributing the floodrisk and offering a more pleasant thermal quality.



Optimistic scenario



Pessimistic scenario



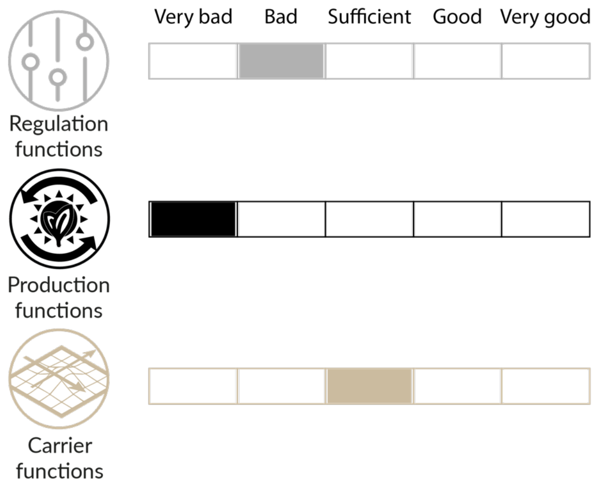
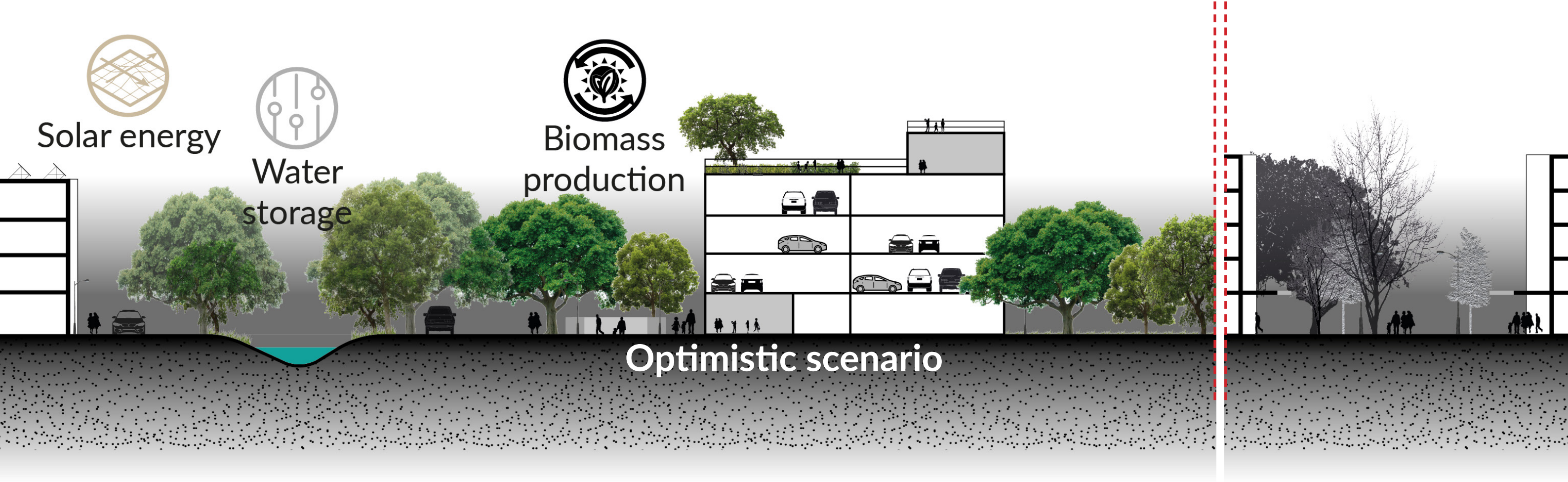
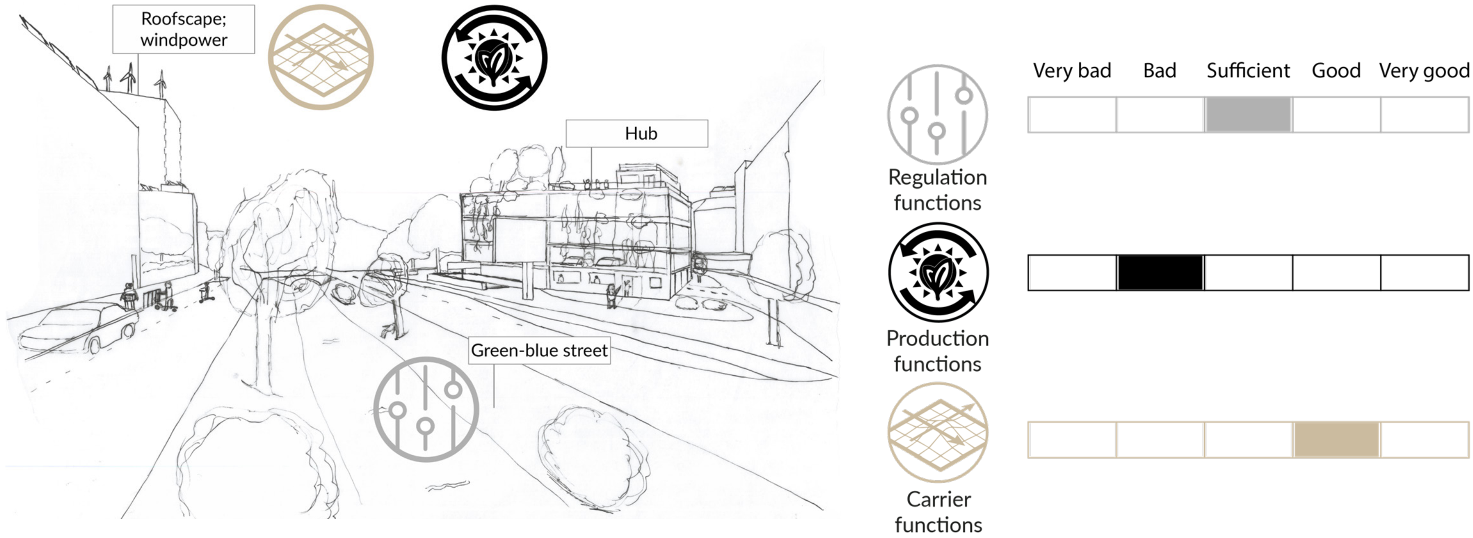


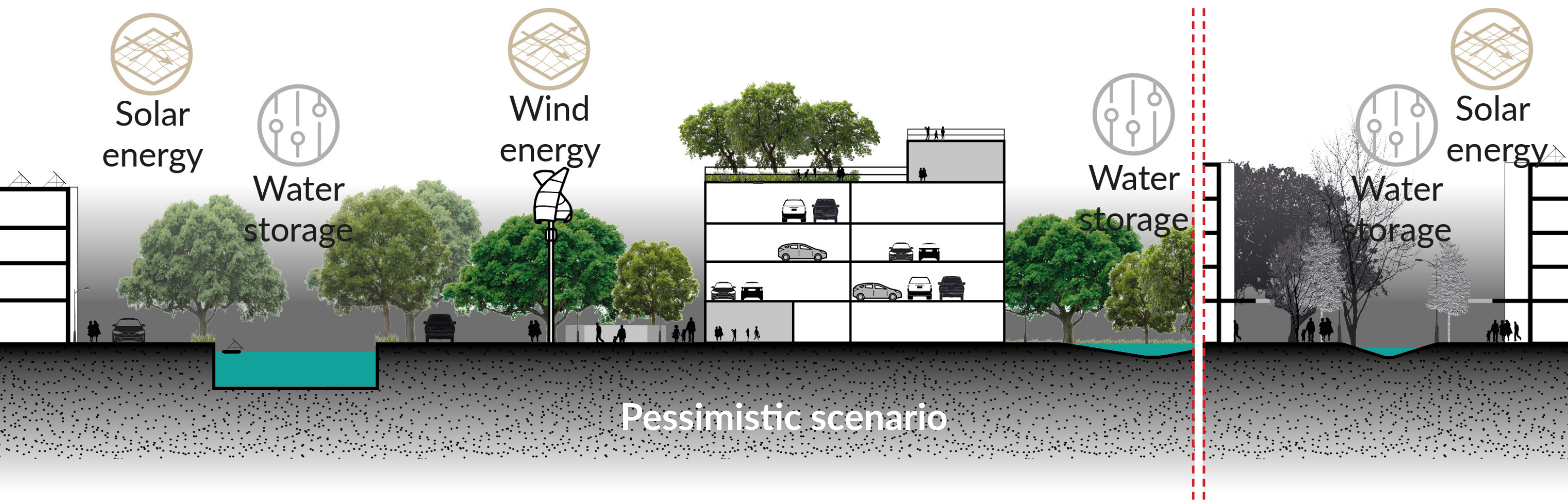
Figure 85: Current situation (above), optimistic (top right) and pessimistic scenario (bottom right) for the historic city centre in eye level view, map and in terms of ecosystem services score (author, 2022).

In the historic city centre, the space for the car is reduced in size. However, the car is not removed, since this is not the goal. However, the transition to a different mode of transport is put into motion. In this changed system, the car is parked in a hub, from which the resident and the tourist continue their trip using either public transport or electric modes of transport, such as a step.

In the pessimistic scenario, the green-blue street is transformed to allocate more space for water retention.


Solar energy
Water storage
Biomass production
Optimistic scenario


Roofscape; windpower
Hub
Green-blue street
Very bad
Bad
Sufficient
Good
Very good
Regulation functions
Production functions
Carrier functions


Solar energy
Water storage
Wind energy
Water storage
Solar energy
Water storage
Pessimistic scenario

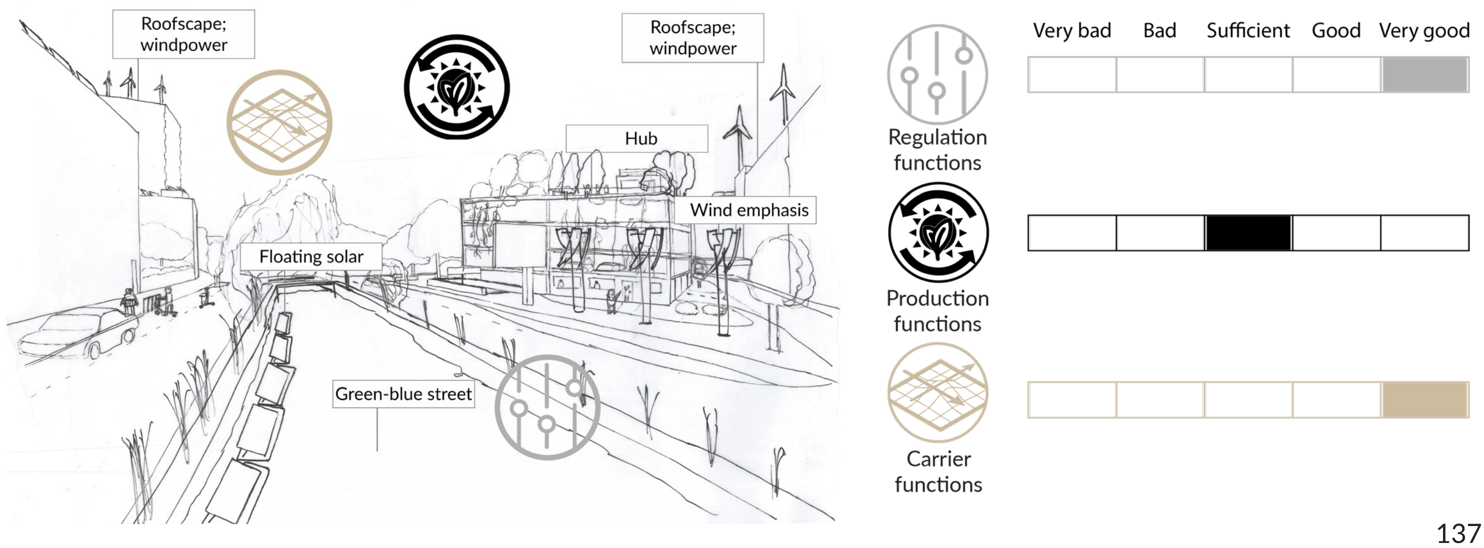
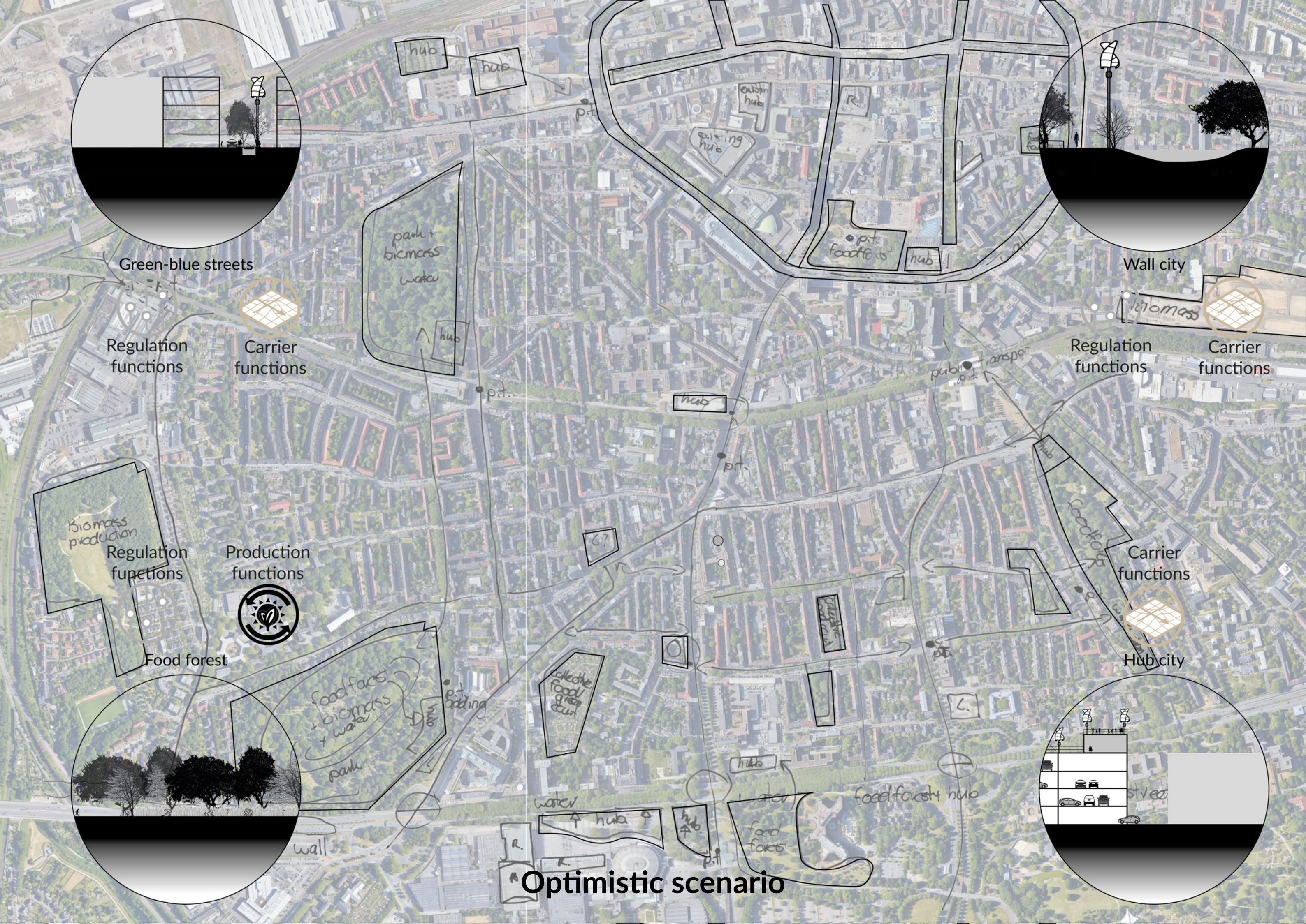

Roofscape; windpower
Roofscape; windpower
Hub
Wind emphasis
Floating solar
Green-blue street
Very bad
Bad
Sufficient
Good
Very good
Regulation functions
Production functions
Carrier functions

Figure 86: Current situation
and pessimistic scenario (right
bird eye view in terms of ecos
202

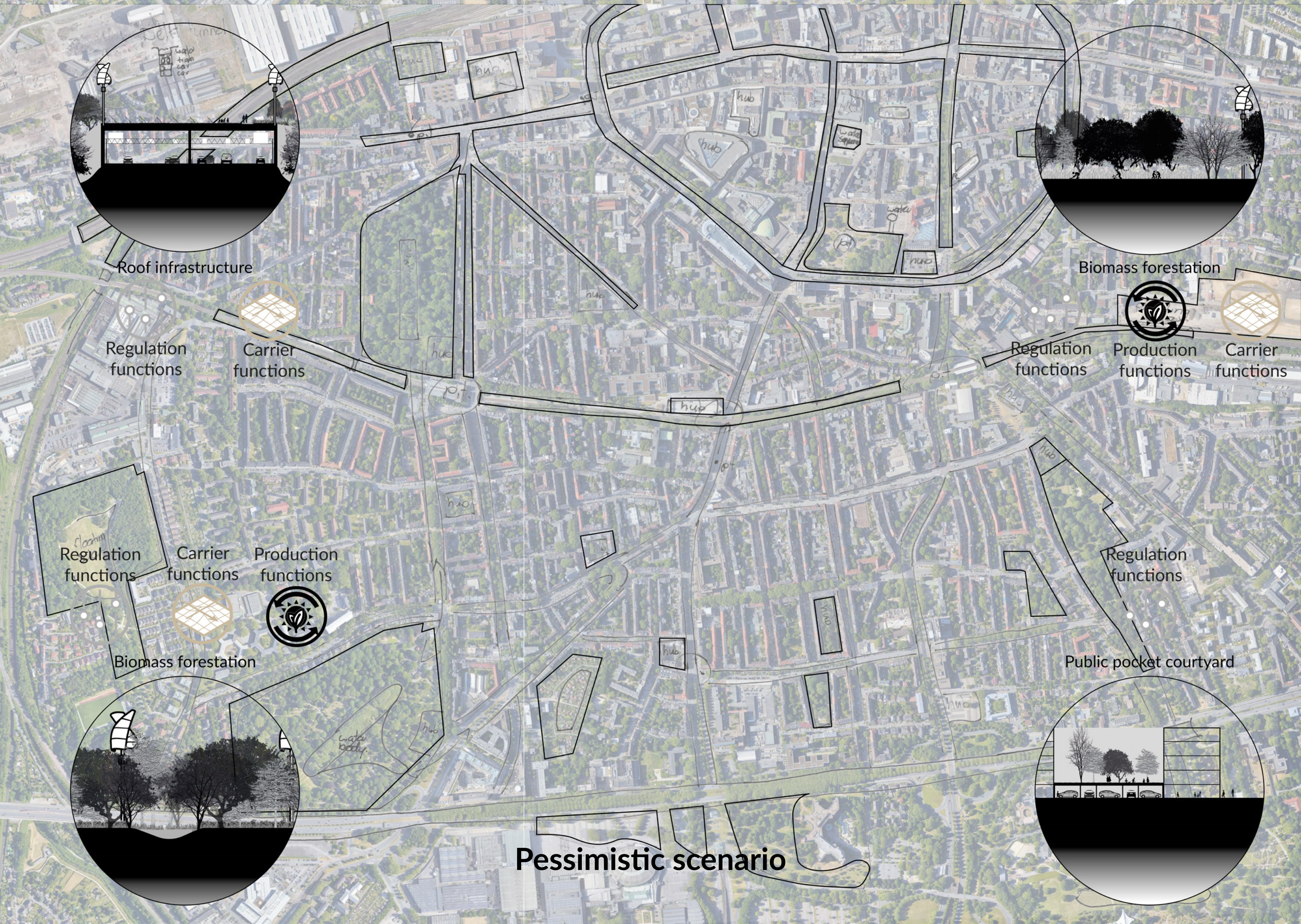
n (above left), optimistic (left) t) for the historic city centre in system services score (author, 22).

Figure 87: Current situation, optimistic and pessimistic scenario for the green urban area patch with implemented concepts (author, 2022).

The green urban area area faces several problems, mostly in terms of bad thermal quality. In the design this is dealt with by linking the ecosystem, offering a better thermal quality. This is done by implementing green-blue streets, wall city and creek city.



Optimistic scenario



Pessimistic scenario

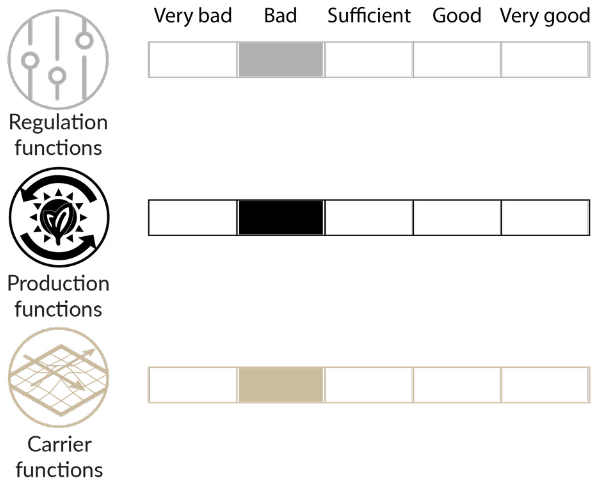
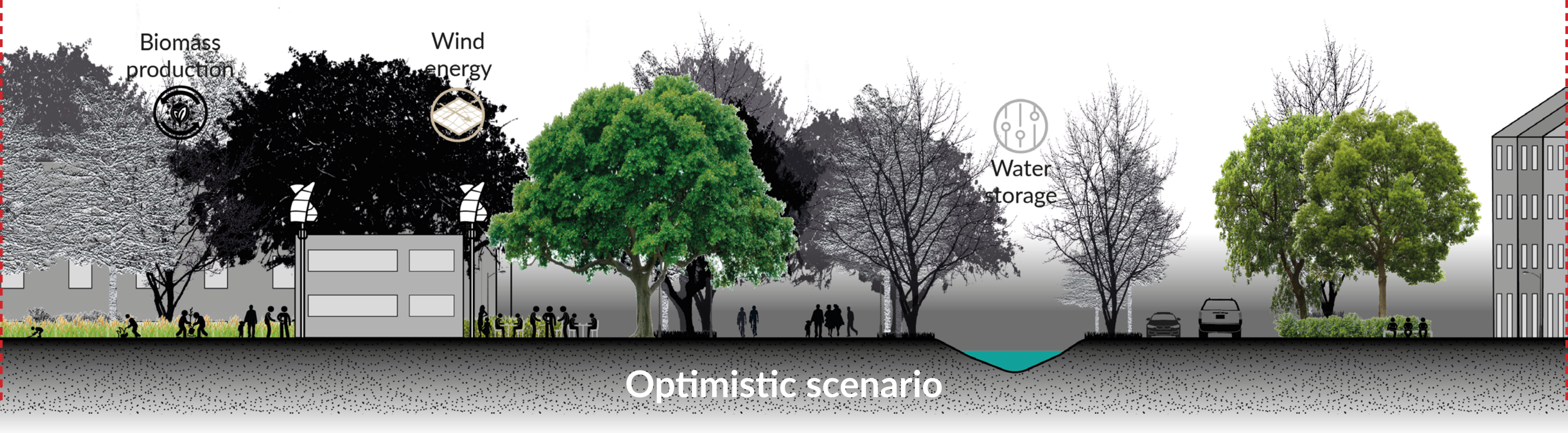
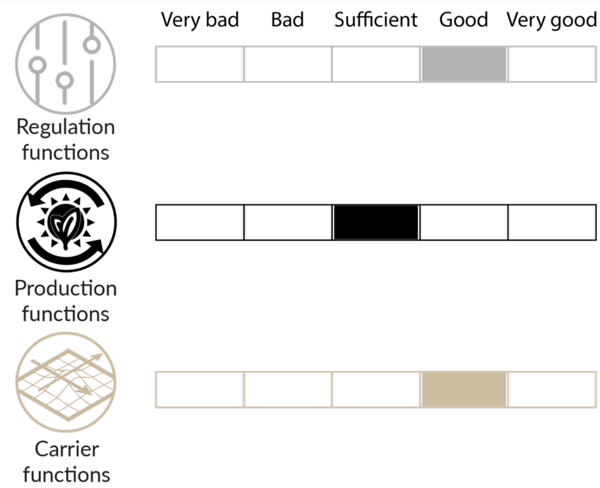
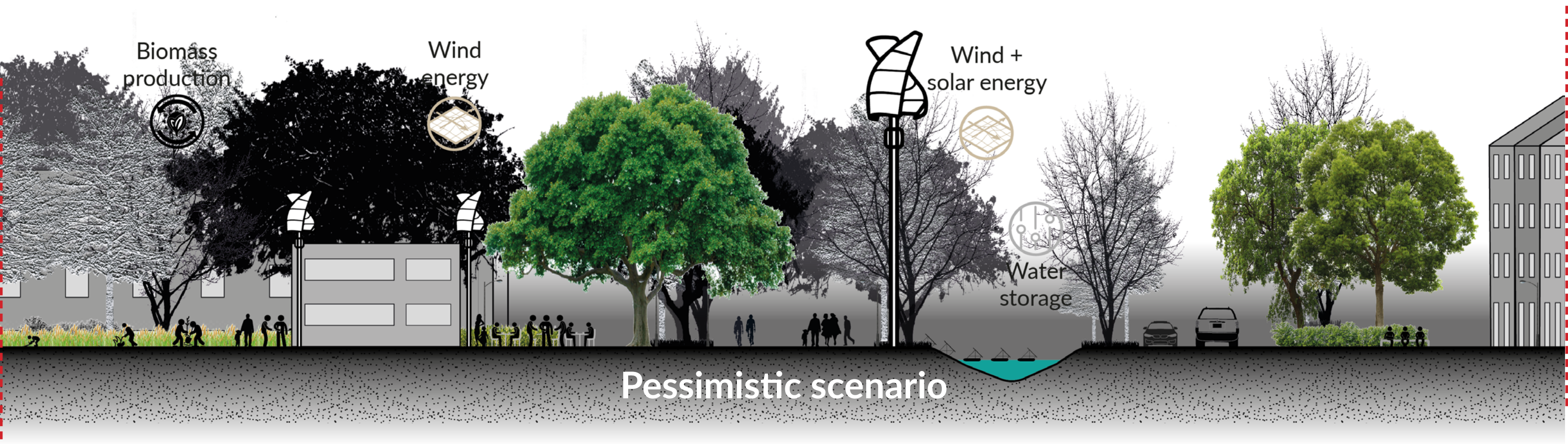


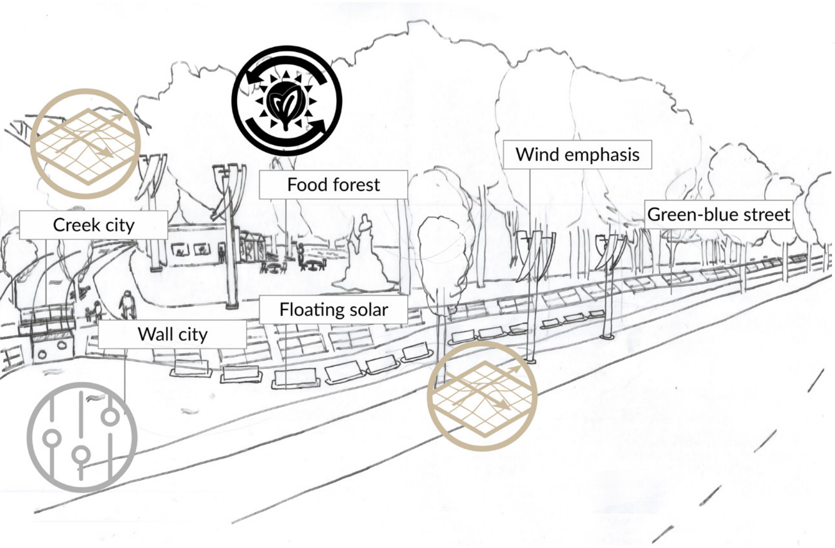
Figure 88: Current situation (above), optimistic (top right) and pessimistic scenario (bottom right) for the green urban area in eye level view, map and in terms of ecosystem services score (author, 2022).


Biomass production
Wind energy
Water storage
Optimistic scenario


Food forest
Creek city
Green-blue street
Wall city


Very bad
Bad
Sufficient
Good
Very good
Regulation functions
Production functions
Carrier functions


Biomass production
Wind energy
Wind + solar energy
Water storage
Pessimistic scenario


Wind emphasis
Food forest
Creek city
Green-blue street
Floating solar
Wall city

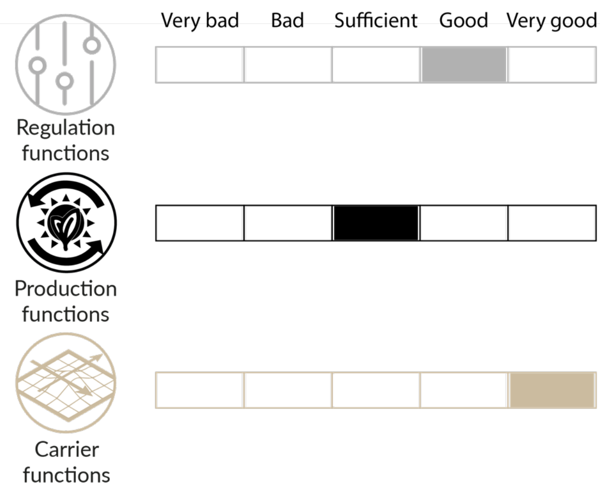

Very bad
Bad
Sufficient
Good
Very good
Regulation functions
Production functions
Carrier functions

Figure 89: Current situatio
and pessimistic scenario (righ
bird eye view in terms of ecos
202

n (above left), optimistic (left)
nt) for the green urban area in
system services score (author,
22).

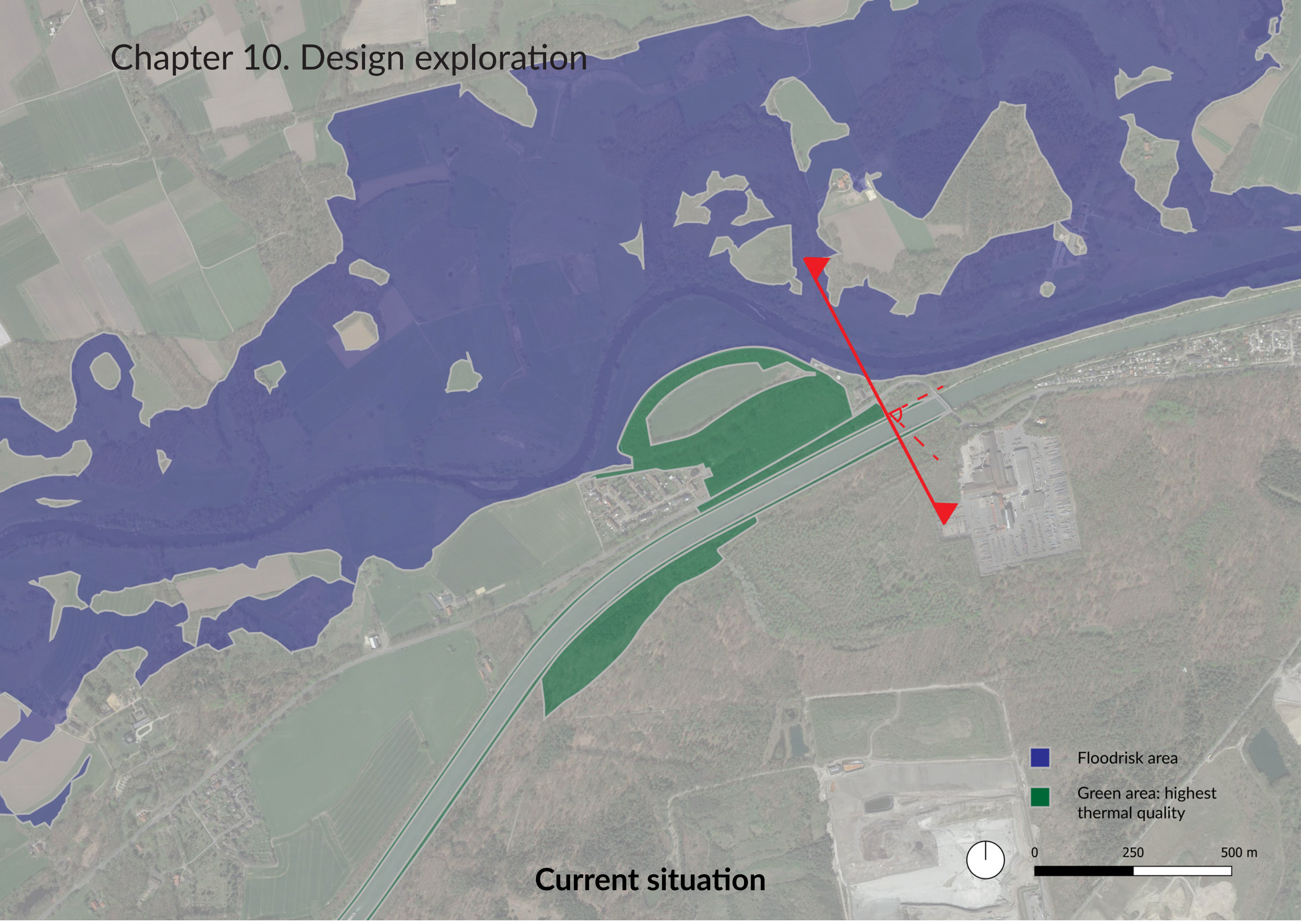
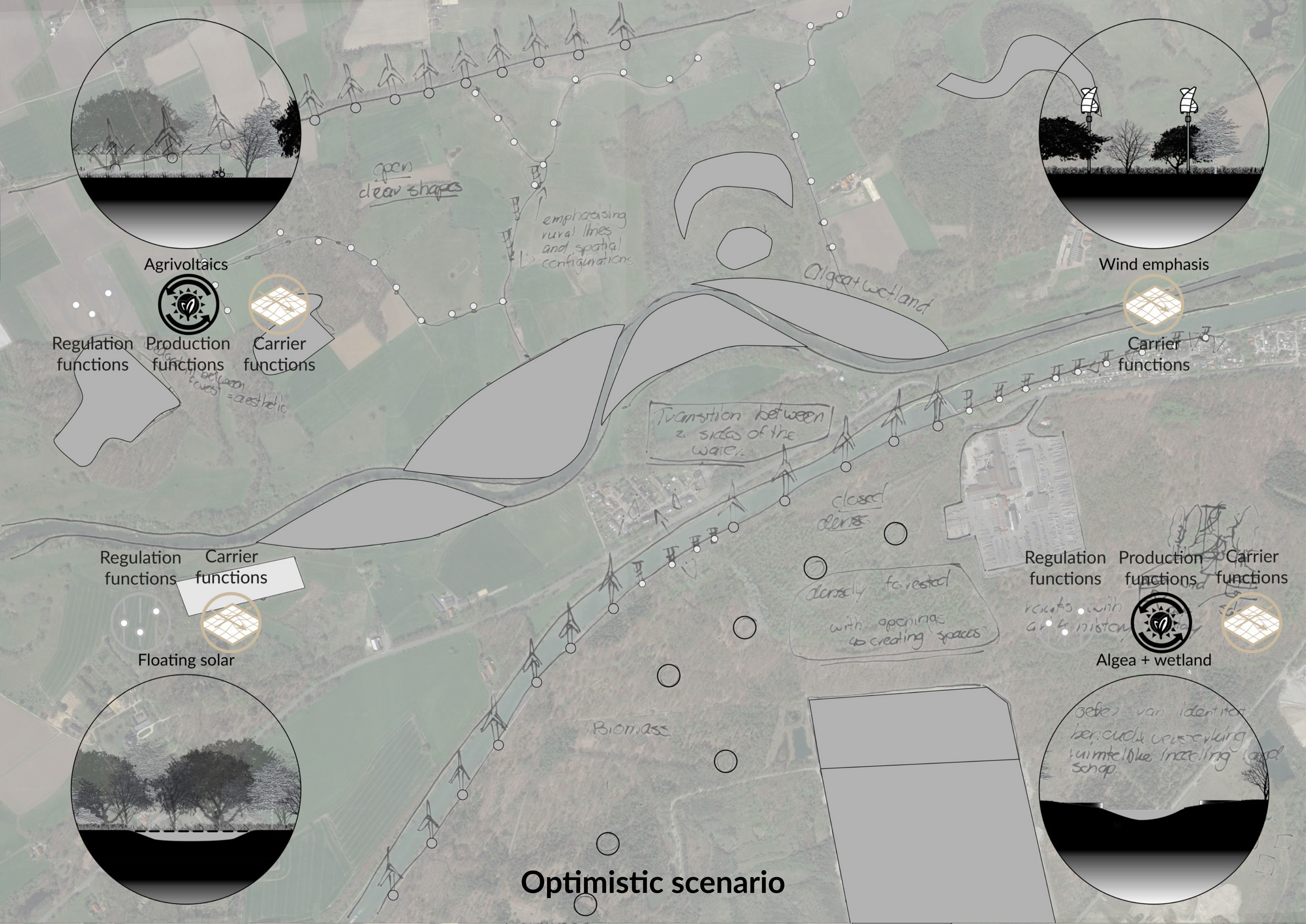
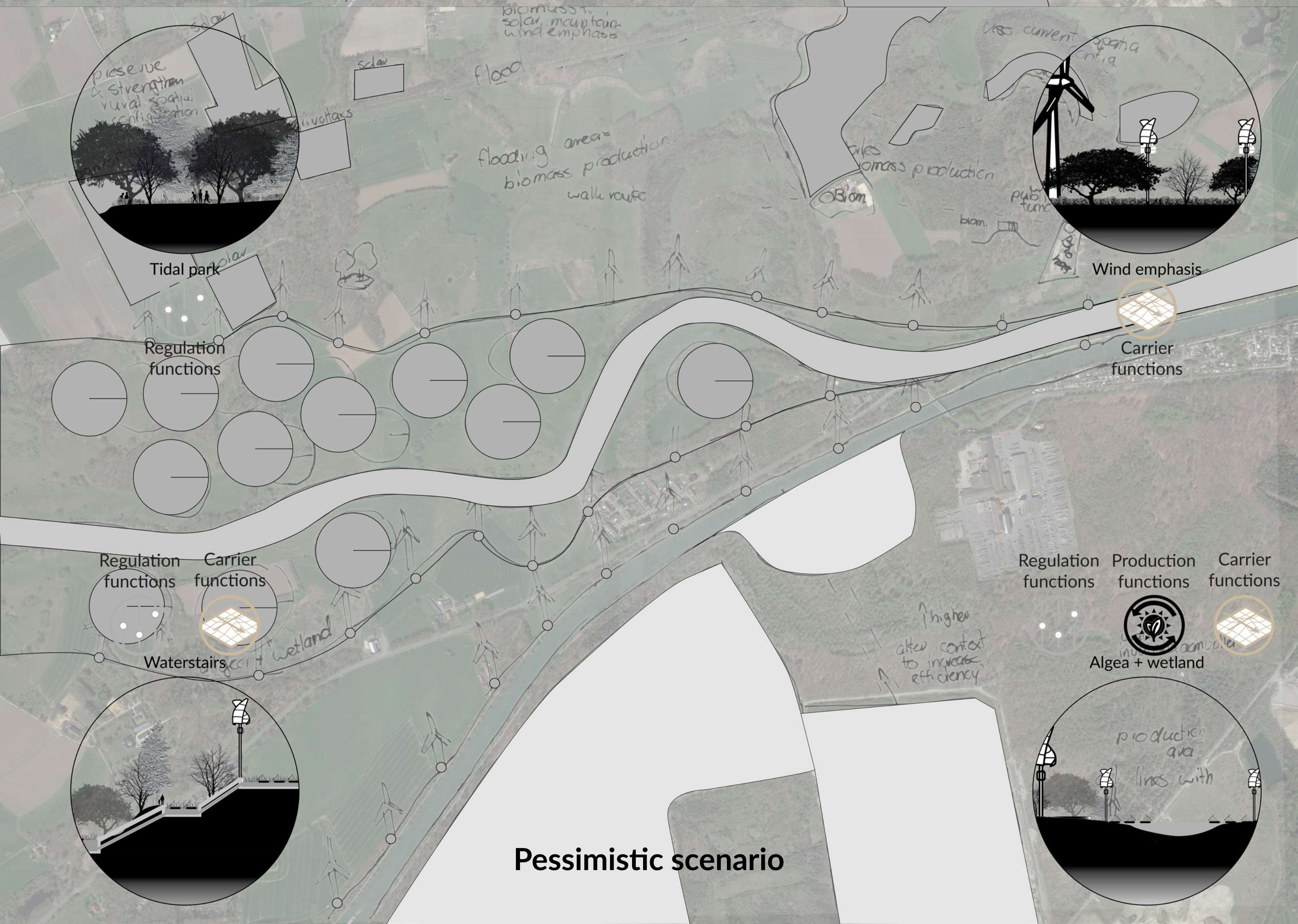
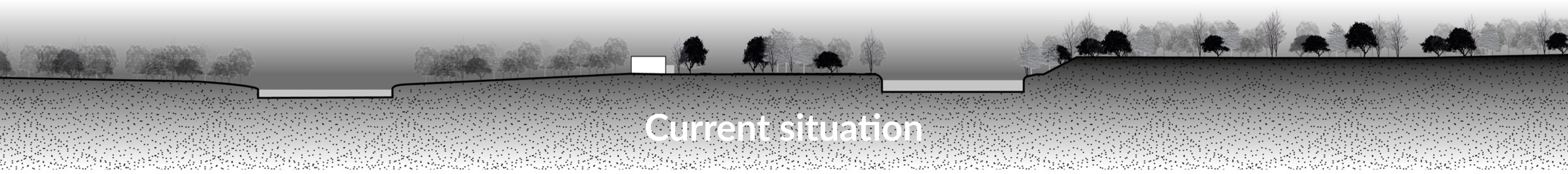


Figure 90: Current situation, optimistic and pessimistic scenario for the riverbank patch with implemented concepts (author, 2022).


Agrivoltaics
Regulation functions
Production functions
Carrier functions
Wind emphasis
Carrier functions
open clear shapes
emphasising rural lines and spatial configurations
Algeat wetland
Transition between 2 sides of the water
closed dense
densely forested with openings creating spaces
Biomass
Regulation functions
Carrier functions
Floating solar
Regulation functions
Production functions
Carrier functions
Algea + wetland
Optimistic scenario


biomass solar, mountain wind emphasis
preserve & strengthen rural spatial configuration
solar
flood
flooding area = biomass production
walk route
biomass production
Tidal park
Wind emphasis
Carrier functions
Regulation functions
Regulation functions
Carrier functions
Waterstairs
wetland
higher
after context to increase efficiency
Regulation functions
Production functions
Carrier functions
Algea + wetland
Pessimistic scenario



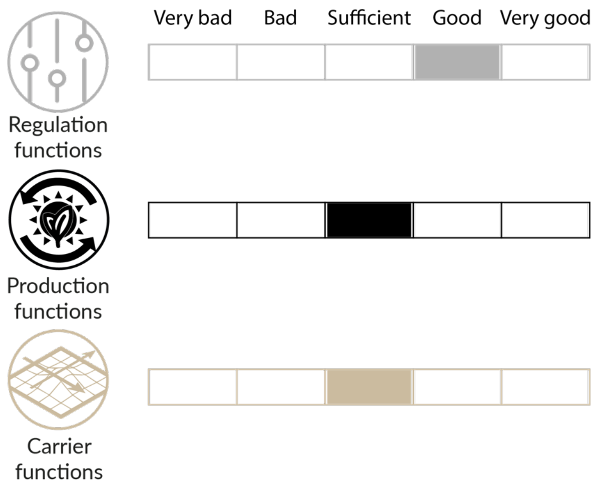
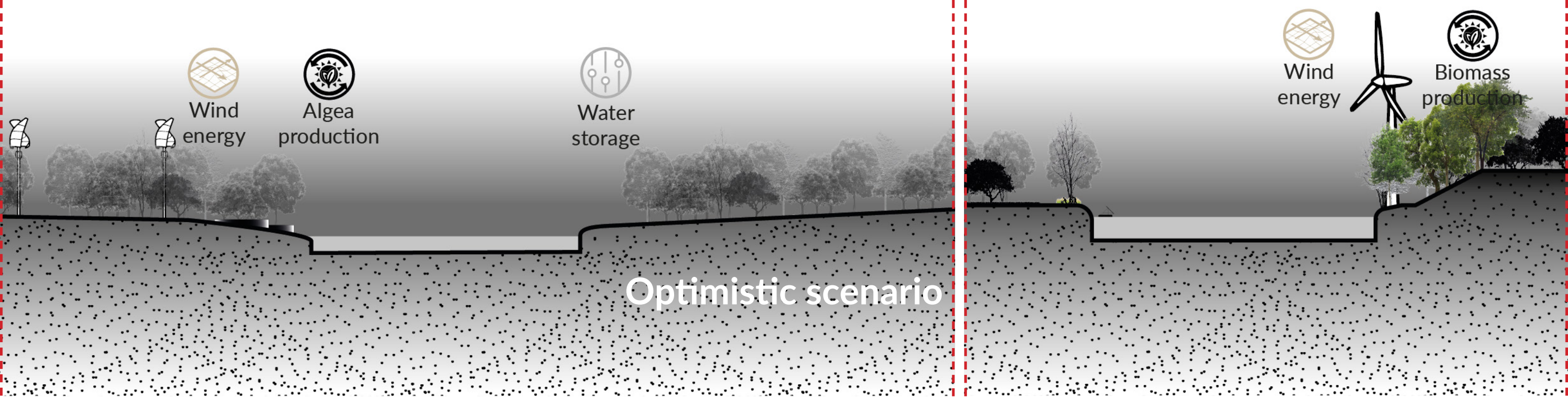
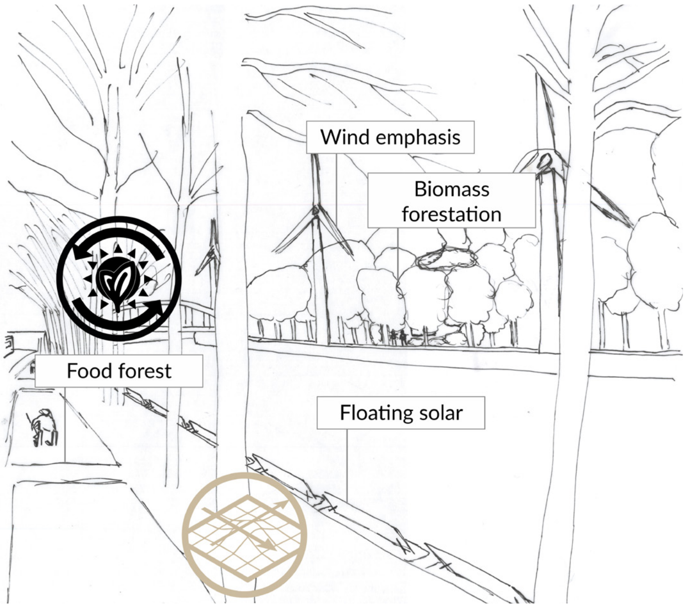
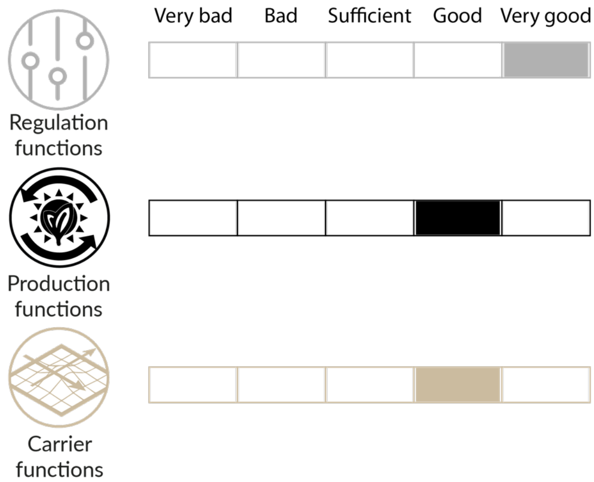
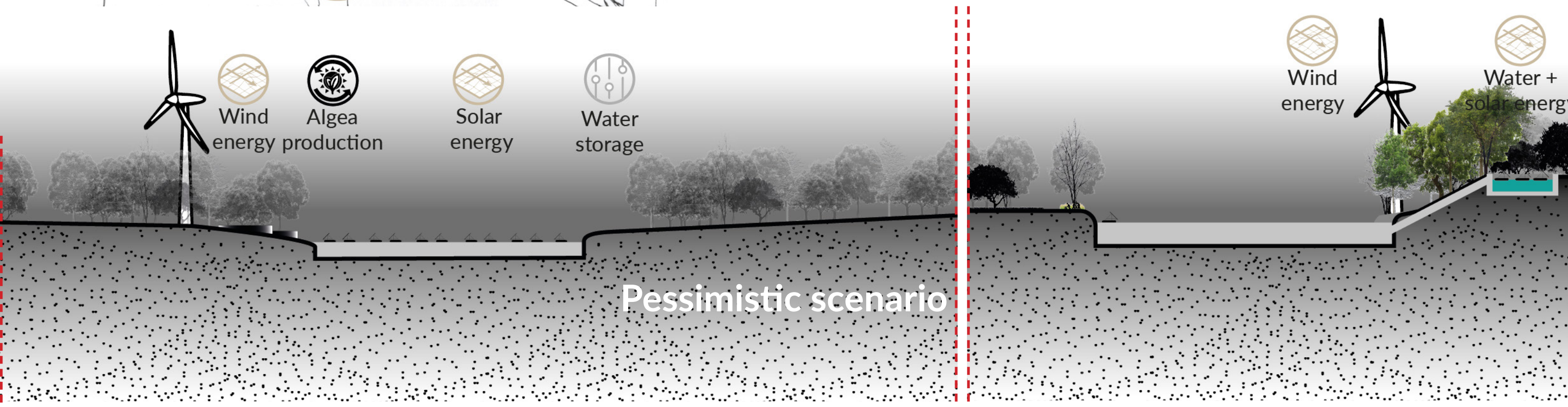


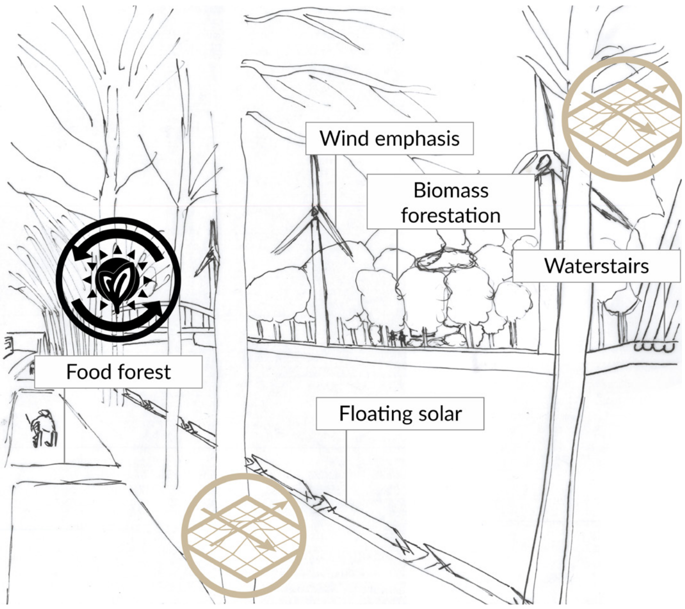
Figure 91: Current situation (above), optimistic (top right) and pessimistic scenario (bottom right) for the riverbank in eye level view, map and in terms of ecosystem services score (author, 2022).

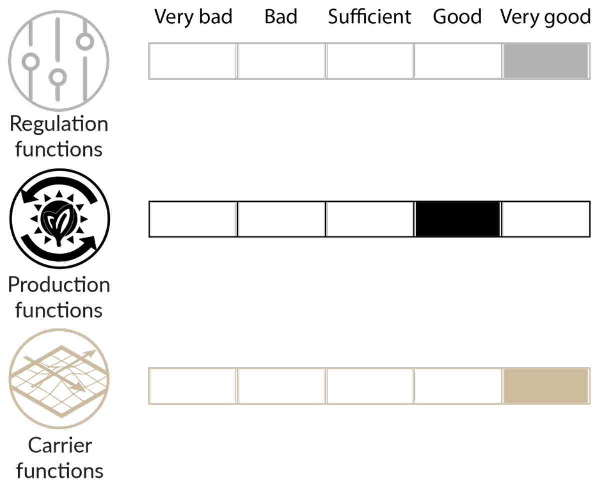

Wind energy
Algea production
Water storage
Optimistic scenario
Wind energy
Biomass production


Wind emphasis
Biomass forestation
Food forest
Floating solar


Very bad
Bad
Sufficient
Good
Very good
Regulation functions
Production functions
Carrier functions


Wind energy
Algea production
Solar energy
Water storage
Pessimistic scenario
Wind energy
Water + solar energ


Wind emphasis
Biomass forestation
Waterstairs
Food forest
Floating solar


Very bad
Bad
Sufficient
Good
Very good
Regulation functions
Production functions
Carrier functions

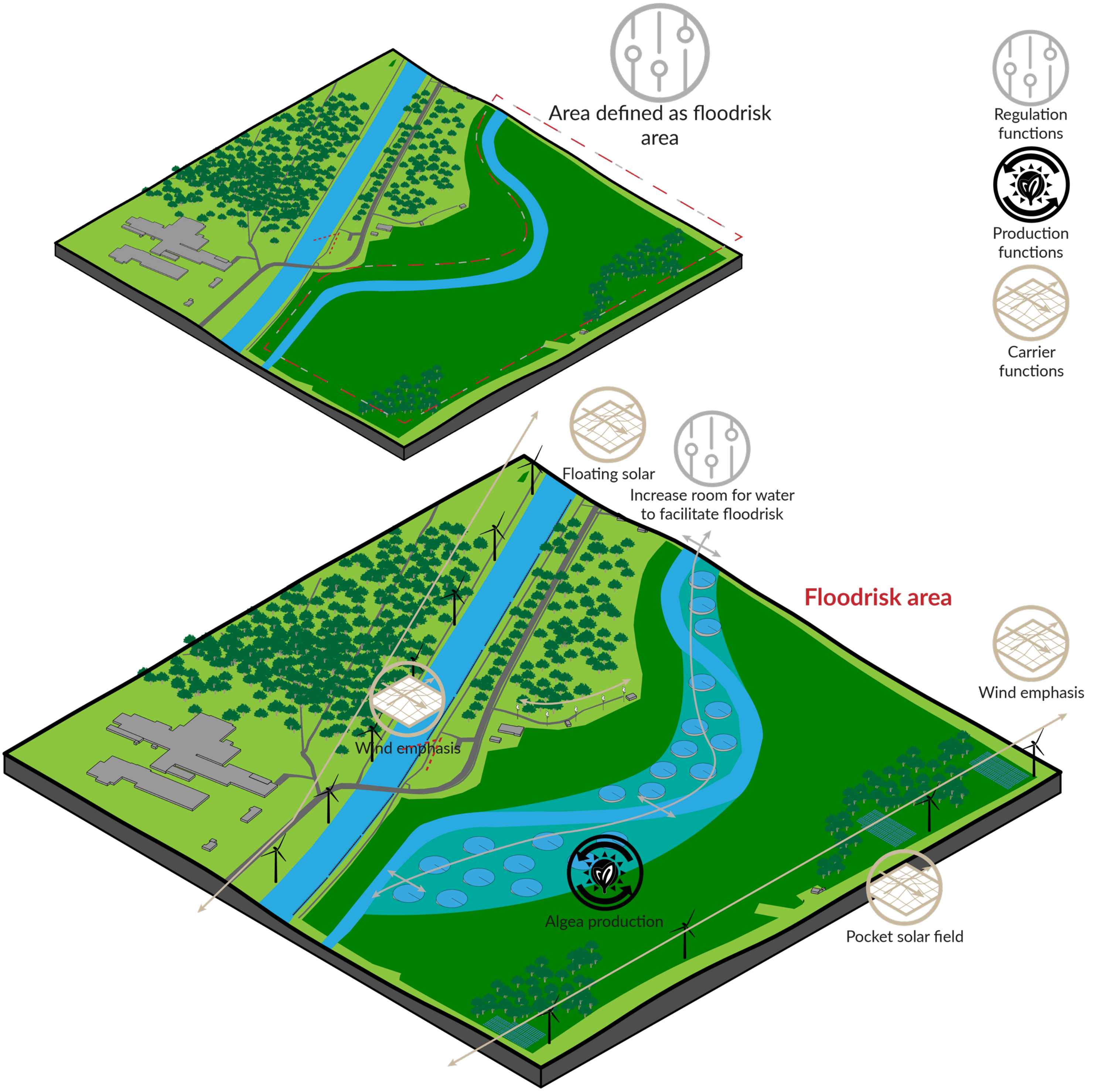
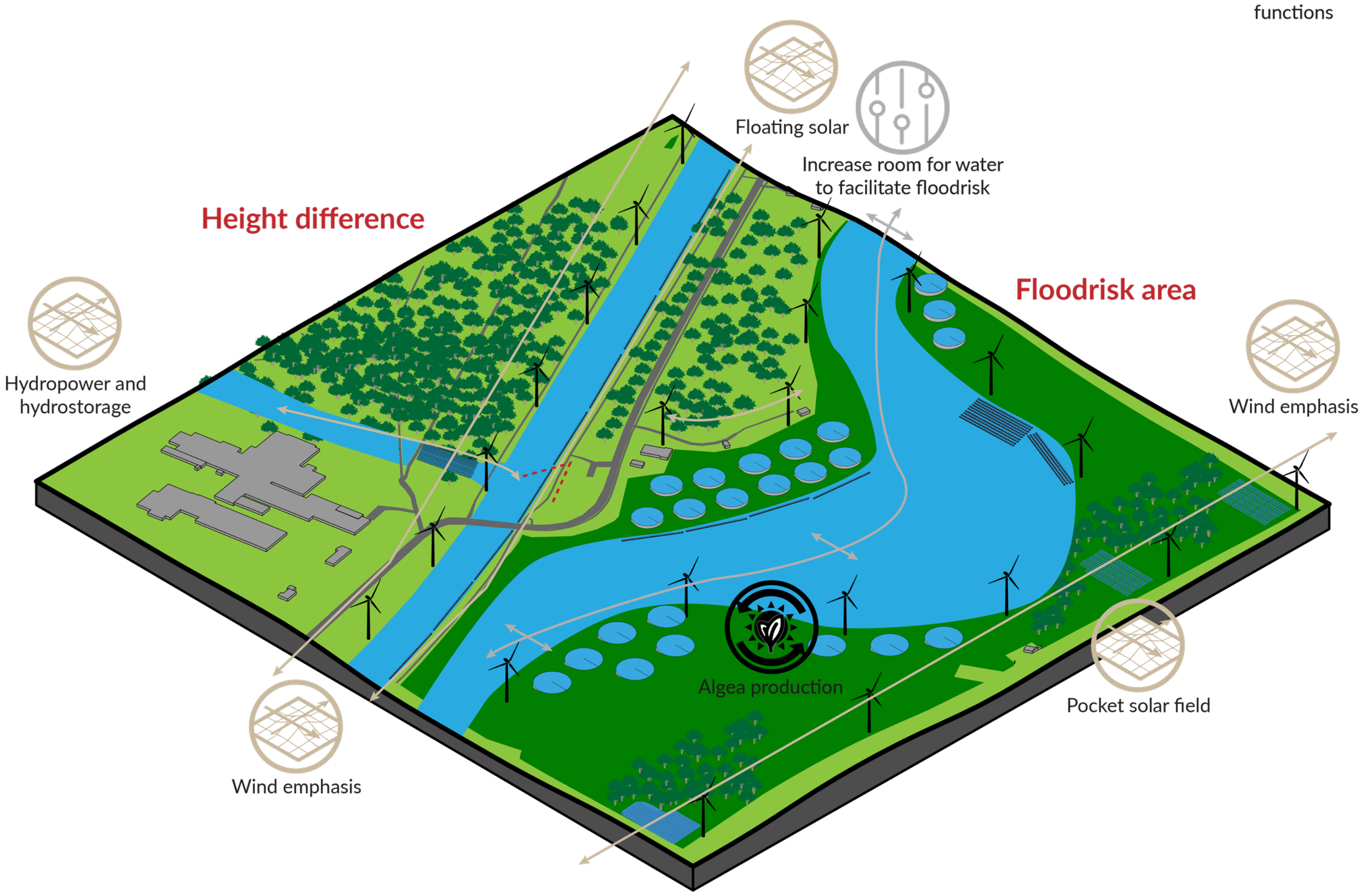


Figure 92: Current situation
and pessimistic scenario (right)
bird eye view in terms of ecos
202



n (above left), optimistic (left)
) for the riverbank / wetland in
system services score (author,
22).

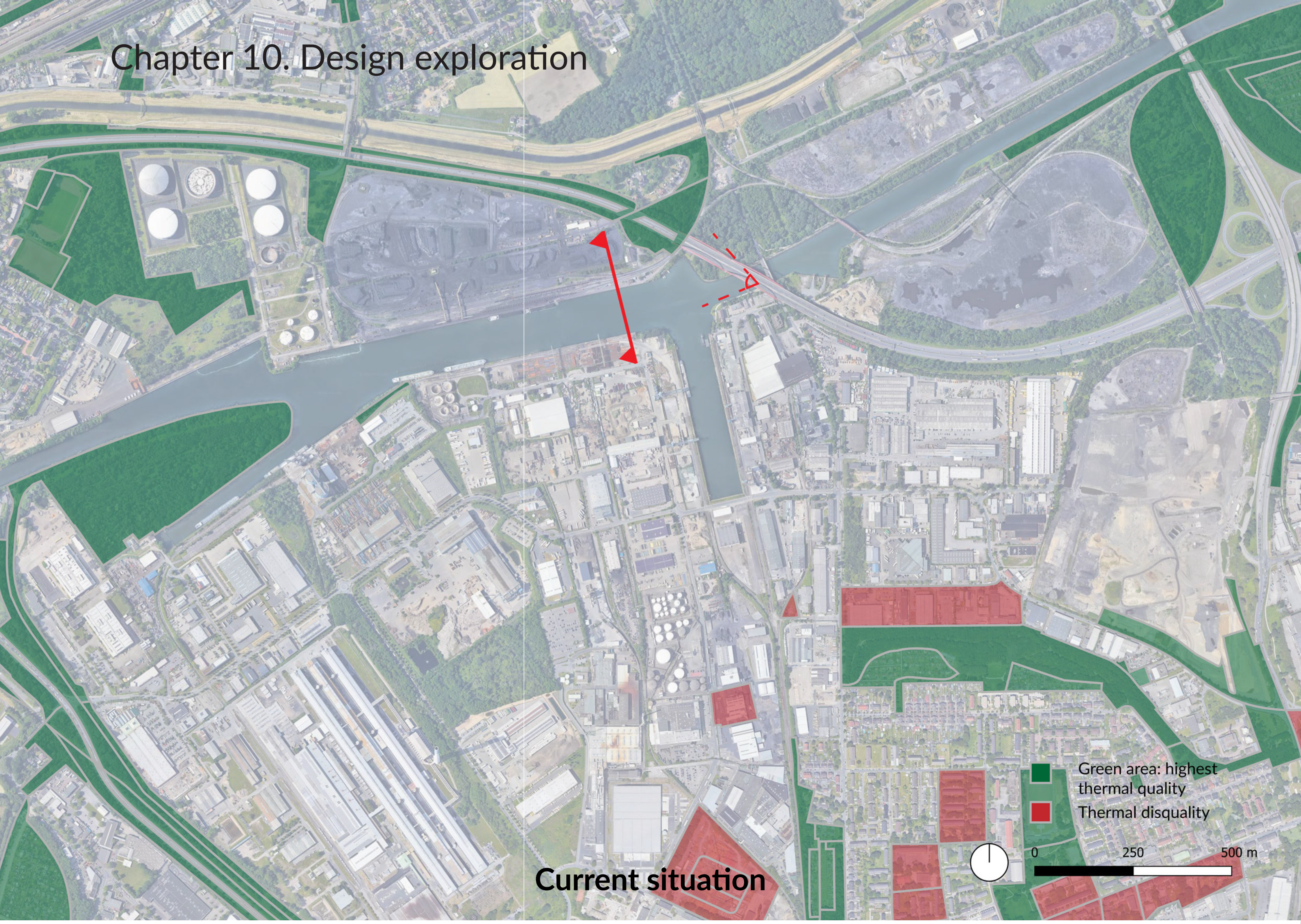
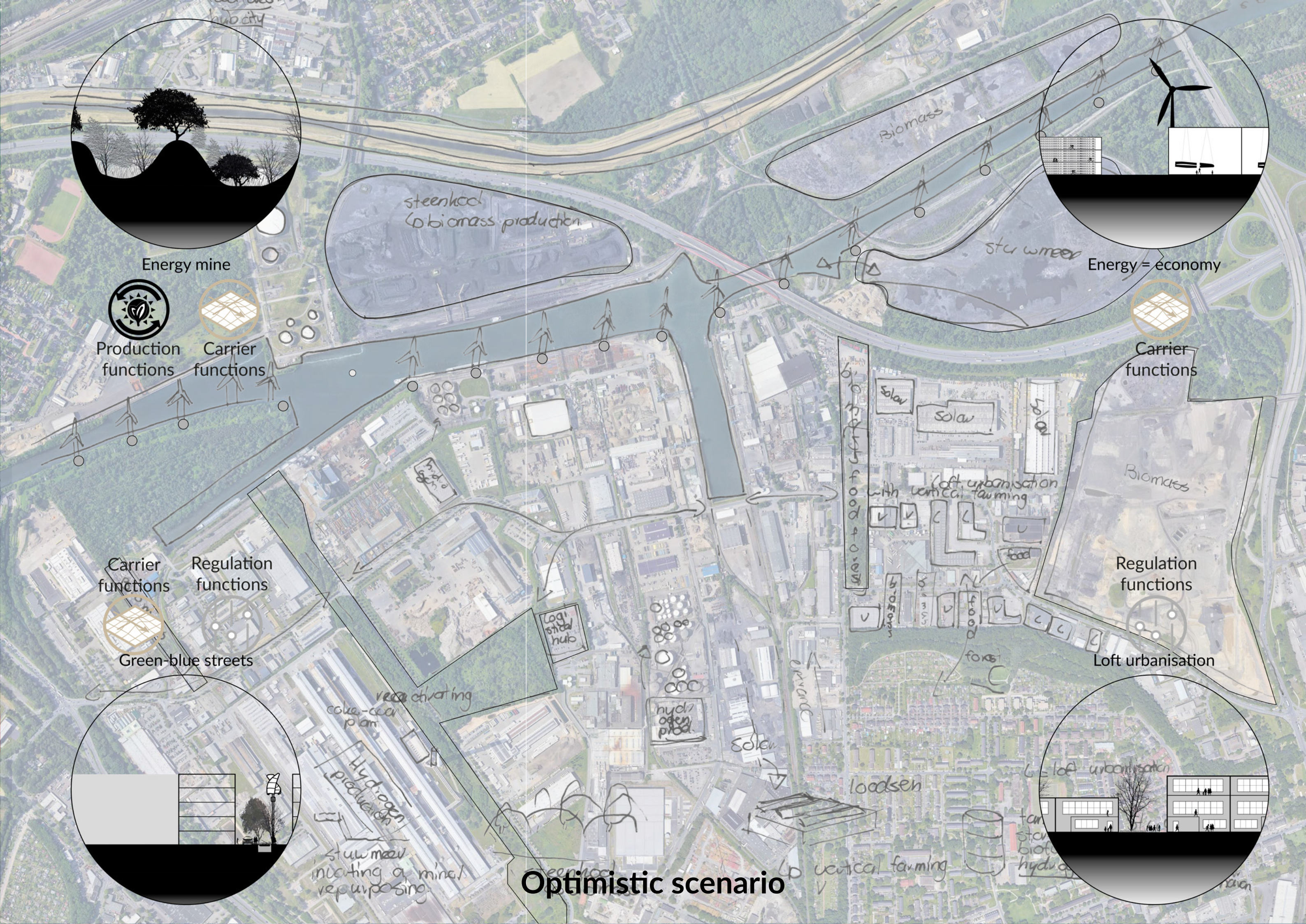
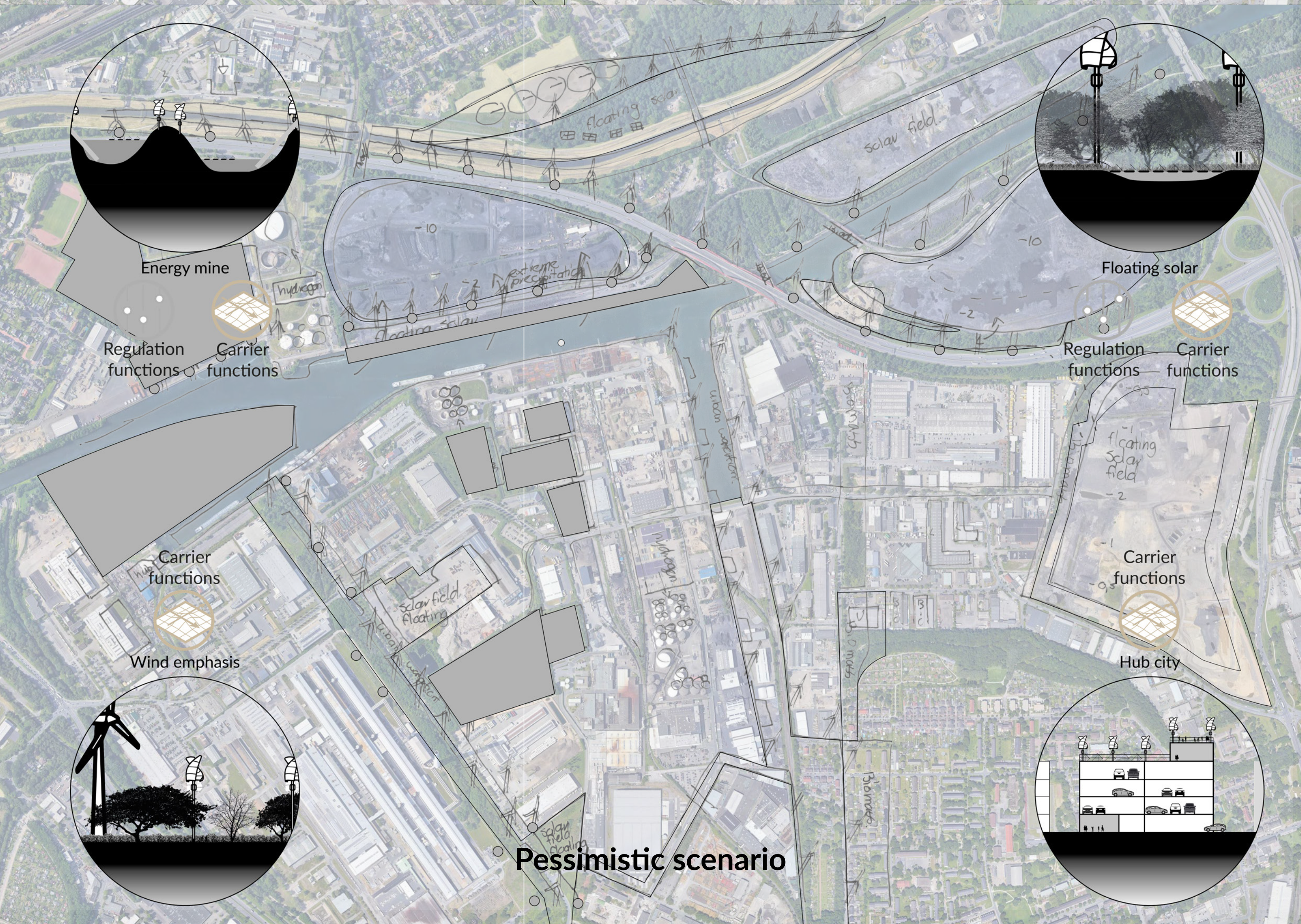
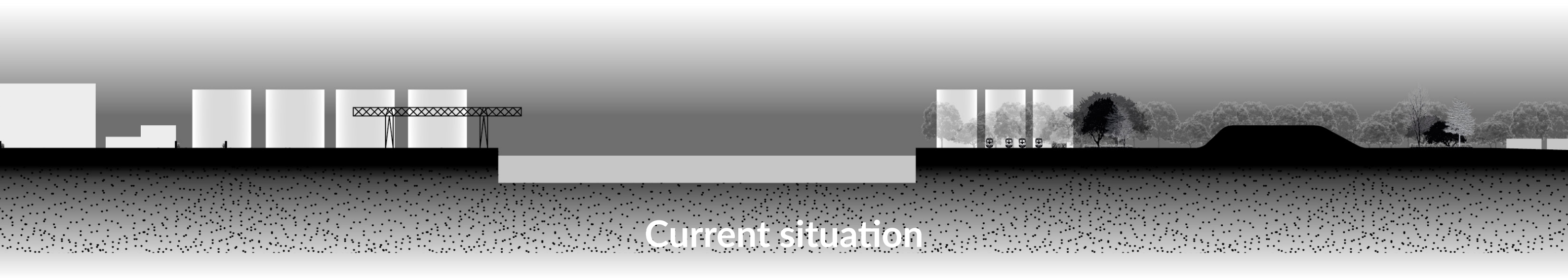
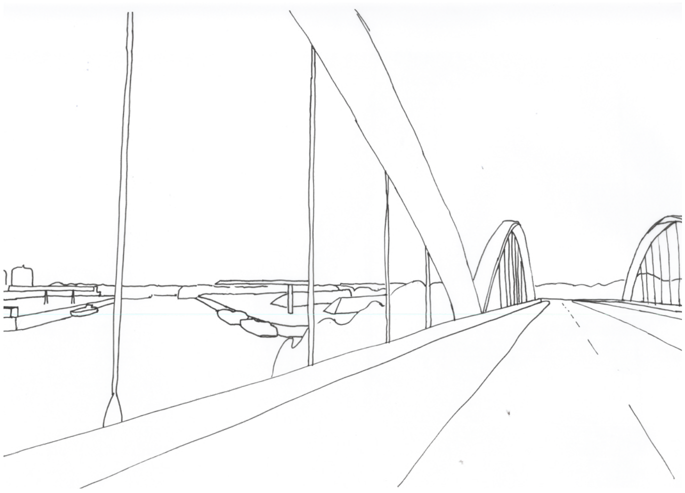


Figure 93: Current situation, optimistic and pessimistic scenario for the industrial area patch with implemented concepts (author, 2022).


Energy mine
Production functions
Carrier functions
Energy = economy
Carrier functions
Carrier functions
Regulation functions
Regulation functions
Green-blue streets
Loft urbanisation
Biomass
solar
loft urbanisation
vertical farming
Optimistic scenario


Energy mine
Regulation functions
Carrier functions
Floating solar
Regulation functions
Carrier functions
Carrier functions
Wind emphasis
Carrier functions
Hub city
floating solar
solar field
hydrogen
Pessimistic scenario





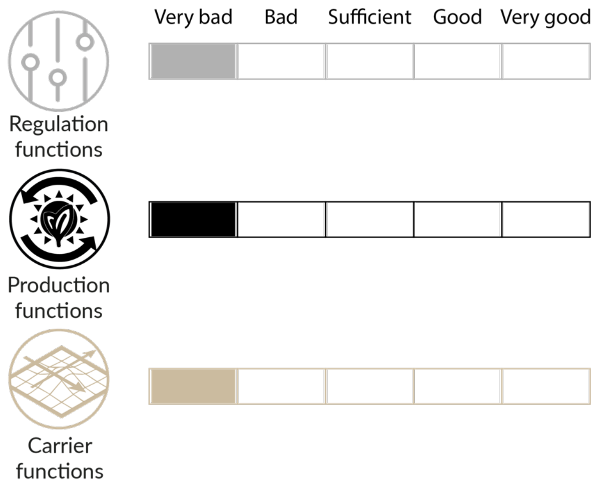
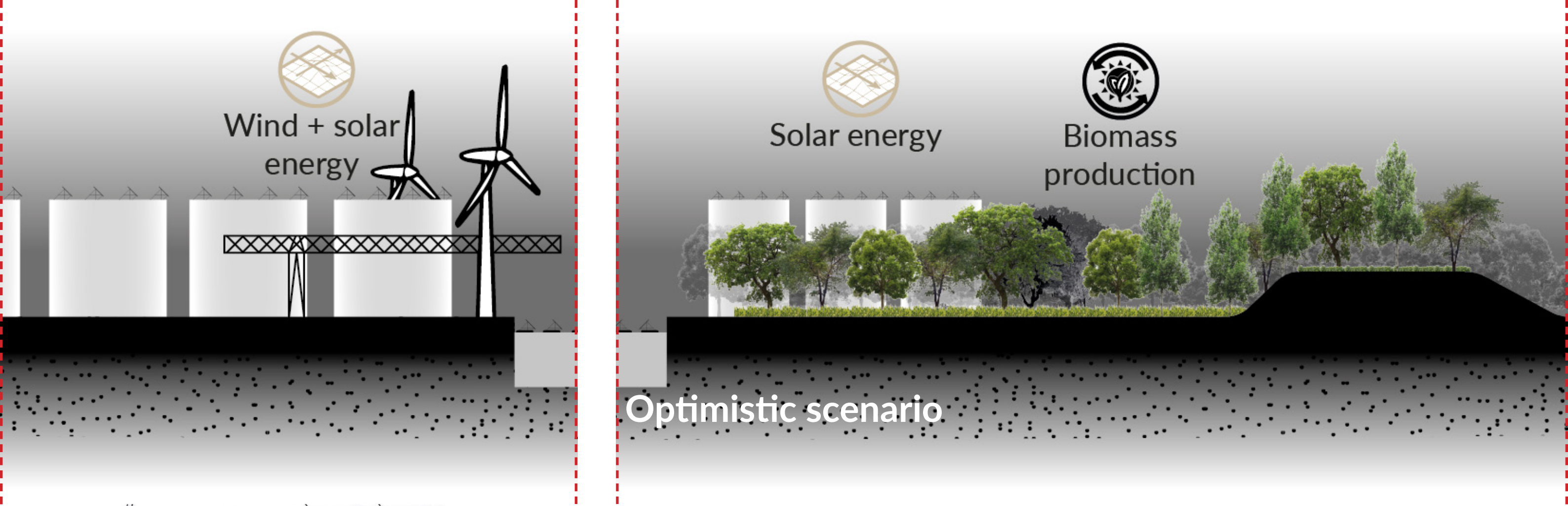
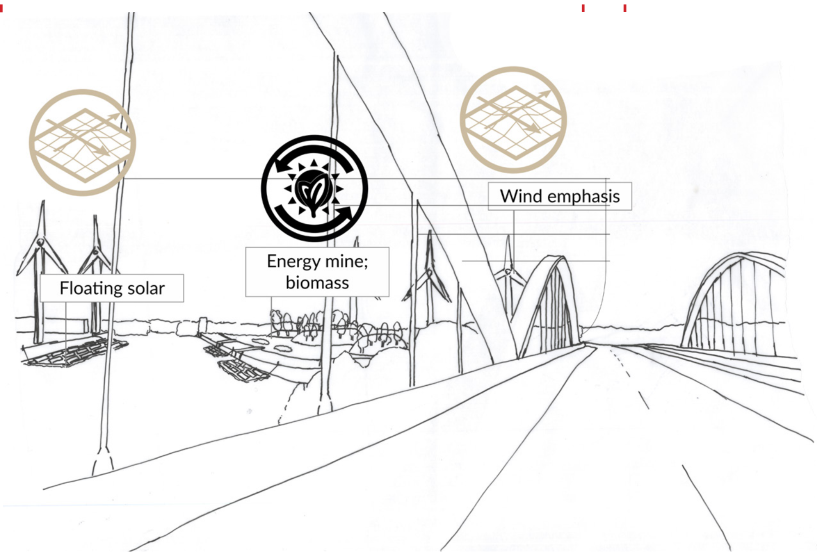
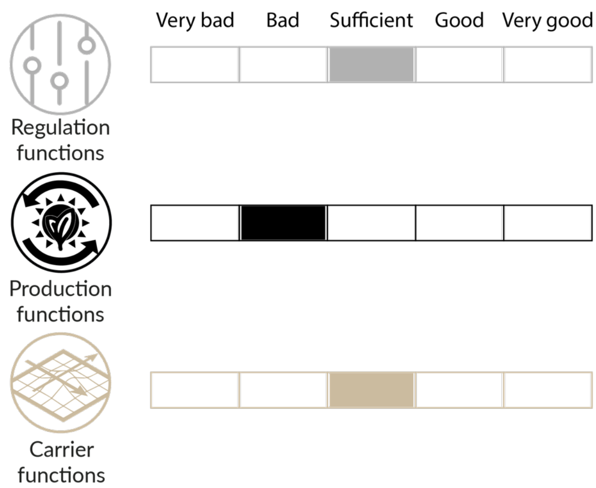
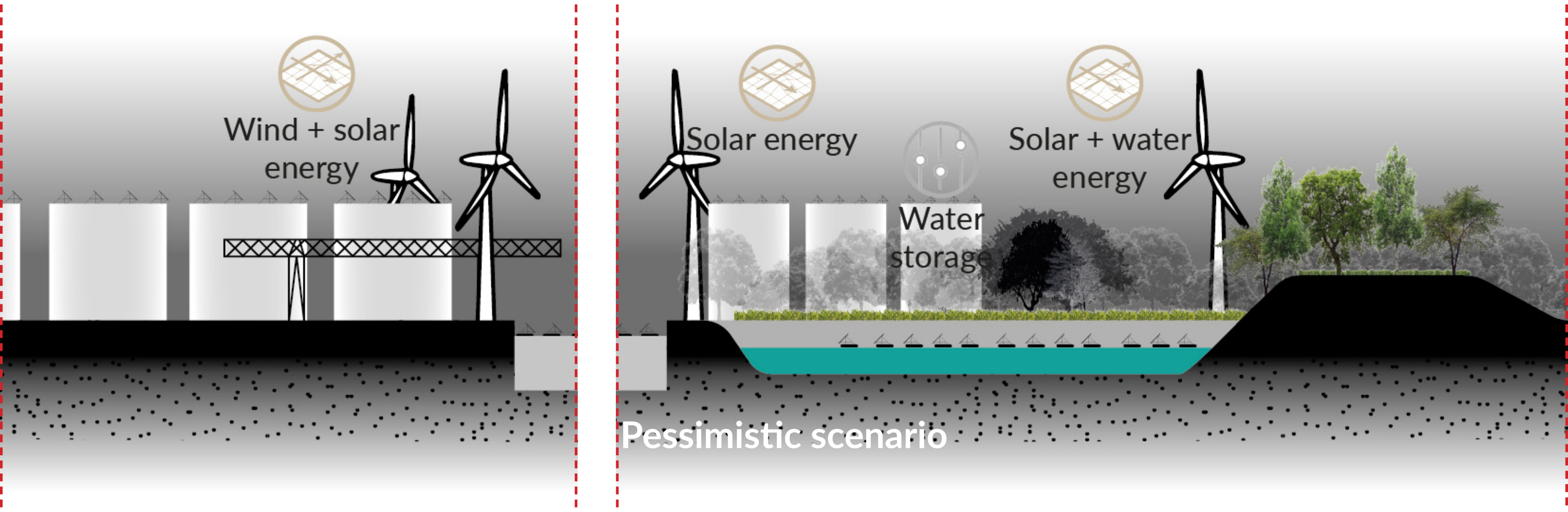


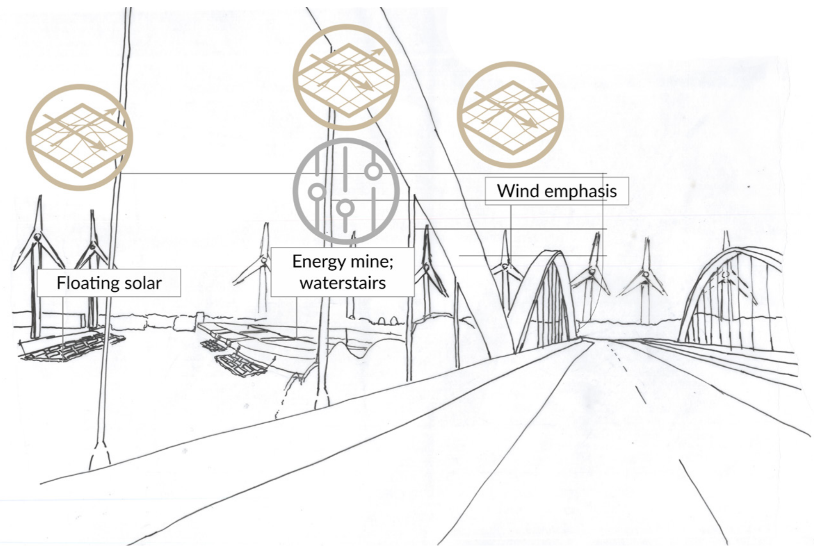
Figure 94: Current situation (above), optimistic (top right) and pessimistic scenario (bottom right) for the industrial area in eye level view, map and in terms of ecosystem services score (author, 2022).

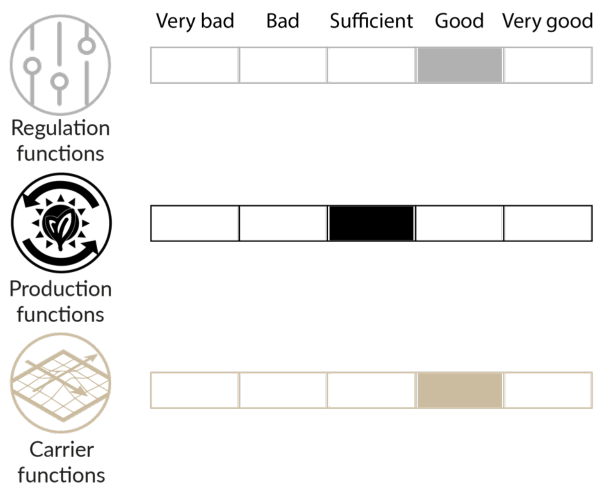

Wind + solar energy
Solar energy
Biomass production
Optimistic scenario

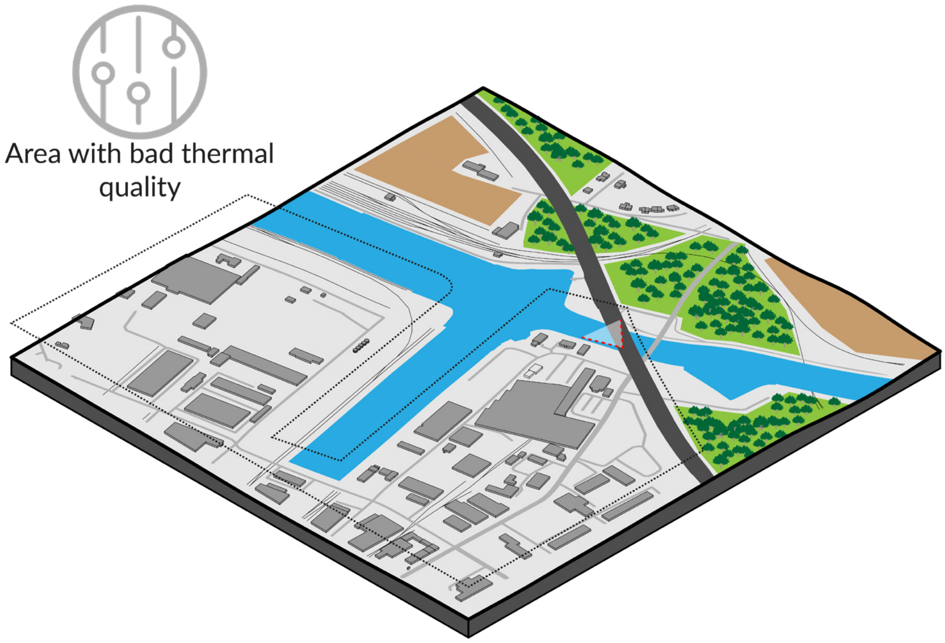

Floating solar
Energy mine; biomass
Wind emphasis


Very bad
Bad
Sufficient
Good
Very good
Regulation functions
Production functions
Carrier functions


Wind + solar energy
Solar energy
Water storage
Solar + water energy
Pessimistic scenario


Floating solar
Energy mine; waterstairs
Wind emphasis


Very bad
Bad
Sufficient
Good
Very good
Regulation functions
Production functions
Carrier functions



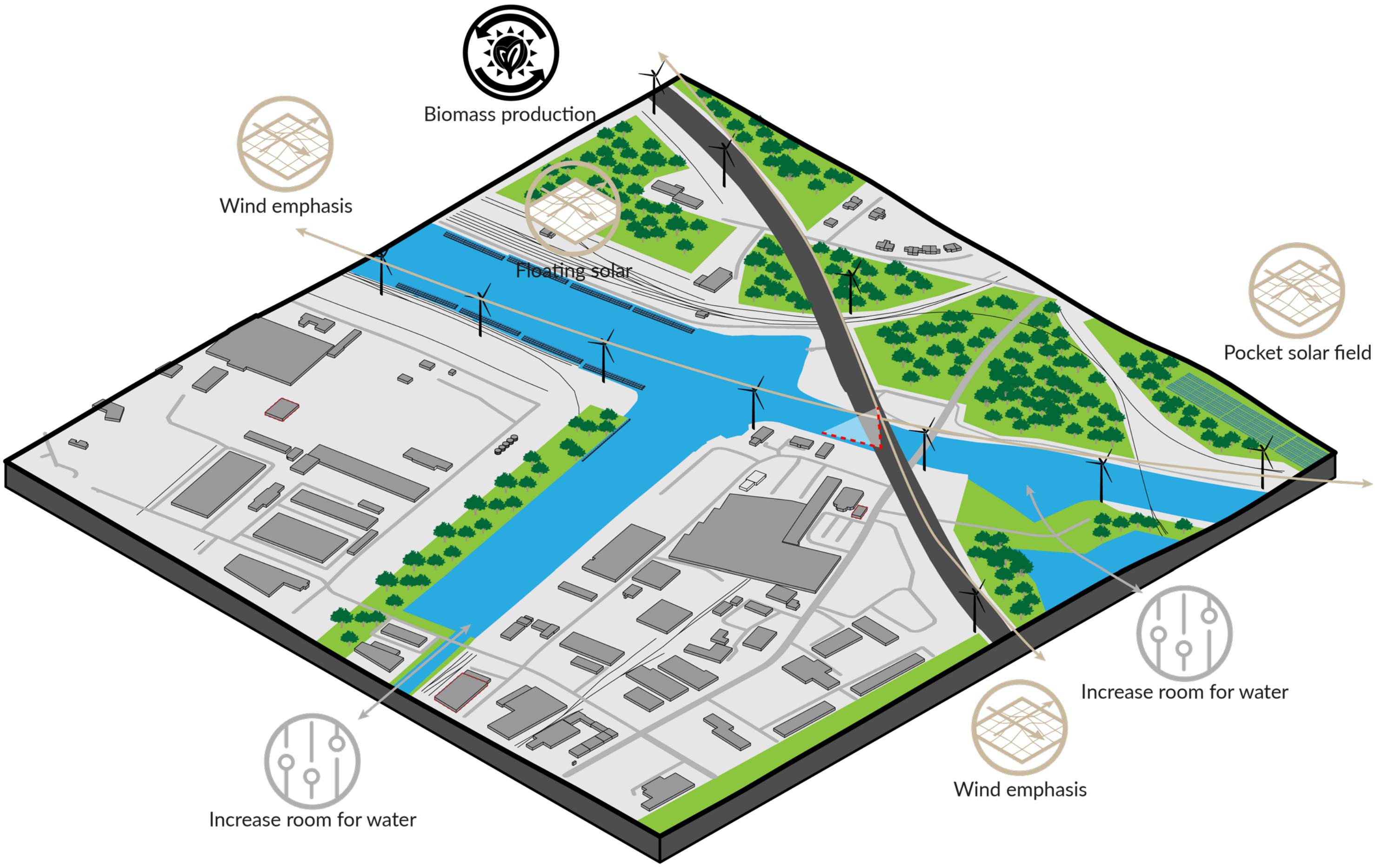
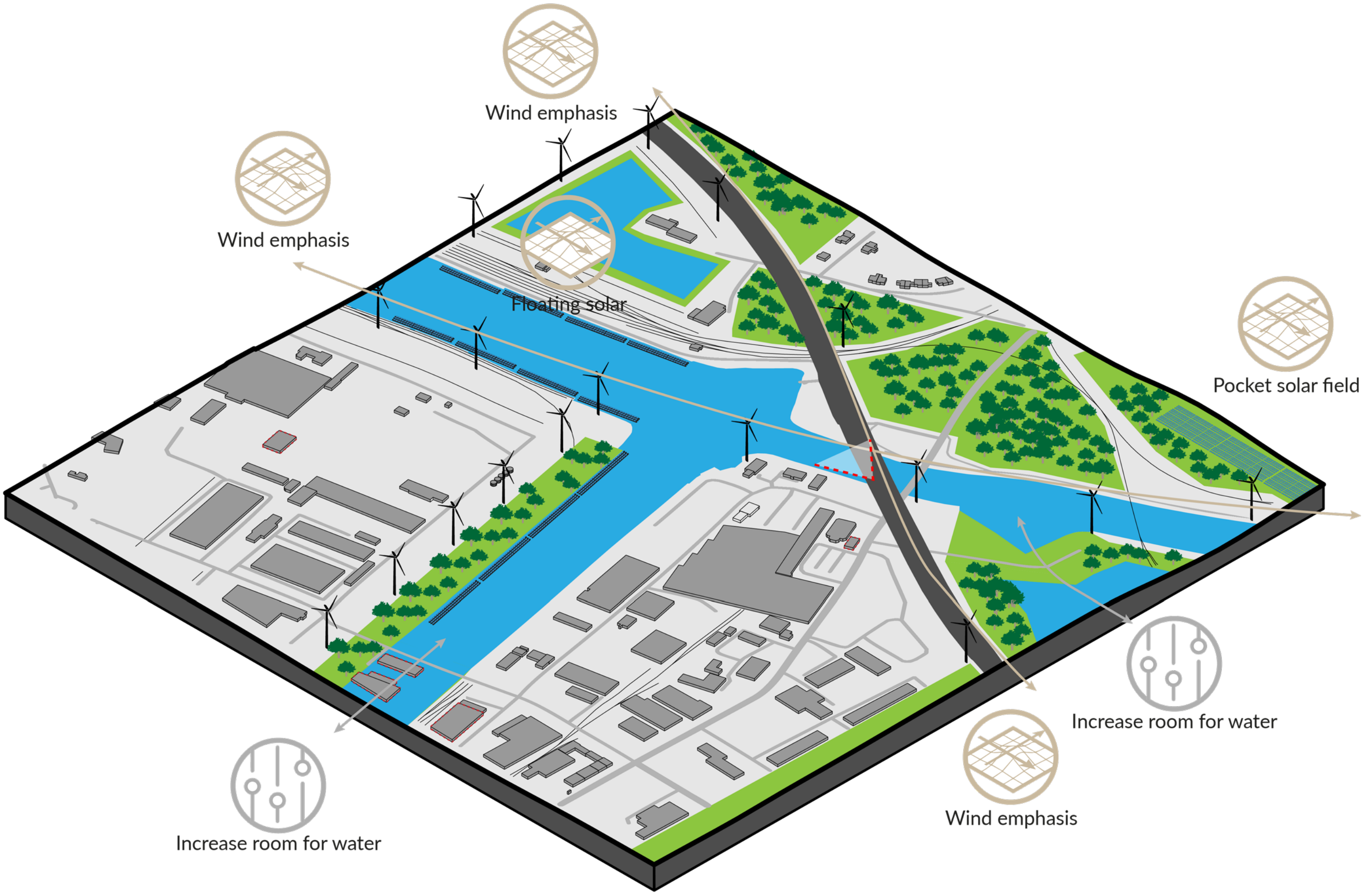


Figure 95: Current situation (a
pessimistic scenario (right) for
view in terms of ecosystem s



above left), optimistic (left) and
r the industrial area in bird eye
ervices score (author, 2022).

viii. Concepts, principles and hierarchy.

With the design exploration executed, several conclusions can be drawn on the outcome of the design solutions. The key notion, is to strengthen the ecosystem in the respected area. This is visualized in figure 97. For the optimistic scenario, this means strengthening the existing ecosystem, to create a system that covers the entire area and is able to offer buffer capacity to extreme events as a consequence of climate change. For the pessimistic scenario, the main principle is to create a buffer capacity, to remain robust, even when thresholds are exceeded. This extreme buffering is done in certain areas, with specific characteristics that define these areas as being the most suited areas for the buffering. Since this extreme buffering has an extreme spatial outcome on the area, I focussed on creating one – or multiple – extreme buffer areas during my design exploration. A system was created in between these extreme buffer areas, that connected these buffer areas and that could face the first shocks and stresses the area would experience as a consequence of climate change.

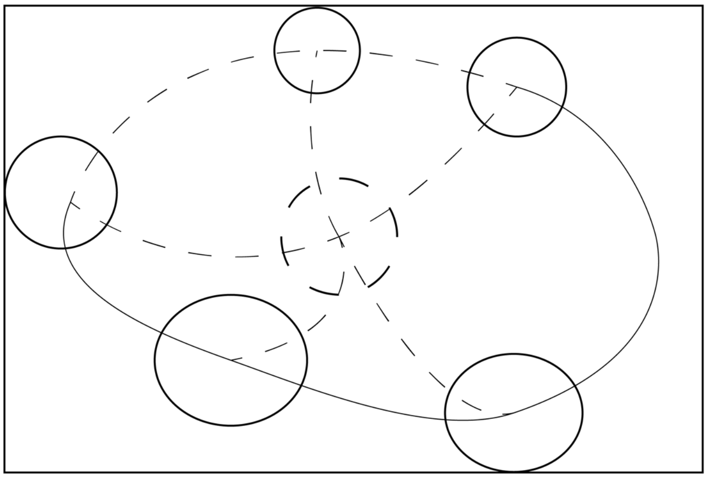
These conclusions can be related to the spatial contextual relations framework, defining key notions in terms of the physical context – implementing height difference to store rainwater -, the functional context – allocating functions to the roofs cape and façade- and to the network of the context, which can be strengthened by implementing the three notions I described previously as nodes or corridors in the network and by, for instance, the implementation of a microgrid.

Furthermore, I used several concepts in this design solution. I describe these design solutions as a concept, because it can be applied throughout the scales and offers a certain notion of adaptability to local demands as well as a set of rules for the implementation and usage, when implemented. Certain key concepts were already described in the design solutions paragraph. All the other concepts, as well as how these concepts can change, when the Ruhr area moves from the optimistic to the pessimistic scenario, is described in the appendix.

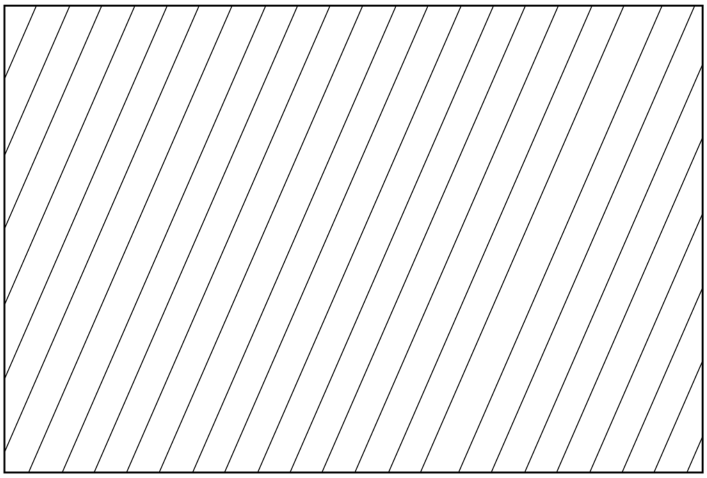
With the design exploration executed, several principles per patch can be defined. These area specific design principles are categorized in a way for the current manifestation, both for the optimistic as well as the pessimistic scenario and for further urbanization. The further development, operationalized through further urbanization, is connected to the sustainable design goals, to see what the possibilities are. These area specific design principles define certain hierarchies. An example is the implementation of hub cities in four out of the five patches, done to create space to further strengthen the ecosystem services, by allocating previously used parking spaces to green-blue infrastructure. This hierarchy is defined as well in the area specific design principles. Furthermore, it is defined how this hierarchy changes, when moving from the optimistic to the pessimistic scenario.

Optimistic scenario - **Connect & Complement**

Network



Buffer capacity



Node in ecosystem network

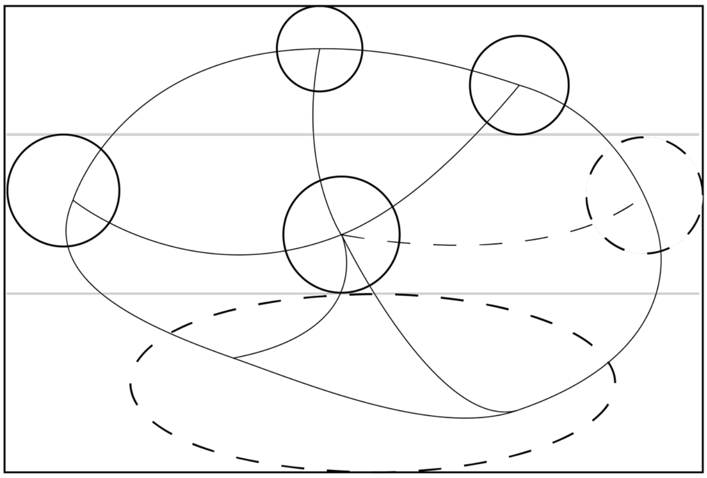
New node in ecosystem network

Connection in ecosystem network

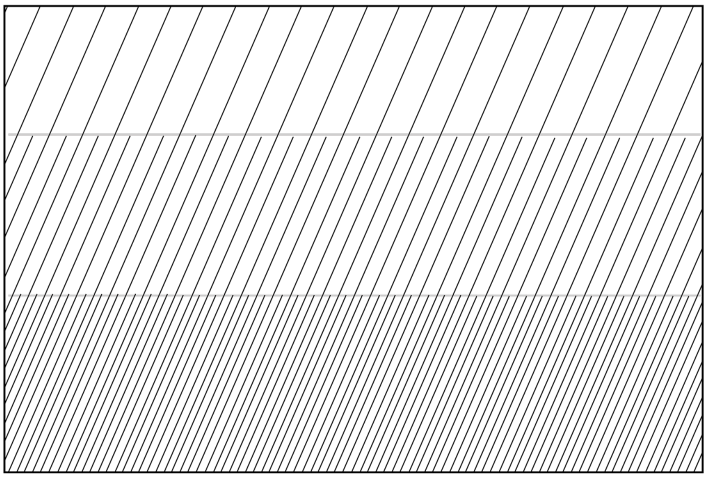
New connection in ecosystem network

Pessimistic scenario - **Buffer capacity (as) main driver**

Network



Buffer capacity



Node in ecosystem network

New node in ecosystem network

Connection in ecosystem network

New connection in ecosystem network

Figure 96: Concluding design principles (author, 2022).

Concluding from the design exploration, the designs solutions can be implemented on the roofscape, facade and ground level. This can be realised by focussing on modularity, which results in being able to implement design solutions on different levels and planes. Furthermore, to be able to implement these solutions, certain planes can be broken up into smaller areas, as indicated in figure 97.

The main question which was raised during this design exploration is if current buildings are able to withstand the pressure from implementing a certain roofscape. This has to be researched, and if the building is not able to withstand a certain pressure, it must be researched which alternative could be implemented.

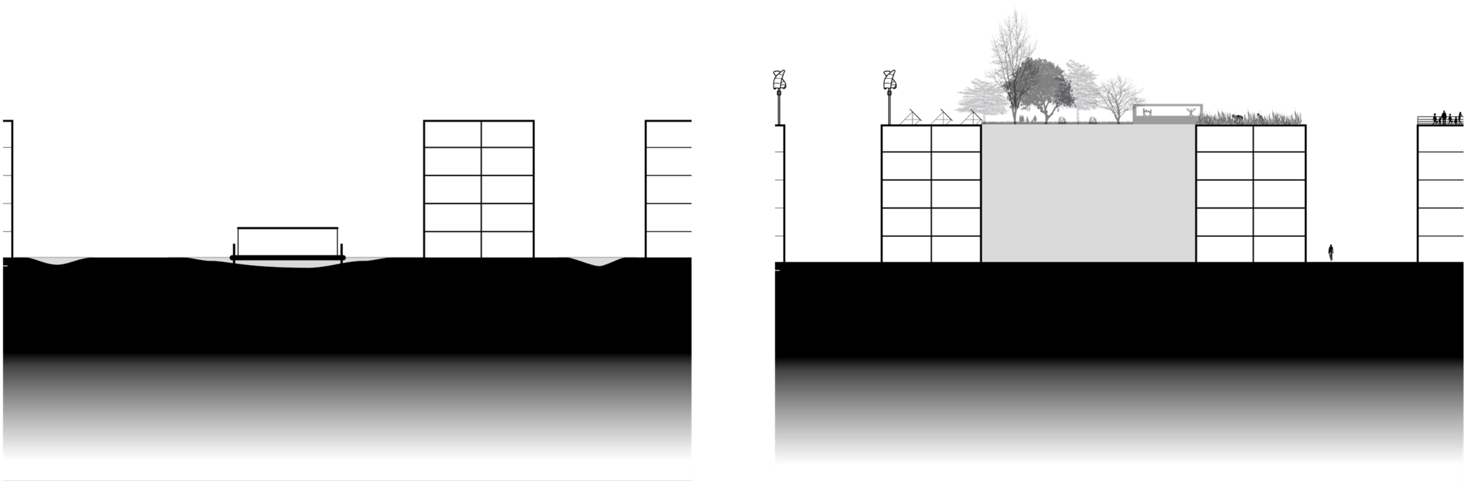


Figure 97: rainwater storage (left) and roofscape principles (author, 2022).

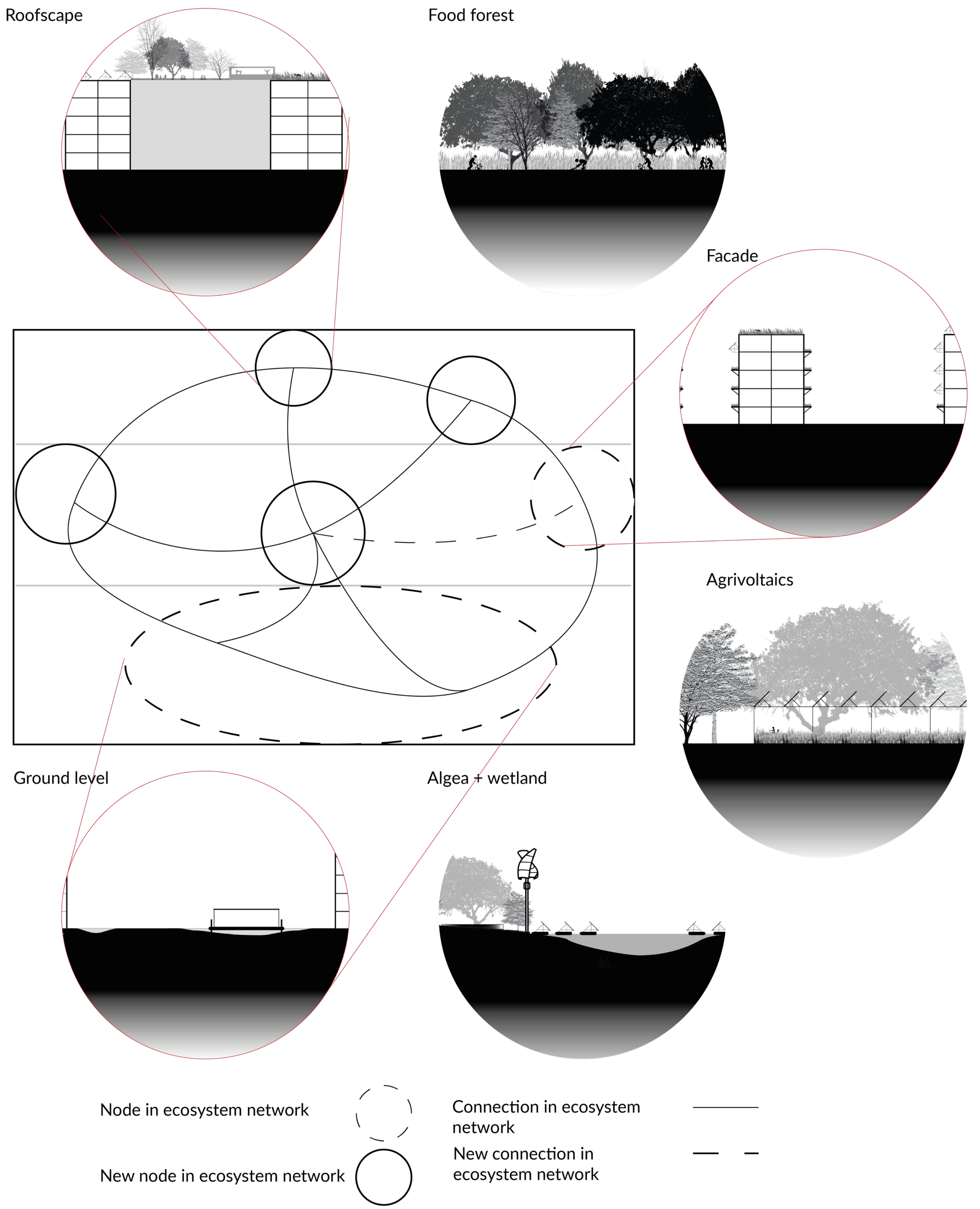


Figure 98: Concluding design principles (author, 2022).

The systemic section visualized in figure 99 indicates how, by strenghtening and expanding ecosystem services, certain problems related to climate change can be tackled. The implementation of these design solutions leads an area which is climate resilient and is able to produce energy using renewable energy sources.

The following pages will show the conclusion of each design exploration which was executed. The design exploration was concluded which lead to a strategy for the specific patch. This strategy defines how the proposed design solutions have to be implemented and where to start with.

This strategy led to the description of the hierarchy for each patch. Furthermore, derived from this, certain strategic components were defined. These strategic components are visualized, in their current spatial manifestation as well as in their proposed spatial manifestation and indicated how they relate to the three key functions of ecosystem services.

this leads to the chapter 11; strategy.

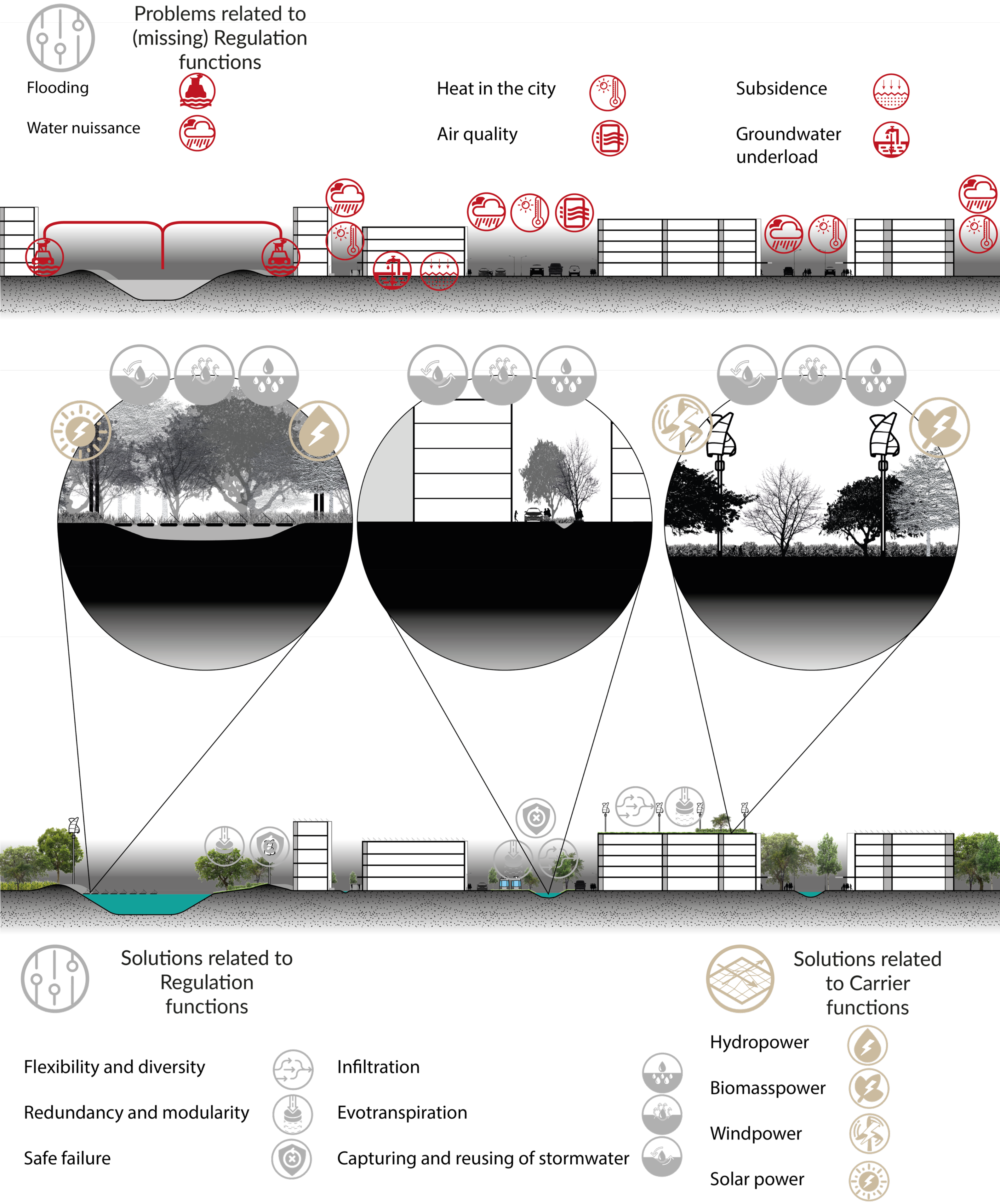


Figure 99: Systemic section (author, 2022).

Peri-urban area | Productive peri-urban area

Optimistic scenario

1 The implementation of the **Hub City**

1 The implementation of the **Food forest**

Economically activated, needs green blue streets as carrier

2 The implementation of the **Greenblue streets**

Network is ready

3 The implementation of the **Energy = economy**

Production can be started, becomes one?

4 The implementation of t

4 The implementation of t

4 The implementation of t

4 The implementation of t

Food forest becomes algea +

1
Regulation:
Tourist are forced to park their cars in these hubs. Where residents are allocated one place per household.
Parks are allocated to have one (or several) buildings with a public function.
Subsidies:
For developers to include (part of) hubs into their new devleopment.
For residents of that city to decrease car usage, switching to shared mobility.
For (urban) farmers to grow crops in these parks/forests, to start their new business.

2
Regulation:
Land use plans are altered to allocate space to greenblue streets as well as creeks and hydro-power plants. Residents co-create locations for parking of shared mobility .

3
Advice: companier are helped (by profession
tion towards a green sector.
Regulation: CO2 maximum per company anc
zero by 2030.
Subsidies: for a business man to start a new

4
Subsidies: for farmers to
ment agrivoltaics, bioma
tation, pocket solar park
wind emphasis on their
Regulation: once accept
solar parks, biomass fore
and wind emphasis can
formed to pessimistic sc
once required.

Figure 100: Strategy for the implementati
202

Pessimistic scenario

2 Converting the **Greenblue streets** to pessimistic scenario

Buffer capacity ready, networks needs to adapt

Network is ready

the **Wind emphasis**

the **Biomass forestation**

the **Pocket solar parks**

the **Agrivoltaics**

2 Converting the **Pocket solar parks** to pessimistic scenario

wetland

5 The implementation of the **Algea + wetland**

6 The implementation of the **Waterstairs**

Water is ready

7 The implementation of the **Floating solar**

als) to shape their transi-

d sector, be brought to

green company, sector.

o imple-
ass fores-
ks and
land.
ed pocket
estation
be trans-
cenario

5 Subsidies: for farmers to transform or sell their land to the metropolitan to let it become a algea production site in wetland.
Regulation: once accepted, this algea + wetland can be transformed to the pessimistic scenario once required. Further subsidies will then be given to the land owner.

6 Subsidies: for landowners with major hight difference to implement waterstairs, this will be connected to the energy network

7 Regulation: land use allows for implementation of floating solar, subsidies for exploiting companies

ion of a productive peri-urban area (author,
22).

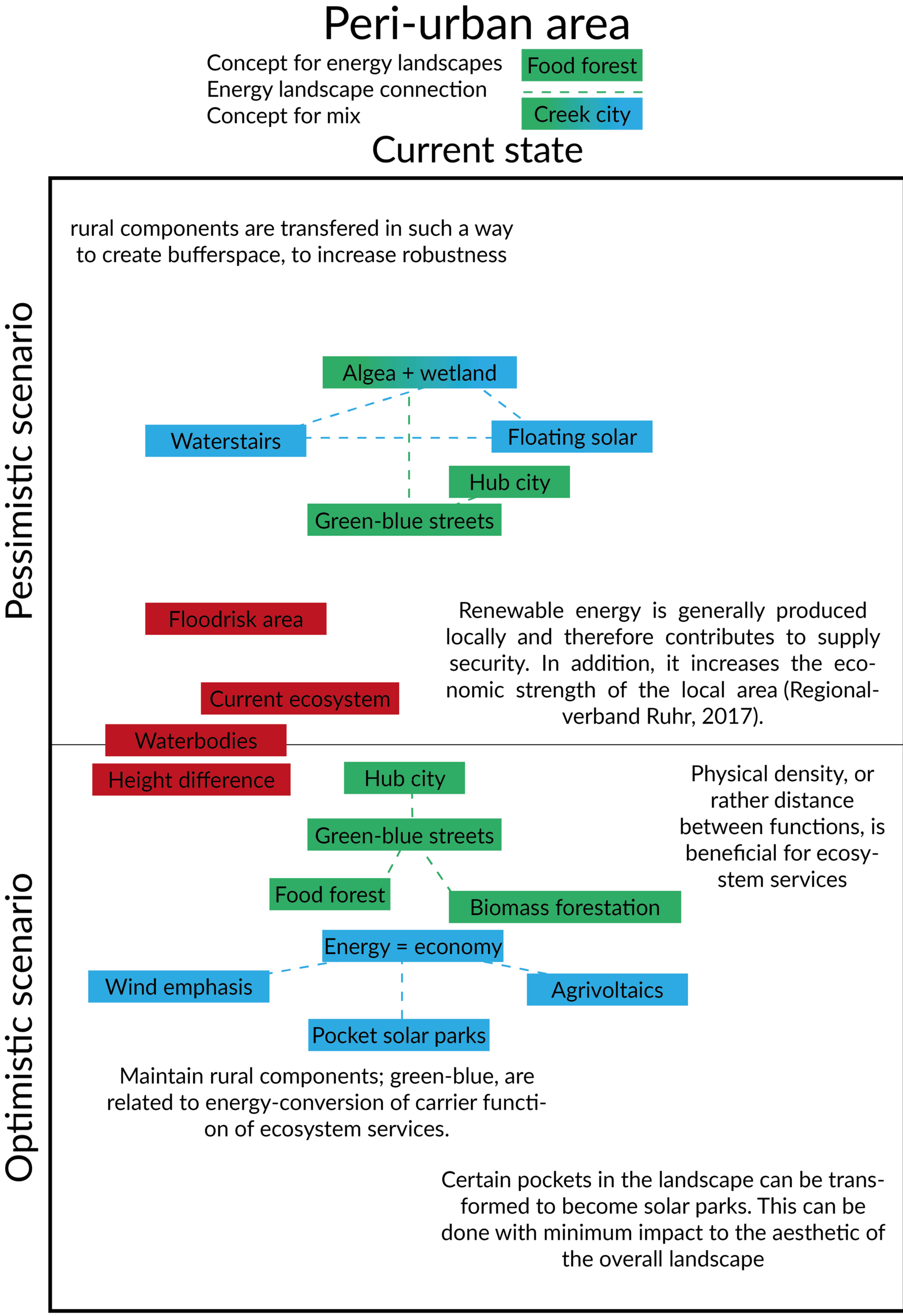


Figure 101: Design principles and hierarc

Strategic component
Concept for climate adaptation
Climate adaptation connection

Floodrisk area

Wind emphasis

Principle for further development

Strenghtened public transport system

Further development

Buffer capacity

Buffer capacity should be main design principle for futher development

Ecosystem network

Maintain green-blue structure, further develop only in existing residential or urbanised areas.

Strenghtened public transport system

Network of green-blue streets as well as wetland should be maintained and strenghtened when further developing the area

chy of the peri-urban patch (author, 2022).

ix. Strategic component.

Category

Physical context

Floodrisk area

Regulation functions | Production functions | Carrier functions

Becomes a productive area, with algea production and solar and wind energy production.

Height difference

Regulation functions | Production functions | Carrier functions

The potential of height difference is used, especially when close to water, where hydropowerplants and a tidal park are implemented.

Network of the context

Current ecosystem

Regulation functions

The current network is strenghtened and expanded, by allocating more space for, for example streams and trees.

Current energy network human landscape

Regulation functions | Production functions | Carrier functions

Becomes the starting point for further development of renewable energy sources and is expanded towards areas with a high energy potential that fits in the human landscape.

Figure 102: Strategic component in thei
(author

Functional context

Underused surfacas; roofs, streets, squares

Regulation functions | Production functions | Carrier functions

Is allocated to ecosystem services and becomes a productive area.

Overpaved areas

Regulation functions | Production functions | Carrier functions

Is divided in smaller areas, with designated areas for food and energy production, as well as energy production.

Waterbodies

Regulation functions

Is linked (above or below ground) to other waterbodies or streams, to be able to cope with heavy rainfall.

Current ecosystem

Regulation functions | Production functions | Carrier functions

Becomes not only a productive area in terms of food/crop production, but also in terms of energy production.

r current and future spatial manifestation
, 2022).

Chapter 11. Strategy

i. Current energy transition strategy.

The goal of this chapter is to define the current energy transition strategy, implemented in the Ruhr area. Notions on how this transition is transformed into a strategy will be defined, as well as what problems are causing this energy transition, to probably, not reach its target (Regionalverband Ruhr, 2017).

The current energy transition in Germany, and in the Ruhr area, is seen as a technical and economic transition, with the hopes of developing a new industrial sector to research and develop renewable energy sources (RES) (Laes et al., 2014).

The current German energy transition is focussed on providing a direct promotion of renewable energy sources (Laes et al., 2014). This has resulted in about a 25% production of primary energy coming from RES. However, only 5% of the final energy consumption in the Ruhr area came from RES. In the Ruhr area, the district heating network is being expanded, which is one of the major interconnected district heating systems in Europe (Regionalverband Ruhr, 2017).

There are several cities however, such as Gelsenkirchen, who have shown a good example of promoting local projects related to RES. This promoting is done, by motivating residents and co-creating plans with local and governmental actors. This has resulted in a 6.1% share of energy from renewable sources, in the final energy consumption. However, this process is disturbed by legislative action on the Ruhr metropolitan level (Regionalverband Ruhr, 2017).

ii. Overall strategy.

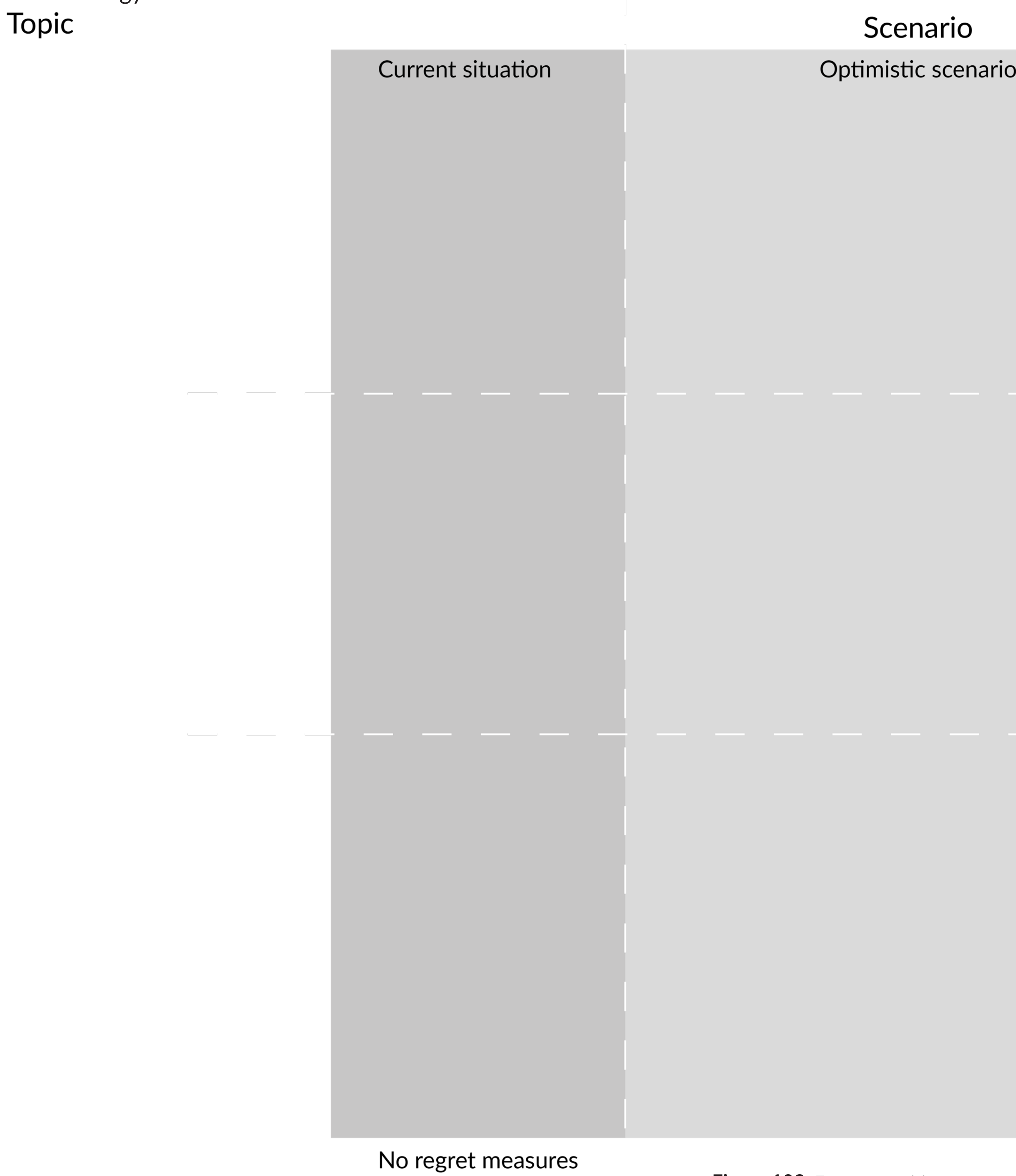
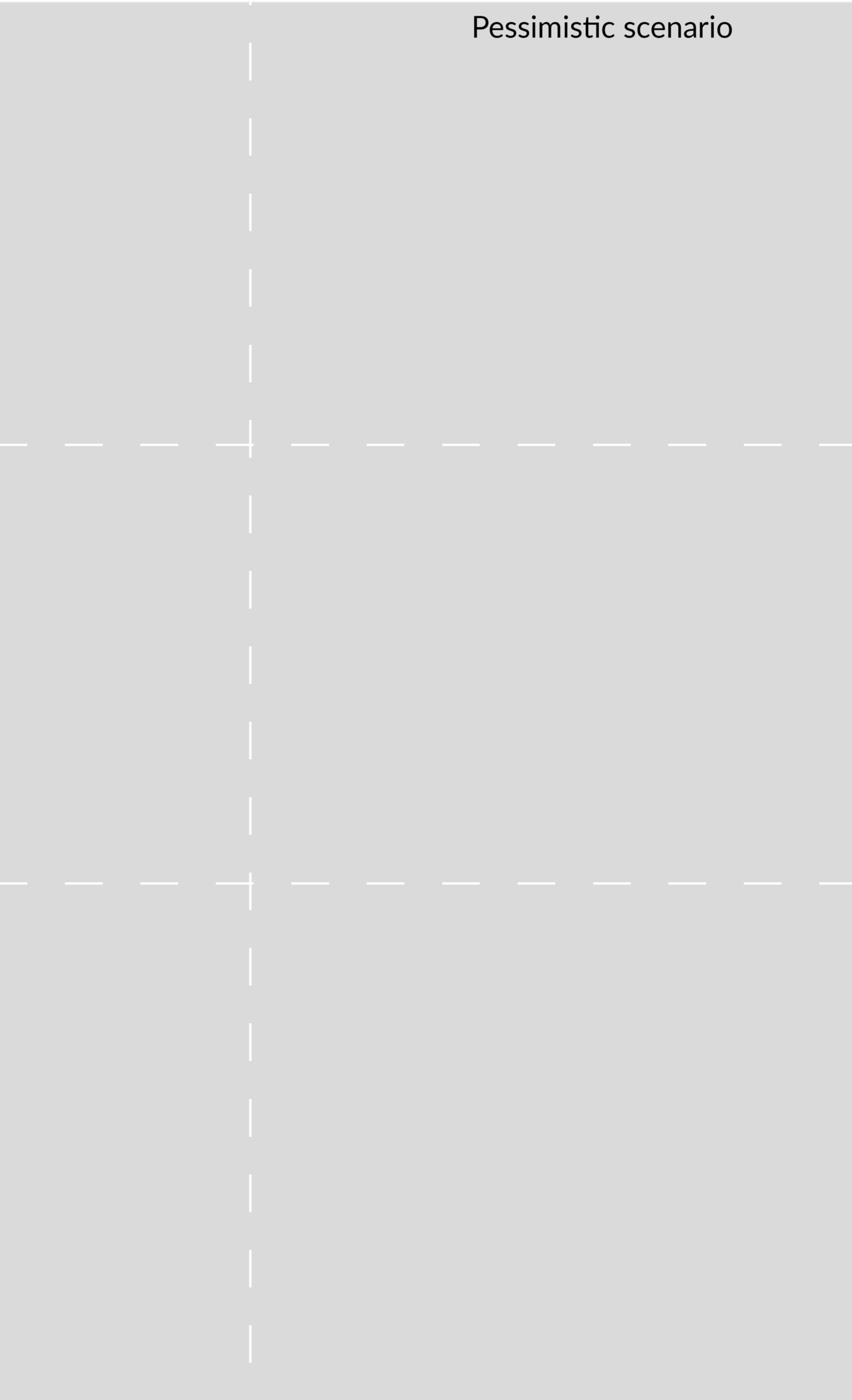


Figure 103: Energy transition strategy

This strategy, with the overall goal to strengthen ecosystem services, and by doing so reach the goals set in the energy transition and prepare the Ruhr for the climate change, is produced based on the notions that were derived from the strategies for the five different patches and their respected design solutions. These strategies on the local scale can be read in the appendix.

This overall strategy is formed up off multiple layers. First, the goals for each level of governance



Governance level

State level:
North-Rhine Westphalia

Incentivice, start and monitor paradigm shifts on a state level to strenghten the energy transition.
Create framework for compen-saion of people and services.

Regional level:
Regional Ruhr association

Define program requirements, start process of implementati-on, keep track of development of scenarios, adjust concepts to changing scenarios.

Local level:
Municipalities

Implement concepts in local scale, adjusting concepts to meet additional local demands.
Co-create the final implementa-tion with residents and users.

with governmental goals (author, 2022).

are mentioned. These goals result in different tasks for each level of governance, which will be described later on. For the State level, this means creating a framework for compensation of residents due to a change in their physical context, functional context or network of the context. Furthermore, the state level should work together with the national government on incentivising, starting and monitoring of paradigm shifts. These paradigm shifts will be mentioned later on.

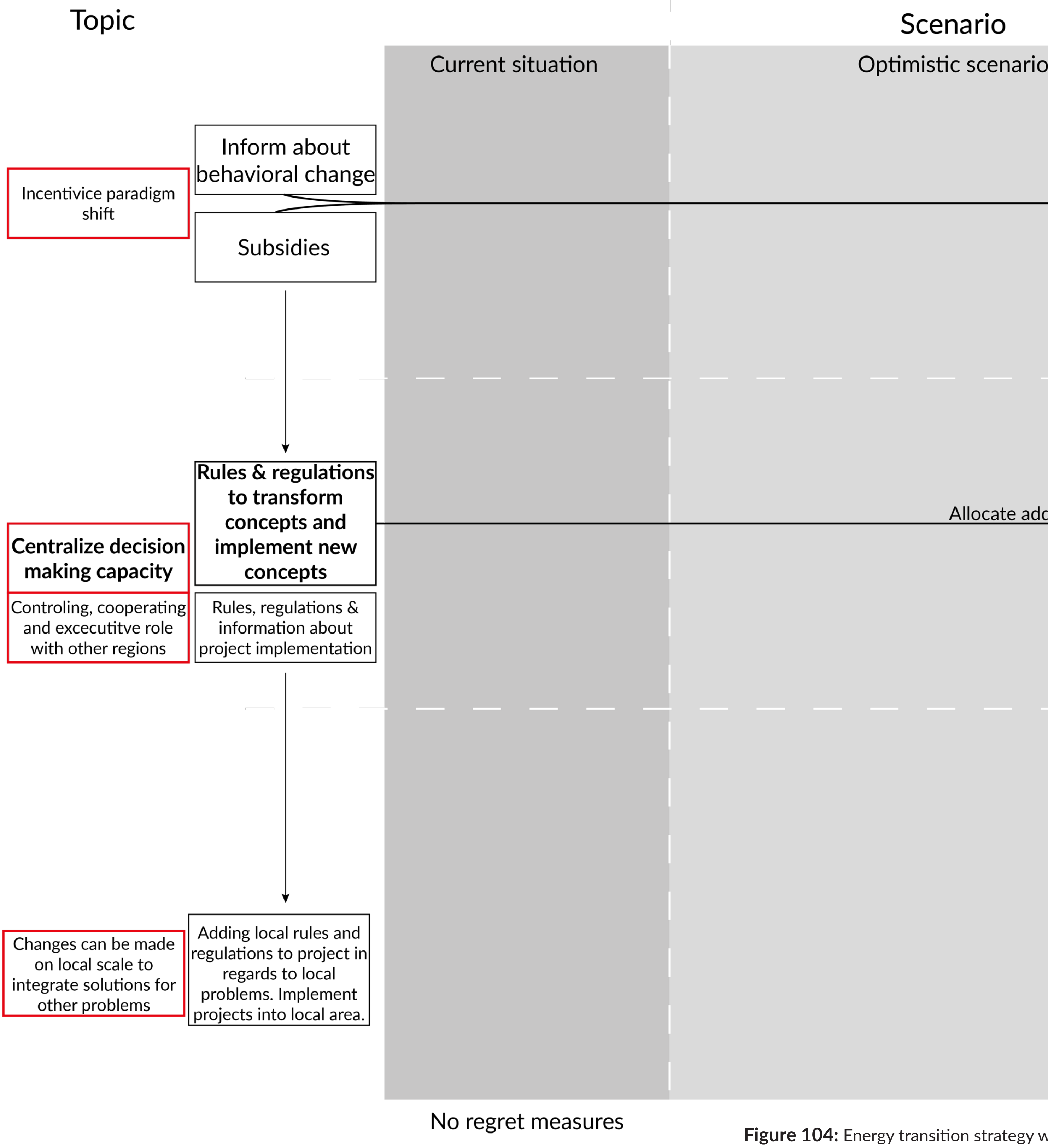
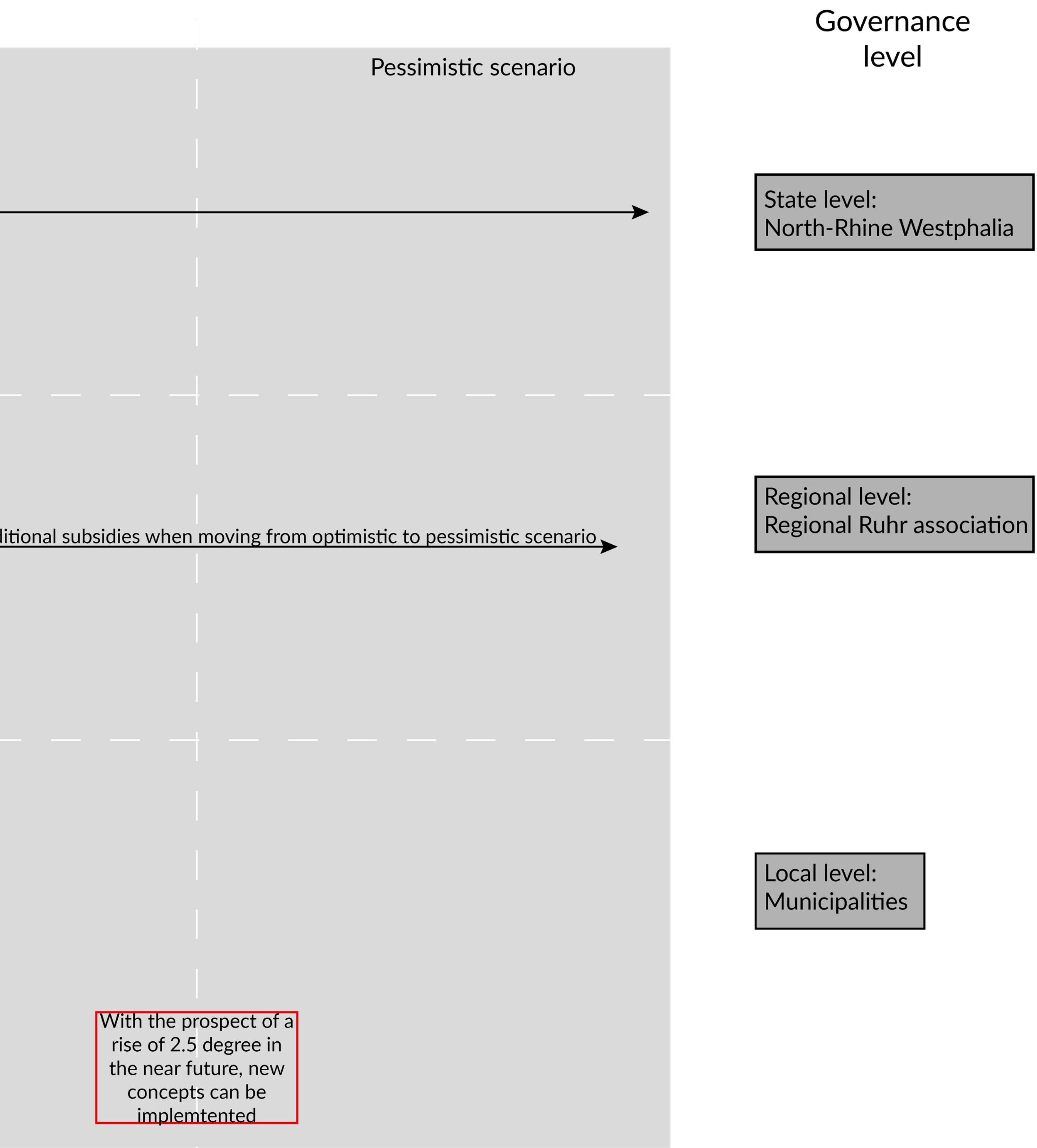


Figure 104: Energy transition strategy w

The overall strategy is constructed based on two key principles; the energy transition, together with the climate adaptation, must be seen as a social transition, with a technical component. This notion is derived from Pasqualetti (2011). This is imbedded in the strategy by focussing on the social considerations when evaluating project proposals, instead of only focussing on the technical characteristics. Furthermore, developers should aim for complete understanding of the human landscape at the proposed location of a project. These notions can be tackled by converting to a co-creation approach to the implementation of the energy landscapes. Lastly, Pasqualetti raises the notion that impacted people need to receive meaningful compensation for the landscape that they value.



vith the strategy principles (author, 2022).

Furthermore, the Ruhr metropolitan association is granted centralized decision making power, from the North-Rhine Westphalia government. This means that the Ruhr association can determine when to convert a certain concept from the optimistic to the pessimistic scenario as well as when to start with the implementation process of a certain concept. This, the centralized decision making power, is an effective tool to cope with uncertainty in planning processes (Ferry et al., 2022).

The state level provides funding for the projects, which are handed to the Ruhr association. This body of governance oversees the implementation of concepts, however municipalities are responsible for the execution of this implementation, to be able to adapt to local developments or problems that this municipality is facing.

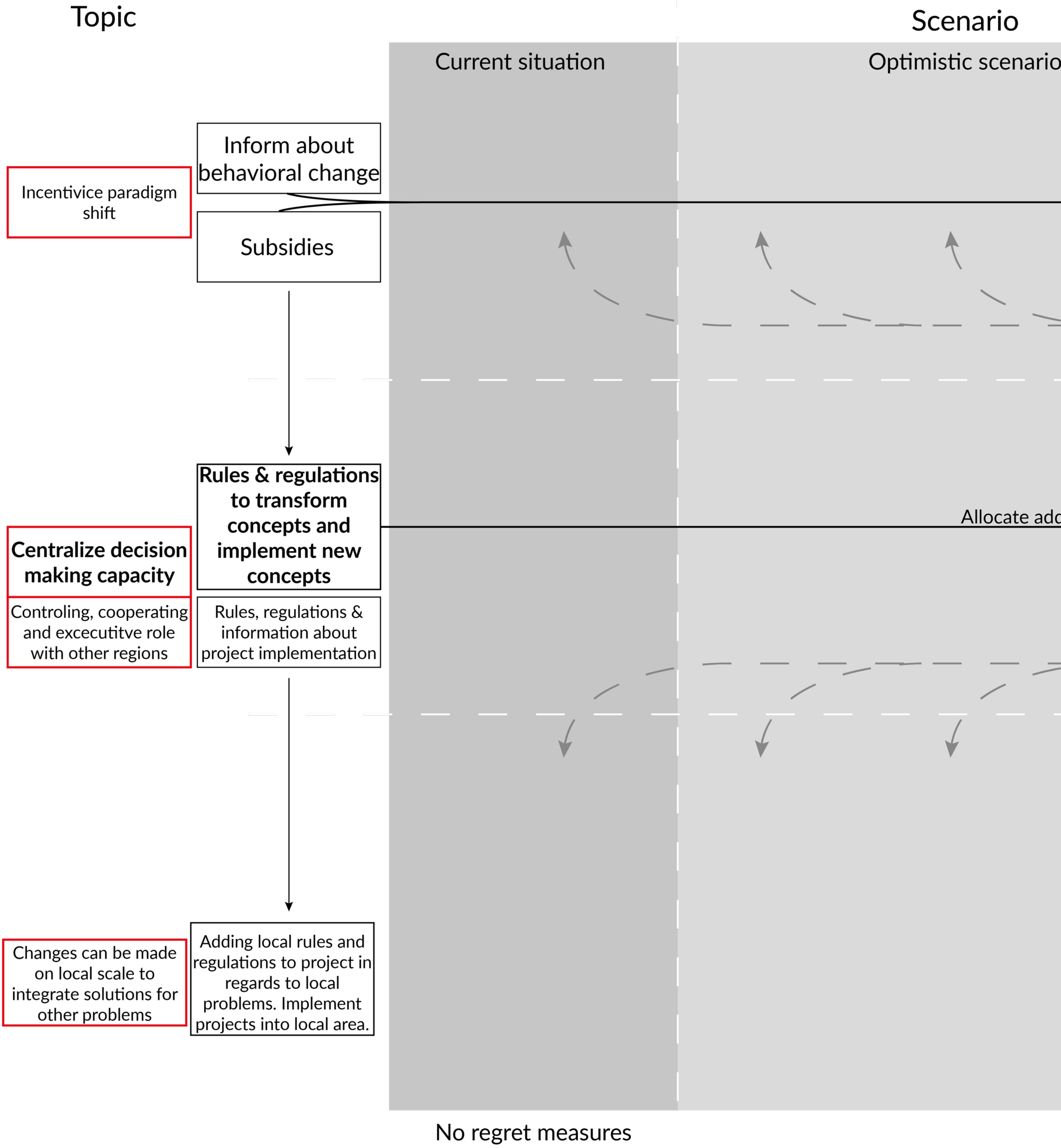


Figure 105: Energy transition strategy w
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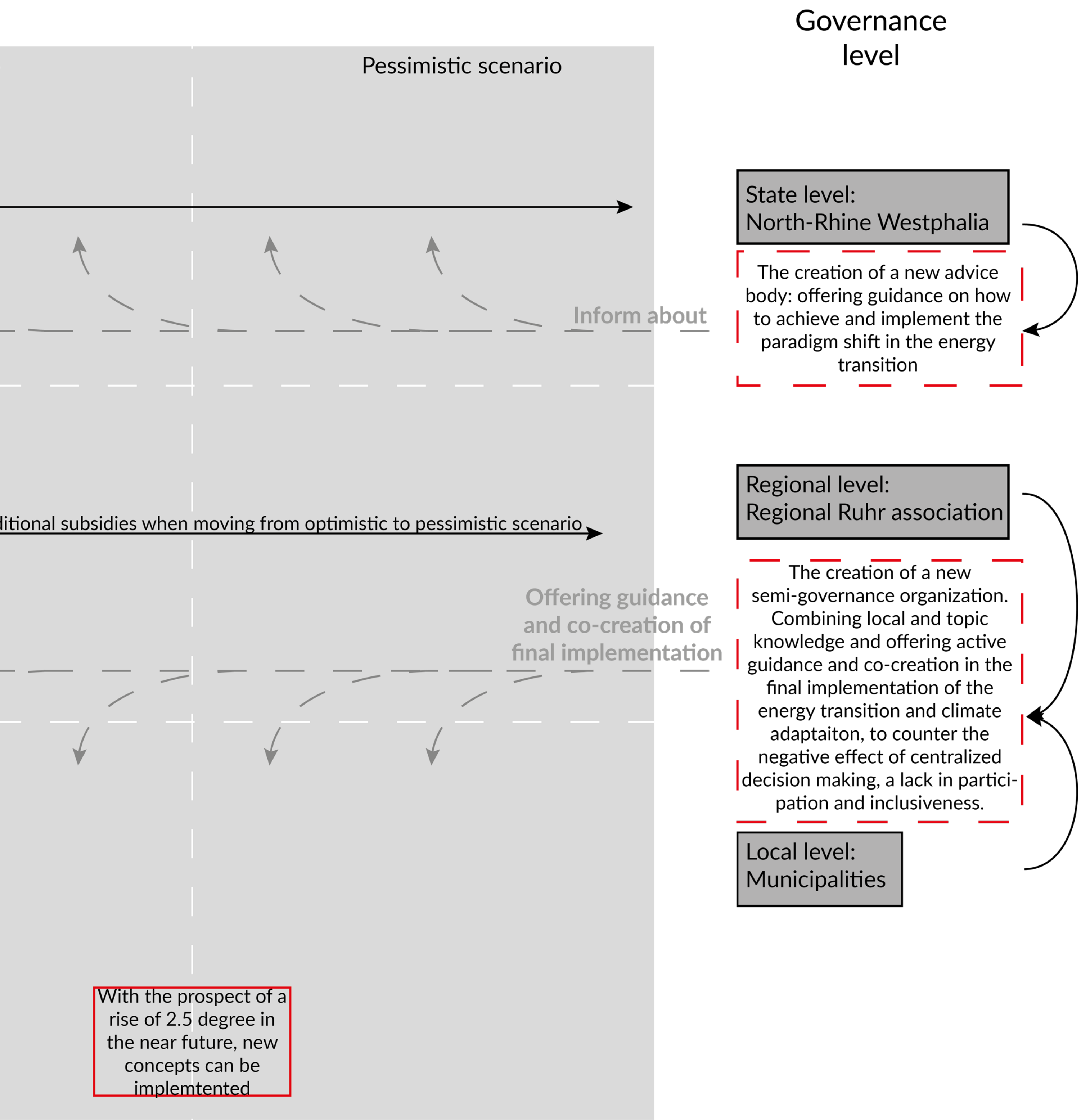
Furthermore, two new governance bodies are proposed. The first one is an advisory board, on how to guide and steer the paradigm shifts in the four most energy consuming sectors. This board advices the state on how to steer these paradigm shifts. More regarding the paradigm shifts, in the following paragraph. The second new proposed body of governance is a governance agency combining local & topic knowledge and focussing on co-creation and residents participation, derived from Pasqualetti (2011) and to mitigate the negative outcome



with the new governance bodies (author,
22).

of centralized decision making (Mack & Szulanski, 2017). This new body of governance aims at strengthening participation and co-creation during the process of design and implementation of sustainable energy landscapes.

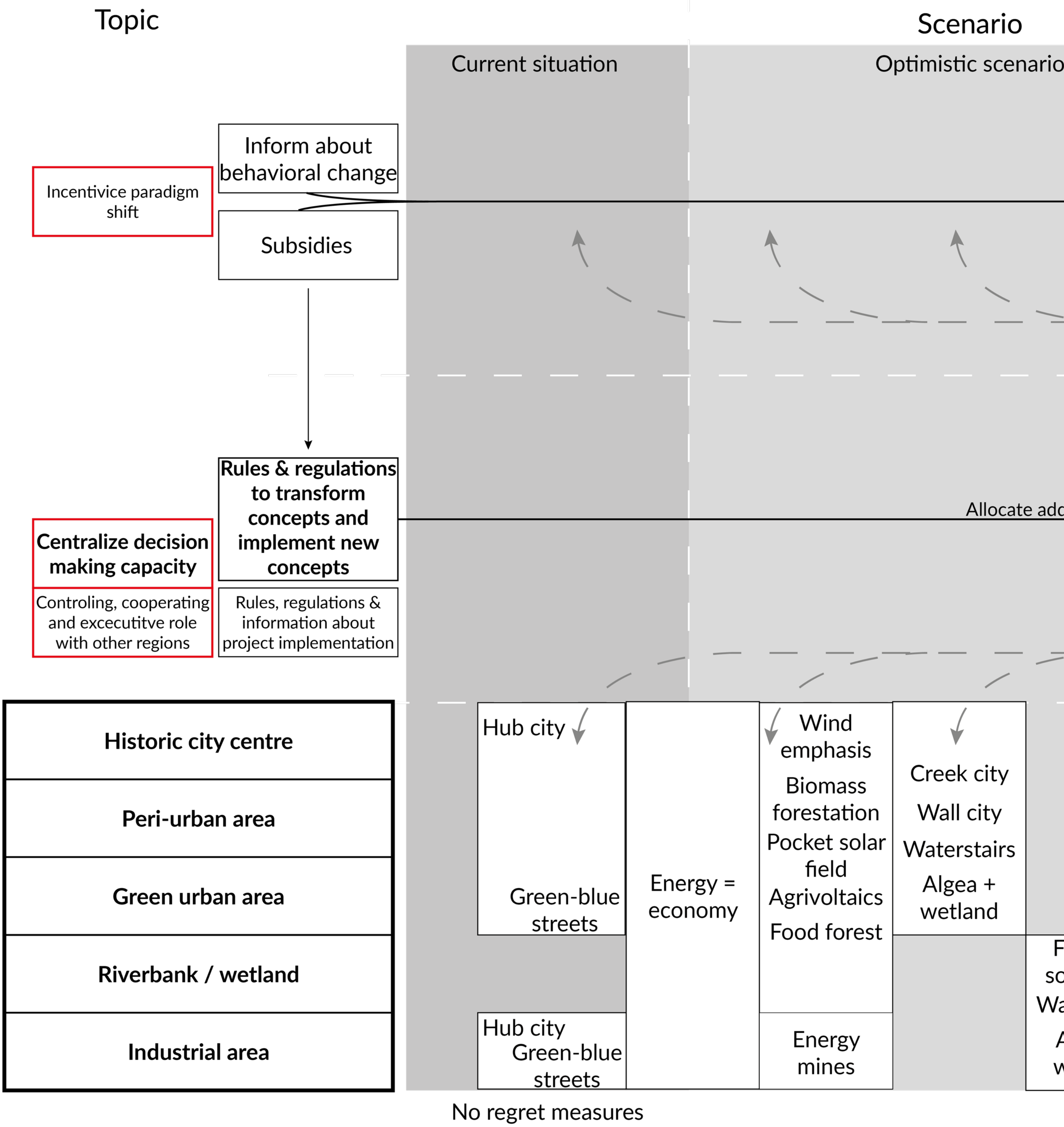
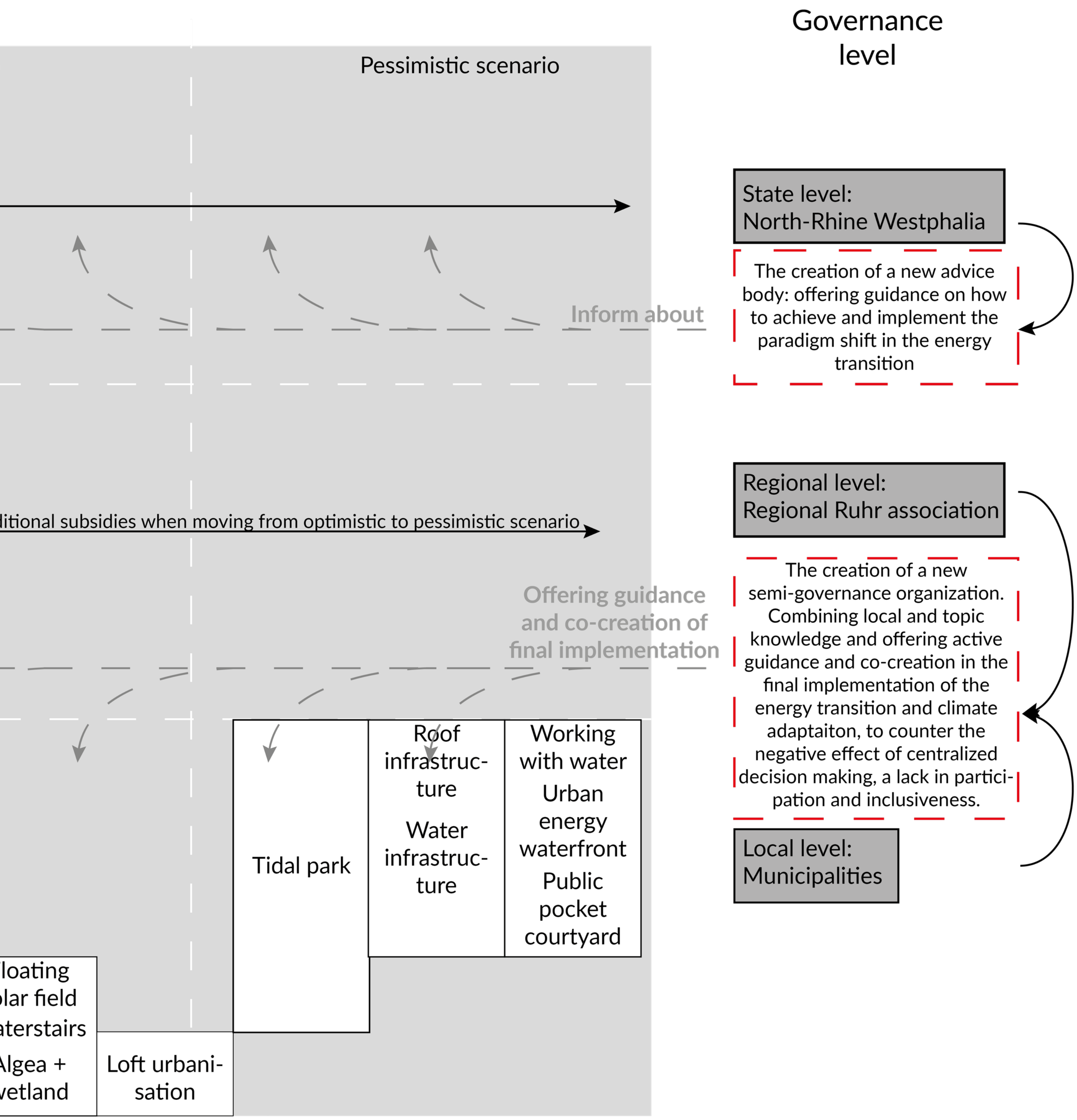


Figure 106: Energy transition strategy wi
202

The strategy, which defines which notions and problems should be dealt with first, is derived from the strategy on the smaller scale. These provided a certain hierarchy in the strategy, for the implementation of the concepts. The hierarchy, which was described in the previous chapter, is implemented in this strategy as well. The hub city, combined with the green-blue streets, are the first concepts to be implemented for four out of the five areas. The hierarchy of the different areas, and their place in the strategy for the local scale, is visualized here. This hierarchy, led to



th the implementation of concepts (author,
22).

the location of concepts on the regional scale.

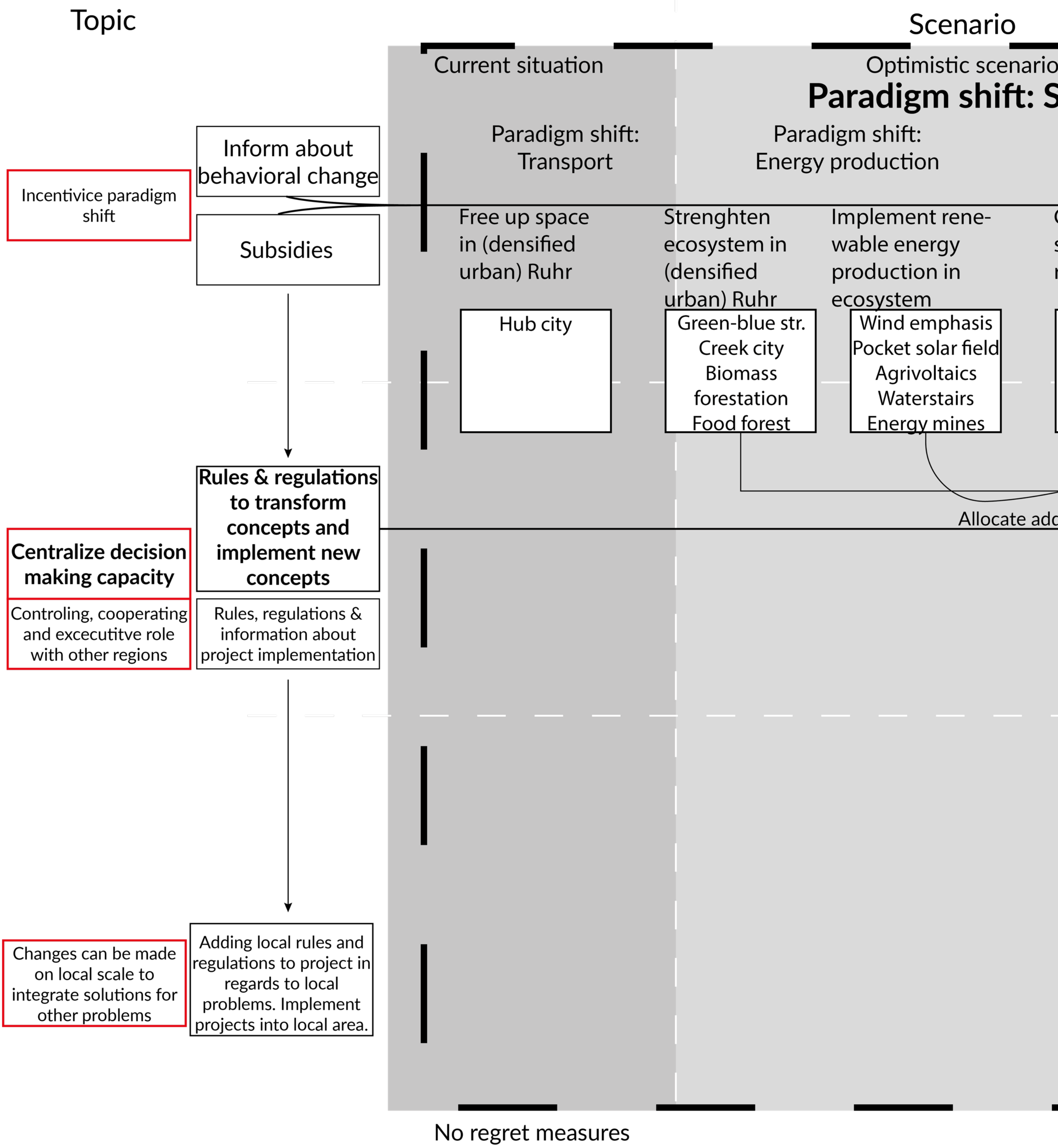
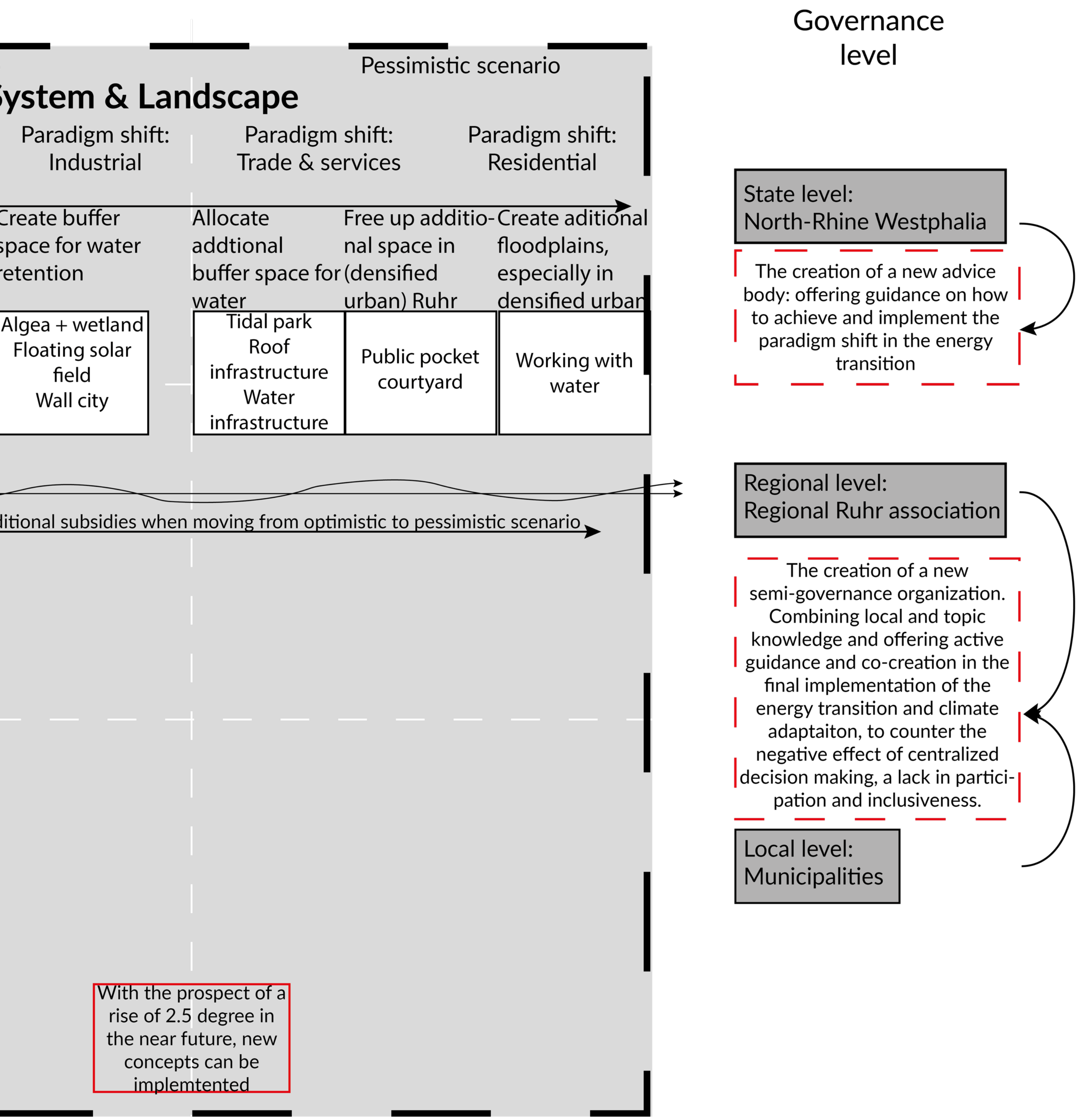


Figure 107: Energy transition strategy wi
regional scale (

Several notions and conclusions were drawn based on the strategy for the smaller scale. These were applied to the larger scale. This resulted in a strategy, which is visualized here. This strategy is based on the implementation of the most urgent notions. The overall goal of the implementation of these concepts, is placed in the strategy. This describes for which goal, each concept is implemented. In the following paragraph, the key notions regarding the physical context, functional context and context of the network is described and placed on a timeline,



ith the implementation of concepts on the
(author, 2022).

to indicate which planning instruments will be required for the implantation of which concept, and what the timespan of this implementation will be.
Furthermore, together with the newly formed body of governance, the paradigm shift regarding the four most energy consuming sectors is kick-started. This is further elaborated later on in this strategy.

iii. Regional representation of strategy.

This regional representation of strategy is described using the categories of the spatial contextual relation framework; the physical context, the functional context and the network of the context. The goal of this paragraph is to further elaborate on the strategy and to spatialize this strategy. This is done using sections and the related concepts.

Firstly, the physical context is described. Following the design exploration, several strategic components were described. Multiple of these strategic components are applicable for the physical context; floodrisk area and height difference. How these strategic components adapt over time, and what the hierarchy is within these strategic components is visualized in figure 108. Furthermore, their main concepts are visualized as well. The current strategic components for this category are visualized in the map.

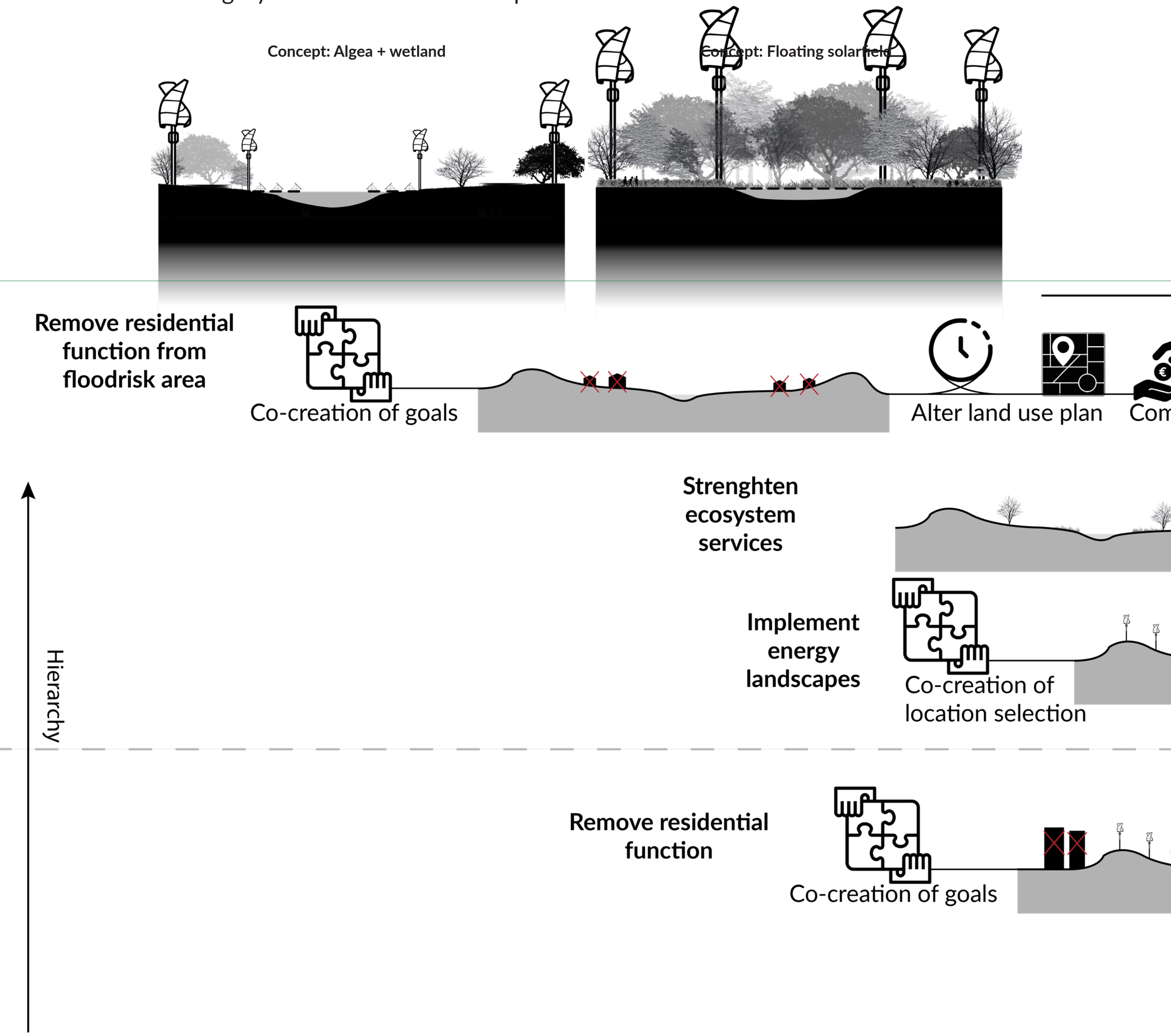
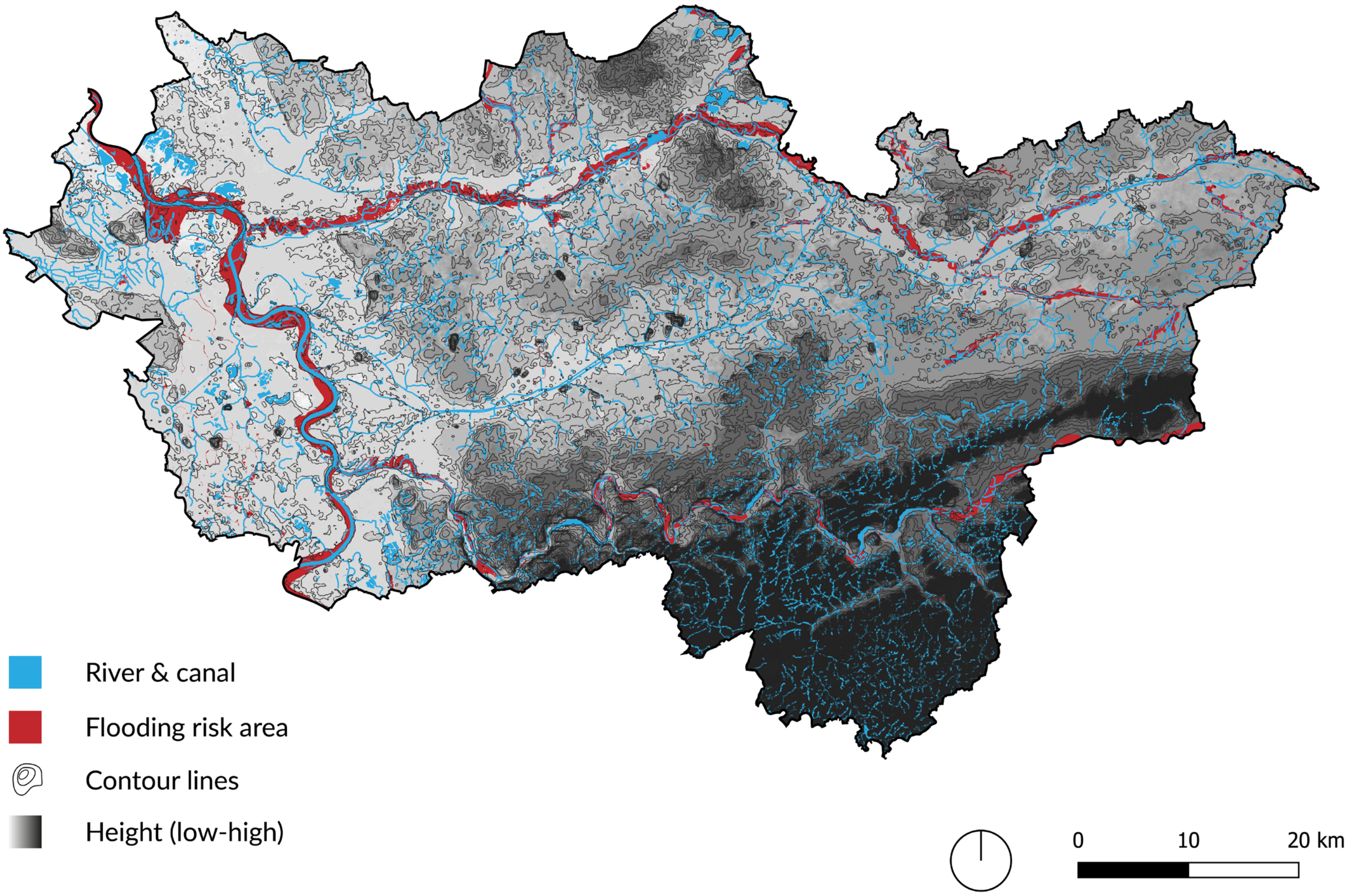
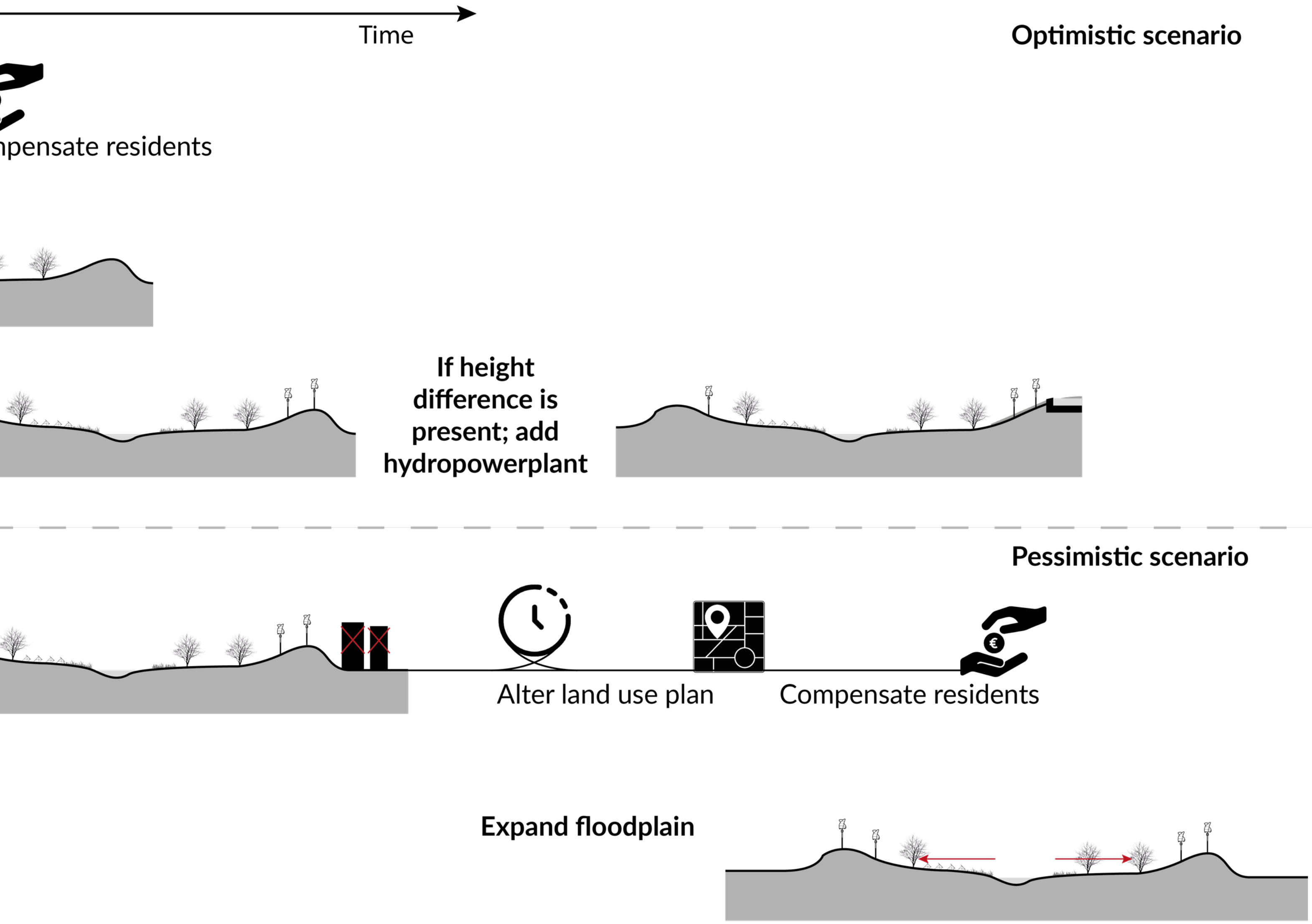
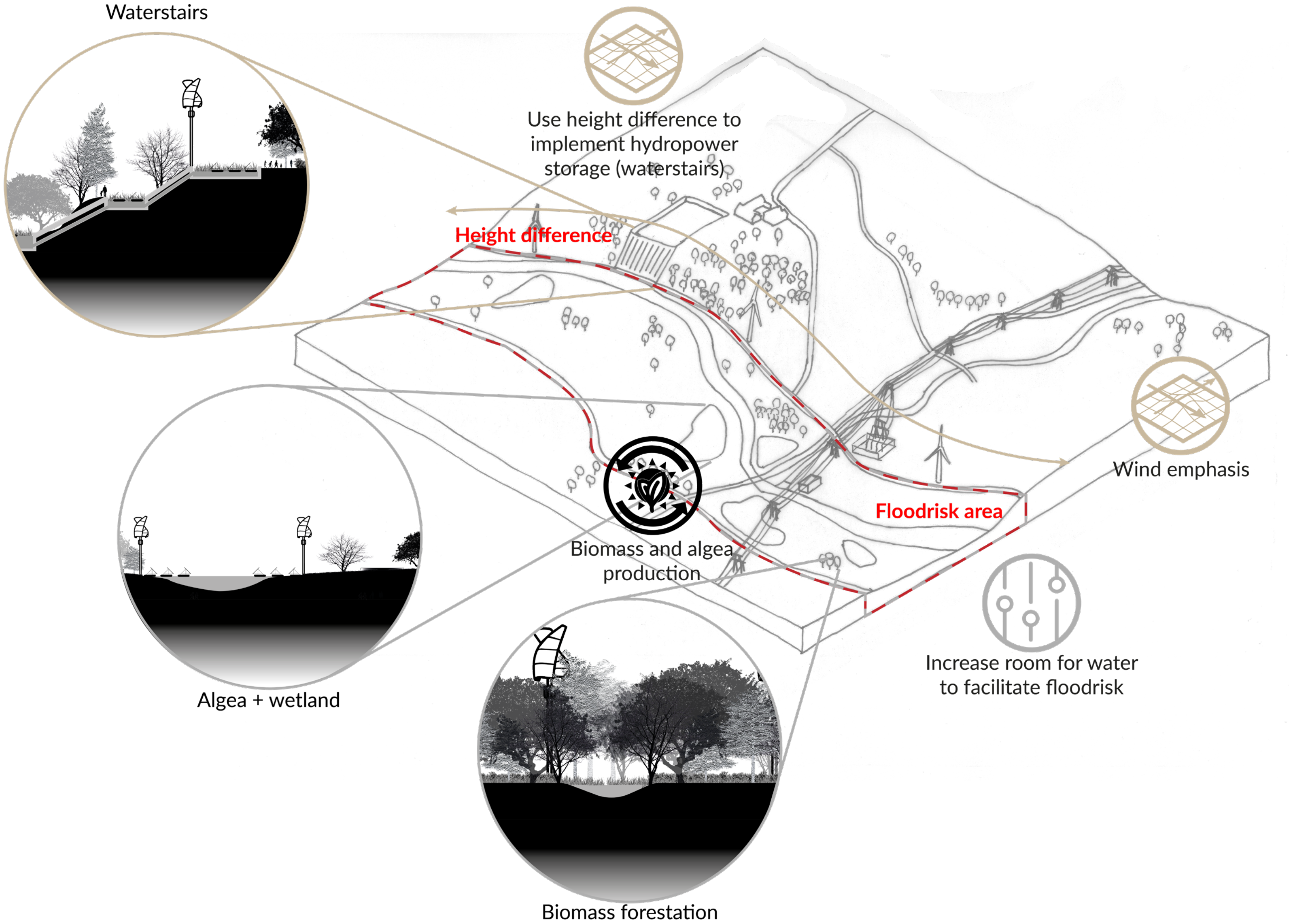


Figure 108: The strategic components strategy (bottom) in concept (top lef





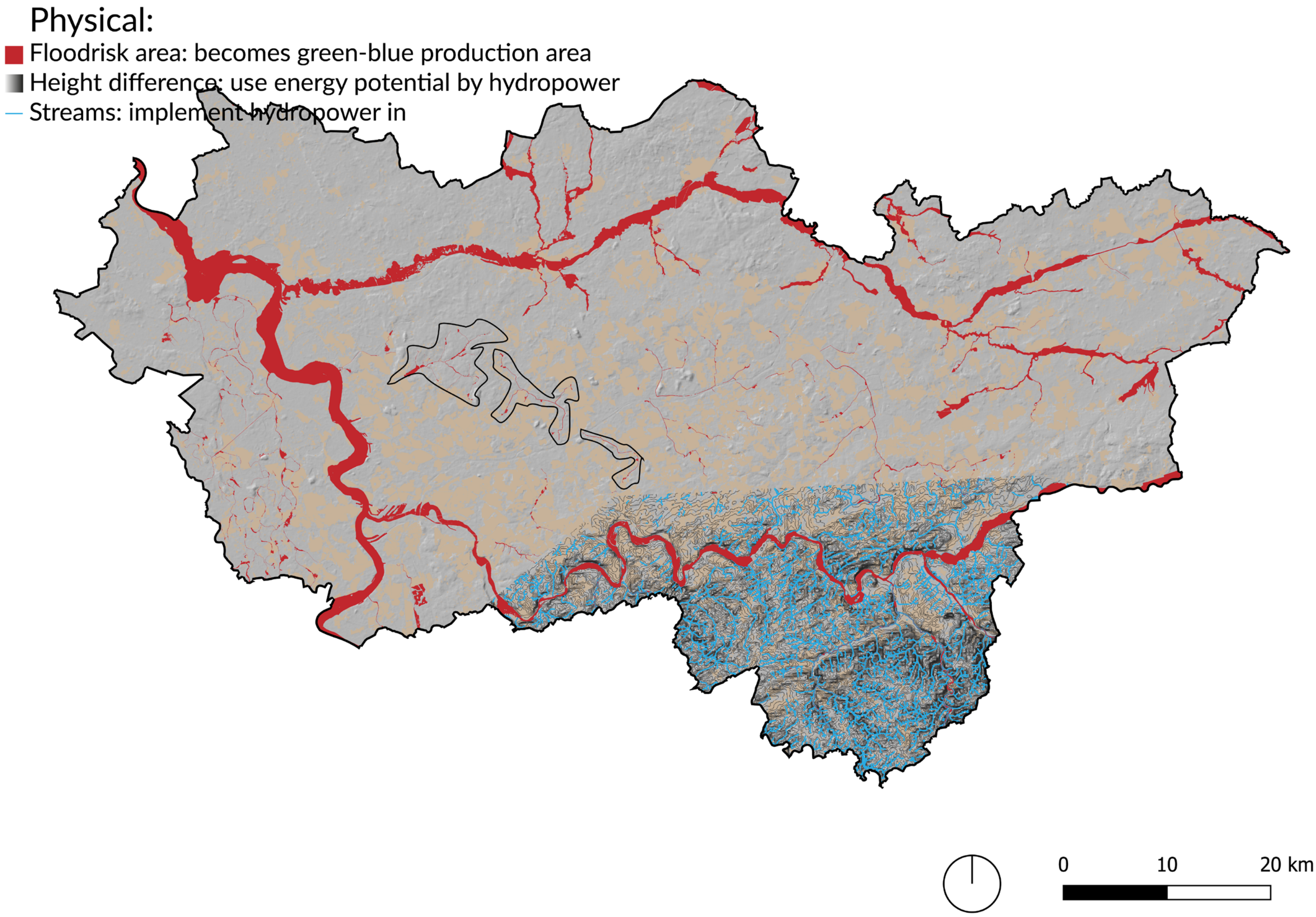
of the physical context of the Ruhr in a
t) and map (top right) (author, 2022).



Height difference

Floodrisk area

Figure 109: Spatial manifestation of noti
strategy (aut



ons related to the physical context for the
thor, 2022).

The functional context is described secondly. The strategic components that were found here, were the waterbodies and the parks and other green areas. The major component in the strategy for this category, is that of the mobility change. By moving towards a more shared and electrical mobility system, road and park space can be allocated to the ecosystem, to provide buffer capacity and to produce energy using RES. This transition, from a car-oriented mobility system to a shared mobility system takes the longest to implement. Parking rules have to be changed, residents are allocated a spot in these hubs with extra space for visitors. Land use rules have to be changed as well, with the implementation of hubs when densifying. Furthermore, public transport should be intensified and connected to these hubs. The current spatial manifestation of these key functions is shown in the map.

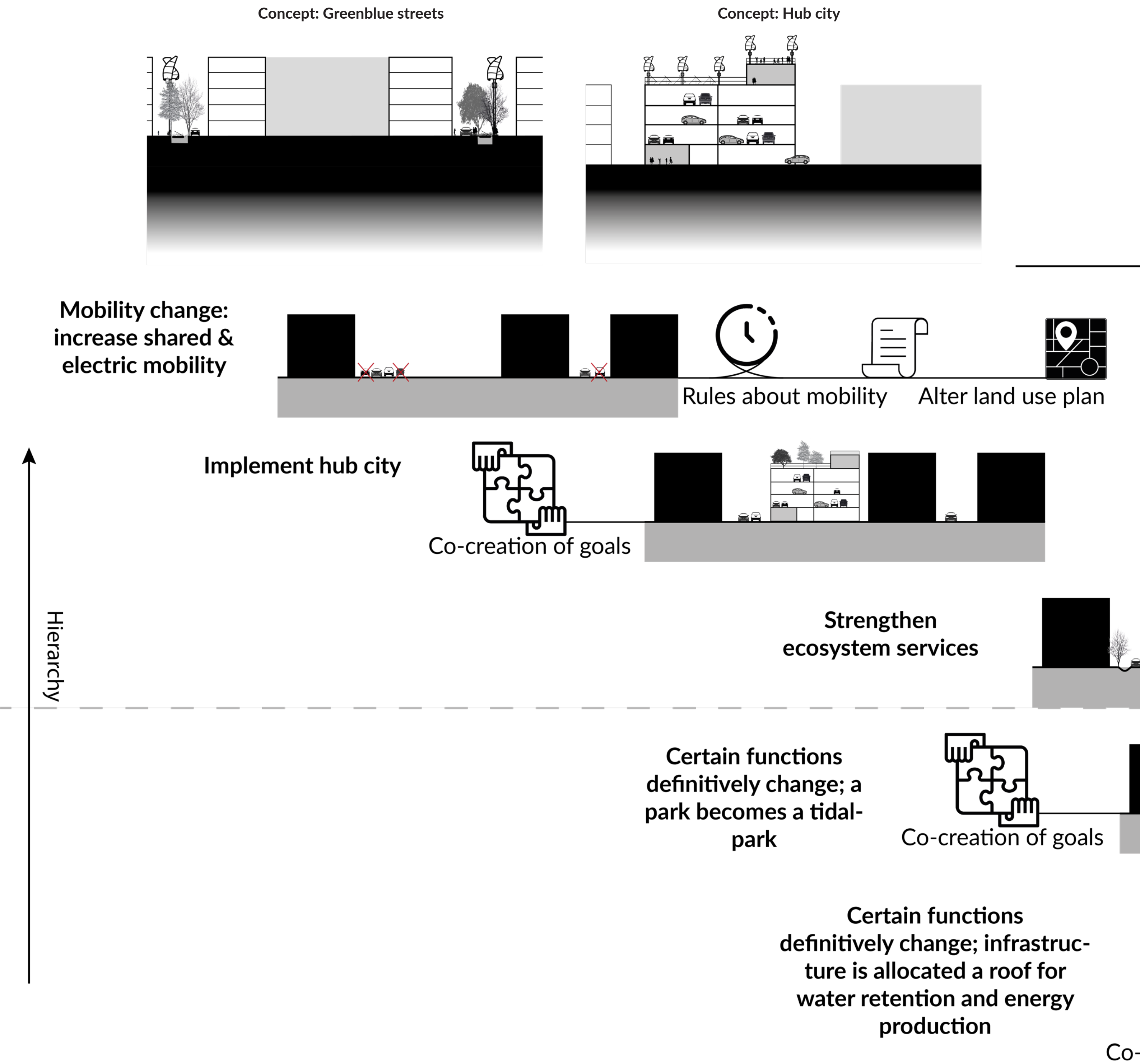
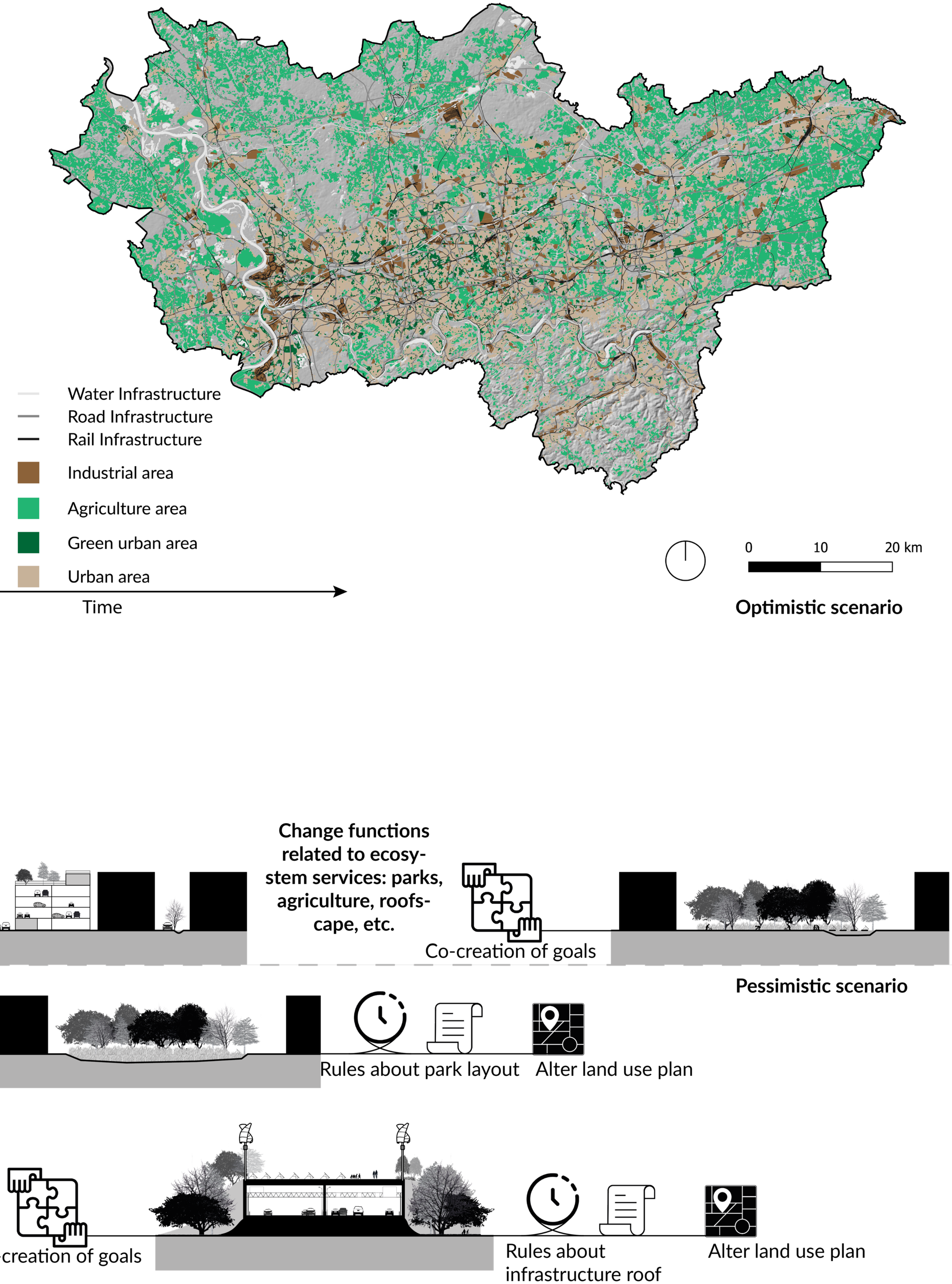
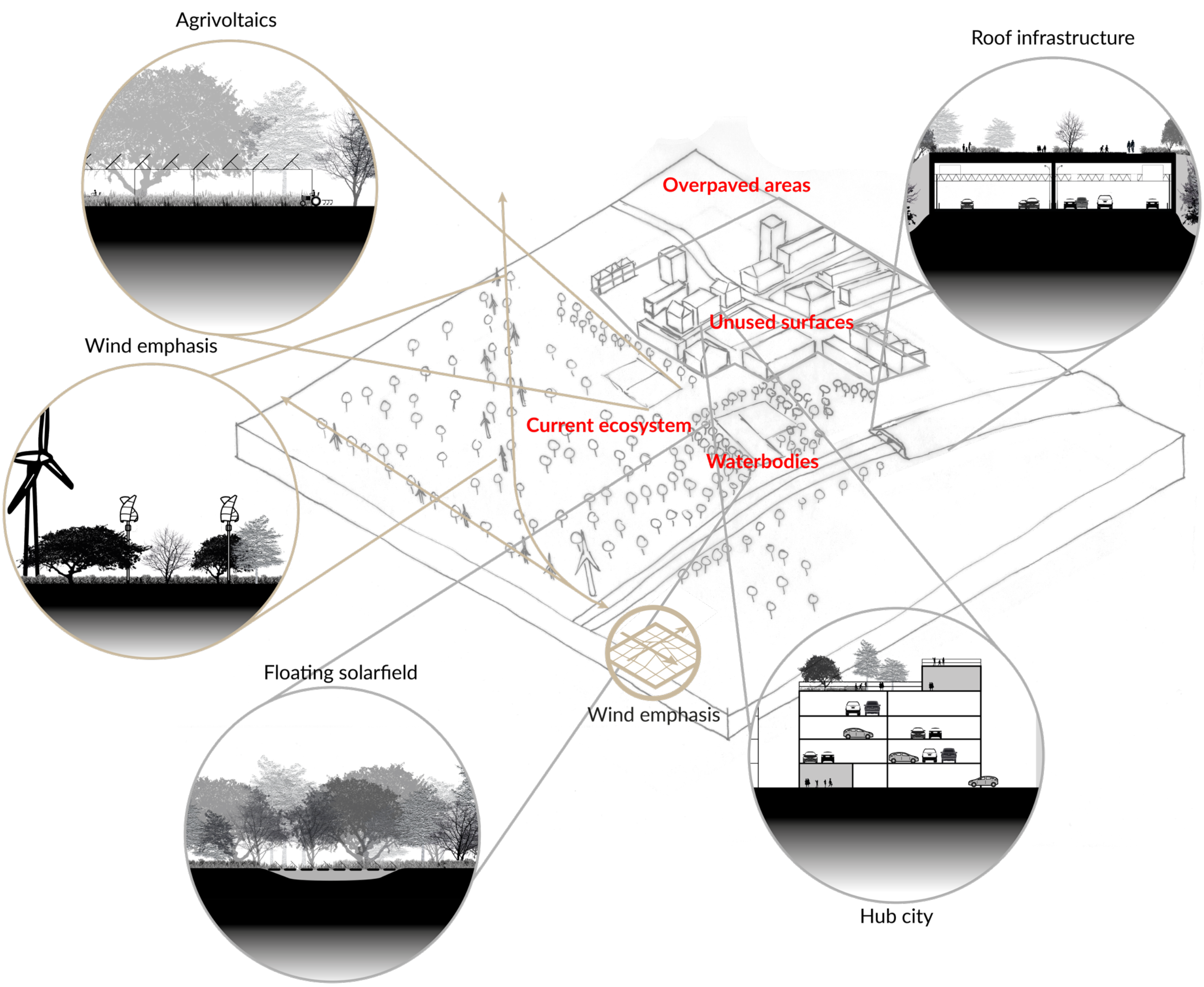


Figure 110: The strategic component c
strategy (au



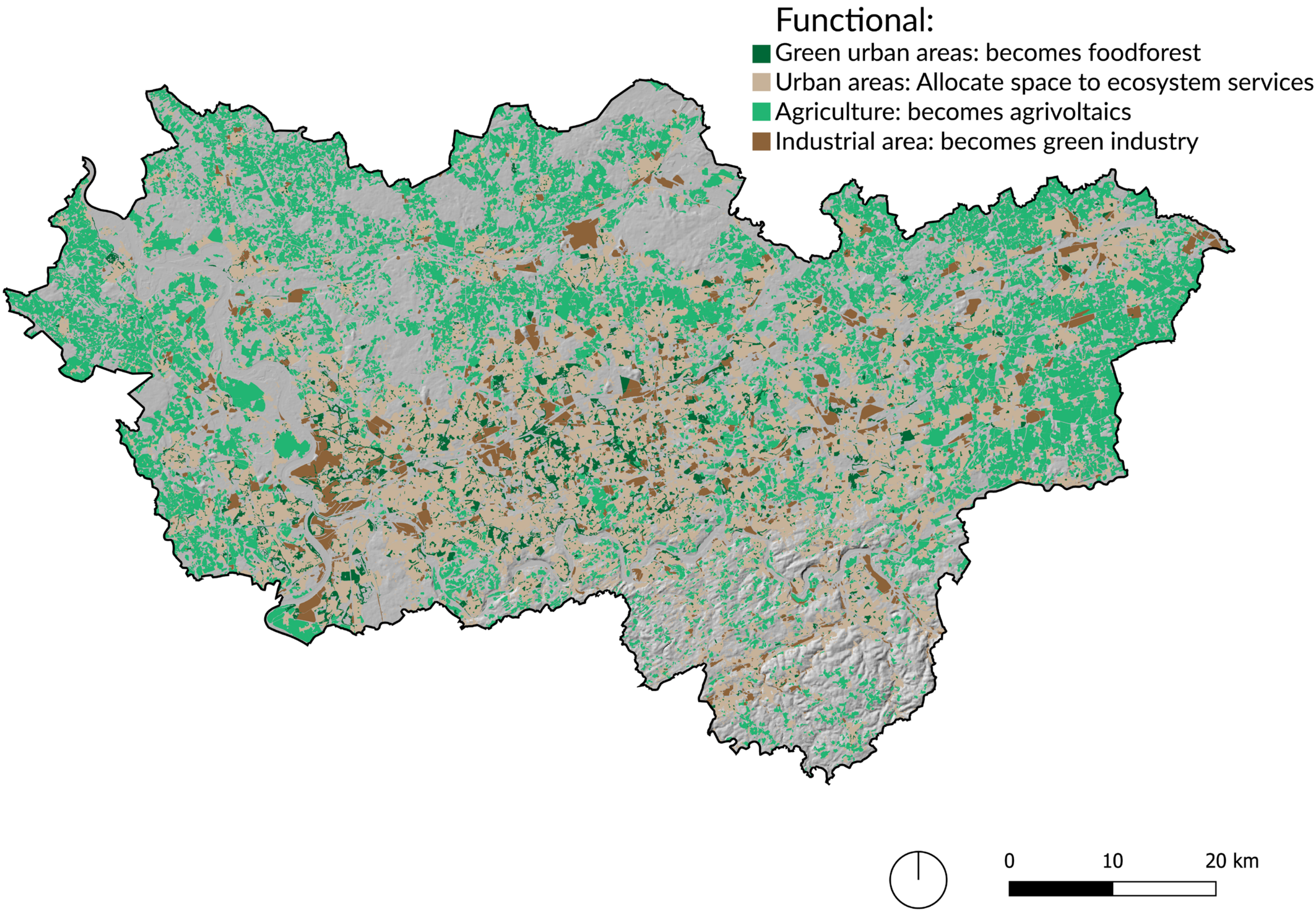
of the functional context of the Ruhr in a
thor, 2022).



Underused surfacas; roofs, streets, squares

Overpaved areas

Figure 111: Spatial manifestation of notic
strategy (au

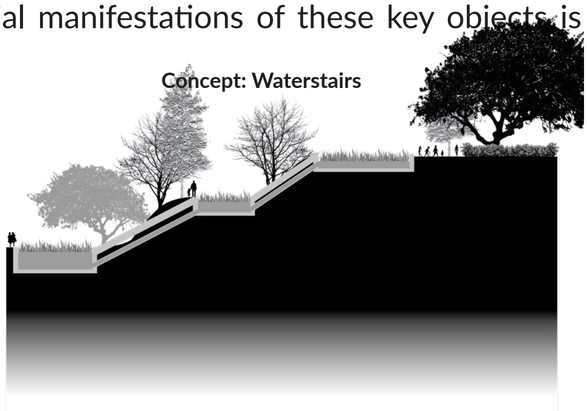


Waterbodies

Current ecosystem

ons related to the functional context for the
thor, 2022).

Thirdly, the network of context is described. The strategic components that were found here, were (sufficient) storage capacity and presence of network. With the less urbanised areas in the north and south, the possibility to create energy valleys is present due to the availability of green and blue infrastructure. However, the cover of the network is not equal throughout the area, which results in certain areas not being properly connected to the powerline system of the Ruhr area. Furthermore, throughout the design exploration, it was concluded that the consequence of adding a node in a network could result in enhancing the environmental qualities of an area. For instance, implementing water stairs as a way to store energy using hydro storage, results in a pleasant environment and could counter urban heat island effect. Furthermore, this is related to the harvesting of storm water. The current spatial manifestations of these key objects is visualized in the map.



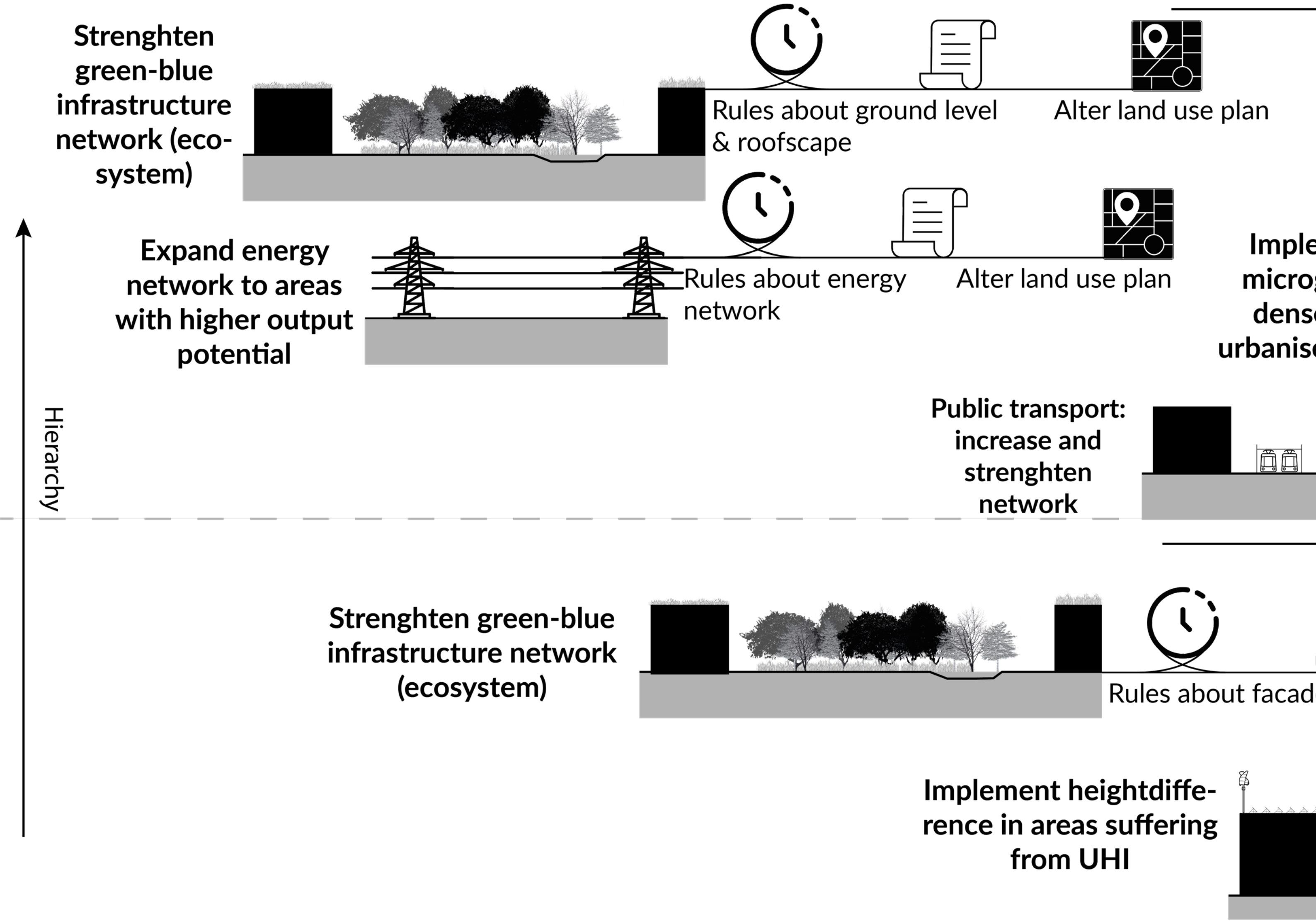
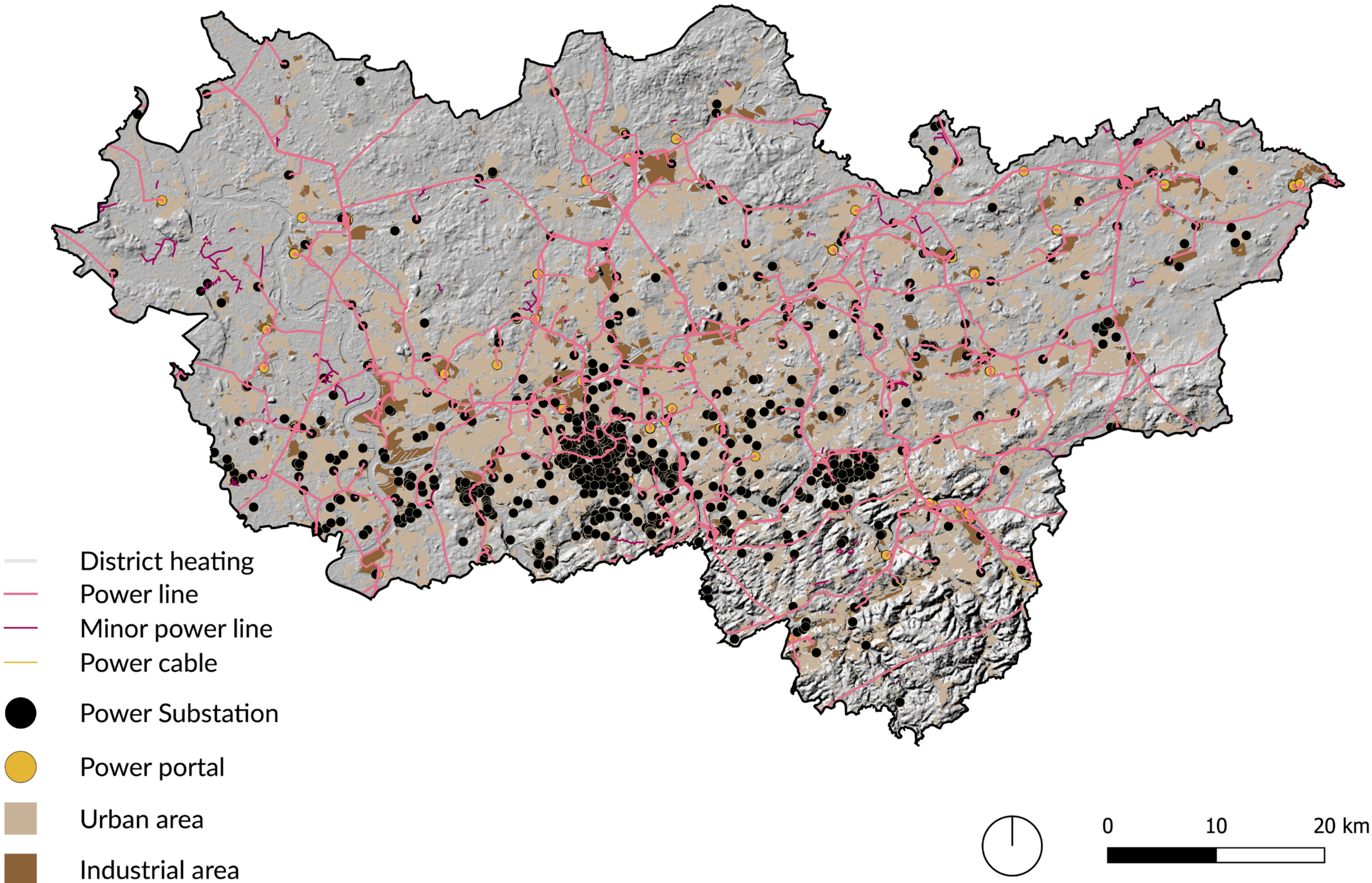
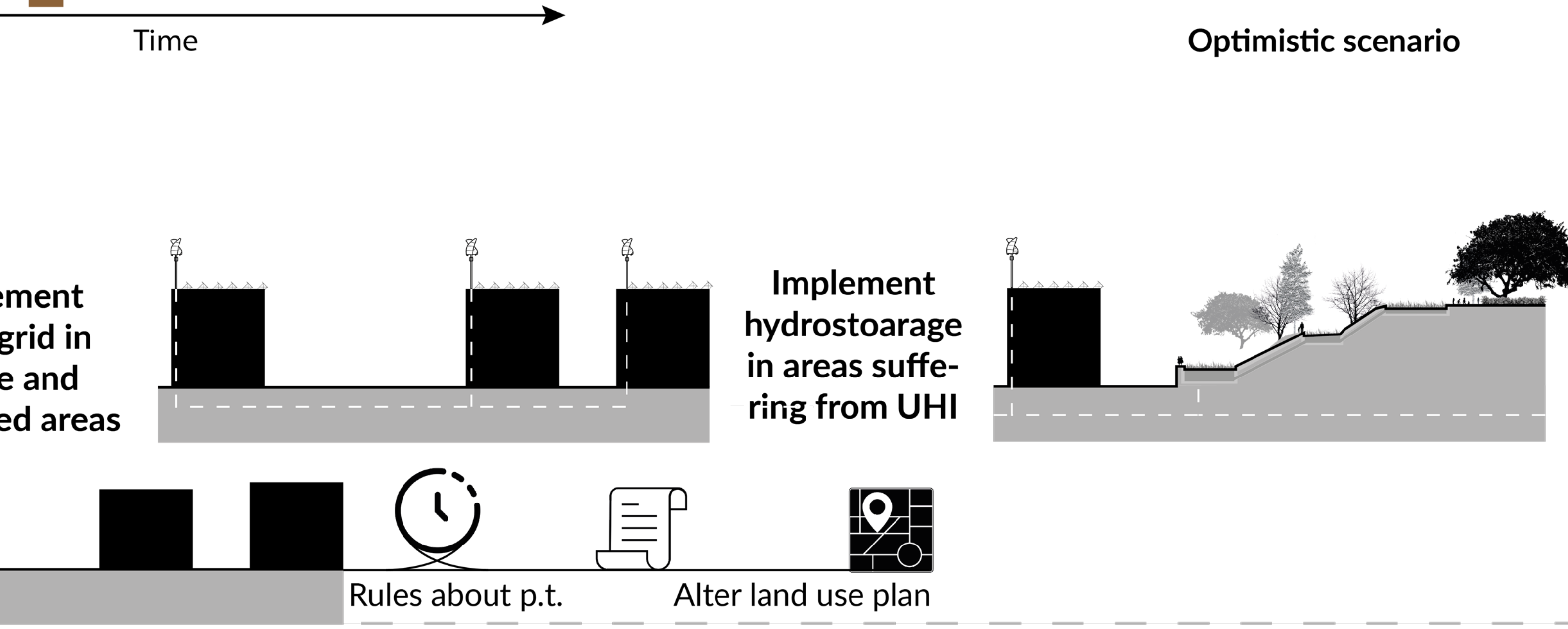


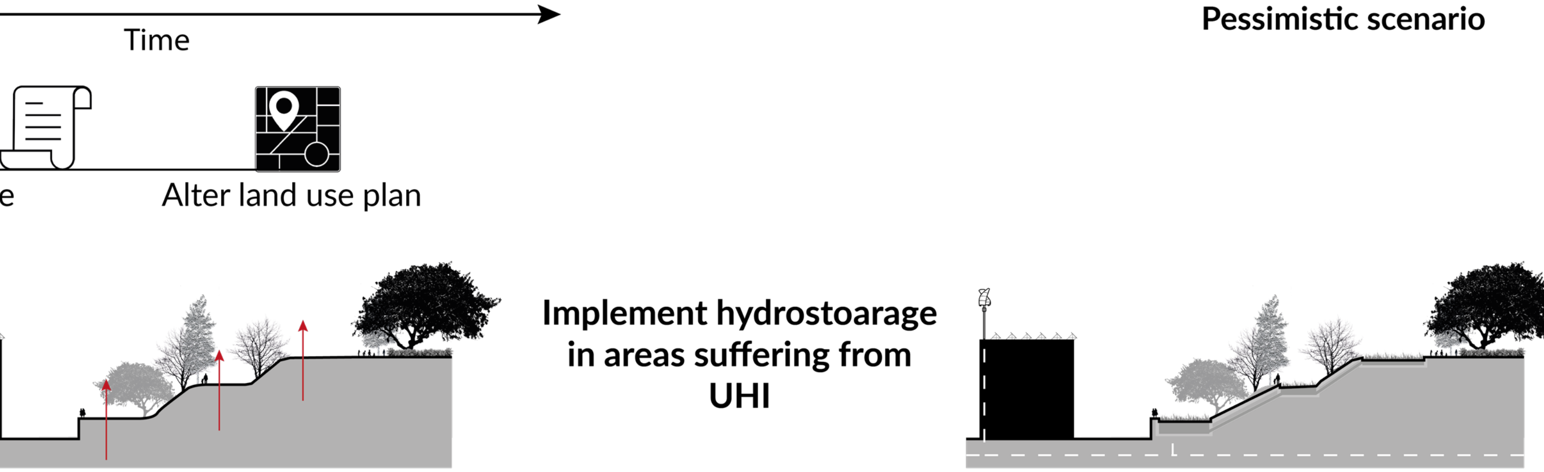
Figure 112: The strategic component of t
strategy (au



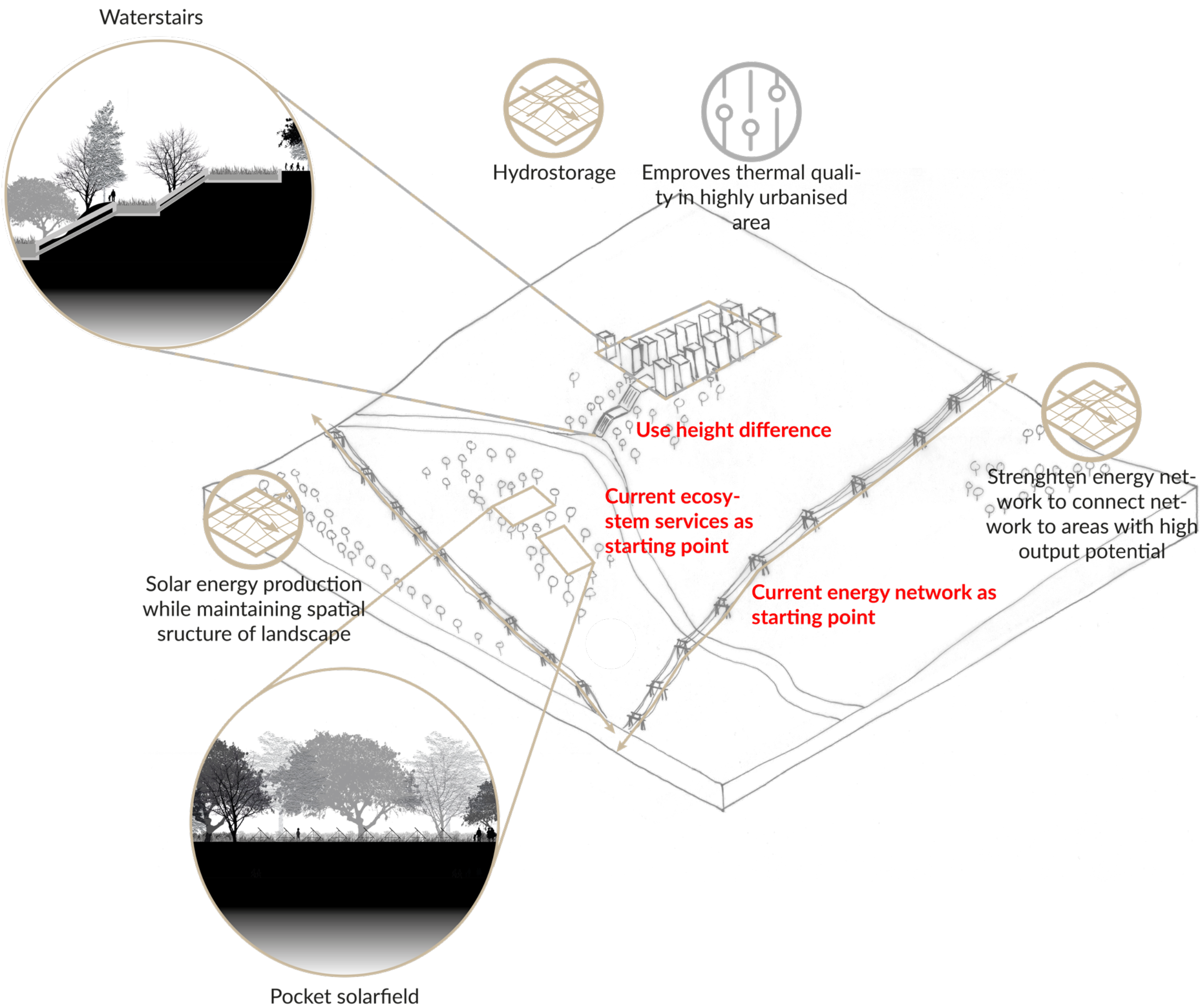


Optimistic scenario

Pessimistic scenario



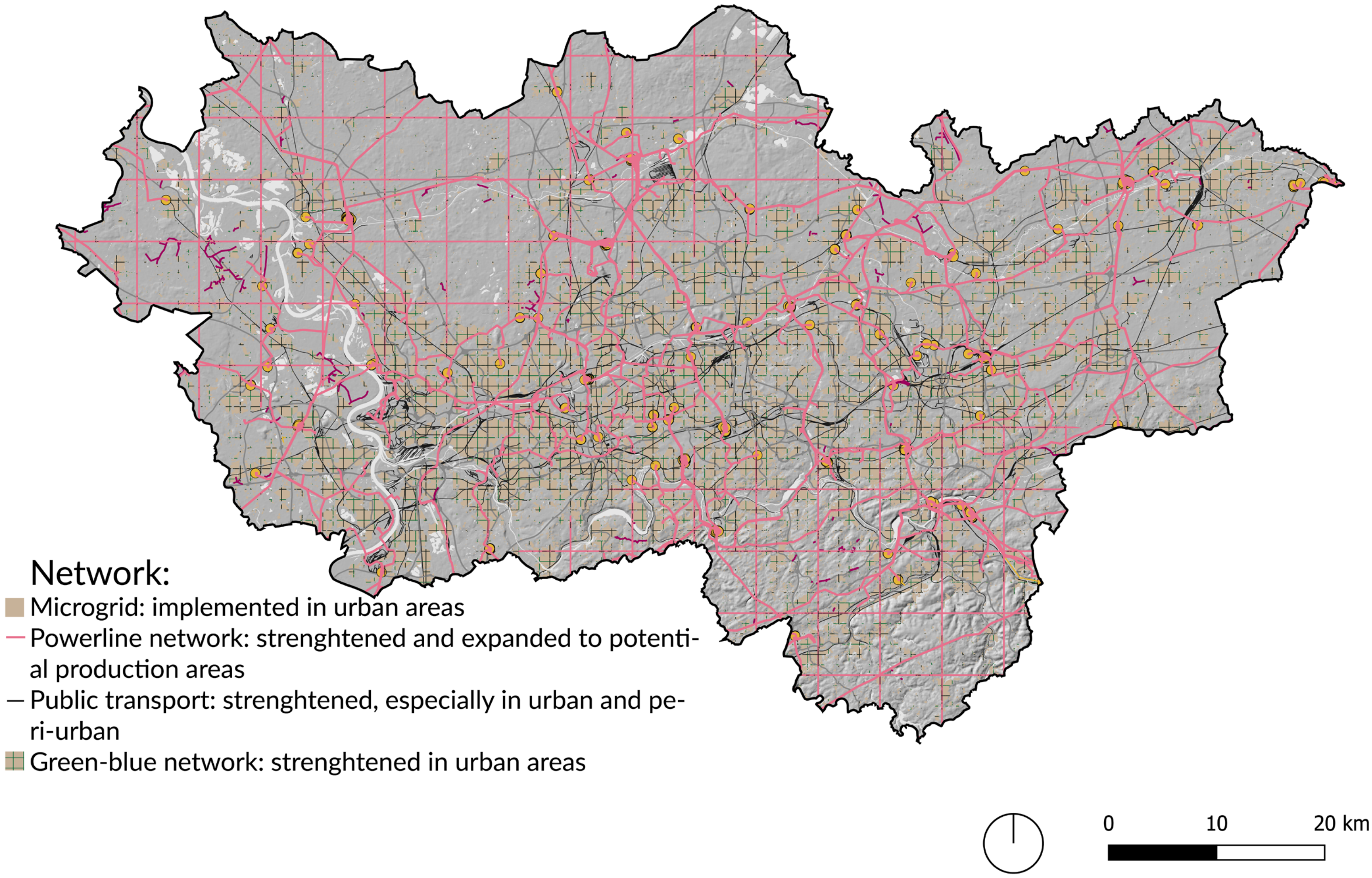
the network of the context of the Ruhr in a
thor, 2022).



Current ecosystem

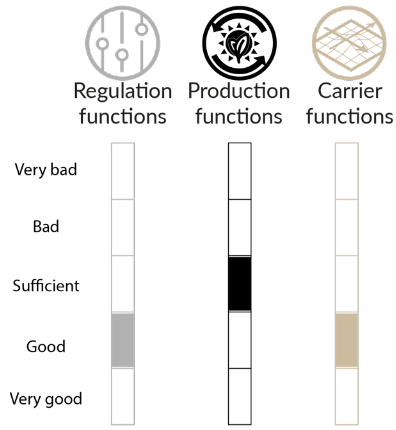
Current energy network human landscape

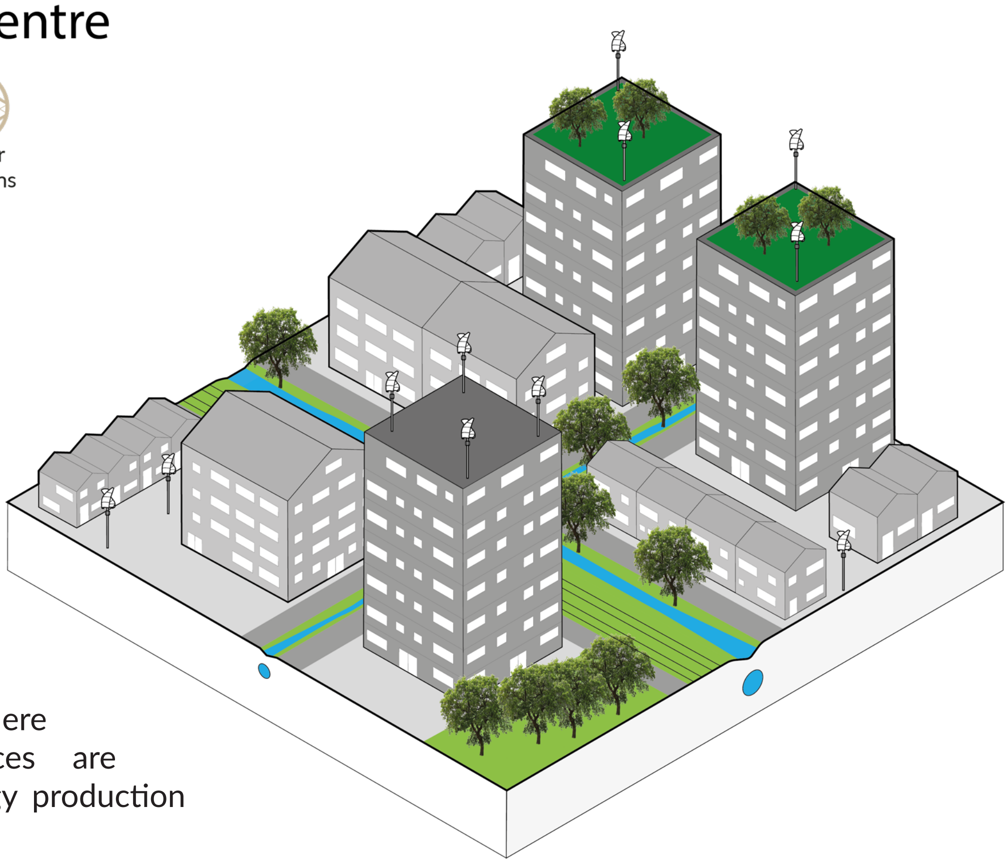
Figure 113: Spatial manifestation of not
the strategy (a



ions related to the context of network for
uthor, 2022).

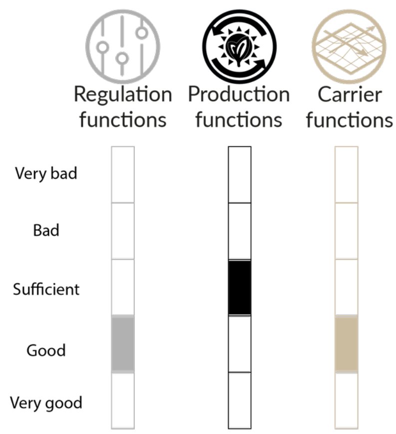
Historic city centre

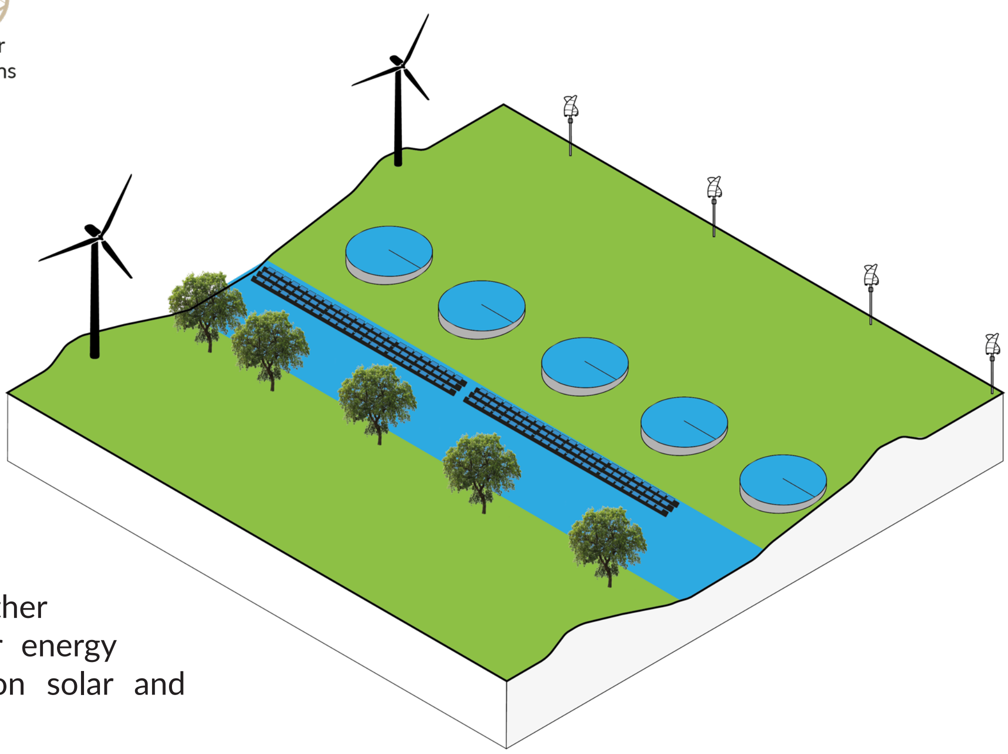




The historic city centre is transformed to become an area where the ecosystem services are strenghtened and energy production is added to this system.

Floodrisk area

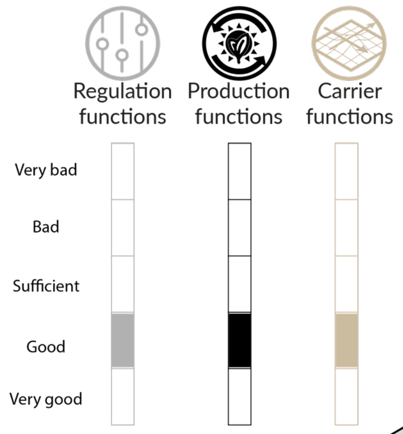


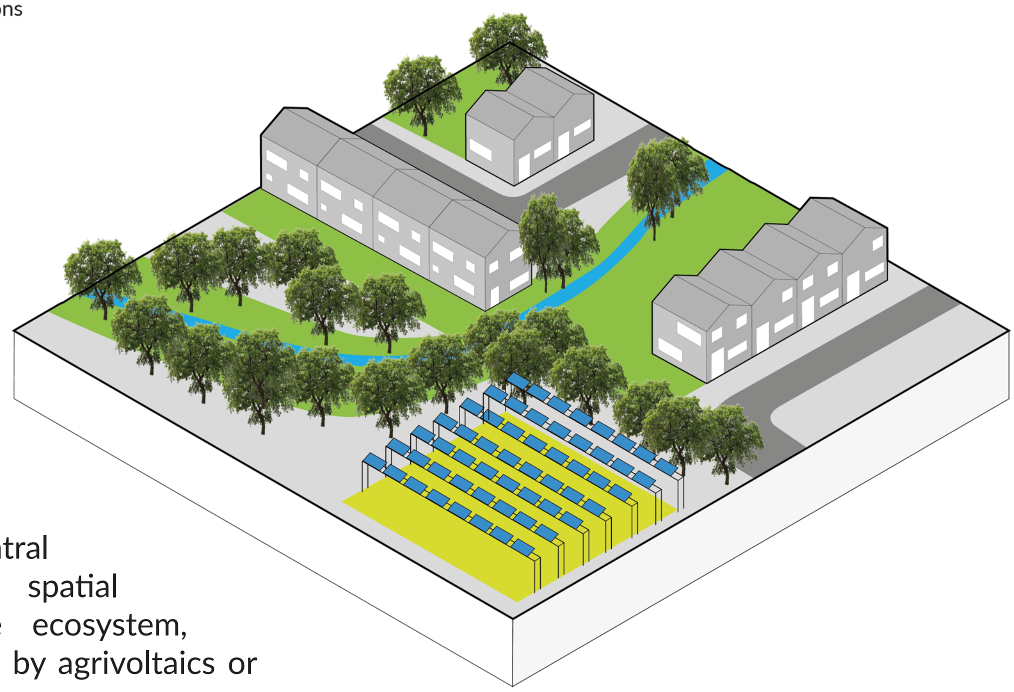


The new floodrisk areas are areas where production is central. Either produciton of algea, or energy production, focussing on solar and wind energy.

Figure 114: Spatial manifestation of spe
relation to strenghtening ecos

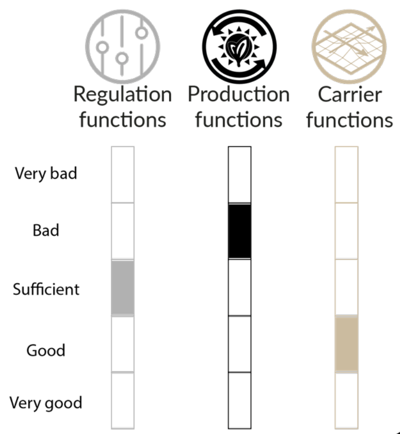
Peri-urban area

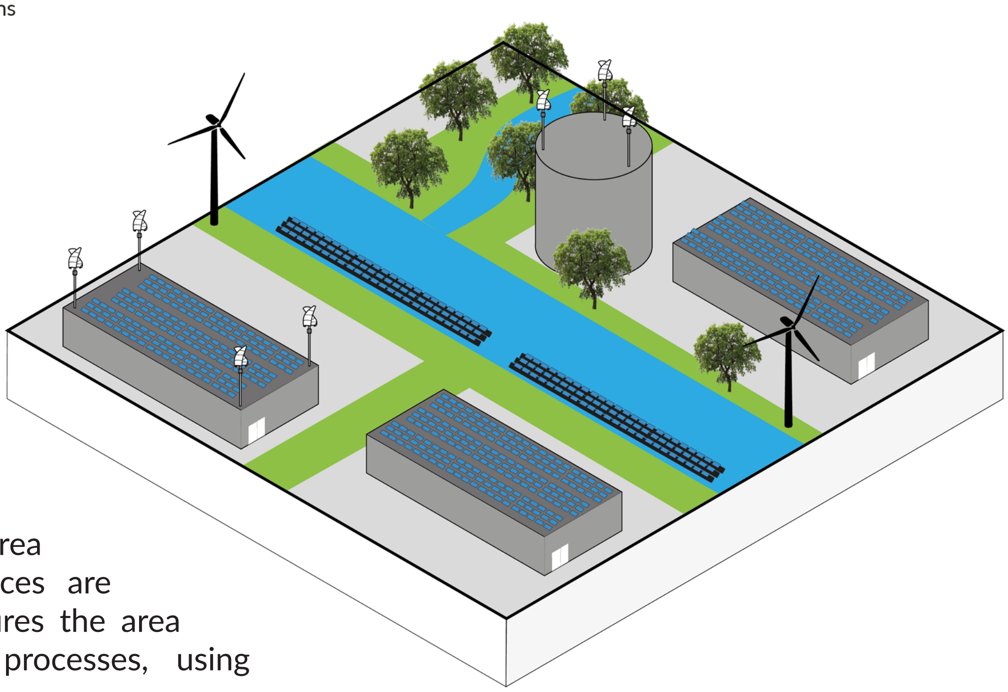




The peri-urban area maintains a mix of urban and rural characteristics. Central in this area are the spatial manifestations of the ecosystem, which are strenghtened by agrivoltaics or green-blue streets.

Industrial area





The industrial area is transformed from a paved area, to an area where ecosystem services are strenghtened. This ensures the area can maintain certain processes, using renewably produced energy.

ecific patches and strategic components in
ystem services (author, 2022).

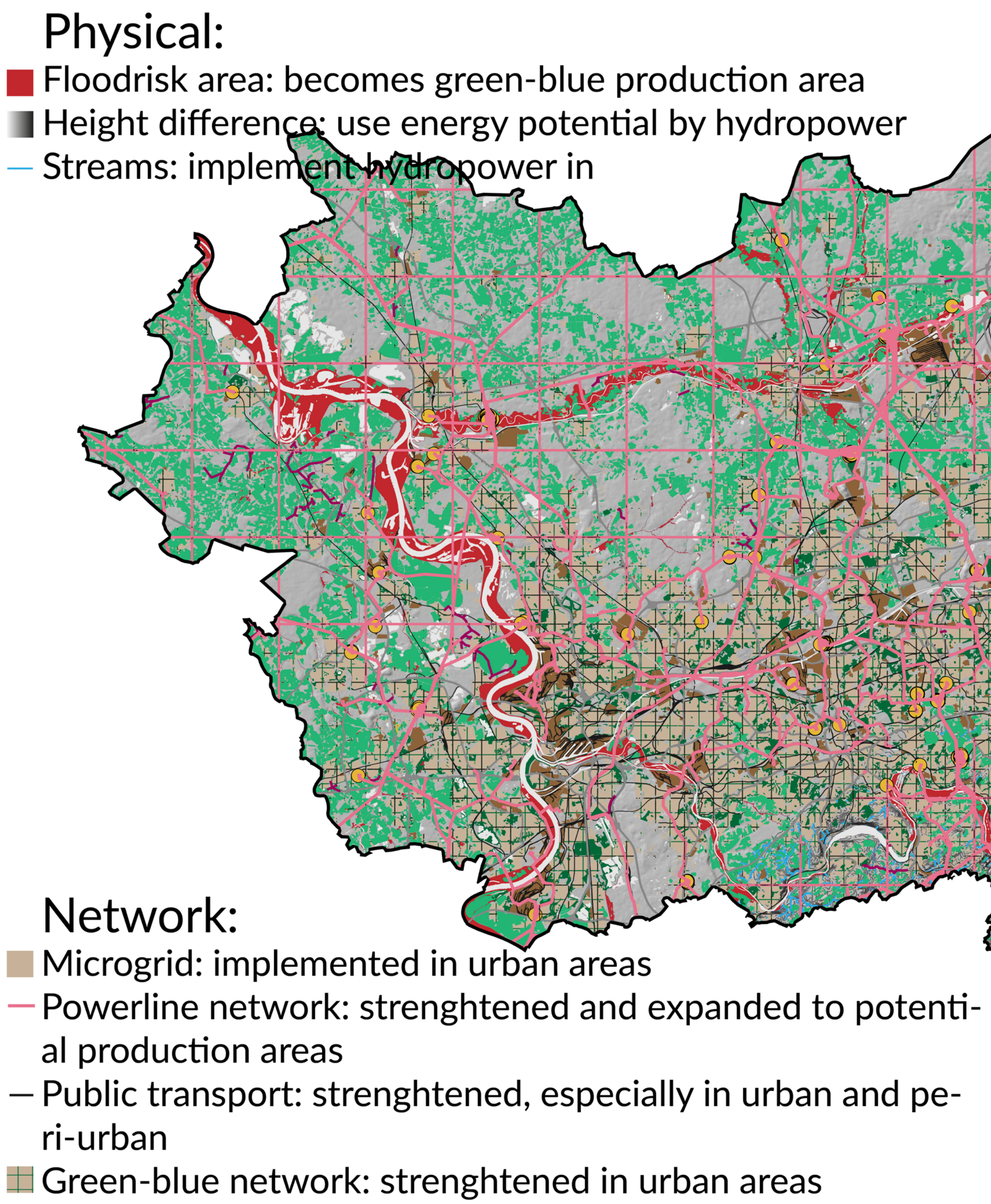
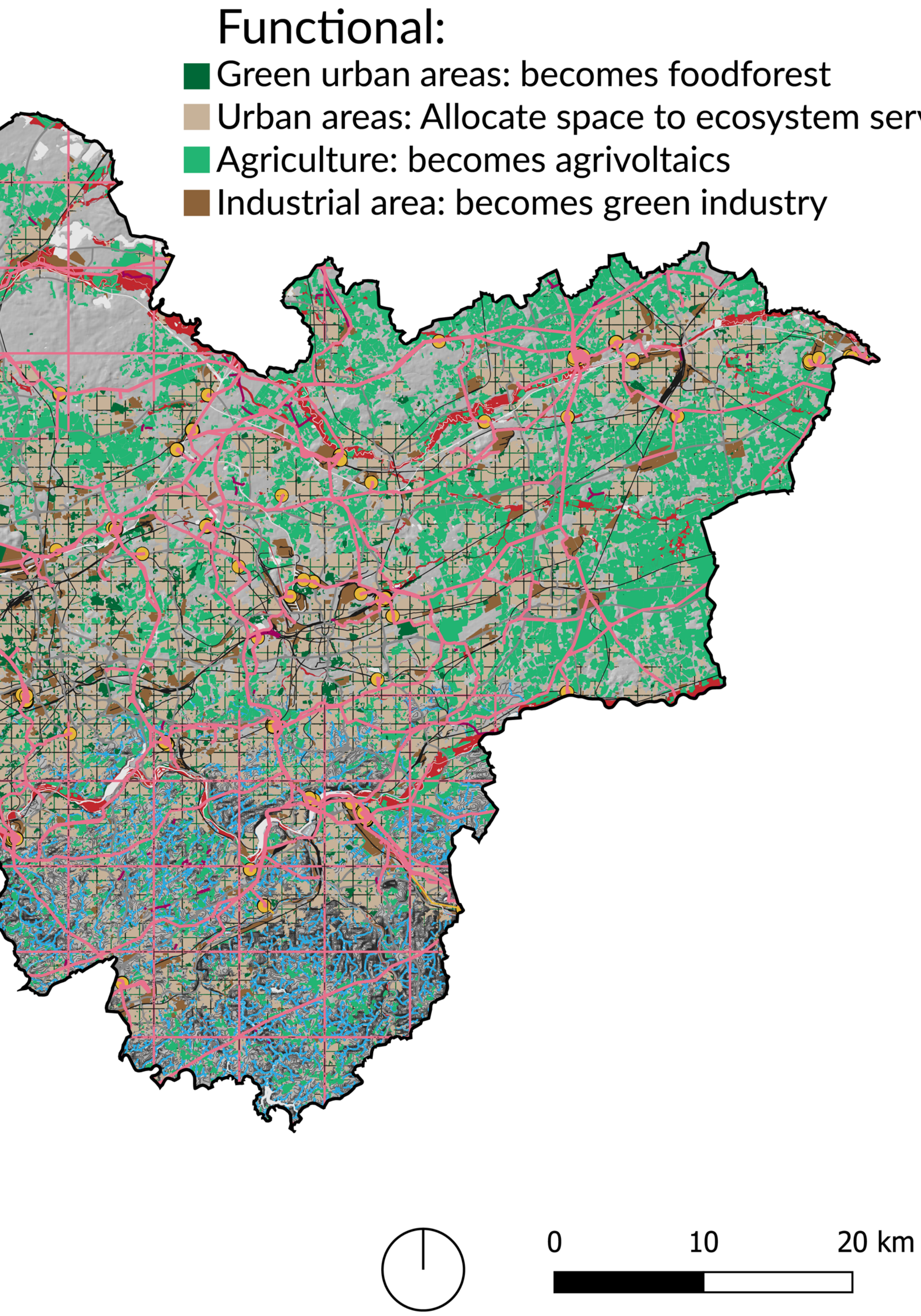


Figure 115: Spatial manifestation of no
strategy (aut



otions of the context of network for the
thor, 2022).

v. Quantified strategy.

The goal for the energy transition are clearly described. With the overall strategy defined, as well as the spatial manifestation of the different patches and their total area in the Ruhr, a brief calculation can be made on the quantification of the propositions.

Following the spatial analysis of the Ruhr area, the dimensions of certain areas were determined. Furthermore, following a literature review, the output potential of several renewable energy sources were defined.

With the dimensions of the patches defines as well, an educated guess can now be made on how many output per area I propose in my design in the optimistic and pessimistic scenario of these patches. Based on a literature review, we assume that the 25% of the potential area for each renewable energy source is available (Barrington-Leigh & Ouliaris, 2017).

This results in the following calculation;
Optimistic: potential output per patch for the optimistic scenario / area of patch * 25% patch area in the Ruhr.
Maximum: potential output per patch for the optimistic scenario / area of patch * 25% patch area in the Ruhr.

This calculation is visualized in figure 120. It indicates that both for the optimistic as well as for the pessimistic scenario, my proposed designs meet the goals for each of the scenarios.

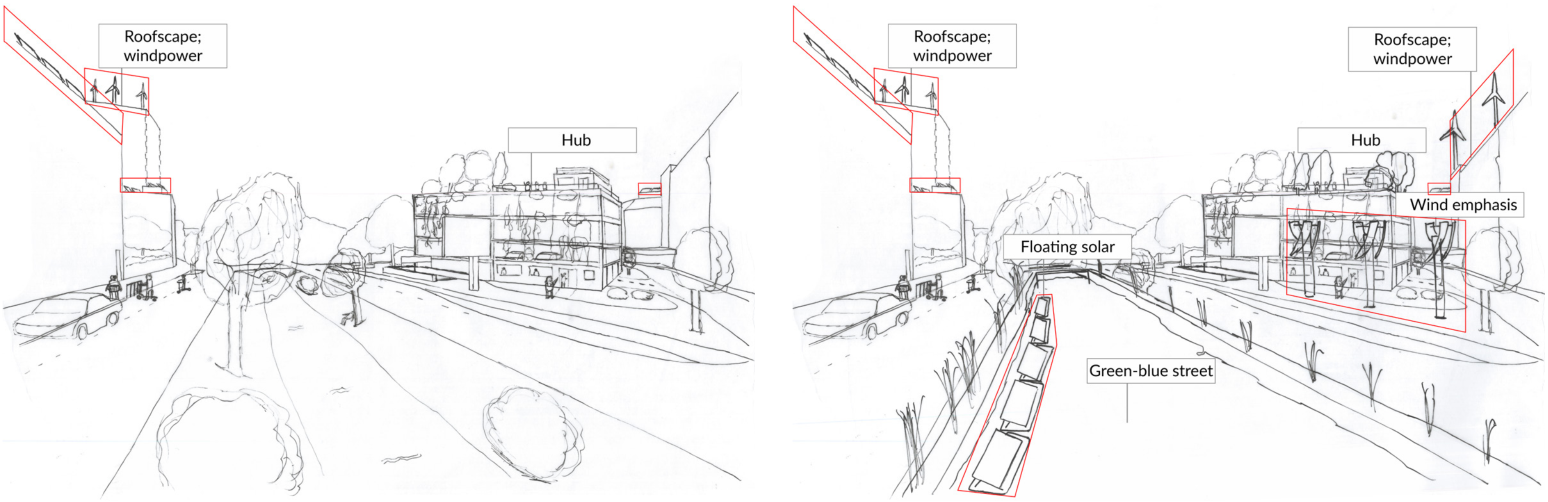


Figure 116: Calculation of energy output per patch in optimistic (left) and pessimistic (right) scenarios (author, 2022. Derived from Barrington-Leigh & Ouliaris, 2017 and Copernicus, 2018).

historic city centre		riverbank / wetland		green urban area	
optimistic	18401976,35	optimistic	35450527	optimistic	35137,2
pessimistic	33762816,63	pessimistic	93236476	pessimistic	2389330

peri-urban area		industrial area	
optimistic	1296632	optimistic	3222934
pessimistic	32835669	pessimistic	8152127

				Goal
total optimistic	58407207	58,40721	GWH	53 GWH
total pessimistic	1,7E+08	170,3764	GWH	115 GWH

Figure 117: Calculation of area and energy potential (author, 2022. Derived from Barrington-Leigh & Ouliaris, 2017 and Copernicus, 2018).

vi. Paradigm shift.

For this energy transition to take place, several sectors have to change. These sectors are the transport, the trade, the industrial and the household sector. These sectors have to transform, to reduce their energy demand.

These sectors will undergo a paradigm shift. The transport sector will be transformed towards a electrical transport system, where sharing parking spaces, cars and other modes of transport are key. The trade sector has to be transformed, moving towards a (more) circular sector. The industrial sector has to focus on electrification of production processes. Lastly, the household sector has to focus on insulation (TNO, 2022). These paradigm shifts are massive and outside of this scope. They are discussed further in the discussion chapter.

Since these paradigm shift have a spatial manifestation, as indicated in the design solution, they will be briefly mentioned in this paragraph. The paradigm shifts can be linked to the following design concepts, as visualized in figure 122. Electric transport can be concentrated in and around the hubs, as proposed in the hub city. Furthermore, these hubs can aid in the transformation to a circular economy, by facilitating space for a circular hub. The transformation these sectors have to undergo are shaped and directed using market shaping tools, which are briefly mentioned in the strategy (Stead, 2021).

Primary energy conspumption

Transport - 30% of primary energy consumption

Industrial sector - 30% of primary energy consumption

Household sector - 30% of primary energy consumption

Trades & services - 10% of primary energy consumption

Paradigm shift

Transport - Move to electrical transport where possible.

Industrial sector - Electrification of production prosesses

Household sector - Motivate households by co-creating goals and strategies

Trades & services - Circular economy

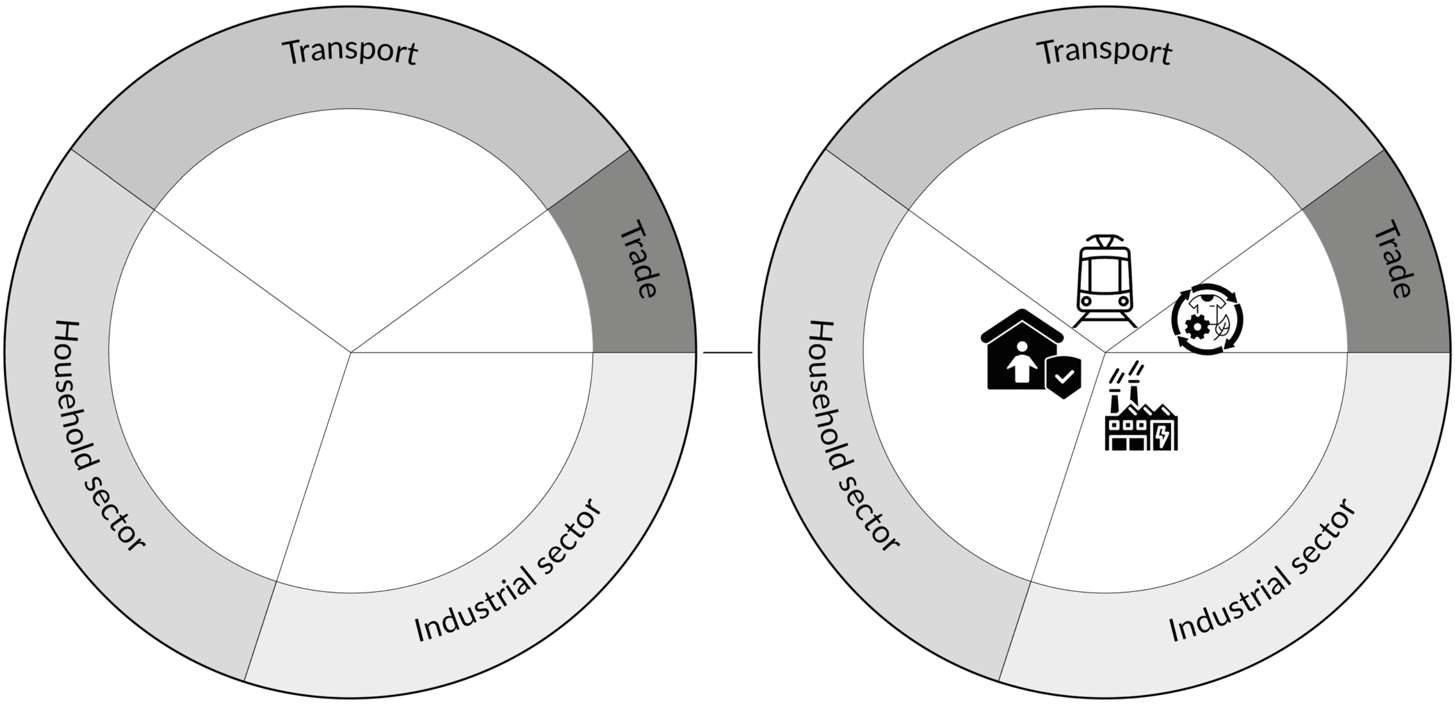
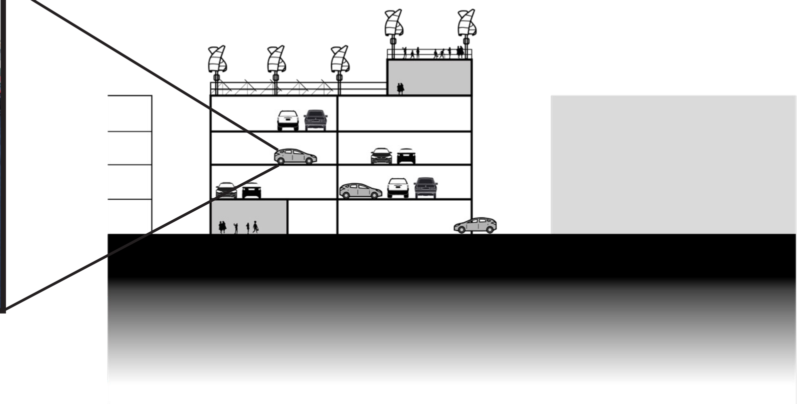
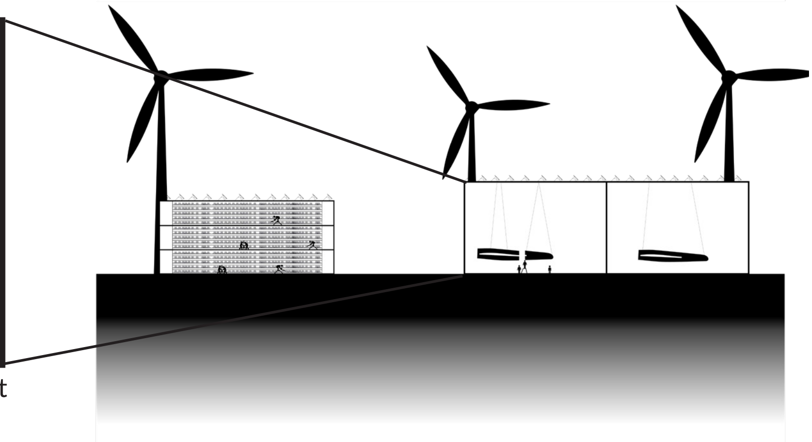


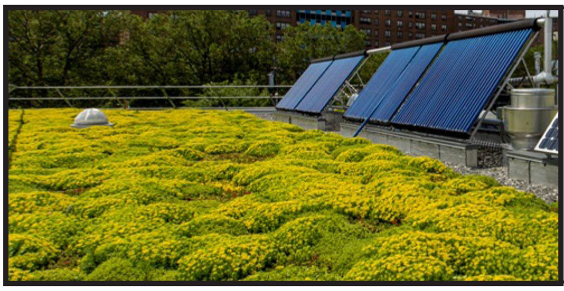
Figure 118: Energy consuming sectors and related paradigm shift (author, 2022. Based on TNO, 2022).

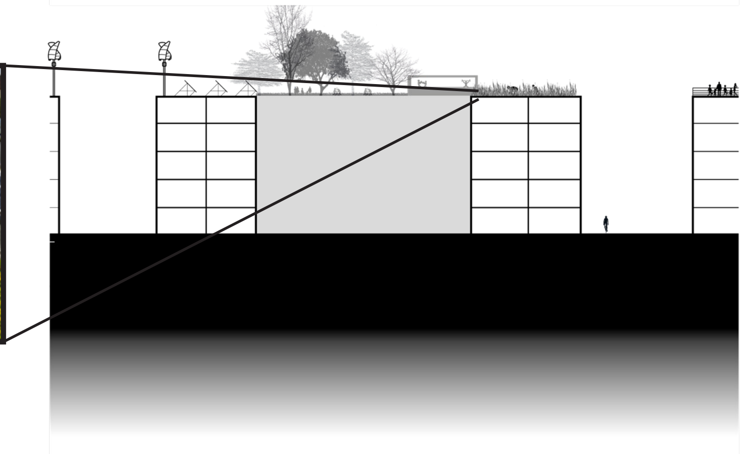


Transport sector - electric transport

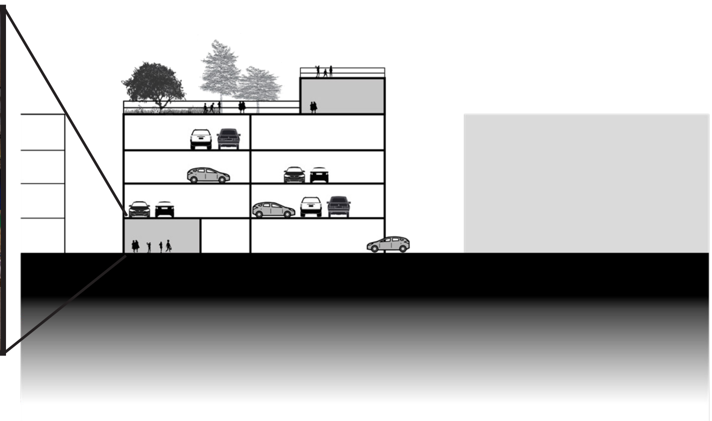


Industrial sector - power to heat (PTH) plant





Household sector - green roof as isolation



Trade sector - circular economy

Figure 119: Future spatial manifestation of sector linked to respected design concept (author, 2022).

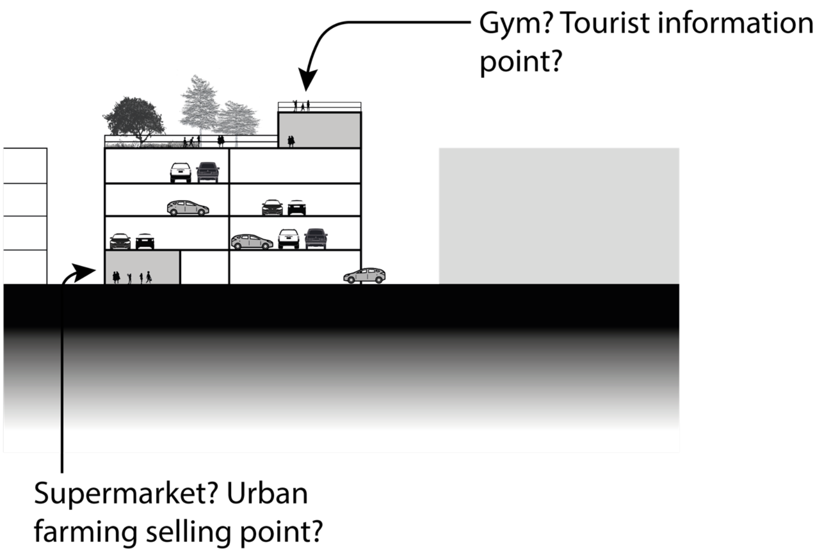
vii. Strategy for smaller scale.

The proposed strategy has a more social approach, which has been visualized in the regional representation of the strategy and is further elaborated here.

The implementation of the concepts on the local scale is a responsibility for the municipality. This has been done to give the municipality the opportunity, to adopt concepts to local problems or opportunities. A hub could be combined with a gym, a supermarket, a selling point for the urban farming or a supermarket.

Furthermore, co-creation is used to aid in the participation of residents as well as other actors. This is done using the method described in figure 116. This moves from the solution of a current problem to the definition of a future problem, and is done using the second new governance body, combining local and topic knowledge.

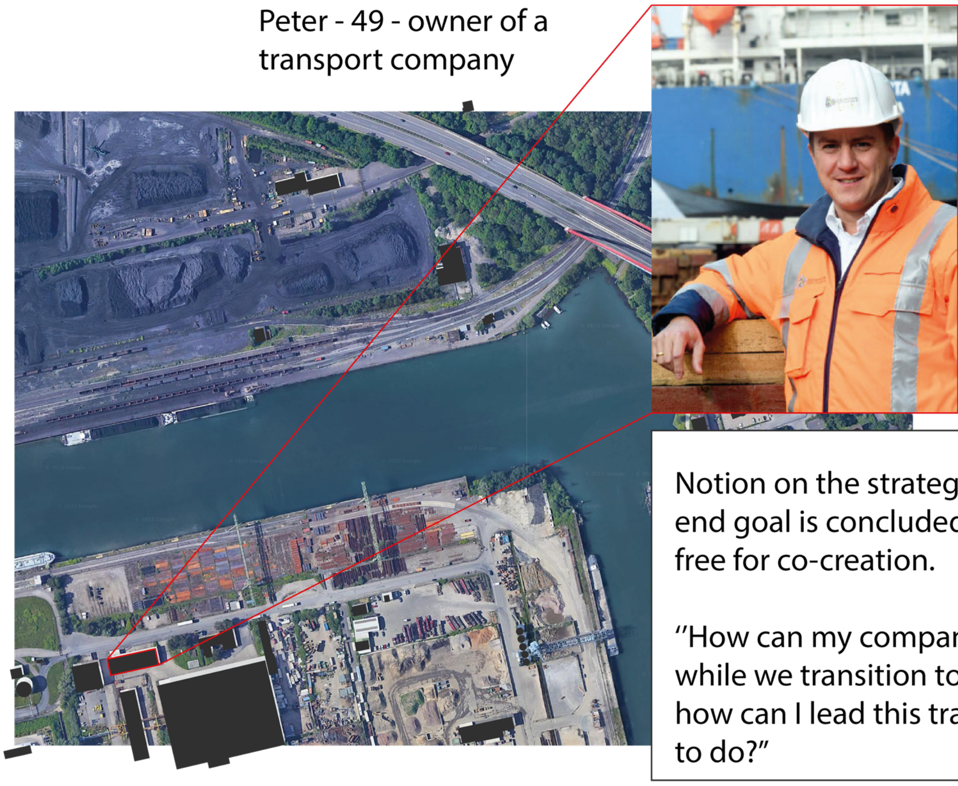
By doing so, Anna and Peter can voice their questions and remarks about the changes they are about to experience.



Moment of interaction between actors and governance body

Figure 120: Co-creation method and impl
Based on Dia

Peter - 49 - owner of a transport company



Adviced by the new local governance body

Transformation proces

Notion on the strategy of greening his business. The end goal is concluded, the road towards that goal is free for co-creation.

"How can my company remain economically feasible, while we transition to a more greener approach and how can I lead this transition, without being told what to do?"

Engage stakeholders → Present current problems and unclear notions → Feedback on current situation

Feedback on future situation → Create strategy & principles measures → Select chosen strategy

Asses adaptation measures

Asses current & future vulnerabilities

Anna - 35 - single mother of two young children

Notion on the final implementation of selling points, the final detailing of the connection of the new creek to the current spatial structure.

"What extra function would be beneficial for the neighborhood and what functions would my two boys like to see added to this neighborhood?"

ementation in the Ruhr area (author, 2022.
s et al., 2020).

viii. Assesment.

The proposed Ruhr area in relation to climate adaptation and the energy transition, as well as the different concepts, are assessed. This assessment is done using a framework. One framework is proposed for the assessment of the different concepts and one framework is proposed for the overall systems change.

As mentioned before, a possible link between energy landscapes and climate adaptation can be found in ecosystem services. This link between energy landscape and climate adaptation has created a base for the creation of a framework, to assess the proposed concepts. These concepts will be analysed using the ecosystem services assessment framework since these concepts form a base for climate adaptation and energy production, using renewable energy sources.

The overall ecosystem will be analysed using the definition of notions related to resilience, since this system will have to deal with uncertainty. Several different notions are added to this framework, defining the synergies with other social, economic and environmental problems in the Ruhr area. Furthermore, the efficiency of this system is analysed. This efficiency relates to the proposed change of landscape and if this is the most suited transformation, when analysed based on efficiency. Furthermore, the timewise efficiency is analysed, to see how efficient this transformation is over time. This framework is visualized in figure 119.

Ecosystem services	Ecosystem processes and component	Goods and services (examples)
Regulation functions	**Maintenance of essential ecological processes and life support systems**	
Climate regulation	Influence of land cover and biological mediated processes on climate	Maintanance of a favorable climate
Water regulation	Role of land cover in regulating runoff and river discharge	Drainage and natural irrigation
Water supply	Filtering, retention and storage of fresh water	Provision of water for consumption
Soil retention	Role of vegetation root matrix and soil biota in soil retention	Mainantance of arable land
Habitat functions	**Providing habitat for wild plants and animal species**	
Refugium function	Suitable living space for wild plants and animals	Maintenance of biological diversity
Nursery function	Suitable reproduction-habitat	Maintenance of commercially harvested species
Produce functions	**Provision of natural resources**	
Food	Conversion of solar energy into edible plants and animals	Hunting, gathering of fish, game, fruits
Raw materials	Conversion of solar energy into biomass for human construction	Fuel and energy
Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion and decoration
Information functions (cultural services)	**Provide opportunities for cognitive development**	
Aesthetic information	Attractive landscape features	Enjoyment of scenery
Cultural and artistic information	Varierty in natural features with cultural and artistic value	Use of nature as motive in books
Science and education	Variety in nature with scientific and educational value	Use of natural systems for scientific research
Carrier functions	**Providing a suitable substrate or medium for human activities and infrastructure**	
Habitation	Depending on the specific land use type, diffferent requirements are placed on environemtal conditions	Living space
Cultivation		Food and raw materials from cultiv. land
Energy-conversion		Energy-facilities (solar, wind, water, etc.)
Transportation		Transportation by land and water

Resilience	Resilience processes and component	Goods and services (examples)
Resilience functions	*HOW TO DESCRIBE RESILIENCE?*	
Flexibility and diversity	*The system can meet service needs under a wide range of climate conditions*	*Multiple, geographically distributed water sources*
Redundancy and modularity	*Spare capacity to accommodate unexpected service demand or extreme climate events*	*Reservoir storage capacity exceeds demand under drought condition*
Safe failure	*Failure in one part of the system will not lead to cascading failures of other elements or related systems.*	*Failure of one node does not lead to system failure*
Synergies with social, economic and environmental notions	*System strenghtens and improves social, economic and environmental processes*	*Outcome of proposed strategy strenghtens the Ruhr area socially, economically and environmetnally*
Efficiency of energy production	*Energy production*	*production of energy using RES*
Efficiency of energy timewise	*Preparation and implementation time the usage of renewable energy sources*	*time before energy landscape is operational or has reached full potential*

Figure 121: Assesment framework for concepts and strategy (author, 2022. Based on De Groot, 2006 and Tyler & Moench, 2012).

Certain ecosystem services are of major importance to energy landscapes and climate adaptation. These are visualized in red boxes. This eventually leads to a proposed assessment framework, which is visualized on the following page.

Ecosystem services	Ecosystem processes and component	Goods and services (examples)
Regulation functions	**Maintenance of essential ecological processes and life support systems**	
Climate regulation	Influence of land cover and biological mediated processes on climate	Maintanance of a favorable climate
Water regulation	Role of land cover in regulating runoff and river discharge	Drainage and natural irrigation
Water supply	Filtering, retention and storage of fresh water	Provision of water for consumption
Soil retention	Role of vegetation root matrix and soil biota in soil retention	Mainantance of arable land
Habitat functions	**Providing habitat for wild plants and animal species**	
Refugium function	Suitable living space for wild plants and animals	Maintenance of biological diversity
Nursery function	Suitable reproduction-habitat	Maintenance of commercially harvested species
Produce functions	**Provision of natural resources**	
Food	Conversion of solar energy into edible plants and animals	Hunting, gathering of fish, game, fruits
Raw materials	Conversion of solar energy into biomass for human construction	Fuel and energy
Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion and decoration
Information functions (cultural services)	**Provide opportunities for cognitive development**	
Aesthetic information	Attractive landscape features	Enjoyment of scenery
Cultural and artistic information	Varierty in natural features with cultural and artistic value	Use of nature as motive in books
Science and education	Variety in nature with scientific and educational value	Use of natural systems for scientific research
Carrier functions	**Providing a suitable substrate or medium for human activities and infrastructure**	
Habitation	Depending on the specific land use type, diffferent requirements are placed on environemtal conditions	Living space
Cultivation		Food and raw materials from cultiv. land
Energy-conversion		Energy-facilities (solar, wind, water, etc.)
Transportation		Transportation by land and water

Resilience	Resilience processes and component	Goods and services (examples)
Resilience functions	*HOW TO DESCRIBE RESILIENCE?*	
Flexibility and diversity	*The system can meet service needs under a wide range of climate conditions*	*Multiple, geographically distributed water sources*
Redundancy and modularity	*Spare capacity to accommodate unexpected service demand or extreme climate events*	*Reservoir storage capacity exceeds demand under drought condition*
Safe failure	*Failure in one part of the system will not lead to cascading failures of other elements or related systems.*	*Failure of one node does not lead to system failure*
Synergies with social, economic and environmental notions	*System strenghtens and improves social, economic and environmental processes*	*Outcome of proposed strategy strenghtens the Ruhr area socially, economically and environmetnally*
Efficiency of energy production	*Energy production*	*production of energy using RES*
Efficiency of energy timewise	*Preparation and implementation time the usage of renewable energy sources*	*time before energy landscape is operational or has reached full potential*

Figure 122: Assesment framework, annotated to indicate the key assesment criteria for the contepts (author, 2022. Based on De Groot, 2006 and Tyler & Moench, 2012).

Ecosystem services	Ecosystem processes
Regulation functions	**Maintenance of essential ecologi**
Climate regulation	Influence of land cover and biologica
Water regulation	Role of land cover in regulating runo
Water supply	Filtering, retention and storage of fr
Soil retention	Role of vegetation root matrix and s
Produce functions	**Provision of natural resources**
Raw materials	Conversion of solar energy into bion
Information functions (cultural services)	**Provide opportunities for cogniti**
Aesthetic information	Attractive landscape features
Cultural and artistic information	Varierty in natural features with cult
Carrier functions	**Providing a suitable substrate or**
Cultivation	
Energy-conversion	

Resilience	Resilience processes a
Resilience functions	*Ability to face future shocks and str*
Flexibility and diversity	*The system can meet service needs un*
Redundancy and modularity	*Spare capacity to accommodate unexp*
Safe failure	*Failure in one part of the system will no related systems.*
Synergies with social, economic and environ-mental notions	*System strenghtens and improves soci*
Efficiency of energy production	*Energy production*
Efficiency of energy timewise	*Preparation and implementation time*

Figure 123: Overall assesment framewor
Based on De Groot, 2006 a

and component

Assesment

cal processes and life support systems	Very bad	Bad	Sufficient	Good	Very good
al mediated processes on climate					
off and river discharge					
resh water					
oil biota in soil retention					

mass for human construction					

ve development

tural and artistic value					

medium for human activities and infrastructure

and component

Assesment

resses	Very bad	Bad	Sufficient	Good	Very good
der a wide range of climate conditions					
pected service demand or extreme climate events					
ot lead to cascading failures of other elements or					
al, economic and environmental processes					
the usage of renewable energy sources					

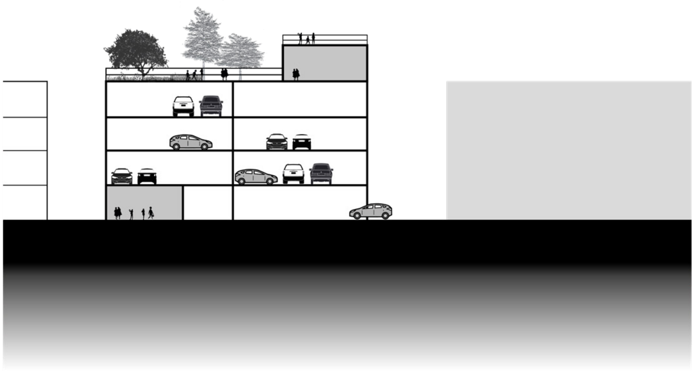
k for strategy and concepts (author, 2022.
nd Tyler & Moench, 2012).

The hub concept is analysed, since this was the highest concept in the hierarchy in four out of five patches. This concept is always implemented with the green-blue streets. When viewed solely, this concept scores a bad on the climate regulation notion, since it houses several trees and bushes, but also adds a concrete area, which is not supportive in climate regulations. However, water storage is implemented in areas below the hub. This grants this concept a sufficient.

The roof of the hub is, partly, an urban farming roof. This aids in the aesthetic information and produce functions. However, this is insufficient, since there is a decrease in production of raw material when compared to a green area. Since this concept is the spatial manifestation of the proposed mobility change, which is a cultural transition, this concept has been given a sufficient on the cultural notion.

Furthermore, due to the urban farming and wind production on the roof, the score for the carrier functions is a sufficient.

Concept: Hub city



Ecosystem services — Assesment

Regulation functions

	Very bad	Bad	Sufficient	Good	Very good
Climate regulation		X			
Water regulation			X		
Water supply		X			
Soil retention		X			

Produce functions

	Very bad	Bad	Sufficient	Good	Very good
Raw materials			X		

Information functions (cultural services)

	Very bad	Bad	Sufficient	Good	Very good
Aesthetic information		X			
Cultural and artistic information			X		

Carrier functions

	Very bad	Bad	Sufficient	Good	Very good
Cultivation			X		
Energy-conversion			X		

Figure 124: Assesment framework for hub city concept (author, 2022. Based on De Groot, 2006).

The proposed ecosystem of the Ruhr in relation to climate adaptation and energy production is analysed. The first notion is of flexibility and diversity. The proposed ecosystem is diversified and flexible. Several types of ecosystem have been implemented in the Ruhr area, leading to a flexible and diverse Ruhr area.

Furthermore, due to the fact that in the pessimistic scenario buffer capacity is my main design principle, redundancy is realised. However, this differs for the several patches analysed in the Ruhr area. This raises questions about redundancy. This is further elaborated in the discussion. Since ecosystem is the base for the implementation of sustainable energy landscapes and climate adaptation, my proposed concepts can be implemented in (almost) all patches. This has resulted in good modularity. The notion of safe failure is unsure, however. This is unsure because my proposed measures in relation to flood risk areas, for example, are based on literature but not tested in a simulation. However, this flood risk, is a strategic component and thoroughly defined in my strategy.

Furthermore, the synergies with social, economic and environmental notions is good. By diversifying for instance the peri-urban Ruhr area, this becomes more active and socially more attractive. Furthermore, the peri-urban area becomes economically strengthened by producing biomass as well as food. Furthermore, by strengthening the ecosystem services, the environmental qualities of the Ruhr area are strengthened as well.

The energy production is sufficient, and is covered in the paragraph quantified strategy. By focussing on co-creation and eye-level perspectives of the proposed ecosystems, together with the energy landscapes, the efficiency and spatial manifestation of this landscape is researched and the most suited solution is chosen. The efficiency of energy timewise relates to the timespan of this transformation. By co-creating, this time span is expanded. However, only biomass and algae production are not operational right away, since it requires time before these renewable energy sources can produce.

Resilience functions

Assesment

	Very bad	Bad	Sufficient	Good	Very good
Flexibility and diversity				X	
Redundancy and modularity				X	
Safe failure ?					
Synergies with social, economic and environ-mental notions			X		
Efficiency of energy production			X		
Efficiency of energy timewise				X	

Figure 125: Assesment framework for the strategy (author, 2022. Based on Tyler & Moench, 2012).

IV. Conclusion & discussion

Chapter 12. Conclusion

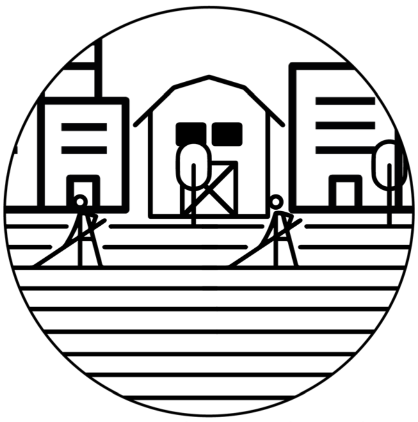
The conclusions will be defined based on their respected sub-research questions. To recap, my main research question is formulated as followed;
How can a spatial development strategy for a climate resilient Ruhr area based on the specific peri-urban condition of the Ruhr lead to fulfilment for the now too limited energy transition?

This main research question will be answered based on the several sub research questions. The following 6 sub-research questions were handled in my thesis.
1. What is the specific peri-urban structure of the Ruhr and how does that relate to energy (production and consumption)?

The peri-urban structure of the Ruhr is a mix of an area with urban and rural characteristics. The more urban characteristics can be found in an east-west urbanised patch, with the more rural characteristics concentrated in the north and south of the Ruhr area. This east-west urbanised area is the result of the merging of several cities.

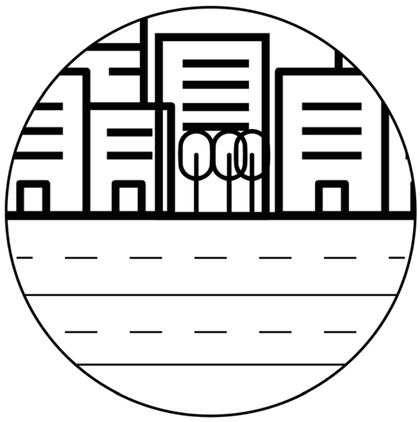
This mix of urban and rural characteristics, which define the peri-urban area, is a consequence of sprawl. Throughout several years, the car rose in hierarchy and with the economy thriving, people moved away from the city, to live in suburbs and to commute to work using their car. This suburbanisation resulted in a spatial structure with more space between houses and more fragmentation of functions. This space in between houses and public functions was designed for the green-blue infrastructure. These parks, streams and meadows were one of the reason people moved away from the denser, compact and less green city centres. These more green and blue peri-urban areas resulted in areas that had a stronger ecosystem when compared to the highly urbanised (historic) city centres. This ecosystem provides the potential for implementation of sustainable energy landscapes, using the carrier function of the ecosystem services. ***For instance, this could result in the implementation of hydropower plant or a solar farm, in a meadow.*** This, the strong presence of green-blue infrastructure, provides the potential for energy production. However, these more green and blue peri-urban areas are designed to be used by car. Often, there is a lack of accessibility by public transport. This design for cars result in a higher energy demand, by the consumption of fuel.

However, the less compact and less dense peri-urban area is less well designed for energy consumption, since its demand for heating and cooling is higher when compared to a much dense and compact historic city centre for instance. The green areas in these dense and compact areas are of major importance, since they provide shading and cooling, which decrease the demand for energy since cooling is required less.



Mix of urban and rural characteristics

Less dense: More space for green-blue infrastructure; strenghtening ecosystem services



Dense area:

The second sub question is defined as followed:
2. How does a peri-urban area designed on the maximalisation of energy consumption & production looks like and what does that result in when applied to the Ruhr area?

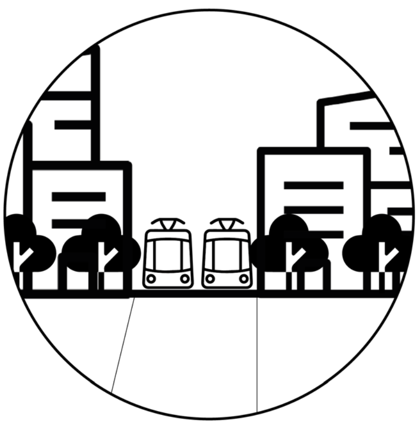
With energy consumption and production as the key driver for design, the new Ruhr area will be an area that is both dense, compact and well connected. However, green areas will be present in the Ruhr area, as they provide shading and cooling. As described in paragraph 10.4, the rural characteristics of the peri-urban Ruhr will almost all disappear.

This peri-urban area is either a very dense and compact city, with green areas to provide shading and cooling, or this peri-urban area is a mix of several smaller, less compact but very well connected by public transport, urban areas. The dense and compact city will have to implement sustainable energy production in these green areas, without tempering the shading and cooling function these green areas have. Furthermore, the implementation of microgrid connects demand better to the supply of residents and other users in these cities. The smaller, less compact cities will thrive for the optimal production of energy, using the ecosystem as a base for this.

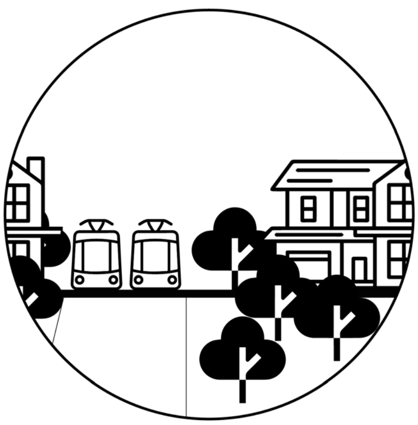
The current modernistic expansion areas will be transformed, to optimise compactness and density in terms of buildings. Furthermore, to minimise the use of the car, these smaller urban areas will have to be given the same level of functions. Furthermore, these smaller urban areas have to work together to be able to offer all of the required function, to minimise energy demand as a consequence of moving to the major urban areas to make use of a certain function.

Furthermore, for the less dense and less compact areas, the energy network has to be properly connected to the rest of the Ruhr area. Only if this is the case, can the optimal potential of energy production be realised. Furthermore, these areas, where there is a major production potential have to invest in buffering and storing of energy, to store the produced energy throughout the day, to be able to ensure energy grid functionality.

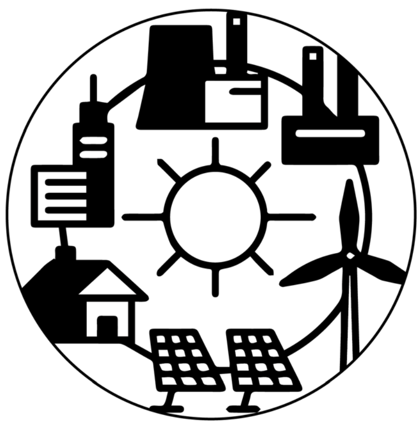
To conclude, fort he Ruhr area this means that the different gradations of urban areas will have to be brought back to a compact city, or a mix of less compact, less dense cities or urban areas that work extremely well together.



Dense, compact, well connected, with green area



less dense but extremely well connected urban areas



energy network

The third sub-question is defined as followed:
3. How can a transition to a climate resilient region lead to an adaptable energy system and what does that spatially mean for the Ruhr?

By Focussing on climate adaptation using ecosystem services, thus green-blue infrastructure. This creates a connection between climate resilience – operationalized by climate adaptation – and an adaptable energy system. Especially, since the uncertainty – the reason behind the climate resilience – is towards how the water cycle will intensify, the focus will have to be towards implementing a transition that focusses on water and the relation with the energy system.

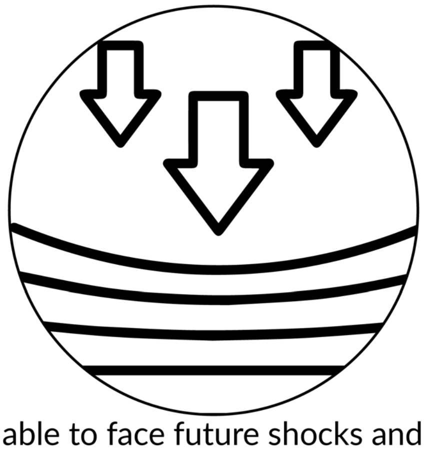
This can be done by strengthening the energy network, to create flexibility, redundancy and buffer capacity. This ensures that the energy system is ready to face stress and shocks as a consequence of the climate change and become an adaptable system. This eventually leads to a system where the notion of safe failure is applicable to. If one part, a node or a connection in the system fails, the rest of the system remains operational.

What this spatially means for the Ruhr area differentiates between areas. This transition to a climate resilience region is done by strengthening the ecosystem services, to create a base for an adaptable energy system. The strengthening of the ecosystem services starts on the notion of the current situation of the ecosystem. For the historic city centre, for instance, this means creating a network of green-blue infrastructure to be able to face shocks and stresses, while, simultaneously, strengthening the energy system. For the historic city centre, this means implementing a microgrid, to create flexibility while better connecting demand to supply of energy.

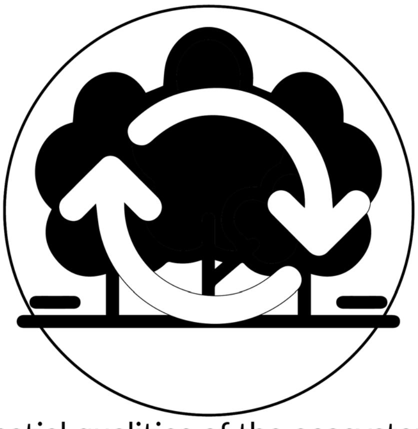
The proposed design solutions have to take into account the different consequences of the scenarios, as they define several shocks and stresses, as well as their intensity and occurrence. These scenarios define the problems in relation to climate adaptation, and can be linked to design solutions for an adaptable energy system by the proposed concepts.

To conclude, the spatial qualities of the ecosystem will change, although the current spatial manifestation of the ecosystem and (urban) landscapes will be used as a starting point, the added energy landscape components will change our perception of these ecosystems.

climate adaptation through ecosystem services



able to face future shocks and stresses



spatial qualities of the ecosystem will change

The fourth sub-research question is defined as followed:

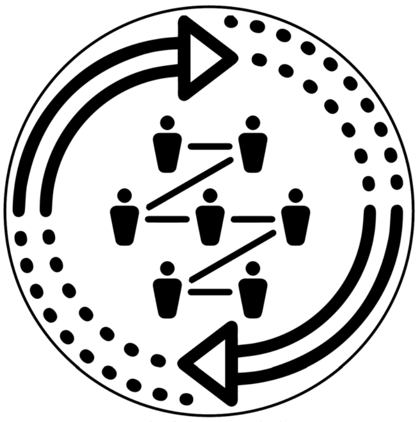
4. How can sustainable energy landscapes be implemented in a peri-urban area, while facing multiple barriers, and eventually facilitate the transition to a climate resilient Ruhr?

The implementation of sustainable energy landscapes, defined as the energy transition, has to be viewed through the lens of a social transition. By placing the human actors and resident's central in this transition, their wishes and demands can be measured and analysed. Furthermore, evaluation of project proposals should shift from a technical point of view, to a social point of view, incorporating these wishes.

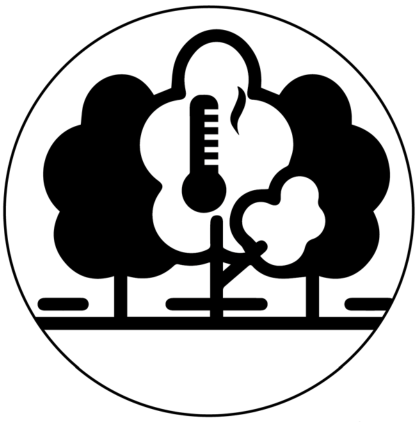
Furthermore, each area or project should be given a proposed energy output, based on the current aesthetic, personal value of residents and energy output potential. By co-creation the participation of residents and other actors can be increased, giving them a voice in the process of evaluating proposals and implementing proposals. Furthermore, a framework for compensation should be proposed, to give residents a meaningful compensation for the changes their landscape will endure.

Lastly, the focus in the implementation of sustainable energy landscape should always define certain notions regarding green-blue infrastructure. These components of the ecosystem directly relate to both energy landscapes as well as climate adaptation, leading to a climate resilient Ruhr.

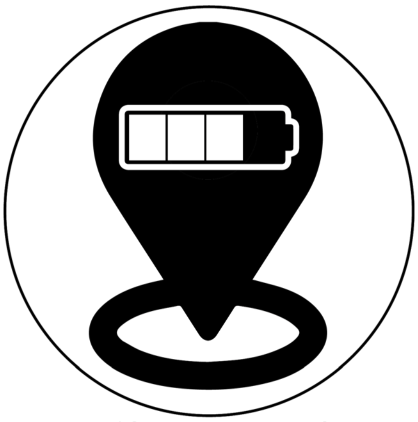
To conclude, the implementation of sustainable energy landscapes should be viewed as a social process, placing the residents, as well as their wishes, central in this process. Furthermore, with the implementation of sustainable energy landscapes, the ecosystem should be strengthened. This climate adaptation will be site specific, proposing solutions for certain specific problems as a consequence of climate change.



social transition



focuss on ecosystem services, leading to climate adaptation



area specific & proposed energy output

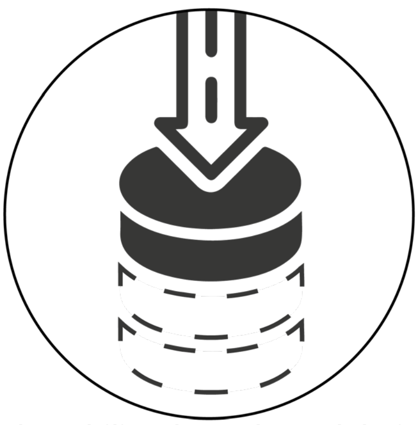
The fifth and last sub-research question is defined as followed:
5. How can a transition from a heavy industrialised region towards a climate resilient region be successfully realised while facing an uncertain future?

The uncertain future poses a difficult context, since a climate resilient region can adapt to shocks and stresses caused by the climate. By proposing different scenarios, several futures can be proposed for the Ruhr area. Regarding the uncertain future, it is of key importance to choose several scenarios and place these on a timeline. By using this timeline, with the changing context, design exploration can be executed, to propose solutions that can adapt to the changing context and eventually achieve a climate resilient region. These solutions are based on principles that ensure the design solutions remain applicable, even when the scenarios change. By focussing on flexibility, the system becomes redundant, and ensures it is able to face future shocks and stresses. By granting centralized decision making power to the Ruhr area, this association can decide when it's time for certain design solutions to transform, from their spatial manifestation for the optimistic to their spatial manifestation for the pessimistic scenario.

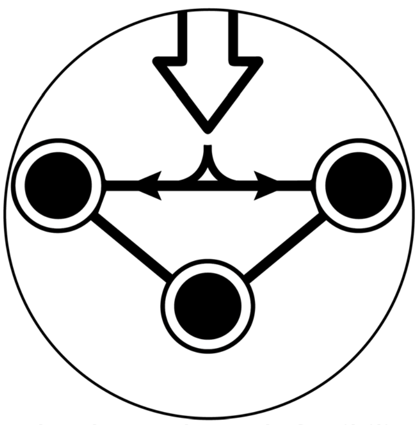
Furthermore, a structure has to be proposed, where these design solutions can be implemented in. The proposed structure must function as a base and must be able to connect to the different proposed design solutions. This asks for modularity in the design, which leads to adaptablity for the system, since new design solutions can easiliy be implemented. The structure of this system is implemented in the current situation, after a thorough analysis of the current situation. Furthermore, based on the current analysis, several principles are derived which shape and guide the future development of these areas.

The heavy industry, the industry that provided the Ruhr area with the economic power to thrive, can be transformed to an industry focussing on the production of elements needed for renewable energy sources, such as wind mills and solar panels. This is currently the guiding principle in the transformation of the heavy industry.

To conclude, by focussing on adaptability through modularity and redundancy through flexibility and, by composing probable future scenarios, systemic safe failure can be achieved. This leads to a structure that can be implemented that can house these several design solutions and face future shocks and stresses and become climate resilient.



adaptability through modularity



redundancy through flexibility

safe failure through scenario building

Chapter 12. Conclusion

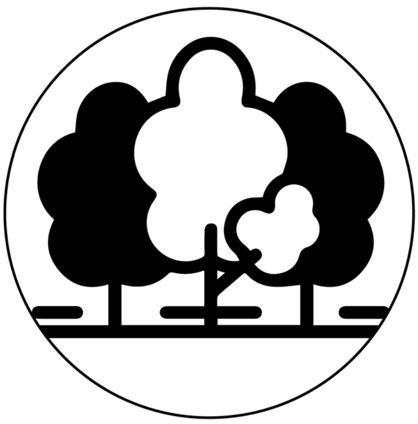
With the fifth sub-research question answered. We can now move on towards answering the main research question;
How can a spatial development strategy for a climate resilient Ruhr area based on the specific peri-urban condition of the Ruhr lead to fulfilment for the now too limited energy transition?

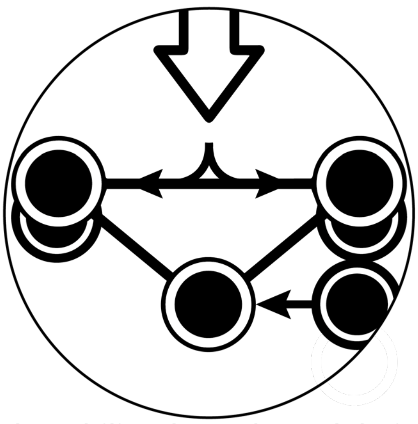
By focussing on ecosystem services as a climate adaptation measure to achieve climate resilience. By focussing on ecosystem services, the carrier function is strengthened, which creates more possibilities for energy production using renewable energy sources. This is the link between climate resilience and the energy transition.

This link, the ecosystem service, will be placed in a structure throughout the Ruhr area, where design solutions are implemented in that both produce and adapt to the changing climate. Furthermore, the proposed design solutions have to be designed based on modularity and adaptability. Furthermore, this strategy is focussed on the specific peri-urban condition of the Ruhr. The current spatial manifestation is used as a base, incorporating the value of actors and residents and reacting to current local problems. This results in project proposal based on the site specific characteristics, but predominantly on the personal evaluation of the landscape. That is because this strategy, the energy transition, is seen as a social strategy, where residents are engaged to participate, by utilising co-creation.

This strategy connect certain key notions of climate adaptation, such as flood risk areas, to ways of producing energy, through hydropower. Furthermore, several functional changes are proposed in this strategy, transforming agriculture, to agrivoltaics or aquaculture, depending on the specific location. Furthermore, the current problems of certain peri-urban areas are incorporated in the strategy and focus, besides climate adaptation and energy transition, on social, economic and environmental problems for that specific peri-urban area.

To conclude, this strategy proposes several changes that will eventually lead to a Ruhr that is prepared for the uncertainty in terms of climate and energy, while utilising the specific peri-urban structure and enhancing it.


ecosystem services


adaptability through modularity
and redundancy through flexibility


site specific characteristics

Chapter 13. Discussion

The research executed in this thesis touches upon several other major topics – such as the mobility transition - resulting in a broad thesis. Because of these links with other topics and transitions, this discussion chapter is formulated. This chapter will elaborate on several key notions of this thesis, such as scope, limitations and further research.

Scope
This thesis focusses on integrated solutions for the energy transition and climate adaptation. These solutions were constructed through a process of research by design.

However, this thesis also focusses on the implementation of these design solutions. The current energy transition and climate adaptation strategy are examined and a new strategy, describing how the proposed design solutions have to be implemented, is proposed. This strategy is proposed based on the uncertainty the region, the Ruhr, is facing in terms of primary energy consumption and expected temperature rise.

This research by design and strategy building is executed on the project area; the Ruhr metropolitan area. The current spatial manifestation – a peri-urban, polycentric and metropolitan region – formed the base to choose for this region. These boundaries describe the scope of this research.

Limitations
This thesis combined design of an energy landscape with a suggested strategy to implement and realise the design. However, the implementation of the strategy in practise is heavily reliant and dependant on other transitions, sectors and stakeholders in the region. For instance, the mobility transition away from a primarily car-oriented mobility system to a more shared mobility system, focussing on public transport and personal electrical modes of transport, results in freed up parking spaces, which can be given back to the ecosystem. This change in mobility system as well as other suggested aspects of the suggested strategy, are heavily reliant on political ambitions and the choices of citizens in the area. For instance, a political party could chose not to build a proposed hub or strengthen the public transport network, or a user could choose not to commute using public transport but choose for the car. Furthermore, political ambitions can fluctuate quite fast. A change could, for instance, happen after a regional or national election and could have serious consequences for the proposed changes that the strategy is based upon. These real life influences can affect the proposed strategy and ask for changes throughout the implementation.

Furthermore, the politics and economy behind the energy transition are unclear. The economic interests of different parties and actors or level of governance are unclear and change often. Currently, the Green party is the biggest in Germany. However, in North-Rhine Westphalia, the Bündesland where the Ruhr area is located in, the CDU is currently the largest party. The level of participation and willingness of actors and stakeholders can change, as our economic and political landscape is constantly changing.
The final implementation of the design solutions in the Ruhr area is done using co-creation. For this approach to work, it is crucial to engage stakeholders. The level of stakeholder engagement can fluctuate. The Ruhr metropolitan association should actively check on the level of engagement, since a lack of engagement could have a massive consequence for the implementation and the changing of the human landscape and affect the overall opinion of the outcome. Tools to incentivise engagement of stakeholders should be implemented. This however, requires political will and economic possibilties, which can reduce or even disappear.

The impact of the chosen patches on the results
My design exploration was based on the 5 patches I selected. These 5 patches were based on the spatial analyses as well as a discussion with my mentor. Although, by covering these 5 patches several different spatial characteristics were covered in this research, it is possible that choosing different patches result in a different outcome of my research.

Coping with scientific uncertainties
The notions regarding the climate uncertainty are derived from multiple sources. These notions are combined to form a scenario. In the proposed scenarios derived from the IPCC, the possible consequences of a +3°C temperature rise are described. In this desripition, the negative effects are described in a However, as the IPCC desribes certain uncertainty in a certain scope, to cover the uncertainty that remains. That scope formed the base for my design.

Furthermore, these scientific papers are based on models, leading to a data driven assumption for the future in relation to the outcome of global warming. However, each of these scientific papers have a uncertainty component in their respected models. Since these models were used for the proposed future, this – a component of uncertainty – is also the case in this thesis. To grasp this uncertainty, I proposed several scenarios. The different scenarios lead to different types and occurrence of extreme weather events. In this thesis, based on literature, I focussed on the intensifying water cycle. For Europe and specifically for Germany this results in extreme heat, drought and precipitation. Although the literature I reviewed did not lead me to other notions, I could imagine that focussing on other extreme weather events, would define other specific notions and design principles.

Furthermore, several educated guesses were made regarding the increasing size of flood risk areas as a consequence of the scenarios I propose. The specific dimensions were an educated guess, based on the current spatial manifestation of the flood risk areas.

Regarding the buffer capacity and safe failure, I propose that a simulation must be created to propose the situation of the Ruhr area and the climate context, to really define if there is a safe failure and enough buffer capacity.
The design solutions I propose are not fully quantified. Notions on this quantification are derived from literature or are calculated. Furthermore, the impact that the scenarios have on these energy landscapes has to be researched further.

To cope with these uncertainties, two different scenarios were proposed. The uncertainty regarding the global temperature rise has been described. The expected primary energy consumption for the Ruhr was derived from literature. With a expected decrease in primary energy consumption and an expected increase in percentage of energy produced using renewable energy sources, a calculation was executed. This led to a clear goal in terms of primary energy consumption. However, this goal is based on assumptions regarding several sectors becoming more sustainable or shrinking in size, leading to the expected decrease in primary energy consumption. Throughout the coming years, the primary energy consumption needs to be closely monitored to see how this matches with the expected primary energy consumption.

Replication of design and strategy
The scope of this thesis is the peri-urban polycentric metropolitan region of the Ruhr. However,

there are many regions in the world facing similar problems of energy transition and climate adaptation as the Ruhr. Are the research by design I applied replicable to other areas? Yes, the multi-layered design solutions I suggested for the Ruhr based on the ideas for modularity and flexibility, can be applied independent of special context.

The replicability of my suggested strategy is less clear. The key notions on how to implement this strategy are generalizable because they can address similar transition challenges in other European peri-urban regions. However, the specificities of the level of heavy industry, current transportation system as well as the governance system, are typical for the Ruhr region, And might be completely different in other peri-urban regions in Europe. This requires region specific finetuning of the strategy.

Wider implications of the proposed strategy
The proposed strategy could, possibly, lead to a totally different image we have of urbanised areas. Currently, we see urbanised (and the different spatial manifestations, including peri-urban) areas as paved areas, with less green. With this strategy, this image could change, introducing the spatial manifestation of ecosystems back into urbanised landscape. This could disturb the current dichotomy between urbanised and rural landscapes, where ecosystem services functions as the connecting component between them.

Furthermore, this strategy could function as a new approach to Urbanism. Where in the modernism movement, air, space and the car, were central design principles, the ecosystem movement would place the spatial manifestation of ecosystem central in the design.
Lastly, this strategy could change the current image of ecosystems as we know it. With the addition of energy landscapes or energy producing elements using renewable energy sources, the spatial manifestation of ecosystem services changes.

Future research
This project proposes focussing on ecosystem services as the solution to tackle the energy transition and climate adaptation, in an integrated way. The energy transition and climate adaptation are of the major challenges we – society – are facing. However, we are facing other major challenges, such as the aging society, the transition towards a circular economy and spatial justice. How does my proposed strategy for strengthening and developing ecosystem services relate to this other developments? Further research should be devoted to understanding if there are relations between these major developments, and what role strengthening ecosystem services could play in addressing other challenges in an integrated way.

The impact of global warming on ecosystems is continued topic of scientific research, since we don't know how far the global temperature will rise in the near and distant future. For that reason it is highly relevant to continue research on the impact of global warming on ecosystems, since we become more and more dependent on the ecosystem in the transition to a more sustainable world. Important questions are: Will certain functions of ecosystem services become less effective or completely vanish and how do certain spatial manifestation of ecosystem services react to this changing climate?. The role that (systemic) design could possibly play in guarding ecosystem services against a more extreme climate should also be more clarified. . Are there certain design principles or design tools that contribute to guarding ecosystem services in a more extreme climate? And how do specific ecosystem services react to this changed climate?

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Chapter 14. Reflection

Overall process
Towards the end of my thesis, I reflected on the process of my thesis and how I arrived at this point. While reflecting, I concluded on several notions. The first notion is regarding my personal growth throughout this thesis. I now have the idea that I can freely discuss notions regarding resilience, ecosystem services, energy landscapes and the energy transition. This feeling has grown to the point where I feel I am equal to other when discussing notions related to the topics I just mentioned.

Furthermore, since the start of my thesis several important aspects were changed several times, as a consequence of a discussion with my mentor team. I used the feedback and critically reviewed the choices I had to make. Although this altering between approaches resulted in time loss, I am really grateful for these changes, since they led me to my current approach and current end product.

During the start of the process, I am now able to say that I was struggling with the correct approach to this thesis. Looking back, I was not sure what methods to use and where to focus on. However, during this process I found methods and focus in my thesis which led me to the current end product. I now feel that I am able to step back, analyse my own storyline and propose my own feedback as to where the storyline could be improved.

Societal relevance
The societal relevance of my graduation project addresses the transformation the region is currently is experiencing. Due to the de-industrialisation, the region is facing several socio-economic problems arising, such as poverty, unemployment, leading to social polarisation. The problem is intensified by the specific peri-urban structure of the region.

In my research I took this peri-urban structure as a starting point to analyse if and in what way the region could be transformed into a climate resilient region covering its energy demand by renewable resources and technologies. I elaborated this idea with the help of the concept energy landscapes and ecosystem services. With the inclusion of citizens and relevant stakeholders, the energy transition and the climate resilience processes in the region will also positively affect energy democracy which might help countering polarisation in the region and strengthening of productive social networks in the region.

The societal sense of urgency to change the current fossil based energy system into a renewable based system has been strengthened by the recent war in Ukraine.

Scientific relevance
This thesis addresses several gaps in scientific literature. The first one is designing and implementing the concept of Energy landscape as a means to design a new renewable based energy environment, and simultaneously facilitating space for other societal challenges like the need for ever increasing human settlements (urbanization) and the adaptation of landscapes to climate change. This thesis showed the potential and limitations of implementing energy landscapes with dual goals, within special limitations.

Second, scientific knowledge on the renewable energy potential of peri-urban areas is minimal. Here too, the thesis research explored the potential and limitations of energy potential production and consumption in the peri-urban region of the Ruhr. Therefore, this thesis for the first time

provides indications of energy production and consumption limits in a peri-urban region.
Third and lastly, this thesis provides one of the few examples in the scientific literature connecting climate mitigation design with climate adaptation design in urban design. The thesis shows a region with an adaptive energy system also improves the climate resilience of a region.

Ethics paragraph
In this thesis, the energy transition plays a key role. Whenever a transition is happening, attention should go out to how just this transition is executed and implemented. Are there people, or institutions that do not equally benefit from this transition? And applied directly to my thesis, what will happen to organizations or factories that are forced to shut down as a consequence of the energy transition?

This is also the case for the overall goal - to reach climate resilience. Will choices have to be made that negatively affect a certain group of residents or stakeholders in order to positively affect the entire region? These are all considerations that have to be carefully weighed and discussed and evaluated, since it could impact the outcome and credibility of the research.

V. Literature list

Glossary of terms

e.p.m. | energy potential mapping

s.e.l. | sustainable energy landscapes

energy c. & p. | energy consumption & production

energy p. & c. | energy production & consumption

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