Research bundle

Integration of decentralized energy systems in an urban context through architectural design

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Submission date 06-05-2021
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Preface

Before you lies the research bundle which combines all the literary works required for the graduation studio: City of the Future. The bundle consists of mandatory written pieces which are required to acquire the degree of MSc architecutre, however additional material has also been added to the bundle. The structure of the main theoretic research is discussed in the Research plan, which therefore is presented first in the research bundle. Additionally, two mandatory written works are added to the Research bundle: Position paper & Reflection paper.

The position paper elaborates on one of three subquestions proposed in the Research plan, discussing the points of intersection between energy systems and spatial design and public life. On top of this, the Position paper will go beyond factual data and search for the role of infrastructures in modern life, and how it impacts what we see around us. Furthermore it will dive into the question whether or not Architecture has role to play in creating sustainabale infrastructures.

The Reflection paper is last component of the mandatory section of the research, reflecting on the research and the methods of inquiry. Additionally, a personal perspective on the research will be given using the duality of 'detail and whole' as a metaphoric backdrop. The Research plan, Position paper & Reflection paper constituted the mandatory written research.

Two additional subquestions are proposed in the Research plan which are not part of the mandatory section of the research, but were however deemed crucial to understand the main question. The two chapters covering these questions are also added to the Research bundle in a separate section.
All contributions to the research bundle support to the quality of the conclusion of the position paper which aims to answer the main question proposed in the Research plan. The Reflection paper shall aim to repercuss on whether or not the chosen methodology and theoretic framework have succesfully been ablo to do so.

Figure 1 - Previous page
View of the Gas silo on the F. aan de Lusthofstraat. Taken from the gas factory on the Oostzeedijk, 02 October 1908 (Edited by Author)

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Research plan

Essay on the underlying theories and methodoligies of the proposed research

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Introduction

Because of the expected growth of the city's population, accelerated by a global trend of urbanization, it is expected that more facets that form the city will either voluntarily or forcibly intertwine with other functional demands because of an increasing pressure on land-use (Tillie et al., 2014; Hocks et al., 2018).
Historically, the task of densification and intensification of the urban fabric has been tackled by architects, civil engineers and planners. However, this has happened at the cost of significant amounts of energy and material. Simultaneously the intensification of the fabric has not prevented the city's energy infrastructure from becoming overly stressed and the city is now only able to sustain itself by consuming vast amounts of resources from rural areas around the globe without creating a reverse flow of valuable resources (Ferrão & Fernández, 2013).

> *"The world's cities occupy just 3 per cent of the Earth's land, but account for 60-80 per cent of energy consumption and 75 per cent of carbon emissions."*
>
> (UN, n.d.)

This makes the global urban region one of the most, if not the most potent domain through which significant reductions of greenhouse gassed (GHG) can be accomplished. Therefore, the energy infrastructure, which crucial to the existence of cities, and a major shareholder within the environmental balance of the city, will take centre stage in this research, because the modern city has become increasingly dependent on its existing energy infrastructures (Belanger, 2016; Burns & Kahn, 2005; Edwards, 2002). Rnergy is produced in fossil fueled centralized power plants and transported over long distances by means of overhead power cables and district heating networks.

The increasing demand for energy and a desire to fulfil this need with renewable energy, has the potential of occupying vast amounts of land in rural areas (Hocks et al., 2018; Stremke & Van den Dobbelsteen, 2012). This sparks the debate whether the urban region itself should instead be able to fulfil its own energy demands, rather than occupying large amounts of ecologically important hinterland. Embedding a renewable, resilient and sustainable energy production network within the city limits is not simply a matter of feasibility and practicability, but rather one of integration (Zanon & Verones, 2013) and is therefore one of the crucial tasks at hand for planners, politicians and architects. This thesis will take centre stage in the research into 'The city of the future'.

Research questions
To explore this theme and demarcate a specific field of research within this theme the following research question is proposed:

> *How can sustainable energy systems be integrated in urban areas through spatial planning and design?*

By placing this thesis within an environment of adjacent research fields, the possibility presents itself to embed the problem statement within both a theoretical and practical framework. In so doing, the following subquestions are proposed to allow for a theoretical embedding of this thesis.

1. *To what extent can a decentralized approach to energy production and storage improve the resilience of future energy networks?*
2. *What renewable energy production and storage methods are suitable in urban areas and what are the spatial implications of these methods?*
3. *What are the opportunities for integration with public life and urban design?*

The following research plan dives in to the planning and procedures involved in the proposed thesis.

Method
The third question will be the central question in the position paper. The first and second question will be covered in the research booklet as they are more geared towards analysing hard data on production systems and network theory. Together, the first two subquestions with the position paper, will be able to asnwer the main question. This is further explained in the research structure.

1. Problem statement

> *"As of 2011, more than 52% of the global population lives in urban areas. In 2006, urban areas accounted for 67–76% of energy use and 71–76% of energy-related CO2 emissions. By 2050, the urban population is expected to increase to 5.6–7.1 billion, or 64–69% of world population"*
>
> (IPCC, 2015. p. 25)

The cities of today account for an enormous amount of rural land use (Ferrão & Fernández, 2013). This exploitation of vast amounts of land, is necessary to provide the desired amount of food, energy, materials, etc. for the non-rural areas. With an ever-growing global population and an ever-growing amount of urban residents, the pressure on production is inescapably going to increase, with an extremely uneven emphasis on consumption within cities. This means that the city is going to rely progressively more on rural production and the providence of the non-urban areas, if today's production methods remain identical. This is especially true for the strongly centralized production of our energy.

Energy, since the industrial revolution, has been a vital condition for modern life within urban areas. Coal, gas and oil provided vast amounts of energy which could be converted to energy in centralized sites within- or far outside the city limits due to the instatement of intricate distribution infrastructures. This subterranean process has caused for urban societies to dissociate from the actual production process that facilitated their daily lives Belanger, 2016).

Fossil fuels are finite, and therefore the production systems together with the global population will have to attune to renewable production methods to be able to sustain the increasing energy demand, as well as to comply with the environmental goals of Paris 2050.

The shift towards a sustainable, renewable and robust energy system will require an enormous effort, possibly radically changing the way we perceive land-use today.

> *"The sheer quantity of renewable energy that needs to be generated to sustain humanity may require us to regard, at least conceptually, every landscape as an energy landscape"*
> (Stermke & Van den Dobbelsteen, 2012, p. 4)

If control of the energy network is not reclaimed, 'The City of the future' is likely to fail in becoming less dependent off of fossil fuels and the accompanying energy systems that have been in place since the second industrial revolution. In so doing the lands used and exploited by the world's urban areas will have to be reorganized and reenvisioned. Through this, the global cityscapes are able to steer clear from an imminent energy unconscious society, and seek to find oppor tunities to become increasingly more self-reliant.

2. Relevance

Much of the realm of energy infrastructure, even though it supports modern life for all urban citizens, lies secluded in the realm of engineering and policy making. The modern engineer is predominantly concerned with effectiveness and exactitudes. It is therefore that the modern energy system has been able to support such an extreme intensification of the global urban regions. A result of this continuous expansion of the systems that support urban life, is that infrastructure has come to be measured by performance, rather than the extent to which it benefits public life (Belanger, 2016). As a result, it becomes almost unthinkable that one should question the very basic fundaments on which modern life is build. Energy was and still appears abundantly available, and abundant it was designed to be.

A growing need to change to renewable sources of energy is challenging the existing system (Alanne & Saari, 2006; Mehleri et al, 2013). The way the grid is designed relies heavily on the energy concentrated in fossil fuels, which after conversion can be transported over long power lines. The sheer size of the challenge ahead can already be grasped when one compares the amount of energy that is captured in fossil fuels versus the amount of land that is needed to produce that energy sustainably (Hocks et al., 2018). On top of that there is an increasing economic pressure exerted on the energy system (Tillie et al., 2014)

> *"As prices climb and energy costs make up an increasingly large share of the cost of living, urban energy metabolism will go from being just an environmental virtue to a core determinant of urban economic competitiveness."*
> (Troy, 2012, p. xi)

This means that the durability of the existing fossil fuel fired system is reaching its expiration date. It is therefore paramount that professionals look for alternatives which can deal with the challenge of a robust and sustainable system. Much of this debate covers the question of 'who' is able to respond to these challenges. This ranges from the individual building (in the case of net-positive architecture) to full urban self-sustainability (urban metabolism) (Yigitcanlar & Dizdaroglu, 2014).

> *"Climate change and energy saving are challenging the city and the territorial organization. Innovative spatial and urban planning methods and procedures are required, and new approaches and instruments must be elaborated and applied in order to shift from the building scale to the urban and territorial ones. In fact, while energy saving and emission control measures are usually applied to single buildings, plants and technological systems, the urban and territorial scales are not fully considered.."*
> (Zanon & Verones, 2013, p. 10)

The questions of 'who', 'where' and 'how', are therefore of the upmost importance to explore. This process is kick-started by the decreasing cost of renewable energy technologies. Simultaneously clean energy production is identified as one of the promising economic recovery strategies after COVID-19 (European Commission, 2020), which will in turn allow for a higher chance of feasibility in future projects. The question of 'where' is especially important in densely populated cities and regions such as the Netherlands, as the human habitat coincides increasingly more with production landscape (Tillie et al., 2014). The challenge of the spatial organisation of the consequences of a renewable energy system is therefore one of the most important tasks of architect and planners (Hocks et al., 2018; Zanon & Verones, 2013) and will therefore take centre stage in the architectural elaboration of this thesis.

3. Theoretic framework

At the base of this framework for the research lies the broader field of 'infrastructure planning'. This is not an official title for a research field, however it is found to be the most appropriate representation of what belanger (2016) calls 'the system'/urban metabolism. It is found to have the best capabilities to draw analogies with adjacent fields of research. Infrastructure as an activity and as artifact is a well-documented field.

An overlay of this field is created through the notion of network-thinking which deals with the way we organize our infrastructure. This directly deals with resilience but also circularity as more connections are drawn between nodes in the network, ergo "activities" in the network. The research field of network thinking goes back to Baran (1962) when he identified the three main structures of networks: Centralized, Decentralized and distributed. His terminology echoes through in modern literature concerning the organization of the imminently changing renewable energy network.

Together they incubate the research field which shall be appropriated. It is given the title of 'infrastructure design', but it should be stressed here that the title is to a degree flexible.

The full width of these research fields, will be further discussed in the research. Simultaneously it will be discussed how these fields of research can engage in complex strategies that are required for climate adaptation.

This an important notion and condition for the following research as it imposes several limits to the research. It is therefore that the framework is framed by the term 'Adaptation'. As complex activity is prone to not be able to produce one all-covering answer.

3.1 Criteria

In the light of this thesis, an additional framework is needed to support the selection of a suitable renewable energy production method. This is due to the specific impact of distinct energy production technologies. For example, smell, sound, size, safety, amongst other characteristics. Due to a proposed decentralized approach, the system of choice must be able to deal with the requirements of the specific scale of the city (Center, Suburban or periphery). Therefore a grading framework is required to score the suggested production methods within selected criteria. This is executed at the hand of the multi criteria analysis proposed by Cristóbal (2012). On top of this the notion of life cycle shall provide insight into the durability that is involved with architectural intervention. If for example a technique has life cycle of 15 years, than the point can be made that the envelop and the additional program need to be flexible to accommodate adaptations. The result of the criteria analysis shall be discussed in the main body of the research.

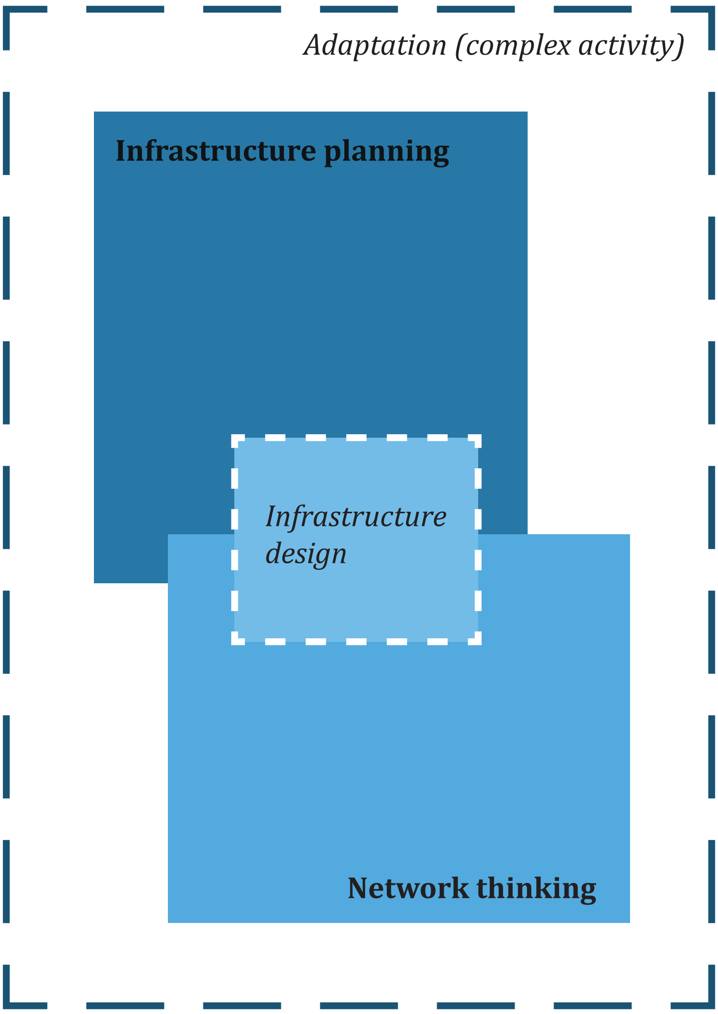

Figure 2: Theoretic framework

4. Methods

The research as will be proposed in this research plan embodies a variety of methods which will be further elaborated on in the research thesis. The research plan will predominantly occupied with the 'what' and 'when' of the methodological framework. This will be done at the hand of variety of key-literature items that have on their turn elaborated on specific elements of the research process.

In the field of qualitative research methods, both within and outside of the realm of design, two frameworks have been identified. The main framework is given through the Qualitative research cycle by Hennink et al. (2020). This framework is supplemented by the Design research methodology of Blessing & Chakrabarti (2009).
Similarly in the field of design research methods (meaning research for design and vice versa), two frameworks have been identified, which deal with the creation of a design assignment from research from two different perspectives. Why these different perspectives are important will be elaborated on further along the research. Important to mention here is that they are not mutually exclusive, and have their own application and purpose. The frameworks at hand are Constructive design research as described by Koskinen et al. (2011) and the Five-step approach by Stremke et al. (2012). The latter is specifically interesting within this field of research, being the imminently changing energy infrastructure, because of the role of design in long term strategies (like climate adaptation strategies).

The research is split up into 4 parts as informed by the frameworks mentioned above. These are the following:

4.1 Research design
The first step of the research consists of the formulation of the assignment. This is kickstarted by the identification of relevant research topics. In the case of this thesis, the topic of 'renewable energy infrastructure' in the broad sense of the word was identified. As this covered a wide variety of topics at a variety of scale levels the topic had to be dissected into manageable parts.

This allowed for the problematization of specific scales of the infrastructure networks. Being a scale which has the potential to be integrated into the fabric of the city; i.e. an architectural assignment.

To look into the relevance of this topic, a literature study was initiated. The literature should then be able to verify the first hypotheses that was formulated during the assembly of the research topic. Through the clarification of the research topic, the field of energy infrastructure was found to be a widely discussed topic, but it was not yet covered on the scale of architecture. This lead to the study of precedents which shall likely become part of the case studies in the research thesis.

4.2 Data collection
The second step of the research consists of the broad exploration of the research field within- and adjacent to energy infrastructure. As the role of architecture in this field of research was found to be not yet part of the discussion, it was believed that a strong theoretic underpinning of the research would be required. This would allow for the identification of relevant subthemes which would be able to deal with the scale of architecture.

The elaboration of the theme at hand is mainly done through a literature study covering a broad variety of adjacent research fields. For this specific research already several themes are identified to be paramount to be able to answer the main question.
These are: identification and assessment of possible renewable energy production and storage methods, selection of framework to grade the available systems for application in urban environments, and the appraisal of (programmatic) hybridization opportunities.

4.3 Analytic cycle
The third step of the research consists of the assessment of the collected data. In this section the main line of reasoning will be formulated. This is assisted by the exploration of studies that already started to deal with (programmatic) hybridization of energy infrastructure. In so doing, together with data collected in the previous data cycle, the theoretic underpinning of the main research question is expected to be adequately explored.

To conclude the analytic cycle additional bodies of research are employed. This is for example done through secundary assingments like '*The historic development of the power plant*'. This will be elaborated on in the research booklet. These assignments are identified to supply further insights into the (architectural) history and future of the energy network.

4.4 Informing design
To conclude the research method the topic of 'design' is briefly touched upon. Although the research does not practically deal with the outcome of the design process, it is however believed that a preliminary definition of the relationship between design and research should be in place. This is already suggested in the introduction of this chapter. This is for example crucial for the selection of the 'building blocks' (as mentioned in the Data cycle paragraph) of the research.
In this case the research is intended to be both capable of supplying a 'program by research' scenario as well as a 'program by scenario' situation, as input for the design assignment. This distinction is further elaborated upon in the thesis.

4.5 Process
How the research leading up to design phase is given shape in a practical sense is shown in the figure on the next page. It outlines the proposed research tasks at hand and how they relate to the proposed research questions and the overall process.

4.6. Process structure

	Phase	Description	Tasks	Output	Question	Schedule
						[Note that the scale is not necessarily 1 week]
	Research					
	Research design	Demarcation field of study. Validating the theme. Preliminary main research question. Crucial to this stage that one can already identify the to-be used research methods as it will influence the type of sources one should look for (qualitative, quantitative/empirical, literature).	1. Formulation of research question	Research plan		1
			2. Problem statement	Research plan		1
			3. Relevance	Research plan		2
			4. Selecting data collection methods (qualitative, quantitative)	Research plan		2-3 [P1 pres.]
			5. Preliminary theoretic framework	Research plan		
			6. Architectural position	Position Paper Research plan	Position essay	3
	Data cycle	Data collection is part of all the cycles, however one should now be concerned with bringing in as much data to broaden one's view. By developing an understanding of the found data, preliminary conclusions can be drawn. This is crucial to be able to start to verify the hypothesis.	7. Literature review	Research plan, Position paper, Research booklet	Q1, Q2, Q3	1-6
			8. Elaboration of theoretic framework	Research plan, Research booklet	Q1	2-4
			9. Research of energy production methods	Research booklet		
					Q2	5
	Analytical cycle	Categorization of the data. The assessment of the data and literature found in the previous cycle, should enable the author to deduce new information. Further research might still be necessary to be able to fully deal with the problem at hand. Either way it shall have implications for the approach to this research topic in the future.	10. Case studies and history of power plant	Research booklet		
			11. Elaboration on *Energy landscape*	Research booklet	Q2, Q3	
			12. Elaboration on *Energy humanities*	Research booklet	Q2, Q3	4
			13. Energy/location mapping	Research booklet		
			14. Data assessment	Research booklet	Q1, Q2, Q3	3-6
			15. Validation of hypothesis	Research booklet, Position paper	MQ, Q3	
			16. Reiterating on literature review	Research booklet, Position paper		
			17. Conclusion (Q3 - Position paper)	Position Paper (Q3)	Q3	6 [P2 pres.]
			18. Conclusion (Main question)	Research booklet (MQ, Q1, Q2)	MQ (Q1, Q2)	
			19. Recommendations	Research booklet, Position paper		6

Figure 3: Research steps in table

5. Research structure

The diagram summarizes the most important facets for the research. The input is the personal fascination supported by relevance and a first indication of the validity of the research topic. First, the Research plan is drafted. This plan outlines the upcoming research and demarcates the literary and disciplinary boundaries. The theoretic framework, which is one of the crucial parts of this plan, determines how these themes are going to be grounded in the wider body of research – anchor points. It is influenced by the position paper as it shall confirm the appropriate precision of the theoretic framework. In this specific field of research the position of the author should be highlighted, because within adaptation and mitigation policies, multiple strategies are possible. A specific strategy will have to be adopted. This will be covered in the position paper

In this case the authors personal architectural position on this matter is very relevant. It is influenced by the preliminary conclusions of the research booklet.
The research booklet will predominantly dive into 'what', 'how' and 'where' to be able to explain the practical consequences of the strategy. The data will be categorised and conclusions can furthermore be deduced. The whole structure is kept in place by the method which is discussed in this research plan. This indicates 'when' and 'where' a research task should happen. The three sources of output (Research Plan, Position paper, Research booklet) are the most important products of the research. The research plan lays the foundation, and the position paper together with research booklet will add to this the main results of the research (Literature, Site analysis, Position essay, etc.)

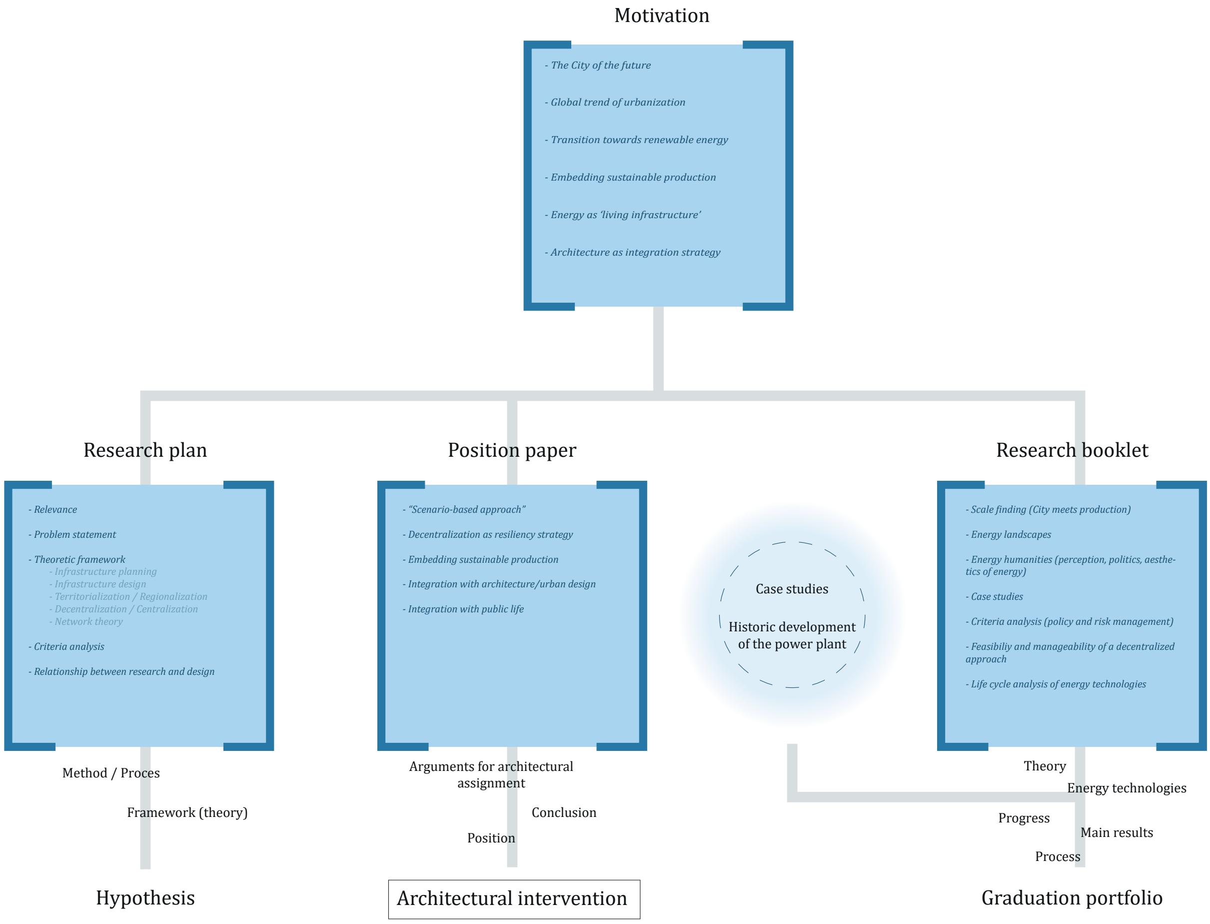

Figure 4: Research structure

6. Precedents

Uppsala power plant
The traditional power plant is seriously challenged in the Uppsala power plant proposal by BIG architects. The power plant has two different cycles. In winter time the plant will be fully operational feeding the district heat networks. Simultaneously educational activites will take place where visitors can get a glimpse of what the production process entices. In the summer, the plant will be largely turned off, allowing more people within the dome. Perhaps even allowing for festivals and large groups of tourists to visits.

By doing this, the Uppsala power plant start to challenge the traditional borders between energy production and public life. Especially in the case of heat production where we will see production occur close to city centers, this approach is perhaps increasingly more required to merge these two worlds.

Source: https://big.dk/#projects-upp

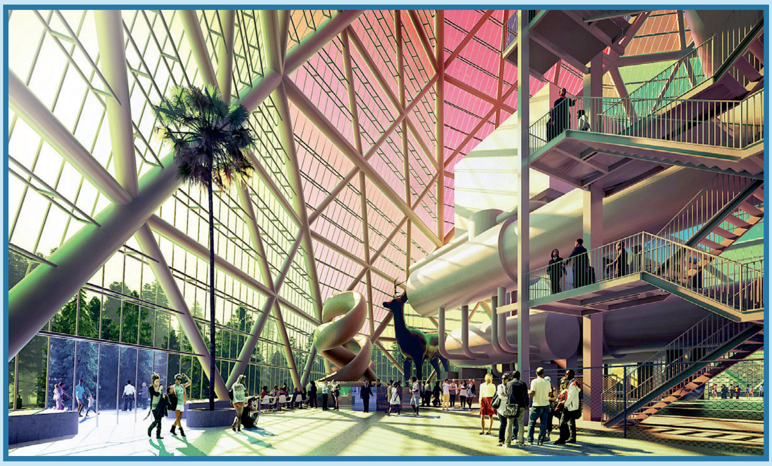

Figure 5
BIG - UPP: Uppsala power plant
Interior render
https://big.dk/#projects-upp

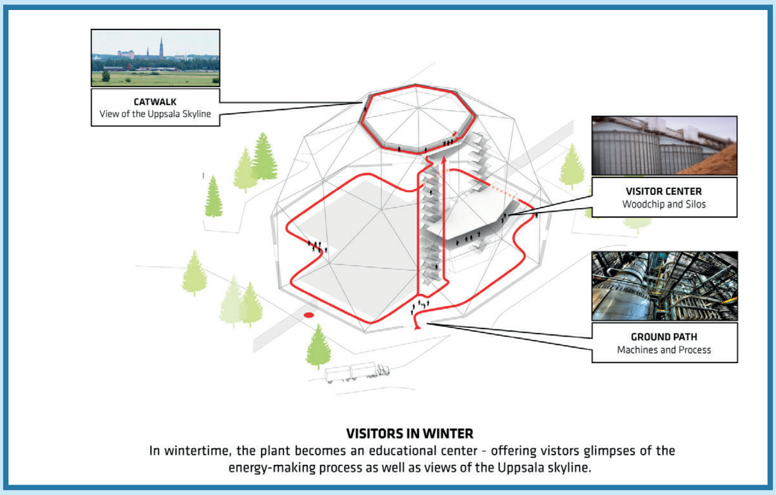

Figure 6
BIG - UPP: Uppsala power plant
Public program scheme
https://big.dk/#projects-upp

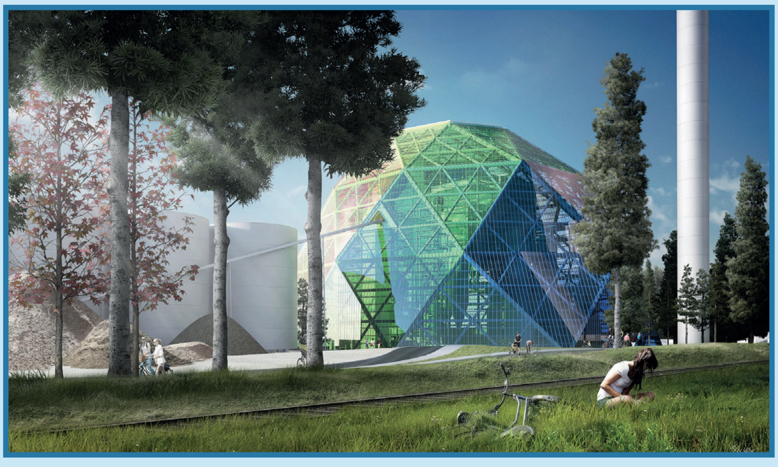

Figure 7
BIG - UPP: Uppsala power plant
Exterior render
https://big.dk/#projects-upp

Energy Cathedral
The Energy cathedral is part of the ‘Central Innovation District’ proposal for the center of The Hague by UN studio. ‘The Energy cathedral combines a pedestrian overpass and a geothermal heat plant in the center. Together with additional program they form the artifact. The architecture is complimented with a lighting program, depicting the hot and the cold side of the thermal well deep under ground. As building heating requirements is one of the major stakeholders in the energy balance of buildings in cities at the latitude of The Hague, these plant are expected to occur more and more within cities. Combining the function of energy production with other neccessary program within the city therefore makes all the more sense.

Source: de Boer, H., Hinterleitner, J., Berkers, M., Buitelaar, E., Cavallo, R., Daamen, T., Gerretsen, P., Harteveld, M., Hooijmeijer, F., Van der Linden, H., & van der Wouden, R. (2020). De stad van de toekomst. Tien ontwerpvisies voor vijf locaties, verbeelding voor een vierkante kilometer stad (2e druk). BNA Onderzoek.

Figure 8
UN Studio - Energy cathedral
Functional diagram
https://www.archdaily.com/907063/unstudio--designs-a-city-of-the-future-for-the-hague

Figure 9
UN Studio - Energy cathedral
Exterior render
https://www.archdaily.com/907063/unstudio--designs-a-city-of-the-future-for-the-hague

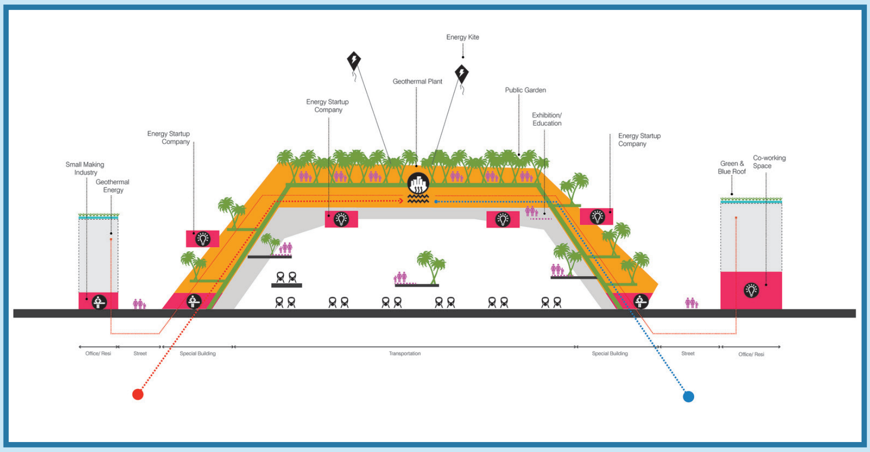

Figure 10
UN Studio - Energy cathedral
Project overview
https://www.archdaily.com/907063/unstudio--designs-a-city-of-the-future-for-the-hague

7. Timeline

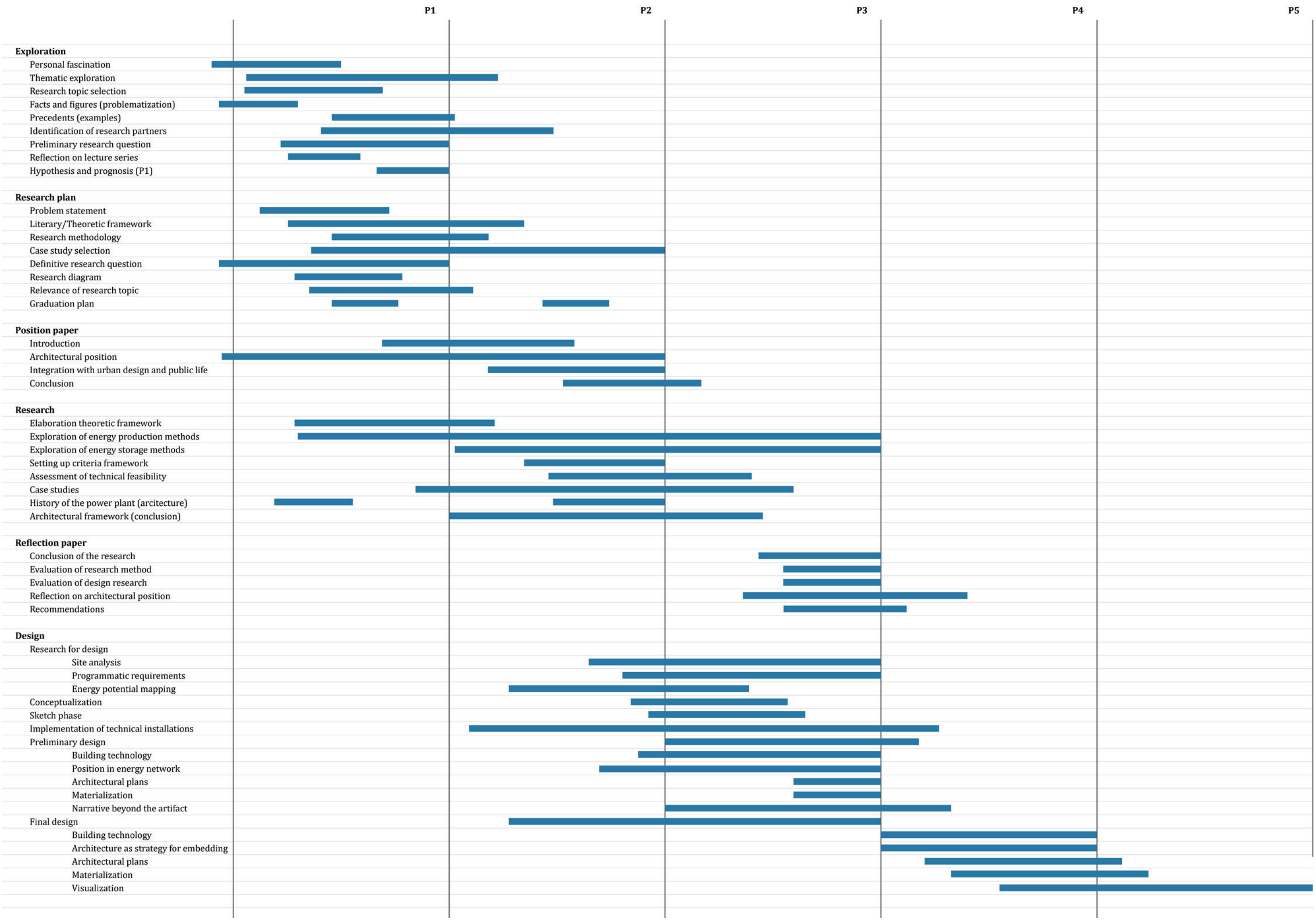

Figure 11: Graduation timeline

8. Self-assessment

The self-assesment section of this research plan was written as a review of the lecture series provided in the course: AR3A010 - Research plan. This course is part of the graduation program of the Msc Architecture, urbanism and building sciences. The lecture series served as preperatory course for this Research plan. In the lecture series a varity of research related topics take center stage. From research methodology, to theoretic frameworks and philosophy. The highlights from this series in relation to theme of the research are discussed in the following chapter.

Recap on the theme
The research proposed in the research plan dives into the problem of creating sustainable, renewable and robust energy systems for the world's urban environments. The cities of today have relied heavily on the fossil fuel fired energy systems to allow for a reliable grid which propelled the growth and densification of the global urban areas (Fahy, 2020). The transition towards a more efficient energy system is a task of great complexity. One crucial component of this transition is the conversion to a more sustainable and renewable energy production system. The embedding of this development within the built environment, is the challenge at hand.

Hypothesizing
The to-be addressed research question dwells within an erratic field of research. This poses some severe implications for the research process. Contrary to research resulting in a contemporary designed solution, the envisioned research trajectory will require a certain degree of 'supposition' or scenario planning. This does not imply that the research problem is obscure for that matter, however the research will not lend itself to be fully conclusive. Rather, it shall project opportunities which individually can become exemplary for the conclusion of the research. This also means that a strong interaction between design and research is likely, as to achieve a research by design scenario. Through this, the hypothesis can be invigorated.

Historic approaches
To reach a deeper understanding of how research in a more conceptive domain can take shape, one has the opportunity to turn to a variety of research methods. A metaphysical approach, literature- and theoretical analysis, as well as a more historicizing substantiation, amongst others. The latter can underpin the line of reasoning by providing relevant precedents through which similarities can be drawn. In light of this research, this can be performed by drawing an analogy with for example: *Oil spaces: The global petroleumscape in the Rotterdam/The Hague area* (Hein, 2018). The theme of the historic development of the systems that have allowed society to function the way it does today, is carefully considered in the light of oil by Hein (2018). The same can be achieved on alternative scales of the energy system by analysing phenomena that have affected the energy production system or the effects thereof over time. This, on its turn can provide relevant starting points for the design brief.

This historicizing approach towards understanding our society today, is valuable concerning the research topic as it might unfold an intrinsic understanding of the theme and provide valuable leads.

Theoretic approaches
The example of aiming for a metaphysical substantiation, is likely going to be able to establish an understanding of how innovation and maybe at an underlying level, creative thinking, influences our abilities to anticipate the future. The studio research and the conclusion, which will follow after the research plan is provided, are in this sense responsible for providing the reasoning through which a 'springboard' can be created. Which on its turn can lead to instances exemplary of the conclusion and hypothesis. The concept of 'the springboard' is a term that is perhaps best represented by conditions as 'speculation', 'assumption' and even 'scenario thinking'. This is relevant because of the lack of maturity within the field of research employed in this research.
The metaphysical approach can support the research in the following scenario. Suppose for example that the topic of inquiry would be an architectural typology and it would furthermore require two research components. On the one hand it would require an historic understanding of the development of said typology over the past decades, while on the other hand it requires an understanding of the current state of the research field. This would furthermore lead to a contemporary design proposal, seeking further improvements on the line of development that has existed for the past decades. This can perhaps be considered to be a more traditional approach to architectural research. If this is the case, the question should be asked if architectural research is still able to provide valuable answers if the development of the research field is less clear or less homogenous? This is where the case of the 'speculative problem' comes in, as stated by Bergson (1998). Suppose that there is existing research and historic precedents but a new typology is suggested by the conclusion. Architecture is then required to fulfil the role of being the source of a scenario based designed solution. According to Heidegger, we should then consider the resources of whatever technological application lies ahead to be directly 'available', as to be able to employ them in the desired solution (Blitz, 2014).

> *"One might just as well say that all truth is already virtually known, that its model is patented in the administrative offices of the state, and that philosophy is a jig-saw puzzle where the problem is to construct with the pieces society gives us the design it is unwilling to show us."*
> (Bergson, 1998 p. 36)

The methods of architecture are in a way not much different from the abovementioned 'truth finding'. It is not concerned with reinventing the elementary components of life. Rather, architecture is concerned with reiterating on what exists to come up with an increasingly more appropriate designed solution. Similarly, drawing on the metaphor of the jig-saw puzzle, architecture may as well have to face the reality of obscurity. The ideal solution is not readily available. This is crucial for understanding the speculative problem, because it deals with obscurity as well, but as Bergson suggests, this is also found to be inherent to solution finding.

> *"a speculative problem is solved as soon as it is properly stated. By that I mean that its solution exists then, although it may remain hidden and, so to speak, covered up: the only thing left to do is to uncover it. But stating the problem is not simply uncovering, it is inventing."*
>
> (Bergson 1998 p. 37)

This means that even though the solution might be speculative it might still have value because of the line of reasoning that was applied to arrive at the end point.
Together, the research methods discussed in the course can, for different reasons, support the research of the theme discussed in this research plan.

9. Annotated bibliograhy

Alanne, K., & Saari, A. (2006). Distributed energy generation and sustainable development. *Renewable and Sustainable Energy Reviews,* 10(6), 539–558. https://doi.org/10.1016/j.rser.2004.11.004

Main body – Broad research on the decentralization of energy production and its implications. Both pro's and con's are involved in this study to also indicate where the problems for a full incorporation of decentralized production lie. Also the article pairs well with network-thinking as described in chapter 4. theoretic framework.

Baran, P. (1962). *On Distributed Communications Networks*. Defense Technical Information Center. https://doi.org/10.7249/P2626

Theoretic framework – Perhaps one of the founders of network-thinking. Resilience in systems are created through the amount of connections between nodes. Also the article includes a very in-depth 'failure analysis' to see where critical limits are likely to be exceeded (for example with nodes that have less than 3 connections). Mentioned in Belanger (2016) as an essential example of network-thinking, it creates a very compendious introduction of the study hereof.

Belanger, P. (2016). *Landscape as Infrastructure*. Taylor & Francis.

Theoretic framework – One of the key-literature items. Major contributor to theoretic framework. Very broad elaboration of all themes and theories which are involved in understanding the infrastructure planning methods of today. Interestingly, Belanger doesn't offer a clear-cut conclusion but opts to remain pragmatic, offering a variety of insights into the statement: Landscape as infrastructure

Bergson, H. (1998). *The Creative Mind: An introduction to Metaphyics.* Dover Publications.

Self-assessment – Part of the mandatory readings for the lecture series and equipped here to explain the thought process that can help address the proposed thesis. Architecture like philosophy is also not concerned with finding 'absolute truths'. Rather, it keeps reinventing itself to come up with an increasingly more appropriate solution.

Blessing, L. T. M., & Chakrabarti, A. (2009). DRM, a Design Research Methodology. Springer Publishing. https://www.springer.com/gp/book/9781848825864

Method - Blessing and Chakrabarti are motivated to find a more common language for design research. The main point is that design research is performed by different professionals from different backgrounds, ergo there is a great variety of terms that are being used. Blessing and Chakrabarti propose a set of common terms and methods to provide a more general framework. This was adopted in combination with another source to make the research plan more insightful and more transferable for non-familiar readers.

Blitz, M. (2014). Understanding Heidegger on Technology. The New Atlantis. Retrieved on 14-10-2020 from, https://www.thenewatlantis.com/publications/understanding-heidegger-on-technology

Self-assessment – Heidegger is perhaps one of the most influential philosophers of the 20th century. His works on: Die Frage nach der Technik (1954), and Die Technik und die Kehre (1962), are amongst the most influential works on philosophy behind modern technology. He argues for a philosophy through which technique doesn't take over life, it is there to support it. Because the study of Heidegger is outside of the scope of this research, an internet article on his works was opted for to get a basic understanding of his point of view. Also it describes Heidegger's point of view on 'innovation', which shall become an important part of the proposed design agenda in this thesis.

Burns, C. J., & Kahn, A. (2005). S*ite Matters: Design Concepts, Histories, and Strategies* (1st edition). Routledge.

Introduction - *Site matters,* is an essay bundle concerned with the discussion around the importance of site-conditions. Already in the introduction of the bundle the discussion commences by opening with the debate on whether 'site' is a fixed and limited condition. Further on the bundle dives into what should be considered when taking into account 'site' and context. Whit what should the architect be concerned? Should the architect be concerned with infrastructures for example, or is it merely his task to fulfil the wishes of the client.

Cristóbal, J. R. S. (2012). *Multi Criteria Analysis in the Renewable Energy Industry*. Springer Publishing.

Theoretic framework - Cristóbal provides a very extensive theory on Multi criteria analyses within the field of energy systems. Often with the construction of renewable energy systems, public money is involved. As this cannot be spend without accouting for feasibilty and functionability, studies likes these are very important as they can support choices made within specific design assignments. The framework with the three categories of criteria is adopted in the Research booklet.

Edwards, P. (2002). Infrastructure and Modernity: Scales of Force, Time, and Social Organization in the History of Sociotechnical Systems. *Modernity and technology*, 185–225. https://www.researchgate.net/publication/256684632_Infrastructure_and_Modernity_Scales_of_Force_Time_and_Social_Organization_in_the_History_of_Sociotechnical_Systems

Introduction - An almost essay-like work concerned with the role of technology, infrastructure, etc., on society. This piece is specifically interesting as source of inspiration for the Position paper as it is essentially a plea for a "non-mirco view" of our shared systems and infrastructures, as it would, according to Edwards, always fail in explaining the bigger picture.

European Commission. (2020, july). Powering a climate-neutral economy: An EU Strategy for Energy System Integration (COM (2020) 209). https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2020:299:FIN

Introduction – Providing hard data to create an introduction to the problem statement

Fahy, D. (2020). Energy Humanities: Insights for Environmental Communication. *Environmental Communication*, 14(5), 712–716. https://doi.org/10.1080/17524032.2020.1758377

Main body – The article provides an introduction to the field of energy humanities. It states that the global population has become disconnected from the infrastructure that supports our urban regions. Architecture, as it is perhaps the most visible object on space is capable of altering this course of disassociation.

Ferrão, P., & Fernández, J. E. (2013). *Sustainable Urban Metabolism*. Amsterdam University Press.

Problem statement – The article provides a broad understanding of the concept of urban metabolism. Metabolism has a strong tendency to steer towards circularity which is not the topic of this essay, however the problem statement is a shared one.

Hein, C. (2018). Oil Spaces: The Global Petroleumscape in the Rotterdam/The Hague Area. *Journal of Urban History*, 44(5), 887–929. https://doi.org/10.1177/0096144217752460

Self-assessment – Case study

Henn, R. L., & Hoffman, A. J. (2013). *Constructing Green*. Amsterdam University Press.

Relevance – Broad description of the problem statement and possible directions to arrive at future solutions

Hennink, M., Hutter, I., & Bailey, A. (2020). *Qualitative Research Methods* (2nd edition). SAGE Publications. https://uk.sagepub.com/en-gb/eur/qualitative-research-methods/book242878#preview

Method - Together with Blessing and Chakrabarti these form the two key sources for the research structure. Hennink et al. specifically was used to create the process chart at the and of the Method chapter. For legibility all the task and expected end results were shown in the chart on said page. Hennink et al. provide a very elementary overview of the tasks at hand as to ‘design’ a suitable research structure. However, addition were made to this structure, as in its general form it was found to be too elementary to encorporate in a literal sence.

Hocks, B., Hugtenburg, J., Kuijers, T., Sijmons, D., Wijnakker, R., Stermke, S., & Vermeulen, M. (2018). *Klimaat, energie en ruimte*. Posad Spatial Strategies. Retrieved from, https://www.rvo.nl/sites/default/files/2018/03/180221_Ruimtelijke_verkenning_Energie_en_Klimaat_LQ.pdf

Introduction / Relevance – Broad elaboration on the spatial impact of renewable energy production techniques

Koskinen, I. K., Zimmerman, J., Binder, T., Redström, J., & Wensveen, S. A. G. (2011). Design research through practice: from the lab, field, and showroom. Morgan Kaufmann Publishers, Inc. https://doi.org/10.1016/B978-0-12-385502-2.00015-8

Method – Critical review of ‘research by design’, provides interesting anchor points to

Intergovernmental Panel on Climate Change. (2015). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Retrieved from, https://www.ipcc.ch/report/ar5/wg3/

Problem statement – Factual statement to support the problem statement

Mehleri, E. D., Sarimveis, H., Markatos, N. C., & Papageorgiou, L. G. (2013). Optimal design and operation of distributed energy systems: Application to Greek residential sector. Renewable Energy, 51, 331–342. https://doi.org/10.1016/j.renene.2012.09.009

Main body / relevance – Article with a broad overview for the challenges ahead for sustainable energy production for the city of the future.

Stremke, S., & van den Dobbelsteen, A. (2012). Sustainable Energy Landscapes. Amsterdam University Press.

Theoretic framework – One of the key literature items. Very broad exploration of how spatial planning and energy infrastructure planning have been- and should be organised. Also it offers a wide body of theoretic anchor points which shall have an exemplary function for this thesis. Mainly, however this article is able to deal with the main body of this thesis as it very practice oriented with numerous case studies.

Stremke, S., Van Kann, F., & Koh, J. (2012). Integrated Visions (Part I): Methodological Framework for Long-term Regional Design. European Planning Studies, 20(2), 305–319. https://doi.org/10.1080/09654313.2012.650909

Method - A key literature item to understand the way the proposed research can support a strategy for future designed solutions. As mentioned before, climate adaptation doesn’t not come with a fixed set of solutions. It is therefore important to gear the research to provide the proper ‘handles’ to be able to produce distant futures or scenarios for which a designed solution can be approached.

Tillie, N., Klijn, O., Borsboom, J., & Looije, M. (2014). Stedelijk metabolisme: duurzame ontwikkeling van Rotterdam. Mediacenter Rotterdam.

Main body / relevance – Major provider of case study material. Example of how research from a planning point of view can deal with this thesis.

Troy, A. (2012). The Very Hungry City. Amsterdam University Press.

Main body – Rich collection of case studies and reference projects. Although very much written through a subjective and more experience-driven lens, it provides useful tying points indicating practical problems and dilemmas that are encountered in sustainable planning practice.

United Nations. (n.d.). Goal 11: Make cities inclusive, safe, resilient and sustainable. United Nations Sustainable Development. https://www.un.org/sustainabledevelopment/cities/

Problem statement – Factual statement to support the problem statement

Yigitcanlar, T., & Dizdaroglu, D. (2015). Ecological approaches in planning for sustainable cities: A review of the literature. Global J. Environ. Sci. Manage, 1(2), 159–188. https://doi.org/10.7508/gjesm.2015.02.008

Relevance – The article reviews the relevant literature concerning environemtal issues that are challenging the city, and furthermore researches possible solutions for planning sustainable citiies. The article takes a close look on the interplay between the (natural) environment and human activities. As it is believed that they spark certain environmental effects which can be both opportunities and threats for the future sustainable city. The conclusion proposes a new conceptual approach to sustainable urban development. The diversity of sources sited in this article was furthermore a valuable source of new information.

Zanon, B., & Verones, S. (2013). Climate change, urban energy and planning practices: Italian experiences of innovation in land management tools. Land Use Policy, 32, 343–355. https://doi.org/10.1016/j.landusepol.2012.11.009

Relevance – Article with a critical stance on urban energy consumption in a European context. It seeks to find the integration of spatial planning with sustainability planning. Therefore it is a useful precedent and is likely to be able to broaden the view of the main body.

Planning the power plant

The role of architecture in the integration of decentralized energy systems

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Preface

Before you lies the position paper which is part of the mandatory research component in the graduation process of the MSc Architecture at the faculty of Architecture, Urbanism & Building sciences (TU Delft). Within the studio 'City of the Future', of which this research is part, a variety of themes have been selected to research in light of architectural design. Ranging from intersections of architecture and urbanism, to landscape, engineering, technology, systems and social sciences. Through this the possibilities for architecutre in creating livable future cities are being explored. This paper in particular is part of a research trajectory involved in researching the possibilities for architecture to assist in the integration of large scale energy production within the limits of urban areas. The paper shall dive into one of the three subquestions which were proposed in the research plan. It is believed that this subquestion is of particular interest to discuss in a position piece because of the nature of the question. Not only is this question, which will be introduced further in the introduction, interesting from the point of view of general literature, but also from a scholarly point of view. From this point of view the relevance of the question at hand and the main research question can be discussed in light of a overarching debate on the position of infrastructure systems in current day, and modern day society. In so doing the integration of energy systems with public life, by means of architecture, will be elaborately discussed.

Image 12 - previous page
View on Hogendorpsplein and Coolsingel. Taken in 1939
(Edited by author)

Abstract

The cities of the 20th and 21st century have gone through an era of unbridled expansion, seizing an immeasurable amount of land and resources from across the globe. To secure a resilient and sustainable urban environment, the city is forced to revisit its networks, systems and land-use. Especially with the growing trend of urbanization. One of these systems, which lies at the core of the daily operations of the city is the energy network. Large amounts of energy are transported through power cables from large plants towards to their final destination, the end-user. However, with upcoming demand for renewable ways of energy production, and the increasing availability of 'clean' production methods, the city has the potential of becoming its own generator.

Taking this stance, the confrontation with existing policies, methods, trends, can be sought; creating opportunity for local production and storage of heat/electricity within the cities limits. In so doing, seeking integration with public and private program, and therefore tightly grounding it within city districts and urban life. By nestling into local communities and providing new program, the local production has the objective to create a broad support for sustainable energy.

The techniques available to produce energy in a renewable and sustainable way are becoming increasingly more verifiably reliable alternatives. To be able to shorten the chains towards a more decentralized system, the city itself has to critically assess its scales and densities, and look for opportunities where renewable energy production can take place. Within the public eye, and with minimal loss of energy due to transportation, which is especially detrimental for district heating solutions. The framework proposed in this thesis therefore aims to combine the appropriate scale of the city with the proper scale of the production method to create symbiotic solutions.

The architect here, has a unique position in being able to work on the infrastructures of the futures as infrastructures will overlap increasingly more with the urban tissue. Moving away from the traditional infrastructures which rely on exactitudes and centralized systems, the decentralized systems will aim to adopt a multifaceted approach, integrating infrastructural, social and operational systems. In so doing, local and regional opportunities for energy production can be seized creating a tailored solution to the demands of the area, aiming to support its demand with renwable energy. Architecture in this will take the position of innovator and integrater, embedding new approaches to infrastructures within the urban fabrics of the future.

Keywords

Renewable energy, Energy systems, Decentralization, Infrastructure, Urban design, Public life, Land-use, Publicness

Introduction

As of 2007, the balance of urban residents versus rural residents hit an historic equilibrium. For the first time in modern civilization, more people lived within cities than outside of them. The cities of today are generally not well suited to house this ever increasing urban population which is pushing the equilibrium in favor of urban residents, up to the point where roughly two-thirds of the population is expected to live in urban areas in 2050. The pressure on existing infrastructures emerging from this influx has the potential to destabilize those infrastructures. This is found to be especially true for urban energy systems (Kammen & Sunter, 2016). The relevance of this energy infrastructure is highlighted with the following statement:

> "*The world's cities occupy just 3 per cent of the Earth's land, but account for 60-80 per cent of energy consumption and 75 per cent of carbon emissions*."
>
> (UN, n.d.)

This development has its roots deeply imbedded within the history of the city, which has occurred at the cost of significant amounts of energy and material. Simultaneously the intensification of the fabric has not prevented the city's networks from becoming jam-packed and the city is now only able to sustain itself by consuming vast amounts of resources from rural areas around the globe without creating a reverse flow of valuable resources (Ferrão & Fernández, 2013).

For cities to now become sustainable in the common sense, or at least in the sense of their resource consumption and agglomeration, they will have to find low carbon alternatives for their current processes. This is not merely a technical issue concerned with innovation, but it also requires durability and resilience to be able to become sustainable in the full sense of the word. This above all starts with the source of our shared consumption: the global urban population. The amount of consumption society demands proportional to the capability of an ecosystem to produce said goods is a fundamental balance in creating a global sustainable society (Weinstein & Turner, 2012). Since the global population is still increasing drastically, the demand for consumption is not likely to reduce in the foreseeable future. Ergo, the opportunity for a sustainable future heavily relies on creating sustainable infrastructures and consumption patterns that can support the growing population, with an uneven emphasis on the nuclei of consumption: the global urban area. The city however cannot be seen as a homogenous construct, which increases the complexity. There is a vast amount of artifacts, processes, infrastructures, social patterns, etc. that make up the city. These actors in the play of the city all play a part in transition strategies. Because of an expected growth of the city's population, accelerated by a global trend of urbanization, more of these components will either voluntarily or forcibly intertwine because of an increasing pressure on land-use (Tillie et al., 2014; Hocks et al., 2018). Urban energy systems will therefore require a broad understanding of how these actors together create the demand, and how they can moreover create their own potential to satisfy this demand.

During the 20th century, the production of energy was moved outside of urban regions because of pollution problems in the city. Now, the increasing demand for energy and a desire to fulfil this need with renewable energy, even more so has the potential of occupying vast amounts of land in rural areas (Hocks et al., 2018; Stremke & Van den Dobbelsteen, 2012). This sparks the debate whether the urban region itself should instead be able to fulfil its own energy demands, rather than sacrificing large amounts of ecologically important hinterland.

Embedding a renewable, resilient and sustainable energy production network within the city limits is not simply a matter of feasibility and practicability, but rather one of integration (Zanon & Verones, 2013) and is therefore one of the crucial tasks at hand for planners, politicians and architects. This thesis will be central in the research into 'The city of the future'.

To create a theoretical framework through which this thesis can be explored the following main question will be posed, which was already introduced in the Research plan. This question will be answered partly in the conclusion;

> *How can sustainable energy systems be integrated in urban areas through spatial planning and design?*

In the conclusion of this position paper this question will be answered from a more philosophical point of view, seeking to develop a more broad understanding of the role of infrastructures in modern society.

By placing it within an environment of adjacent research fields, the possibility presents itself to embed the problem statement within both a theoretical and practical framework. In so doing, three subquestions were proposed in the Research plan to allow for a theoretical embedding of this thesis. The first two are not considered in this position paper as they deal with the practical and theoretic conditions of the thesis. To reflect the position of the author and deepen a more fundamental and metaphysical understanding of the thesis, the third and last subquestion shall be the central thesis in this paper:

> *What are the opportunities for integration with public life and urban design?*

The position will be further supported by a position essay approaching the topic at hand from a more systemic point of view whilst reflecting on the importance of grand themes such as infrastructure within the domain of architecture.

1. Embedding energy systems

> "*People tend to be aware of vehicle energy use. They see gasoline stations everywhere and if they own a car routinely fill their tank with gas or diesel as well as motor oil. Like cars, the energy used by buildings may come from petroleum products such as heating oil and may run on coal, natural gas, and other fossil fuels used by the electrical generators that supply energy over electric lines. But people do not typically "fill up" their buildings*"
>
> (Henn & Hoffman, 2013, p. x)

The presence of energy infrastructure has integrated with urban landscapes with impunity over the last centuries. However, this hasn't prohibited any form of dissociation by the public from modern infrastructures, illustrated by the quote above. The car, often seen as one of the major actors in the realm of infrastructures, has been normalized to such an extent, that gas stations have become omnipresent. The relics of today's energy systems raise an interesting question however. How can the renewable energy systems of the future be integrated in the urban fabric as such that they on term become normalized and omnipresent. This question will be the topic of discussion throughout the next paragraph, shedding light onto this question from two perspectives, starting off with an introductory section on policy and strategy to introduce the inherent complexity of climate adaptation strategies.

1.1 Policy and strategy

Simultaneously with the rollout of climate adaptation policies, the study of integration strategies commenced. The development of integration strategies brings to light both key actors through which considerable energy savings/production can be achieved, as well as to propose possible applications. Already an early example of policy dealing with the sustainability of buildings was the "Merton Rule" (Merton Borough, London), with its instalment in 2003. Every new building with a floor area over 1000 m2, had to supply 10% of its own energy with on-site renewables (Keirstead & Schulz, 2010). Quickly after this was tested in Merton borough, the strategy became widely adopted throughout greater London. The policy, most notably, led to the formation of coalitions of relevant stakeholders, being: Building service engineers, Architects, Building engineers and Developers (Keirstead & Schulz, 2010). The challenges set out by the local government, sparked the collaboration of multiple fields of profession to be able to produce new solutions which could comply with the new building code.

Much like the policy in the example above sparked new collaborations between professionals, the strategy proposed in this thesis aims to spark new ways of integration. In the words of policy this would mean that firstly the identification of 'architectural stakeholders' is required to be able to draw new relationships. In the case of this thesis, this relationship, on a macro-level, would need to form between; Architecture (as disciplinary backdrop), energy production/storage and existing/new public functions within the city. This would in practice come down to disciplinary mergers of different fields of expertise. Like the Merton-rule example, this might lead to previously unexplored integration strategies. It is in this light, that the discussion on the integration with public life and urban design will take place.

The central question in this chapter shall be approached from two angles to simultaneously highlight the multifacetedness of the discussion, as well as to confront the lack of precise responses in literature. This approach aims to narrow down on the question at hand while simultaneously building on the specific research field in light of spatial design. This is necessary because the central question for this chapter requires both the exploration of energy network adaptation strategies as well as a socio-economic component, which influence each other to incubate integration strategies. Which in the case of this thesis applies to a scenario where energy production and storage are becoming more integrated within architectural- and urban design (as proposed by Sijmons et al, 2014, p. 224, in their Rotterdam case study).

Inherent to climate adaptation strategies is that they are, to a degree, location specific (Vandevyvere & Stremke, 2012). This means that a holistic approach to integration strategies is most likely a fruitless endeavour. There is no one list of specific solutions that would consistently supply a mutually advantageous integrated result (this depends of course on the environment of the project) (Stremke & van den Dobbelsteen, 2012). Therefore the discussion on this topic shall commence with the identification of adaptation strategies on a policy level to produce an indication of where these fields of disciplinary encounters are likely to emerge. These would namely give an indication of the fields where the challenges and opportunities would arise.

Important to mention here is that this particular chapter concerns policy and adaptation strategies on the local/regional level. This is important because of two reasons. Firstly, because the thesis aims to support an architectural design assignment which benefits from an approach on the local scale (through to the regional scale in specific scenarios). Secondly, because of the fact that policy on a national scale embodies radically different measures as it cannot prescribe a specific outcome, but rather remains focused on supplying guidelines.

Kern & Bulkeley (2009) identify a rudimentary understanding of how climate adaptation policies haven been generated by local governments. At first, the increased amount of GHG emissions is negated. However, as soon the effects of climate change start to influence the city more directly (flooding, rising energy prices, etc.), the local authorities are forced to adapt to the new conditions. Finally, "linkages and synergies between climate policy and sustainable development become most obvious at the local level, and motivate cities to generate the social and technological innovations that help in the reduction of GHG emissions and adaptation to new challenges" (Kern & Bulkely, 2009, p. 172). The invigoration of sustainable policies and strategies withal demands a remodelling of spatial planning practices (Zanon & Verones, 2013; Eames et al., 2013).

1.2 Spatial strategies

Zanon & Verones (2013) establish three imminent challenges for urban planning with regards to its energy performance. Firstly, the energy performance of the built environment is brought up. This is a widely discussed topic both in light of energy production as well as a reduction of consumption (see for example: Carbonara, 2015; Vandevyvere & Stremke, 2012; Cabeza & Chàfer, 2020). Secondly, urban form is recalled. The relationship between spatial planning (morphology) decisions and energy demand is a theory already discussed in the 80's (Vandevyvere & Stremke, 2012). Stremke & van den Dobbelsteen (2012) take this point further and suggest that also the potential for on-site renewable energy production is also strongly dependent on the urban morphology. In practice this could come down to a significant decrease in electricity production based on photovoltaic cells, due to a disadvantageous morphology (rooflines, profiles, positing). The third and final challenge is identified in the field of mobility. The compactness of urban systems has determined the preferred choice of transport and i.e. influenced the resulting energy demand for transport (Zanon & Verones, 2013).

In similar fashion, suggestions for disciplinary intersections are made by various other scholars. Vandevyvere & Stremke (2012) add to the catalogue of intersections: Building orientation to maximise the positive effect of solar irradiance. Secondly, the exchange of waste heat, and the integration of CHP or boiler plants for district heating and cooling. The proximity of producer and consumer is especially relevant in the case of district heat networks, due to relatively high energy losses over long distances. Finally the implementation of geothermal energy is proposed in larger building blocks (see also: Kammen & Sunter, 2016).

Stremke & van den Dobbelsteen (2012) follow up by going beyond pragmatic thinking, suggesting that a balanced mix of functions can significantly contribute to the performance (amongst other benefits) of the separate functions by pursuing an integrated energy system. Spatially this would mean that a more diverse mix of functions is desired. A balanced mix of functions has the potential to exchange flows of heating and cooling creating a mutually beneficial system. Sijmons et al. (2014) in their case study on Rotterdam, explore another strategic path. Seeking the intersection between architecture/urbanism and the economics of the energy transition.

> *"At the same time, the energy transition must be initiated. This will become a quest for smart combinations of renewable energy production with existing and new urban functions that can reinforce the image and competitiveness of Rotterdam's industries"*
>
> (Sijmons et al., 2014, p. 222)

The limited available lands in urban/metropolitan areas such as Rotterdam, requires the development of solutions for the generation and storage of renewable energy within the urban fabric. Seeking coherent mergers of energy production and other urban functions (Sijmons et al., 2014). The resulting intensification of urban areas, in combination with climate adaptation and the evolution of renewable energy, demands the development of integral spatial and technological solutions (Daamen & Van der Linden, 2020).

The opportunities for the integration with urban design, and to some degree public life (which will be covered more elaborately in the next paragraph), are not limited to 'net-positive architecture', or smart grids for that matter. The integration strategies at hand range from urban planning like morphology and mobility, through to spatial design challenges such as; building orientation, function mixing and local energy production and storage, which require both a designed envelop as well as built implementation strategy.
The reach of this research however does not allow for a quantitative underpinning of the hypothesis. The results of this chapter shall be used as indicators for the many challenges ahead for architects and planners. Therefore being able to indicatively answer the question posed in this chapter. It is believed that the spatial integration of a sustainable energy grid has become a necessity for future planning strategies. The optimization of spatial planning and the proposed strategies for integrated systems have the potential to create significant potential for energy production and energy savings in urban areas, and is therefore of crucial importance for future adaptation strategies on local and regional scales.

1.3 Energy infrastructure as social system

Society is severely intertwined with our shared energy infrastructure (Miller et al., 2013; Szeman & Boyer, 2017; Fahy, 2020). This relationship is broadly explored in the light of architecture and urbanism in the research on 'Petroleum landscapes' by Hein (2018). Hein poses that material witnesses of the oil economy have become omnipresent since the industrial revolution. "Together the physical, represented, and everyday practices form what I call the global palimpsestic petroleumscape. Each of these layers has similar functions and typologies (style, location, or architectural form), and these layers interconnect to form a single landscape." (p. 888). Henn & Hoffman (2013) make the analogy that citizens have to fill up the tanks of their cars at gas station, however people's houses require nothing of the sort. Power is generated off-site (with fossil fuels) and transported to houses and cities. This further portrays the interaction and simultaneously the disassociation which society has developed in relationship to energy infrastructure.

Going beyond oil as a theme, various scholars have attempted to unravel the energy system to get a better understanding of the development of modernity and the present-day society. In so doing, similar approaches as covered in 'Petroleum landscapes' (Hein, 2018) are held to explore the dependencies, morphologies, sociological patterns, that the energy infrastructure brought forth on a macro- but also on a meso and micro level. These fields of research will be employed in this chapter to explore the missed opportunities, challenges and pitfalls ahead for the integration of renewable energy infrastructure with public life.

It should be noted that contrary to chapter 1.1 Policy and strategy, the spatial scale in which the research operates is less of a limiting factor. The relationships described in the upcoming section provide a variety of insights which can all provide valuable starting points for integration strategies. If and when there is a sense of scale (regional or greater) involved, it is believed that within the research field of Energy humanities/Energy communication, the proposed concepts are transferable to a local-scale based solution.

Society and energy (infrastructure) have become the topic of debate in a variety of research fields (see: Miller et al., 2013; Belanger, 2017; Cozen et al., 2017; Szeman & Boyer, 2017; Feldpausch-Parker et al., 2019; Fahy, 2020). The fossil fuel ran energy infrastructure allowed for widespread agglomeration and economies of scale. However, the global trend to progressively fulfil this energy demand with renewable energy sources requires new ways to approach the chain from producer to consumer. Energy systems lie at the core of technological arrangements which made possible the modern industrial economies (Szeman & Boyer, 2017). A transformation of this energy system propelled by climate adaptation policies, therefore requires not only technological changes and financial incentives, but also alterations in the societal and economic spheres that have formed around energy systems. (Miller et al., 2013; Vezzoli et al., 2018)

> *"Energy systems are socio-technological systems that involve not only machines, pipes, mines, refineries, and devices but also the humans who design and make technologies, develop and manage routines, and use and consume energy. In turn, energy systems include financial networks, workforces and the schools necessary to train them, institutions for trading in energy, roads, regulatory commissions, land-use rules, city neighbourhoods, and companies as well as social norms and values that assure their proper functioning."*
>
> (Miller et al., 2013, p.136)

Just as the socio-economic perspective provides a fuller understanding of modern society, its role in building the historic and contemporary material infrastructure and societal patterns points to locations and spheres through which climate adaptation (strategies) can be developed (Szeman & Boyer, 2017). The discussion as to how to achieve this has taken many shapes in scholarly literature. Miller (2013) discusses; energy infrastructures, energy epistemics and energy justice, progressing from 'what is', to 'who does', to end up with 'what should it be'.

The two last points are of particular importance here. The question is raised of whom should be the driving force behind the development of possible energy futures. Inevitably, this comes down to the question of bottom-up versus top-down. If the answer is 'bottom-up', then the potential for integration with public life is enormous, because the strategy at hand would be to facilitate local initiatives. If the preferred answer is 'top--down', then the challenge ahead would be to identify the sites of possible intersections with publicness and the energy transition strategy at hand.

> *"The creation of new publics around energy can bring into public discussion a more diverse set of ideological voices to discuss energy futures…-… making the topic potentially less politically divisive and a ground where public discussions about climate change can be held in a constructive manner"*
>
> (Fahy, 2020, p. 715)

Feldpausch-Parker et al (2019) take the notion of 'energy justice' even further by proposing a future with 'energy democracy'. Defying existing ownership and governance patterns and stimulating participation in decision-making processes and composing adaptation policies (both on local and national scale). The underlying thought of this is that the transition should not be contained within the realm of technology (a point further invigorated by: Stremke & van den Dobbelsteen, 2012). The feasibility of a bottom-up approach like this remains to be tested, however the idea of participation from a sociological point of view is an interesting one and worth exploring further in urban planning.

To create a system based on renewable energy sources, various steps have to be taken. Scheer (2005) speaks of 'practical hurdles' and supplies three examples of common sources of resistance which have to be dealt with in the steps of the process of transition, being: Administrative, technological and economic. However, the biggest hurdle of all is thought the be psychological (Scheer, 2005; see also, Hoffman & Henn, 2008). As a result, planning for a future system based on renewable energy system remains insufficient. This is one of the reasons that the integration of distributed energy production and public life is believed to be a crucial component of the transition and of the major challenges to tackle by architects.

1.4. Interim conclusion

Hein (2018) makes the analogy between gas stations and the 'neighbourhood centres'. They became the places of the 24-hrs economy and often doubled as restaurants and small shops. This normalized the existence of gas stations to the point where they have become part of many a person's daily routine. To conclude this chapter the reverse is proposed. Can the energy suppliers within sustainable energy futures have the same effect on public life? Not merely as functional entities, but rather as an integral part of the urban fabric and with opportunities to engage with public life. In so doing, creating a new socio-technical organization around the imminently changing energy infrastructure. Seeking the integration with public life and bridging the gap between the technocratic realm of infrastructures and the social realm of society and public life.

The results of chapters 1.1 and 1.2 are summarized in the image below. It summarizes the most important insights that were touched upon in the previous chapters. These terms will be used to underpin the programmatic choices to be made for designers in future design assignments.

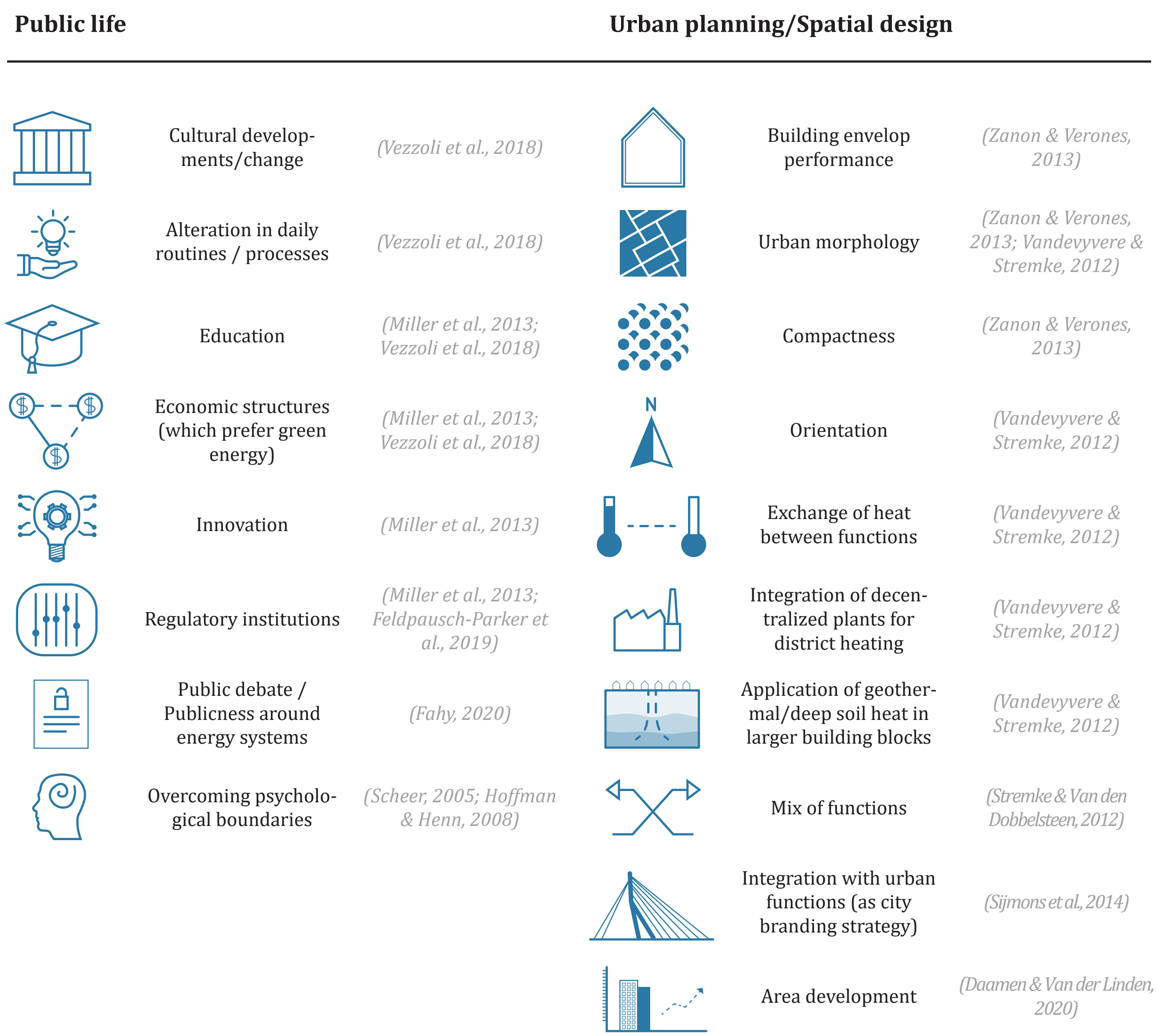

Figure 13: Opportunities for integration with public life and urban design

2. Position essay

Where the previous chapter has focused on uncovering the potential fields of interest which contribute to a mutually beneficial relationship between energy systems and spatial design, the following chapter will take a step back from the practice of implementing these strategies. Focussing on the relevance of this question in general. This will require an inquiry into the history of infrastructures and their relationship to the public realm. This will lay bare the weaknesses and strong suits of today's infrastructures and create a new playing field for discussion on matters of integration of infrastructures. Simultaneously the position essay will shed light on the relevance of this topic seen from the perspective of architectural design. It will namely be made clear that this field of expertise, being infrastructures and energy systems in particular here, were historically not part of the task of designers. Why this is becoming increasingly more the case will therefore be a major point of order. To conclude, a call will be made for a designerly approach towards today's complex questions in general, deepening the research and moving towards an understanding of the broad relevance of these types of inquiry.

2.1 The status quo of infrastructures

The term 'infrastructure' is a relative recent term, originating in the late 19th century in France. The term, which is a contraction from two Latin words is now defined as followed by the Cambridge dictionary: "*the basic systems and services, such as transport and power supplies, that a country or organization uses in order to work effectively*" (Cambridge Dictionary, 2021)

The introduction of the word coincided with the start of the Second industrial revolution. The Second industrial revolution saw the first development of an electricity grid in the early 1890's in London. From an energy infrastructure point of view, these were the first system to generate enough electricity for entire neighbourhoods. It marked the beginning of an era. Alongside with many other organized public infrastructures, they started creating the building blocks of modern life. Especially in urban areas this effect became noticeable due to the high demands for new infrastructures (rail transport, domestic electricity, telecommunications). In urban areas the defining elements within the fabric shifted more and more towards infrastructural landmarks like streets and highways, at the expense of the more traditional landmarks like distinct buildings and market squares (Williams, 1993).

During the 20th century technology matured and became available throughout the entire western civilization. The 20th century consequently is characterized as a period of the engineer whom made possible the mechanization of society (belanger, 2017). Large quantities of resources (water, waste, energy, materials, etc.) had to be handled to support concentrated urban life. Subsequently, there was no room for error, creating an firm authoritative basis for the field of civil engineering.

Simultaneously, the productivity of a single person greatly increased because of this as the workday could be infinitely extended with artificial light, whilst telecommunication sped-up the distribution of information. The fundamental faith in the permanence of these modern infrastructures however is proving to be unjust, due to the long-term unsustainability of grand systems.

> "*The infrastructure that made possible the last half millennium of urbanization was conceived as a one-way system providing a predictable flow of resources in lieu of nature's volatile processes. It derived the stability required for economic and cultural progress. This modern infrastructure implies dependence, though, on a fragile premise; stability breeds reliance on increasingly vulnerable centralized authorities. The freedom to invent new form was thus predicated on a false sense of security.*"
>
> (Belanger, 2017, p. 12)

This sense of stability is directly related to modernity (Edwards, 2002). Things are readily available as long as consumers do their duty by financially supporting these underlying infrastructures by consuming resources. To go beyond this sole responsibility has therefore become almost superfluous because the system has ultimately shown very little signs of decay. The exceptions to this rule are however present and can be found in several major events which highlighted the fragility of modern infrastructures. An example of this are the oil crises in the 1970's. Oil, was made artificially unavailable by Arabic countries. In this case the source was the cause for a worldwide crisis. Similarly, the demand-side of the spectrum can be equally disruptive. Overconsumption is already causing a wide gamut of disastrous effects (insecurity, desertification, pollution) (Annan, 2017). Even more practically, the demand for car transport has visibly extended the required space for highways, and it is in these ways we see the effects of society's desire for infrastructures and its capability to produce goods and transport resources.

Consequently, the ecosystem has arrived at a point where the demand for infrastructure no longer proportionally represents the landscape's capability of providing the necessary resources to support this infrastructure. Now, greatly exceeding the available supply of said resources. Bewilderingly, the vast physical- and social impact of modern infrastructures, have put it in a state of monumentality by virtue of its representation by landmark projects (Belanger, 2017). This attitude towards infrastructure contributed to a dystopic view, driven by the optimistic undertones that this form of representation outwardly projected. Infrastructures generate a ready-made portion of desirable resources and eliminated the need to question its broad impact or its origin. The infrastructures and agencies that produce these resources and services boast an interesting opportunity here in changing this dystopic view for the better.

> "*Infrastructure space possesses disposition just as does the ball at the top of an incline. Few would look at a highway interchange, an electrical grid, or a suburb and perceive agency or activity in its static arrangement. Spaces and urban organizations are usually treated, not as actors, but as collections of objects or volumes. Activity might be assigned only to the moving cars, the electrical current, or the suburb's inhabitants. Yet the ball does not have to roll down the incline to have the capacity to do so, and physical objects in spatial arrangements, however static, also possess an agency that resides in relative position. Disposition is immanent, not in the moving parts, but in the relationships between the components.*"
>
> (Easterling, 2014, p. 20)

The relationships that Easterling (2014) describes are particularly interesting, as well as the potential impact of static infrastructures. Firstly, this means that whenever a piece of infrastructure is exchanged for a more renewable and sustainable process, it will immediately have impact on the rest of the system following the analogy of the ball at the op an inclination. Secondly, the sphere of influence of static pieces of infrastructure can be regarded as an actor as much as the vehicles or flows of resources that make use of it. This means that there is perhaps a hidden potential lurking in the expression of infrastructures. If the expression of infrastructures has been dominated by the engineers of the 20th century, than the integration of infrastructures within urban architecture could prove to be mutually beneficial. In the first place because 'the ball' can be aimed to roll in a different direction, namely a sustainable alternative for todays infrastructures. In second place, because the design and impact of future infrastructures can have a more sociologically beneficial character, highlighting the impact that users have on the environment when consuming resources or energy. The status quo of infrastructures could then for the first time in perhaps a century be altered, to become beneficial throughout all scales that influence our shared future, going beyond mere functional objectives. Providing capacity to instruct users on responsible use of infrastructures, diminishing the ecological impact of infrastructures, and creating a more distributed and therefore resilient system.

2.2 Architecture and infrastructures

Building on the conclusion of chapter 1. *Embedding energy* systems, this paragraph shall aim to develop a meta-scale approach to integration strategies. In so doing, envisioning mechanisms through which architecture and infrastructure can interact in the future to create a mutually beneficial scenario through which a more sustainable future can be foreseen.

The first point of order here is understanding what it is that infrastructure means here. Since a lot of the research as proposed in the research plan, has been concerned with the technical aspects of infrastructures it should be stressed that these systems are not limited to the technical sphere. Infrastructures are deeply rooted in social, political and economic systems as well (Easterling, 2014). The interplay between society and infrastructures/technology in the development of networks like infrastructures has its roots within a broad variety of research fields, among with: social sciences, arts, economics, history, science, engineering, history of science, management studies, informatics, media and communication and architecture and urban design (Easterling, 2014). Being so widespread and embedded within multiple fields of research produces some long-term concerns. To merge all stakeholders into one system has meant that system relies on minute planning to satisfy the majority of stakeholders. This has resulted in a system of containment with an emphasis on monofunctional components (Belanger, 2017).

To change these infrastructure for climate adaptation reasons is therefore not a matter of product engineering, where the emphasis would come to lie on individual components, but rather a systemic one (Eames et al., 2013).

> *"The critical challenge for contemporary urbanism is then to understand how to develop the knowledge, capacity and capability for public agencies, the private sector and multiple users in city-regions (i.e. the city and its wider hinterland) to re-engineer systemically their built environment and urban infrastructure."*
>
> (Eames et al., 2013, p. 505)

Belanger (2017) here pleads for more autonomy through distributed patterns. Through this the infrastructures are likely to be able to be better adaptable to regional demand and opportunities (territorialization). Through the regionalization of the currently centralized infrastructures, the underlying structures can be redesigned (Belanger, 2017). When doing this, the scale of infrastructures changes and so does the underlying science. This boasts potential for expanding across multiple disciplinary spheres overcoming the limitations of the central narrative (Easterling, 2014). The comparison being that the current approach to infrastructures is to a degree 'one size fits all', relying on production methods with a high energy density (when regarding energy infrastructures),where a possible future approach to infrastructures could be one of 'local solutions'. At this point the previous chapter 1. *Embedding energy systems*, start gaining momentum, because it is at this point that integration strategies can provide a beneficial scenario. Incorporating local opportunities and negotiating with local threats and demands. It also at this scale, that architecture can intersect and develop new systems around infrastructures. Seeking to find a more multidisciplinary approach to infrastructure planning. A first attempt to find these areas of intersection in the case of energy infrastructures has already been produced in paragraph 1.4 *Interim conclusion*

> "*Insofar as designers bring distinctive forms of spatial intelligence and visualisation capacities to the sites in which they are engaged, they have an invaluable role to play in constructing new cognitive maps of the planet's unevenly woven urban fabric*"
>
> (Brenner, 2015, p. 125)

Architects are in a unique position here. The engineers described in paragraph 2.1 were the founding fathers of traditional infrastructures. They relied on the development of strict models of the world to plan the infrastructures that we still use until this day. When system-level alterations are proposed, as has been done throughout this research, the architects of the future must maintain a variety of perspectives, approaches and strategies to be able to constructively respond to the threats protruded through traditional infrastructures (Stermke & Van den Dobbelsteen, 2012). Edwards (2002) proposes that these designers become "tinkerers" and "inventors" to create new technological prospects, but with a focus on being able to integrate these solutions back into the existing system. The perspective of the architect should therefore be simultaneously that of the engineer, the designer, the sociologist and the operator. In so doing, creating an attractive mix of functions through which system efficiency increases, public awareness goes up and system resiliency improves. By creating a new architectural toolkit for this purpose, it is believed that distributed energy infrastructures can achieve this goal, building on the ongoing commitment to supply our demand for energy renewably.

Conclusion

In the introduction an inquiry was proposed into the potential for spatial design and spatial planning to improve the integration of sustainable energy systems in the urban context. In the position paper this is researched through the lens of literature concerned with uncovering the aspects from sociology and architecture which are able to directly contribute to the integration. Furthermore the relevance of this development to further integrate infrastructures with architecture and public life in general is discussed in the position essay. Through these two components, in conjunction with additional research, it is believed that the main question can be largely answered. Considering the fact that the main question also requires the study of the technical possibilities of distributed energy systems which will be covered in further research.

The relationship between energy systems and spatial planning and design here, is defined as a two way street. On the one hand does infrastructure in general and energy systems in particular influence the development of the built form and urban morphology. In the most obvious example this can be found in case of overhead cables intersecting with neighbourhoods, clearing out a large section of buildable terrain. On the other hand, it was found that spatial planning and design itself also influences the performance of the urban energy system. For example, in a scenario where all the roofs are perfectly aligned to allow for the highest irradiance for on photovoltaic systems.

In light of research into distributed or decentralized energy production, of which this position paper is part, the benefits are proportionately available. Obvious examples of this mutually advantageous situation are the following. Firstly, the possibility for decentralized energy production nodes to become public buildings should be considered. The presence of the system does not exclusively inform the urban population on matters like their energy system and their shared developments to become increasingly more sustainable. Rather, the possibility to engage with these infrastructural installations in an educational and playful manner, has the potential to further increase inhabitants' understanding of sustainable energy production.

Secondly, the addition of other neighbourhood- or regional scale public program can also have mutual benefits, due to the fact that within sustainable energy systems the potential for 'cascading' has significant potential in creating sustainable systems. Finally, from the point of view of the urban population this relationship offers another unique opportunity. That off inspiring a new generation in becoming a workforce to work on sustainable energy systems. In so doing, making visible and present the decentralized energy production has a mutually beneficial effect, because it can aspire a new generation of innovators, taking this system to yet another level.

This is especially where architectural- or spatial design can make significant contributions to the overall acceptance of these interventions and the way the interrelationship of infrastructure and urban society proliferates. The electricity plants of early 20th century London, were abandoned in functional sense but still are appreciated for their form and history. In similar fashion, the architecture of tomorrows sustainable energy system has the opportunity to improve the shared appreciation of infrastructures and their function in society in particular.

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Additional research

The potential for decentralized energy production in an urban context

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1. Decentralized energy systems

Modern society has had the opportunity to enjoy a seemingly endless and largely continuous supply of energy. This made possible the intensification of urban areas and even daily life, in the sense that facilities became available 24 hrs. a day. The stability perpetuated by the combustion of fossil fuels, which were readily and abundantly available, provided a reliable energy network. The potential that the fossil-fueled system provided was already harnessed in the second industrial revolution (Ushakov, 2017). It was the distribution of the energy produced by the first large scale power plants, however that limited the reach of the energy grid. When the production and consumption, through the development of household electrical appliances took off in the late 19th and early 20th century, the full rollout of the electricity grid took off. Famous for its many power plants, the city of London is one of the best examples of how major increase of consumerism sparked a wild sprawl of plants. Large energy cathedrals (referring to their specific architecture) arose along the Thames. The 20th century earmarked the rapid development of energy infrastructure as electricity became gradually more available throughout urban and rural areas. The development of distribution networks and the increasing awareness of health and safety risks (due to the proximity of plants to urban areas) eventually made it possible to organize energy production on strategic industrial locations. This development essentially created the conventional power plant. Being a largely centralized fossil-fueled phenomenon (Alanne & Saari, 2006).

How the current energy system is configured and how this is likely to change due to infeed of renewable energy is the first question that needs to be answered in this chapter. Already a brief history is provided of the development of the electricity system, which will spark the discussion on the conventional approach versus possible 'energy-futures' in the broad sense of the term.

Contrastingly to the production of energy, energy consumption is a decentralized phenomenon by default (Alanne & Saari, 2006).

This means that if a centralized organization of energy production has been favourable historically (due to fuel sources, efficiency, risks), large distribution networks will have been necessary to provide long-distance transportation.

The non-renewable energy system as described above is summarized in the five stage energy generation process developed by Ushakov (2017)

1. Production and concentration of energy resources including extraction and enrichment of a fuel.
2. Delivery of energy resources to power engineering systems.
3. Transformation of primary energy into secondary energy most convenient for distribution and consumption; electric power and heat are most typical.
4. Transmission and distribution of the transformed energy.
5. Primary and transformed energy consumption.

(Ushakov, 2017, p. 23)

As part of the strategy to transition to an energy system fed by renewable energy sources, an 'un-centralized' approach to energy production is likely to play a major role in meeting the renewable energy targets. In such a scenario significant alterations to the existing energy system can be expected (Ma et al., 2013). It is therefore that the energy system will be examined in the light of network theory.

The terminology for this theory was already introduced by Baran in the early 60's (Baran, 1962). Baran spoke of Centralized, Decentralized and Distributed networks in the context of communication networks. Although this appears to be a mismatch with the theme of the thesis, the terminology has since made its way in various fields of study, as well as the field of energy systems. The three network typologies are given in the figure below:

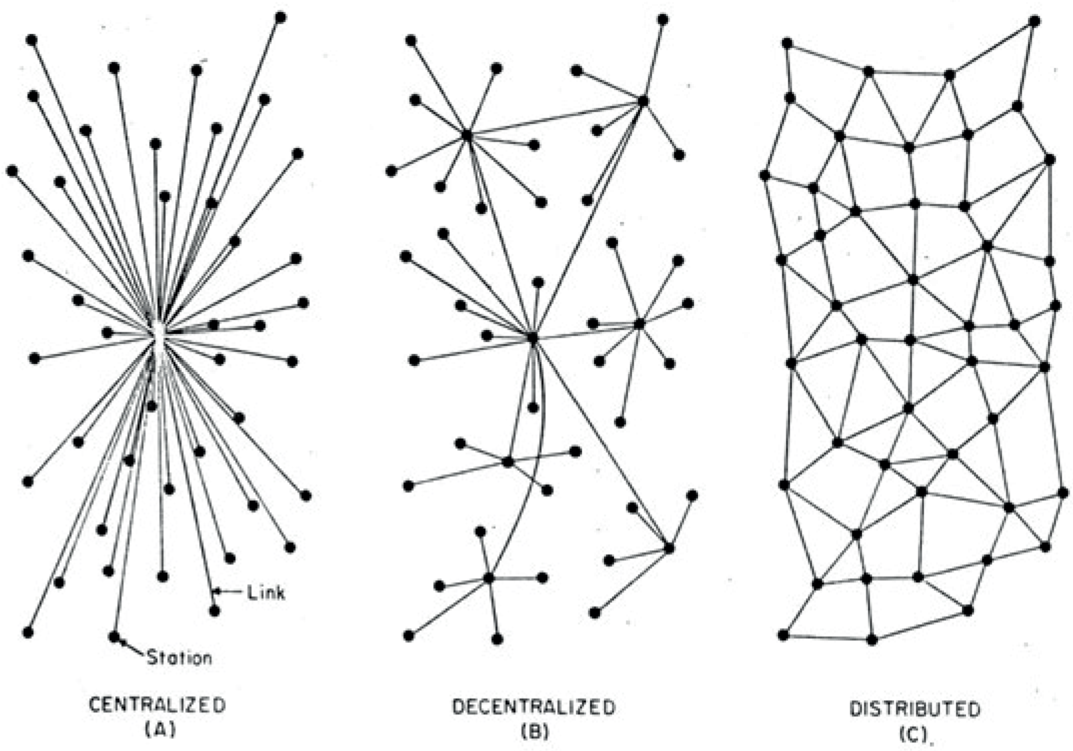

Figure 14: Centralized, Decentralized and Distributed networks (Baran, 1962)

The centralized network is most vulnerable. If the central node fails, then all other stations will fail to operate. Second in line of resiliency is the decentralized network. Multiple central nodes have to fail within system to provoke a full malfunctioning. If one node fails, most of the system will remain operable. Particular for this network typology is also the introduction a new hierarchical level: The decentral node. In the case of the centralized network one could identify just two levels, being: the central node, and the substation. The introduction of the decentralized node, could offer unique characteristics for the interrelations within the entire system. The third and final system is the distributed network. This is considered to be the most resilient typology in network theory (Baran, 1962). The essential difference here is that there is less or no sense of hierarchy. All substations act as nodes and vice versa. When one node fails, the whole system acts as back-up.

The conventional plant has been operating within a centralized network which was made possible by the continuous availability of fossil fuels. Ergo, even though this was an inherently unsecure system, the supply lines of fuels were designed as such to create an ostensibly resilient system. However, with the transition to renewable energy this approach to the organization of our energy system this will become untenable (Stremke & van den Dobbelsteen, 2012; Orehouing et al., 2015). One of the major reasons for this is that the low energy density of renewable energy fuels and production methods does not allow for the production to occur in isolated centralized locations (with a few exceptions). In so doing, creating a more resilient future system based on infeed of renewable energies.

Within the field of energy, the decentralized- and distributed network are defined as the following:

- ***Decentralised energy systems*** *could be defined as small-scale energy generation units (structures) that deliver energy to local customers. These production units could be stand-alone or could be connected to nearby others through a network to share resources, i.e. to share the energy surplus. In the latter case, they become locally decentralised energy networks, which may, in turn, be connected with nearby similar networks.*
- ***Distributed energy systems*** *could be defined as small-scale energy generation units (structure), at or near the point of use, where the users are the producers— whether individuals, small businesses and/or local communities. These production units could be stand-alone or could be connected to nearby others through a network to share, i.e. to share the energy surplus. In the latter case, they become locally distributed energy networks, which may, in turn, be connected with nearby similar networks.*

(Vezzoli et al., 2018, p.25)

Because renewable energy systems produce a more uneven output of energy, based on a variety of location-specific factors, the development of a distributed- or decentralized network is required (Ushakov, 2017). The main difference between the two being that a decentralized system takes into consideration the nodes up until the point where they consist of local production and management units, whereas a distributed system also allows for the infeed by prosumers while simultaneously allowing these prosumers to exchange flows of energy amongst each other.

The latter scenario is significantly more difficult to organize, as the nodes are also expected to share a 'common language', which allows them to exchange resources on a micro scale. However, this scenario does allow for a more profound focus on a bottom-up approaches to the energy transition as has been argued for by (Zanon & Verones, 2013). It will be argued nonetheless that although resiliency may improve further from a theoretic point of view in the case of distributed systems, it is not likely to become a part of the energy transition as a key stakeholder if considered on the scale of the prosumer. This is due to the fact that the techniques linked to prosumer production have a limited potential, as they largely involve building-integrated renewables (Photovoltaic cells, Micro turbines, Heatpumps, etc.). Therefore, they will only have a limited impact on the future energy system. This, amongst other reasons, puts the focus on decentralized systems. It should be mentioned though that the clear benefit of interconnections between decentralized nodes (in the broad sense of the term) as proposed in the distributed networks theory should not be overlooked (Vezzoli et al., 2018). As this thesis is not concerned with the research of distribution networks, the term 'decentralized' is held as it is believed to best represent the approach taken in this research. Even though this is the case, the potential for linkages between decentralized nodes, creating a distributed network on a macro-level, is believed to be a valid strategy (as prescribed by Vezzoli et al., 2018)

In the decentralized network, the mix of centralized and decentralized production and management nodes work together to produce the demand for energy, however, their relationship is not unilateral. The decentralized nodes on their term interact with consumers and manage the flow of energy. They embody the opportunity to employ regional/local renewables and provide a way to integrate them into the energy system. Nonetheless, the resources that flow between the three hierarchical levels (Centralized node, decentralized node, prosumer/consumer), do not necessarily have to develop a 'common language'. For example, on the local scale, low temperature can be shared and managed by a decentralized node, while still being dependent on the majority of its electricity demand from a centralized node. The decentralized node could in an ideal scenario furthermore act as temporary storage unit for electricity when there is an overproduction of renewable electricity on-site, or to cover intermittency scenarios (Troy, 2012), while the demand on the centralized system is also low (as proposed by, Narayanan et al., 2019). In so doing, becoming an energy hub (Orehounig et al., 2015)

> "*To increase the reliability of renewable and sustainable energy systems, current trends are towards integration of smart grid technologies and demand side management with the goal to use the available energy more efficiently. Thereby peaks in electricity demand can be shifted to periods where energy from intermittent renewable sources is available [2,3]. The idea of an energy hub is building on that concept, by extending controlling demand and supply from electricity to multiple energy sources. It is a combination of multiple conversion, distribution, and storage technologies which are controlled in order to supply various consumers of energy. Thereby consumers can be a single large building complex but also a city quarter, neighbourhood, city, region, or even a country. An energy hub at district scale focuses on urban energy systems, where building integrated renewables such as photovoltaics, solar thermal collectors, hybrid collectors, or wind turbines can be combined with local and regional scale distribution technologies such as smart grids, micro-grids, district heating and cooling networks.*"
>
> (Orehounig et al., 2015, p. 278)

This approach to a decentralized system (Energy hub) is thought to have significant potential both from the point of view of network theory, as well as applications on an urban-architectural scale, because of the implementation of the decentralized nodes within the existing fabrics around consumers of energy. This idea will therefore be further researched to explore the potential for both the integration with available renewables in the Dutch context (The Netherlands) as well as the opportunities for the integration with urban planning and design, and public life. Hereby creating a proposal for the future energy system from the macro scale (Energy network) down to the micro scale (integration and implementation strategies).

2. The future of production

In 2018, roughly 13% of the total global energy production was produced with renewables and biomass (International Energy Agency, 2018). The EU targets for the contribution of renewably energy to the grand total of energy production are set at 32% in 2030. Even with this seemingly manageable leap in production share, the practice of the energy transition is conversely complex. Therefore an abundancy of action plans, adaptation strategies, long-term visions, on continental, national and local scales are being produced to make this transition possible (see for example: Sijmons et al., 2017; Frijters et al., 2018). The development of these strategies is paramount to enforce the transition to renewable energy, as this transition creates several compatibility issues with the existing energy system. Stremke & Koh (2011) introduce three of these issues in their study on thermodynamic concepts in energy landscapes:

1. Intermittency: The fluctuation in energy production due to natural influences. For example in the case of wind- and solar power. This requires planners to rethink the system to ensure that the system can handle these variations.
2. Energy density: Coal and oil technically are ancient solar collectors. Densified over millions of years which transfers to their relatively high calorific characteristics. The relative low energy density of renewable energy provides specific challenges for the organization of renewable energy systems. According to Stremke & Van den Dobbelsteen (2012) the amount of renewable energy that is required, combined with the low density of renewables, requires planners to view every landscape as energy landscape (as a potential source of energy).
3. Energy utilization: To consume vast amounts of renewable energy sources, as primary source of energy, requires a meticulously planned system. The characteristics of renewable energy (more fluctuant, less potent, etc.) requires new ways of using energy to allow for its most effective use. Examples are: low temperature heating systems, virtual power plants, short distance distribution networks (de Waal & Stremke, 2014), etc.

To reach the desired targets for renewable energy production, renewable energy production and energy storage methods will have to be assessed and weighed. If not, the barriers as indicated above, will not be overcome, as production methods lie at the core of the imminently changing energy system. This chapter builds on the previous chapter and will therefore assess available renewable energy technology in the context of decentralized production. Since the territory of human settlement increasingly overlaps with the territory of energy production (Tillie, 2014), the integration with the built environment has become a likely scenario.

Even though the decentralized energy system demonstrates clear advantages over centralized production, the technical implantation of this system is not a simple matter (Mehleri et al., 2013). Needless to say, the centralized production system has also never ceased to cause controversy, however the decision-making process in planning centralized plants has been streamlined over the years (for example due to having a fixed set of available non-renewable fuels). The overhaul of this process propelled by the transition to a more decentralized process requires the investigation of available resources (on a local and regional scale), development of the (technical) systems and new management structures to produce a fitting solution to the location. (Mehleri et al., 2013)

- Maturity: The technology at hand is a proven concept. If this is not the case it is of great importance that the technology has recently been tested in a published study or pilot project, and it boasts exceptional opportunities for integration with the Energy Hub concept as described in the previous chapter.
- Appropriateness: The technology at hand is applicable in an urban environment within a margin of fairness (meaning to not be unnecessarily risk-taking). This criteria appeals to some degree to a subjective opinion. To objectify this decision, later on a Multi-criteria model will be employed to support the assumptions
- Scalability: The technology at hand is able to be scaled up and down (in literal plant-footprint). As this thesis aims to support a designed solution in urban or peri-urban location, the footprint of the technology has to be able to scale linearly with the on-location demand and available land.

A lot of the decision-making process hinges on 'Site' and Appropriateness. A decentralized approach could benefit from an innovative approach, stretching the limits of conventional technology (i.e. defying the point of Maturity), however if the site conditions do not support the method in question (due to the unavailability of a resource for example), the whole concept will be unfeasible. The same line of reasoning can be applied to Appropriateness. Nevertheless, a wide array of available technologies remains available. Therefore in a realistic scenario the different methodologies would have to be weighed in a Multi criteria analysis (MCA).

> "*Another factor that has completely changed the energy planning scenario over the last two decades, from an almost exclusively concern with cost minimization of supply-side options to the need of explicitly multiple and potentially conflicting objectives is the increasingly complex social, economic, technological, and environmental scenario. Multiple criteria that affect the success of a renewable energy project must be analyzed and taking into account. The literature traditionally divides the used criteria into four aspect technical, environmental, economic and social...*"
>
> (Cristóbal, 2012, p. 3)

The framework of Cristóbal (2012) was partially applied to the selection of production and storage methods. Economic criteria were left out of the scope because the scope of this thesis doesn't allow for a full feasibility study. Similarly, Social criteria were left out of the scope. For one because of the lack of data within this field in relation to specific technologies, and thereby this specific criteria will be part of a broader discussion in chapter 4.2. Although this chapter will not go into the specific benefits for each separate technique, the conclusion are thought to be transferable. The results of the MCA are given in Appendix 1.

2.1 Interim conclusion

To conclude this chapter we shall point out the main contenders for the production of renewable energy and storage of heat/electricity in light of decentralized energy systems. Wind and solar energy were eventually not considered to be part of the discussion. Even though they can provide significant contributions to the production of renewable energy, they exceed the scale of the decentralized Energy hub entirely. Of the remaining, the three most potent technologies for application in decentralized energy hubs are Biomass, Biofuel and Geothermal. Correspondingly, these are also the three typologies applied mostly in the current best practices and competition entries in architecture at the moment. The five most potent technologies for the scale of the Energy hub are Battery, Hydroelectric, Vehicle-to-grid, Hydrogen and Cold-heat-storage.

These require further study to investigate their applicability in the context of a specific assignment. As each case provides different opportunities and threats, the outcome of every mix of techniques in the future Energy hub, might be radically different. Important to note here is that the techniques who are not considered further in this thesis are still valid production and storage methods, however they often do not match the scale and functionality which is compatible with a decentralized system, and more specifically the Energy Hub. Essentially going beyond local production methods like solar and opting to look at large scale energy production such as geothermal heat for district heating.

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Reflection paper

On the sphere of influence of architecture and the role of design research in the context of academic research

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Introduction

> "*Learning, especially in the workplace, does not always occur as a "light bulb moment", it can be hard to pinpoint due to its gradual and ongoing nature. This means that it is often hard to track back where that learning came from, and you may even struggle to remember when you did not know how to do a certain thing. This gradual learning means you do develop skills - but you do not always give yourself credit for them or acknowledge when and where you use them or when they might need polishing*."
>
> (Helyer, 2015, p.22)

If learning is a way to absorb new knowledge, than reflecting is a way to make this a long-lasting memory. Our ability to gather new insights is perhaps even beyond our own comprehension, but our ability to make this a permanent part of our representative consciousness is contrastingly difficult. A good way to test this would be to learn something and then force yourself to reproduce it when teaching somebody else. The mechanisms of consciousness have made the knowledge so much a part of our representative memory, that we are now able to replicate the theory. As this is a skill in itself, the method to develop this is to reflect on the amount of new knowledge that is acquired. As such, this reflection piece will actively, and retroactively engage with the academic findings and personal developments of the graduation process.

In the graduation process and the design phase the focus came to lie on architecture and the intersection with infrastructures. More specifically the focus converged on a branch of energy systems: Decentralized production. The idea of decentralized and distributed systems goes back well into the 20th century. However, the implementation of these systems within western society has been underdeveloped.
The research, within this context, did not focus on 'why' this did not happen, but rather focused on 'how' it could be implemented in today's day and age. In so doing, architecture was put in a position where it could actively contribute in the race to create a more sustainable and renewable future.

The design and concept were to a large extend research-driven. Providing a design process with evidence-based starting points. The introduction of a few key literature works within the research was a key strategy in this. What works were selected for this purpose, and how they played a role in the process, will be discussed in the reflection on the methodology (*4. Reflection on methodology*).

While doing the research, it was found that the challenge of sustainable energy production is a hugely complex task. Very early on it was made perfectly clear that proposing one finite solution to solve a problem like renewable energy production would be virtually impossible. The pitfall within this is that when the solution or the formulation of the solution becomes so obscure to create a satisfactory answer on paper, that it at this point does not provide any tying points for the formulation of architectural intervention. This will be reflected upon on the chapter on the relevance of architecture in this field of research (*3. Sphere of influence of Architectur*e)

The central line of thought within the following chapters will be the coexistence of detail and whole. This concept was not formally part of the research, but it boasts interesting opportunities here as a backdrop to discuss the progress of the projects and apply some specific points of reflection for architectural research. Because of this, the paper will commence by exploring what I mean with this discussion between detail and whole, and why it played a relevant part in my line of thinking throughout the graduation project (*2. Detail and Whole*).

1. Detail and Whole

If we look at history, we detect something of a grand scheme of events that have occurred. All of history combined allowed us to arrive at the point where we are today taking into account revolution, war, tragedy, disease, prosperity and more. Each one of these events, occurrences and developments has built on one another but has also been only a small particle in a larger scheme (Landsman & Wolde, 2016), being just as prone to be forgotten as to be remembered.

It is with this analogy that I would like to introduce the concept of 'detail and whole'. To be part of something larger than what the sphere of influence of the individual or the individual project might be, was something that struck me most definitely in this graduation process. The power of 'The Detail' has historically been illustrated when we for example look at the Bilbao-effect, which had an immensely powerful effect on the prosperity of the Northern Spanish city. Small (relative to the scale of the city) scale intervention, but an international impact. The opposite, where 'The Detail' was of inconsequential importance, can be found in for example the architecture of 'de Wederopbouw' (The great rebuild after the Second World war). The economic and social impact of 'The Whole' outweighed the arguments for the detail and therefore we can now find a lot of monotonous and austerely finished 60's and 70's housing. The relevance of sheer quantity, the whole, trumped the value of architectural expression, the detail.

We shall here reflect on the research and the design within the context of the metaphor of detail and whole. In so doing, the pitfalls, difficulties, but also opportunities, will be brought to light which were encountered during the research and design phases.

1.1 Within research

Common academic research theory dictates that a research question must delineate a limited section of theory, so that the written work does not lose value through being overly broad. This to me, means that in academic research, the emphasis has asymmetrically come to lie on the detail (comparing to the field of research at large). I would argue that this is done for good reasons, as writing is a difficult enough task on its own, that the addition of a very broad perspective only prohibits the writer from composing an acceptable result. However, at what point does then the written work bear any meaning for the betterment of the research field at large. Is research into the detail always authoritative enough to make a meaningful contribution within a finite amount of words?

I would like to respond to this in the following manner. During the research I noticed two things. Firstly, there was not one all-covering solution to the problem of finding renewable sources of energy. The solution to this, as a whole, appears to come down to a balanced mix of different production strategies which each on their own bring a unique set of benefits and drawbacks to the mix. The whole, here being a state where society is capable of supplying its demand for energy renewably, was the elephant blocking the view on readily available strategies, which in time will contribute to the development of more holistic solutions. The detail, here, and also in my personal research into decentralized energy systems, provided an appropriate perspective on today's energy infrastructures. Allowing the development of 'the whole' through exploring the long term potential of 'the detail', here being a specific branch of energy systems theory.

Secondly, researching this specific string of theory (decentralized energy systems) has brought to my attention the fragility of the lines of reasoning through which very specific theories are proposed. This has to do with the fact that within research the 'self-fulfilling prophecy – effect', by then, makes its way into the mix. By making the research question so specific, the chances of the main question being positively confirmed becomes synthetically high. The question does then arise whether the detail, being a very specific research question, bears any meaning for development of the field at large. Counterintuitively, I would like to claim here that it does. I especially noticed this when moving from the research phase to the design phase, feeling backed-up by research-based starting points.
Especially for the more 'applied' sciences such as Architecture, this approach bears fruit. Important to note here is that no matter the amount of abstractness that is applied to develop a specific research, it should be capable to develop further recommendations to the larger literary context. If this relationship is taken into account, through contributions to 'the whole', I would argue that that is eventually mutually beneficial for both parties. The whole doesn't exist without the details and vice versa. This is something that I initially lacked in my personal approach, and which I would like to now further develop to make clear how this project can have long-term value.

1.2 Within design

The duality can also be found in the design process. The tendency for architecture to think in big brush strokes often overshadows the general discussion. Whether this is a limitation of human interaction, which is often based on brief dialogues, or whether this is a result of a personal preferences to overlook the impact of details, remains to be discussed. However it does raise the question of whether or not details (in the metaphoric sense) are underexposed in the early stages of the design process.

The tendency to neglect the small scale is largely unjustifiable. In my personal graduation process, this tendency has been a direct consequence of the scope of the research, focussing on a large complex issue. Architecture doesn't deal well with an abundance of insecurities. Perhaps the most difficult assignment to work with is the Tabula rasa. Constraints create threats and opportunities with which architecture can interact, therefore creating a basic set of tying points with which the designer can engage. Ignoring the differences between distinctive sites and contexts, I would like to continue here on confronting the 'Tabula rasa – effect'. By opting to work with infrastructures and large scale systems, the context of the design was enlarged.

Do the tying points for the design then lie in conclusions of the research which is concerned with decentralized systems in general? Do they sprout from the area of effect of the proposed intervention: the district heating system of Rotterdam? Are they generated by the vision of the architect through a strict concept? Or do they originate in the principles of user experience as the proposed intervention is as well a public building?

The answer to this is of course is quite nuanced, but what occurred is that the large scale (the research) absorbed so much of the available resources, that the small scale received a more retroactive role. This was restored later on, but the lesson here is that no matter the scale of the research and the context of the design, there should always between a balance between the detail and the whole. The whole was overrepresented in the early phases of the design as this felt like the most crucial hurdle to take as to create a satisfactory response to the research. The detail, represented by for example interior architecture, is of equal importance. I would argue that all architects have a unique position within this framework, which enables the wide variety of available styles and approaches, which on its turn enriches the architectural debate. However it should be mentioned that there is a margin of error in which the detail and the whole should coexist. The whole cannot be fruitful without the detail and vice versa.

1.3 Between design and research

Architecture being a manifestation of tradition, creativity, policy, culture, and many more sources, takes the position of 'the detail' within a larger field of artifacts and built structures. These constellations can be urban fabrics, cities, neighbourhoods, streets, but what it is proposed here, as that we look at the position of the artifact within the larger body of research, innovation and progress as a human society. Architecture then becomes a detail in a larger historic tradition. How to deal with these fundamental principles continues to be deeply fascinating to me. The metaphor here becomes that architecture or a design task is a detail in the development of architecture, urbanism, science etc. To be aware of this, enables a profound sense of long-term developments. What does it then mean to add to this long history of architecture?

Very practically this meant that I have always considered the functional life span of the building to be one of the most important gauges for the design. However, it also meant that I perhaps refrained from making decisions based on the direct context of the design, because I considered it to be of subservient level compared to the contributions of this design challenge to research into decentralized systems.

2. Sphere of influence of Architecture

While doing the research I sensed that a lot of the themes that were touched upon significantly exceeded the scale of what I thought would be in reach of architecture. Whether or not this did end up being the case in the end will be topic of conversation in the final paragraph. Within my graduation this manifested itself by making it significantly more difficult to allocate my resources to all the layers of architecture (façade, space, material, detail, etc.) simultaneously.

By tapping into society-wide problems, like sustainable energy, 'getting to the bottom of the problem' is a herculean and frankly impossible task. Problems that are so deeply rooted and interwoven within political, cultural and economic systems are difficult to understand. Putting resources and effort into researching the possibilities for decentralized energy systems, resulted in the fact that a lot of my decisions were based on long-term strategies, rather that favouring the position of, for example, the short-span interactions of visitors in the building. To put it polemically, "What is more important in the end?" The bigger story, or the individual expression? My first and brief response would be, that it's both. However, depending on the context of the project, one is more likely to gain a slight preference over the other. Nonetheless, they always coexist. Would the Guggenheim in Bilbao have had such a global impact, if it weren't for the metal-clad façade panels, or the curved interior walls? I would argue here that it wouldn't have, ergo architecture did have a significant impact on 'the whole', being the reputation of the city of Bilbao.

Taking this further, an additional point of discussion can be raised; Architecture's desire to be reactionary versus proactive. In architecture we often try to address social issues. Ranging from social segregation, to unaffordable housing and developing a circular economy, amongst others. The question here for me is whether or not, as an architect, I am reacting to a trend negatively impacting society as a whole, or whether I am proactively improving on a current state of being. This is a very profound question when we consider that it might be able to bridge the gap between architecture and research in the context of what has previously been discussed (Architecture's struggle to deal with large scale research topics). If we assume that architecture is proactive, then this problem is negligible, because architecture will always be on the forefront of development and in way prototypical. Therefore the design proposal is always an interpretation of a vision or a scientific theory. This role, being the architect of perhaps a prototypical system and design, was relished in my design process, and allowed for a more liberal position. In a way, it puts the architect in a position where he can freely move between 'the whole' and 'the detail'. Especially this last thought has helped me personally to develop the project at the level of the system as well as on the level of the detail.

Architecture is then, I would argue, concerned with making the necessary leap of faith. Written research has the tendency to become ambivalent and leans towards being retroactive, building on previously performed research. Architecture on the other hand has the unique ability to proactively create new innovations and prototypes, pushing the limits of what we know to exist, raising new questions and developing new insights into existing scientific/academic research. A quality which is especially valuable when researching 'The city of the Future', and I would therefore argue that this stance is therefore justified. To be aware of ones position in the spectrum (reactive – proactive) poses interesting benefits. However, architecture eventually takes both shapes to respond to context specific challenges.

In this search for my personal position within my graduation project, I found myself reading into the work of Cedric Price's. Arguably liberal in his approach to design and continuously looking to break with tradition and proposing proactive architecture:

> "*Cedric Price picked up on this new way of looking at the city in the Fun Palace, aiming to make it a node of urban infrastructure that would offer a forum for situation-based experiences. Serving as a prototype for cultural architecture that chimed with the zeitgeist, the Fun Palace design pulled together a diverse spectrum, of infrastructural types, envisioning that their signature connectivity would generate an entirely new form of experience.*"
>
> (Herdt, 2017, p. 49)

3. Reflection on methodology

Moving away from reflective research driven by personal insights, the focus will finally come to lie on the effectiveness of the chosen research methods. Additionally, the theoretic framework will be briefly touched upon.

The objective of the proposed method was to come up with a very rigid scheme of actions that had to be undertaken to achieve a satisfactory answer to the main research question. This was particularly valuable, because the specific field of research entails a broad variety of additional research topics. These are comfortably able to distract from the core line of reasoning. To be able to adhere to the rigid schedule of the methodology is now considered to have been beneficial in handling complex research fields, such as energy systems. The allocation of several key literature works in the data collection cycle, furthermore boasted significant advantages to the flow of the research. This strategy, being a form evidence-based design in this case, is moreover an often canonized approach to complex issues (See for example Lawson, 2013)

The research was designed to provide several rudimentary starting points for the formulation of a design challenge (particularly subquestion 3 which was handled in the position paper). Additionally, the proposed research would aim to prove the validity of the decentralization strategy. This last point was mostly covered by research outside of the position paper. Keeping these two separated, because of practical reasons, actually proved to be valuable, as the strict methodology prescribed in the Research plan allowed for a solid basis to develop a position paper from.

The research plan with the introduction of the theoretic framework simultaneously suggested the investigation of infrastructure planning. The intention of this venture was to develop a more meta-scale understanding of infrastructures. On its turn, the design challenge could propose future alterations to this theory. Whether or not it achieved this will be briefly covered in the chapter Recommendations. Because of certain uncertainties this was always believed to be an endeavour operated parallel to the main research question as proposed in the research plan. The methodology describes how the basic building blocks for the research can be configurated, which supplied a core body of literature which provided valuable tying points for the functional layout of the design. The development of the theoretic framework, in the position paper, subsequently allowed the research to seek for a broader relevance for further research.

The strategies proposed in the Research plan are therefore considered to have been effective. Even though clear caveats have come to light, which have been elaborated on in previous chapters, the approach of creating a rigid schedule at first has bared fruit on the long term. The ability of this core written works to expand to new insights through a broad inquiry through the theoretic framework, has been mutually beneficial process. Consequently allowing for evidence-based design decisions (functional design) as well as more speculative approaches (the future of energy systems, power plant architecture) through the theoretic explorations in the position paper.

Recommendations

For future research I would like to raise the following points:

- Within research one should be aware of ones position in the larger context of the research and preferably the research should, however specific and marginal the research question, make recommendations towards the betterment of its larger theoretic context.
- Within design one should always consider the detail and the whole as mutually dependent products, requiring an even distribution of resources to develop. This means, that the impact of very minute details might have a big impact on the appreciation of the whole.
- For architecture to have influence on larger societal issues, one should try to make the research into those issues considerably 'applied'. This means that the main question should really zoom in on a specific problem or on in another case, that the expected results are relatively clear. This means that either plenty research on the topic already exists, or that the newly revealed research field is relatively specific. In both cases, in the end, there will be adequate tying points for an architectural intervention to take advantage from.
- As architect operating in a constantly shifting context, we should be aware of our ability to take a liberal position, allowing ourself to move from detail to whole and vice versa, no matter the circumstance. This means that no scale is overlooked in the search for future innovations and new designed approaches.

In conclusion, I want to briefly reflect on the effectiveness of the position paper and the design process, in providing recommendations to the broader relevant body of research. In the end, I would argue, that this is one of the most important goals of research into more applied fields of research. This I have tried to cover generously when discussing the role of 'the detail' and 'the whole' in chapter 2.

I would like to refrain here from claiming that the result satisfies the demand for future recommendations in the field of decentralized energy systems entirely, however I would like to highlight a selection of accomplishments and shortcomings.

Firstly I think that the more liberal approach taken in the position paper has proven to be beneficial, creating wiggle room for the design to negotiate with, aiming to solve multiple complex challenges simultaneously. This whilst, the first two subquestions have always aimed to create a solid basis creating a central body of knowledge from which the necessary 'leaps' could be taken. This complementary relationship has proven beneficial in creating the necessary shackles in the chain from research to design and vice versa.

The position paper mentions the relevance of 'people' and society in making grand changes to systems and infrastructures. This sounds like it should be part of political strategies or nation-wide campaigns, but I would like to add to this the unique position of architecture in this line of reasoning. Space, Material, Expression, only a hand full of the tools available to the architect, are able to influence the way society acts and moves forward. I would say that the design and research could have gone beyond to take this perspective of the individual visitor. By experiencing this new system and taking in the visual information he receives, the knowledge will spread further making us of all the advantages of bottom-up changes.

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Appendix

Figure 15: The development of the power plant

Figure 16: Energy storage and production matrix