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.

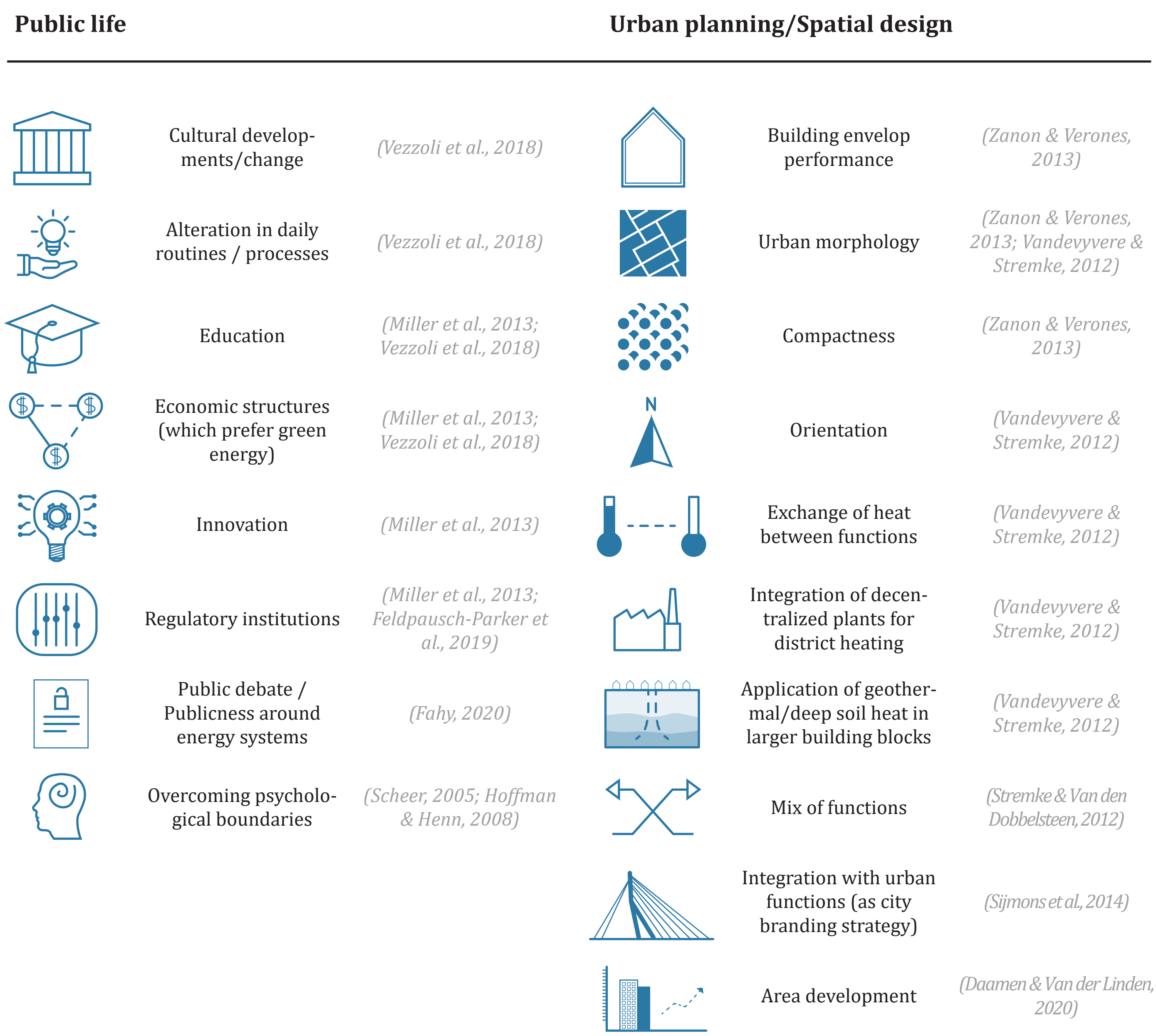

Figure 13: Opportunities for integration with public life and urban design

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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