THE POWER TRANSITION: FROM CONSUMER TO PRODUCER

Shawn Zimmerman 4641744
Faculty of Architecture & the Built Environment, Delft University of Technology
Julianalaan 134, 2628BL Delft
s.e.zimmermanm@student.tudelft.nl

ABSTRACT

The world is becoming more environmental cautious by continuing to search for new ways to create a better future. As a large amount of people are living in cities, new trends of more sustainable cities are emerging. This paper aims to answer the question; How can renewable energy be produced in future cities and how would It change public perception of power plants? By researching renewable legislations and future innovative technologies the world will transcends towards a decentralized production system implicating different types of renewable production. Based on simulation research, scenarios can be envisioned where future structures will become producers of energy and new ways of producing energy within our cities can be established.

KEYWORDS: *Energy, smart city, performative architecture, urban metabolism, power plant, sustainability*

I. INTRODUCTION

Our modern world is driven by energy and in order to maintain our standard of living, we require a vast amount of energy. As energy counts for 59% of our global emissions, we must find more sustainable solutions in order to meet our high standard of living (Ritchie & Roser, 2017). This war against climate change has escalated drastically over the years with countries uniting together in order to create a better future for our succeeding generation. Countries have agreed with multiple agendas and goals in order to reduce their environmental impact. These implementations could change the landscape of our energy production and energy consumption. The United Nation sees this issue as a societal issue, as one of its sustainable developments towards a better future. The transition away from fossil fuel will close different fossil fuel-based power plants with new renewable power plants replacing them. Stating the obvious question how and where will the energy for our future cities be produced?

Nowadays most of our energy is being produced in the outer city, which is then transferred to our inner cities, creating this barrier between production and consumption. With new sustainable developments within the energy sector, it has given us the possibilities to implement these technologies closer to the consumers. Breaking the old the traditions of what we perceive as power plants. It is projected that 68% of the world's population will live in cities, creating a much denser society in the future (United nations department of Economic and social affairs, 2018). In order to answer these demands, we must evaluate the way we consume and produce energy in our inner cities. Thus, making the main research question: How can renewable energy be produced in our future city and how would It change our public perception of power plants?

Firstly, researching future power grid trends creating the sub-question: How will energy transition change the future of our power grid? Secondly and thirdly researching new sustainable technologies and how they are applied within our modern society. Thus, answering the sub-questions: What are the new developments in renewable energy production and how are the new technologies applicable within the built environment? These sub-research questions lay the groundwork for the research's future implications within our cities, using Kattenburg as a case study, where different scenarios could be made in order to play out different future strategies. Therefore, Answering the sub-question how can sustainable energy production change Kattenburg's future developments? From these sub-questions, a conclusion can be made to answer the main research question.

II. METHODOLOGY

In order to answer the first sub-questions a qualitative research will be done through literature and case studies. The literature will be based on current energy developments and future EU legislation implications. The second and third sub-questions will be based on quantitating research, where future technologies are analysed. Third sub-question will rely on qualitative research of literature in order to understand the social capabilities of the researched technology in sub question two. The last sub-question will be answered through simulation research, where findings of sub-question one to three will be used in order to create different future scenarios. These scenarios will be used as a form of research in order to foresee the different projections of renewable implications. Based on these methods a conclusion can be made to answer the question of how our future cities will produce their own energy.

III. THE FUTURE OF ENERGY

The world continues to electrify, with electricity consumption growing slowly. The shift in source has started to grow drastically with renewable energy continuing to gain importance. BP (British Petroleum) foresees a 70% increase in primary energy usage that will be used for power (BP energy economics, 2018). Thus, foreseeing a world where we electrify most of our technology relying on electricity to meet our daily needs. This shift from fossil fuels will have a significant impact on our future power grids.

3.1. European Energy transition

The European Union has passed different legislation and agreements in order to create a more sustainable future. The EU is committed to decarbonising their energy production by cutting emissions by 80-95% below 1990 levels by 2050. Thus, compiling a roadmap to a low-carbon economy, which paves the way towards a competitive low-carbon economy by 2050. (European Union, 2018)

The EU sees the energy efficiency as a fundamental part of the goal towards a low-carbon economy. In 2009 the EU enacted the 2020 climate & energy package to ensure that the union meets their domestic targets. The 2020 climate & energy package sets three goals: 20% cut in greenhouse gas emissions (from 1990 levels), 20% of EU energy from renewables and 20% improvement in energy efficiency. (European Union, 2018) These targets have their own short-term goals in order to see that every nation meets the 2050 goal. The EU adopted the 2030 climate & energy framework in 2007 which, builds upon the 2020 energy package by setting a goal of 27% from renewables. Based on these goals, the European Union suspects a transition in energy where a better and more sustainable future is created.

3.2. Netherlands energy problem

Netherlands has agreed upon the 2020 and 2030 energy packages of the EU, agreeing to meet the EU goals, pushing sustainability within the country. The Netherlands itself does not have a vast amount of sustainable resources, with its flatlands and a low average amount of sunshine it must rely heavily on wind energy. This creates an energy problem for the Netherlands as it must find another way to produce renewable energy. Current statistics show that only 12% of Netherlands current energy production comes from renewables, falling short of the 14% goal of the 2020 energy package (Energie vergelijken, 2018). Thus, the Netherlands will have to make significant changes in order to meet future energy goals. In order to meet these future goals, Mark Rutte has agreed to close all coal plants by 2030, cutting their emissions to 49% (Climate home news, 2017). In the process focusing their investments on new renewable solutions such as onshore and offshore wind and solar farms.

3.3. Future power grid

Electrifying our world has its benefits, however by straying away from fossil fuel we need to rely more on sustainable electricity solutions. Which puts us in a predicament as most of our energy is still produced through fossil fuel-based plants and not renewable sources. Thus, electrifying our daily lives can be seen as pushing the problem to another source, as electrifying sets more pressure on our power plants. Therefore, in order to have clean renewable electricity, we need to solve it at the primary source in order to have a green cycle. Currently, our power structure is based on a centralised system. Fossil fuel-based power plants produce large amounts of electricity, which is then transferred to our inner cities. This system requires a large power network in order to reach every single user. Experts predict that this type of network will seize to exist with new future renewable technologies, as they are implicated in a more decentralised matter. Thus, not creating one big power plant, but relying on different smaller renewable solutions.

The energy atlas 2018, has created a 12 brief lessons infographic on Europe's energy transition (Annex figure 1). Stating that Europe will transition towards a 100% renewable decentralised power grid, creating innovative sustainable business models along the way. Europe's energy transition focuses on teamwork in order to reach their 100 % renewable goal, implementing policies on different scales in order to motivate sustainable innovation. The energy atlas states that "Changing national laws and policies is cumbersome, time-consuming and risky: what if the law or policy proves to be a dud? Cities, on the other hand, can be a hotbed of innovation. They are big enough to try out new ideas on a large scale, but small enough to brush them aside if they do not work out – and the best ideas can be scaled up to the national level" (Böll,, 2018). Meaning we can use cities as a testbed where innovations can be tested and implemented on a large scale. (Böll, , 2018)

First of all, with prognostications moving us towards a decentralised community, we must ask the question: what does decentralisation actually mean? Decentralised electricity generation means "an electric power source connected directly to the distribution network or on the customer side of the meter'' (Karger & Hennings, 2007). Meaning that the electric energy only travels short distances, reducing its transportation losses. The most common technical term is "distributed generation" (DG). Like solar panels, wind turbines and other forms of renewables can be seen as DG's contributing to a big decentralised system. These implications will change the way we produce energy as DG's will be implicated within our society changing our old power structure. Even though, there is no explicit statement or research that prognosticates DG's as a clear renewable solution, the world will transition as it gives us the opportunities to include different type of power sources. These DG's could be dispersed within our communities producing energy from different sources contributing to a bigger picture where we work as a team to reach the ultimate goal, A 100% green power grid.
(Karger & Hennings, 2007)

3.4. Smart city

The EU's sustainable vision creates the opportunity for us to take a role within the energy transition. Thus, giving different scales of opportunities for the population to take part in. These opportunities will be part of the bigger picture, therefore creating a smart grid where different sizes of DG's contribute. We are now in the information age, where information is key through technology with devices connecting and communicating with each other in order to resolve one particular issue. Thus, with technologically advanced sustainable implications, a "smart city" is created where data from different implications and other smart technologies work together.

The concept of a smart city is still emerging, as the meaning is still being defined. Therefore, the concept is used all over the world with different meanings, creating different variations of the definition smart city. Within this paper smart city is defined as "The use of Smart Computing technologies to make the critical infrastructure components and services of a city—which include city administration, education, healthcare, public safety, real estate, transportation, and utilities—more intelligent, interconnected, and efficient" (Washburn & Sindhu, n.d.) siding with Doug Washburn and

Usman Sindhu's point of view , as a collection of smart computing technologies applied to the city's critical component (Chourabi, et al., 2012). Thus, using smart technologies to solve or reach goals of that given city.

Smart cities fixate on hard data to help make daily lives better and more efficient, using different technology implications to create a well-oiled machine. The smart city concept fixates on working together with the different flows in order to achieve its highest rating. This type of observation an interpretation can be seen as urban metabolism. "Urban Metabolism is a framework for modelling complex urban systems' flows – water, energy, food, people, et cetera – as if the city were an ecosystem. It can be used to analyse how urban areas function with regard to resource use and the underlying infrastructures, and the relationship between human activities and the (natural) environment. What is more, it can be used to shape the urban environment in a more sustainable way" (Research Group of the Department of Urbanism – Delft University of Technology, 2018). Thus, analysing the city as a living organism by analysing its input and output flows in order to create a more sustainable environment.

3.5. Conclusion

These methods of approach could help cultivate new smart cities, by analysing and implicating different methods in order to reach the ultimate goal. By using the Urban metabolism framework, you could create an energy flowchart of a city, analysing its input and outputs, therefore creating a framework where sustainable solution can be implicated in order to reach a sustainable energy structure. This approach can facilitate a smart grid, creating balanced system of DG's to meet the city's energy needs.

IV. ENERGY PRODUCTION

The world is currently in a green technological boom, with new sustainable concepts emerging every day to solve our current and future energy problem. These solutions could make significant strides towards a sustainable future. Based on the main research question, the research will look upon renewable technologies that are applicable and game-changing within cities and the built environment. Therefore, the research has divided energy production into three sectors: electricity, heating and cooling. Thus, searching for new technologies within these sectors could change the way we look at power production within our cities and our built environment.

4.1. Electricity

Electrifying our houses and offices has created a big demand for electricity, making the transition towards renewables even more important. Within the built environment we have seen solar panels being used in order to produce energy on top and on façades of buildings. This sustainable trend has become one of the leading design principles within the built environment, creating green and liveable spaces that can be independent from the grid. This research has looked upon active renewable technologies that could be applied within or around a building.

Solar technology is leading the way within the built environment using different faces in order to produce energy. Buildings have become solar powerplants optimising their angels in order to produce energy. With new solar technology, we can now produce cheap printable photovoltaic and photovoltaic glass that produces electricity. These applications have broadened the horizon on how solar technology can be applied within the built environment. Wind energy on the other hand, does not have the same scalability as solar panels as big wind turbines are not seen as city friendly. Therefore, new technologies such as "Nemoi wind turbines" have emerged where one small vertical wind turbine can produce enough energy for one household. This researched looked upon other technologies to harvest energy from different sources. Using for example, microbial fuel cells to produce energy from wastewater, E-plant technology to produce energy from living plants through electrons and by implicating Pavegen flooring technology to produce energy through kinetic energy

by letting people walk on its floors. These implications could help a structure squeeze electricity out of each square meter, becoming a producer of goods and not necessarily seen as a consumer.
(data and information about technologies can be seen in the Annex)

4.2. Heating

Creating a conformable work or living environment has drastic implications for our energy production, as heating is one of the biggest consumers of energy within the Netherlands' energy spectrum (CE Delft, 2016). By finding renewable ways to produce heating, we can lower our dependencies on fossil fuels to produce heating. Starting from solar collectors to heat our spaces and water. The same kind of heat transmission can be used through geothermal heat pumps to produce heat. Within the heat sector most technology advances have come within the heat recovery spectrum. Emerging technologies such as home waste water heat recovery and sewage water heat recovery can be implemented within our cities to create more sustainable loops. Most of our daily electronics produce heat when being used, utility buildings such as supermarkets and data centres create a vast amount of heat through refrigeration, these buildings can be used as heat source for other buildings. These types of solutions use heat recovery to minimise heat production making the overall system better and more efficient. By using renewable heat sources and recovery implications we can create a smarter system that would have more significant effect on our world.
(data and information about technologies can be seen in the Annex)

4.3. Cooling

With hotter climate emerging, we must find solutions to cool of our buildings in hot summers. In the Netherlands there's a big consumption difference between housing and utility buildings. Where most utility buildings cool their buildings to create a comfortable work environment, it does not cool their housing buildings. Cooling units generally use electricity to power their production, as 54% of offices'' yearly consumption is being used for cooling (ECN, 2016).Because of the fact that most cooling units use electricity its primary source can be solved through green electricity production, but in order to reduce its consumption and production other solutions must be found. Therefore, by using renewable source, the Netherlands can cut its cooling consumption drastically. Technology such as geothermal cooling can be used to harvest the cold in order to help cool off buildings. Emerging technologies such as deep-water source cooling and deep-sea water cooling can cut cooling cost up to 90% (State of Hawaii Department of Business, 2002). These implications are very site based as these solutions cannot be implemented everywhere as passive systems should be implicated in order to reduce cooling consumption. All these technologies are based on a district cooling system centralising the production in order to create a more efficient system. Even when not using a renewable source, district cooling has promising potential with a 30% drop in electricity consumption, producing cooling in a much more efficient way (Rosen, et al., 2005).
data and information about technologies can be seen in the Annex)

4.4. Conclusion

Based on the technological findings, an analysis table was created in order to understand the technology's implication within the built environment. Even though extensive research was done into future renewable technology, the research would be a never-ending tale, because of the fact that there will always be new emerging technology. However, what truly matters is how these technologies will be applied within our cities or structures. Therefore, in order to maximise each technology's performance, the structure should focus on what its's trying to achieve. This type of approach can be correlated with the performative architecture design principle where performance is placed above or on par with form-making (Kolarevic, 2013). In this day and age sustainability has become such an essential factor that buildings should produce and not only consume. Thus, buildings should be performance-based, becoming part of a bigger picture not only consuming energy but becoming an area for production.

V. FUTURE CITY SCENARIOS

Based on future prognostications and technology findings a step process infographic could be created to facilitate these future ideas (figure 1). The step process is based on the idea to create new structures or cities with a future in renewable energy. However, in order to test the future city powerplant hypothesis, a simulation scenario had to be done. This research would help create different scenarios in order to analyse how different technologies and implications could change our cities.

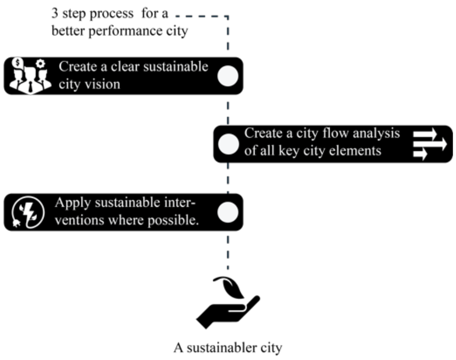


Figure 1. 3 step process (own image)

5.1. Kattenburg as an organism

For this research Kattenburg has been chosen as a case study, analysing and using its buildings in order to predict different types of future scenarios. Kattenburg is a prime location within the city of Amsterdam, with a vast amount of open spaces to build. Thus, creating the right situation for predicting future city scenarios.

In order to envision Kattenburg as a smart city, you will need to dissect and analyse its current situation. Kattenburg is currently build up out of 20th-century buildings, creating a nostalgic classical typology within the city. Based on the step process, a current flow chart could be made for Kattenburg. (Index figure 2) It illustrates that Kattenburg has a linear metabolism where most of its recourses exits the city as waste. Within this research we only focus on the energy flows of Kattenburg, therefore to create a more sustainable resilient city, we must harness its waste as resources in order to create a circular metabolism. On this notion, the following energy flow chart of Kattenburg was created (Annex figure 3).(Musango, et al., 2017)

On the basis of the energy flow charts, implications could be made to produce renewable energy for Kattenburg. Kattenburg does not currently produce any form of renewable energy, therefore to let Kattenburg run on renewable energy counter measures should be applied. By separating energy into tree flows we can determine what the yearly consumption of electricity, heating and cooling is. Based on the numbers and the step process, a new flow chart could be made where new DG's, and recovery systems are applied in order to create a more sustainable system. This creates a flowchart with potential implications where energy can be harvested. (Annex figure 3)

5.2. minimum implications

The current situation sees Kattenburg as a consumer, as any renewable intervention has not been done. Therefore, Kattenburg starts with a negative balance because there are already buildings consuming energy. In order to create different scenarios and energy predictions, an energy excel balance sheet has been created where consumption and production could be calculated. Consumption statistics are calculated on the basis of the type of building's square meters (ECN, 2016). Kattenburg consumes roughly a total of 13662905 kWh in a year, which is equivalent to two onshore wind turbines. Consuming 6015204 kWh of electricity, 902179.78 kWh for cooling and 2127594 m3 gas for heating. By implementing minimal implications such as solar panels (70%) and solar collectors (30%) on Kattenburg's building's rooftops, Kattenburg can produce 6457832 kWh of electricity and 9621547 kWh of heating yearly. Thus, already producing more electricity and half of the total heating that is needed. Therefore, By even applying the most basic measures you can already produce enough electricity. Thus by implicating even more interventions, the system could get smarter and better to a point where it produces more then it consumes. (Annex figure 4)

5.3. Kattenburg as a solar power & wind power plant

Decentralisation creates the opportunity to bring power generation closer to its consumer. Kattenburg could be seen as a prime location for Amsterdam's energy production. This scenario uses all of Kattenburg's footprint to produce electricity. Covering the area with solar panels could produce a total of 17181015 kWh per year, enough to power 5284 Dutch houses. Based on wind turbines proximity limitations, only three wind turbines could be placed on kattenburg's footprint. Thus, producing roughly 18000000 kWh per year, enough to power 610 Dutch households. These interventions could be placed simultaneously together using the terrain for wind and solar production, creating a renewable power plant within Amsterdam that is able to produce renewable energy for eleven thousand households, which counts as 2 % of Amsterdam's total households. Kattenburg counts as 0.0006% of Amsterdam's total square footage. Meaning that such a small area can already produce enough electricity for 2% of Amsterdam's total households. Even by using the bare minimum of renewable productions through solar and wind, Kattenburg as a power plant could have significant impact for the community, as a centre for renewable production within Amsterdam.(Annex figure 5)

5.4. Usable space

The first scenarios were based on Kattenburg's footprint and square meters of roof space, thus using open flat terrain for renewable interventions. A densely populated city does not have vast amounts of open space where renewable interventions could take place. Thus, cities must find other ways to maximise their renewable production. By incorporating solar glass, urban turbines and other renewable technologies within the city structures, cities could start using structures to produce the cities energy needs. Therefore, by using structures façades, the area of implications could be increased. However, this means that buildings should be designed with these implications in mind, meaning a city or building should be designed in a way that it maximises its performance.

5.5. Future scenarios

These numbers are based on yearly kWh consumptions and production, but when breaking down these numbers into summer and winter periods, we can see when the different DG's produce their most energy. From the last two scenario's, we can see that the most production is done during summer periods producing 72 % of the total yearly energy production. Therefore, in order to meet peak demands storage must be taken into consideration. Based on the current power-grid structure, EU foresees the smart grid as a giant battery where DG's can plug into. However, with the world moving towards more sustainable energy we must find ways to store power during off-peak times in order to meet high demands during peak times. This, also entails cold and heat storage, by storing heat during the summer for winter periods and vice versa.

By using the excel energy scenario program, different results could be manipulated in order to see how the fluctuation of summer and winter would vary. Hereby it can be concluded that by only focusing on solar energy it would have significant implication during the winter as huge storage would be necessary in order to facilitate winter peaks. However, varying the energy production winter and summer production could be facilitated by other means, therefore balancing the city's needs. However, storage will remain as one of the key factors within our city's power grid, as we move towards a decentralised power system, we must move toward decentralised power storages as well. (Annex figure 6 & 7)

5.6. Summer and winter periods

These numbers are based on yearly kWh consumptions and production, but when breaking down these numbers into summer and winter periods, we can see when the different DG's produce their most energy. From the last two scenario's, we can see that the most production is done during summer periods producing 72 % of the total yearly energy production. Therefore, in order to meet peak demands storage must be taken into consideration. Based on the current power-grid structure, EU foresees the smart grid as a giant battery where DG's can plug into. However, with the world moving towards more sustainable energy we must find ways to store power during off-peak times in order to meet high demands during peak times. This, also entails cold and heat storage, by storing heat during the summer for winter periods and vice versa.

By using the excel energy scenario program, different results could be manipulated in order to see how the fluctuation of summer and winter would vary. Hereby it can be concluded that by only focusing on solar energy it would have significant implication during the winter as huge storage would be necessary in order to facilitate winter peaks. However, varying the energy production winter and summer production could be facilitated by other means, therefore balancing the city's needs. However, storage will remain as one of the key factors within our city's power grid, as we move towards a decentralised power system, we must move toward decentralised power storages as well.

5.7. Conclusion

By creating different scenarios on Kattenburg, different outcomes can be made. This creates an endless loop of outcomes, but creates different conclusions on how a sustainable future city can be made. Based on the different scenarios it can be concluded that the vision of the scenario is what really matters. Because kattenburg's is being analysed as a whole every statistics is seen as a whole, and is not divided between buildings, thus seeing different statistics as a total goal and not an individual goal. This creates a new way of thinking where every building becomes part of a bigger picture and each one having its own role. Thus, by creating energy masterplans and city legislation you can determine how a building should take part of the city's energy consumption, for example creating an area where the sun is at his best in order for solar structures to produce energy or other sections for energy crops harvesting where biomass is planted to produce energy during the winters. By creating masterplans and city goals, the city could make significant impact on how the city operates. Therefore, by applying different energy strategies, we can create a more sustainable resilient city, where we gain the most out of our city by creating a circular urban metabolism.

VI. DISCUSSION

This research has looked at how future technologies and legislation could shape the future of energy production within our city. Based on the literature and research findings, cities can implicate different technologies to improve their sustainability. This research only looked at the architectural and urban planning implications of sustainable technologies, but it does not look at the finance expect of it. Within this power transition, there will also be a wealth transition, as these implications would require a vast amount of capital to implement. These shifts in capital could have significant impacts on our cities. Our current structures are owned by developers who do not take part in the energy businesses, with this paradigm shift in energy implications, what type of business do structures become? The EU sees neighbourhoods becoming part of the energy business, creating opportunities for locals to produce energy for the city (Gancheva, et al., 2018). This changes the socio-economics of consumers as they become active producers taking part in the energy problem (Gancheva, et al., 2018). Therefore, the finance expect of sustainable implications within cities should be part of the research framework, as it changes the way we think about city structures from investment to completion. Thus, in order to truly understand how our cities' will change with sustainability we must analyse the finances of our city structures, in order to understand from whom the investments would be coming from.

VII. CONCLUSION

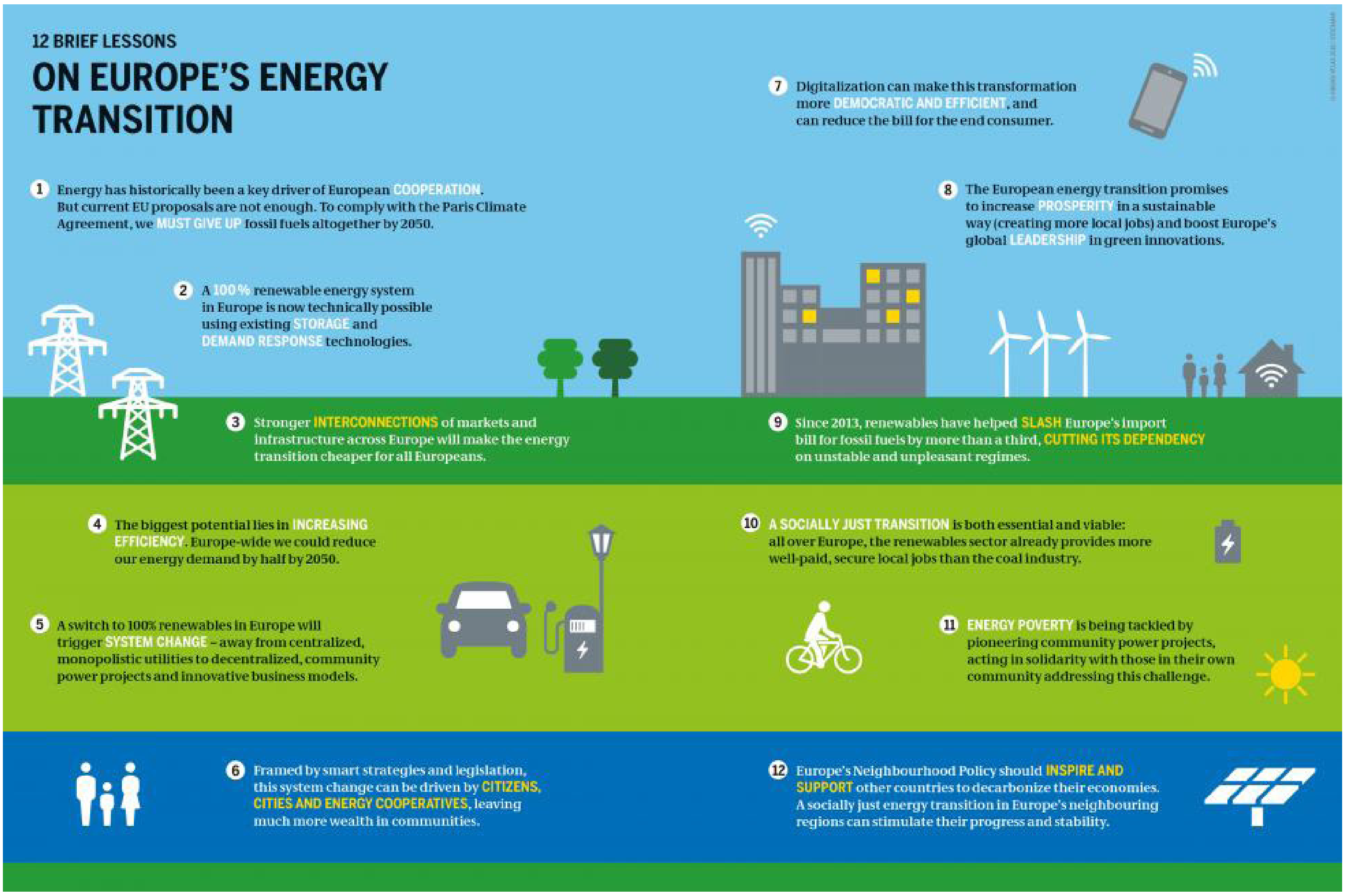
The built environment shapes our world, our cities and our communities. Therefore, in order to progress into a more sustainable future, we must rethink the way we look at our structures. By analysing our cities flows we can comprehend what our demands are, and what implications the city can implement in order to create a more sustainable resilient city. Based on legislations and technologies we are moving into a more decentralised energy structure where there is different distributed energy production. There will always be new technological innovations, but in order to implicate these innovations we must create a framework for them to be implicated. With advancements in the built environment, structures have become part of the energy transition producing their own energy in order to meet a zero-energy design goal. Based on the energy scenario predictions, a sustainable future can be created by looking at our energy problem as a city scale problem and not as a single structure problem. Therefore, by looking at it as a whole we can communally solve the problem, becoming more sustainably active. Thus, this paradigm shift of energy production in our city will change the way we look at structures. On this basis, we can answer the main question: How will renewable energy be produced in our future city and how would It change our public perception of power plants? There will be an abundance of ways to produce energy within our cities, but with the transitions from centralised to decentralised systems our city energy structure will change. In the future, structures will become future power plants, producing more energy than they consume. Therefore, being part of a bigger picture producing what is needed to solve the city's energy demands. This creates a new framework within our cities, where cities become energy smart from planning to execution taking everything into their own hand. Using planning to optimise energy production, regulating energy production zones, creating new sustainable business ventures and in the process changing the powerplant perspectives from a private dirty plant to a normal sustainable city structure. This energy transition will fuse energy production with our daily lives, bringing us into an age off a sustainable resilient energy independent city.

REFERENCES

1. Ritchie, H. & Roser, M., 2017. *CO_2 and other Greenhouse Gas Emissions.* [Online] Available at: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions
2. United nations department of Economic and social affairs, 2018. *Urbinazation prospects.* [Online] Available at: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html
3. BP energy economics, 2018. *BP Energy outlook 2018,* s.l.: BP.
4. Energie vergelijken, 2018. *Energie productie in Nederland.* [Online] Available at: https://www.energievergelijken.nl/nl/energiemarkt/energieproductie-in-nederland
5. European Union, 2018. *2020 climate & energy package.* [Online] Available at: https://ec.europa.eu/clima/policies/strategies/2020_en
6. Climate home news, 2017. *Energy.* [Online] Available at: http://www.climatechangenews.com/2017/10/11/netherlands-agrees-coal-phase-calls-stronger-2030-eu-emissions-target/
7. Böll , H., 2018. *Energy Atlas.* Germany: Heinrich Böll Foundation, European Renewable Energies Federation.
8. Karger , C. R. & Hennings, W., 2007. Sustainability evaluation of decentralized electricity generation. *Renewable and Sustainable Energy Reviews 13,* p. 583–593.
9. Washburn , D. & Sindhu, U., n.d. *Helping CIOs Understand "Smart City" Initiatives,* 2010: Forrester.
10. Chourabi, H. et al., 2012. Understanding Smart Cities: An Integrative Framework. *45th Hawaii International Conference on System Sciences,* pp. 2289-2297.
11. Research Group of the Department of Urbanism – Delft University of Technology, 2018. *urban metabolism.* [Online] Available at: https://urbanmetabolism.weblog.tudelft.nl/what-is-urban-metabolism/
12. CE Delft, 2016. *Top 10 milieubelasting van de gemiddelde consument,* Delft: CE delft.
13. ECN, 2016. *Nieuwe benchmark energieverbruik utiliteitsgebouwen en industriële sectoren,* s.l.: ECN.
14. State of Hawaii Department of Business, 2002. *SEA WATER DISTRICT COOLING FEASIBILITY ANALYSIS,* Hawaii: Department of Business, Economic Development & Tourism Energy, Resources, and Technology Division.

15. Rosen, M. A., Le, M. N. & Dincer, I., 2005. Efficiency analysis of a cogeneration and district energy system. *Applied Thermal Engineering,* 25(1), pp. 147-159.
16. Kolarevic, B., 2013. Computing the Performative in Architecture. *eCAADe digital design,* Volume 21, pp. 457-464.
17. Musango, J., Currie, P. & Robinson, B., 2017. *Urban metabolism for resource efficient cities: from theory to implementation,* Paris: Paris: UN Environment..
18. Gancheva, M., O'Brien, S., Crook, N. & Monteiro, C., 2018. *Models of Local Energy Ownership and the Role of Local Energy Communities in Energy Transition in Europe,* Belguim: Commission for the Environment, Climate Change and Energy.
19. Karger , C. R. & Hennings, W., 2007. Sustainability evaluation of decentralized electricity generation. *Renewable and Sustainable Energy Reviews 13,* p. 583–593.
20. Kaundinya, P. D. & Ravindranath, P. B. . N., 2009. Grid-connected versus stand-alone energy systems for decentralized power—A review of literature. *Renewable and Sustainable Energy Reviews 13,* p. 2041–2050.

Annex

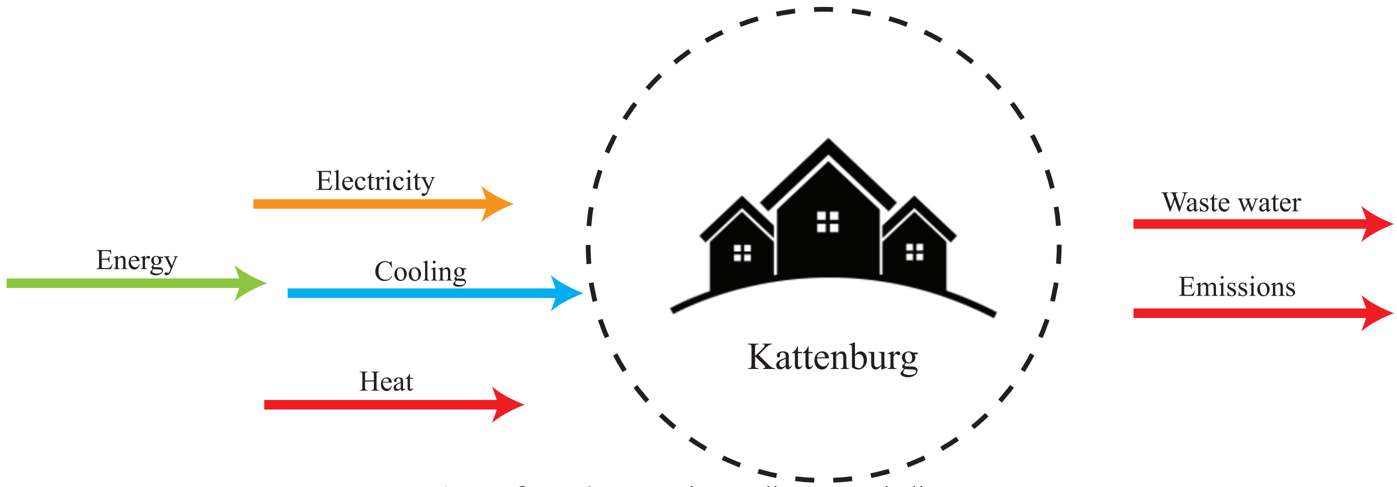


Annex figure 1: Europe's energy transition
(Energy atlas Europe. (n.d.). 12 brief lesson Europe energy transition [Digital image].
Retrieved from https://gr.boell.org/en/2018/05/10/energy-atlas-nutshell)

Figure 2

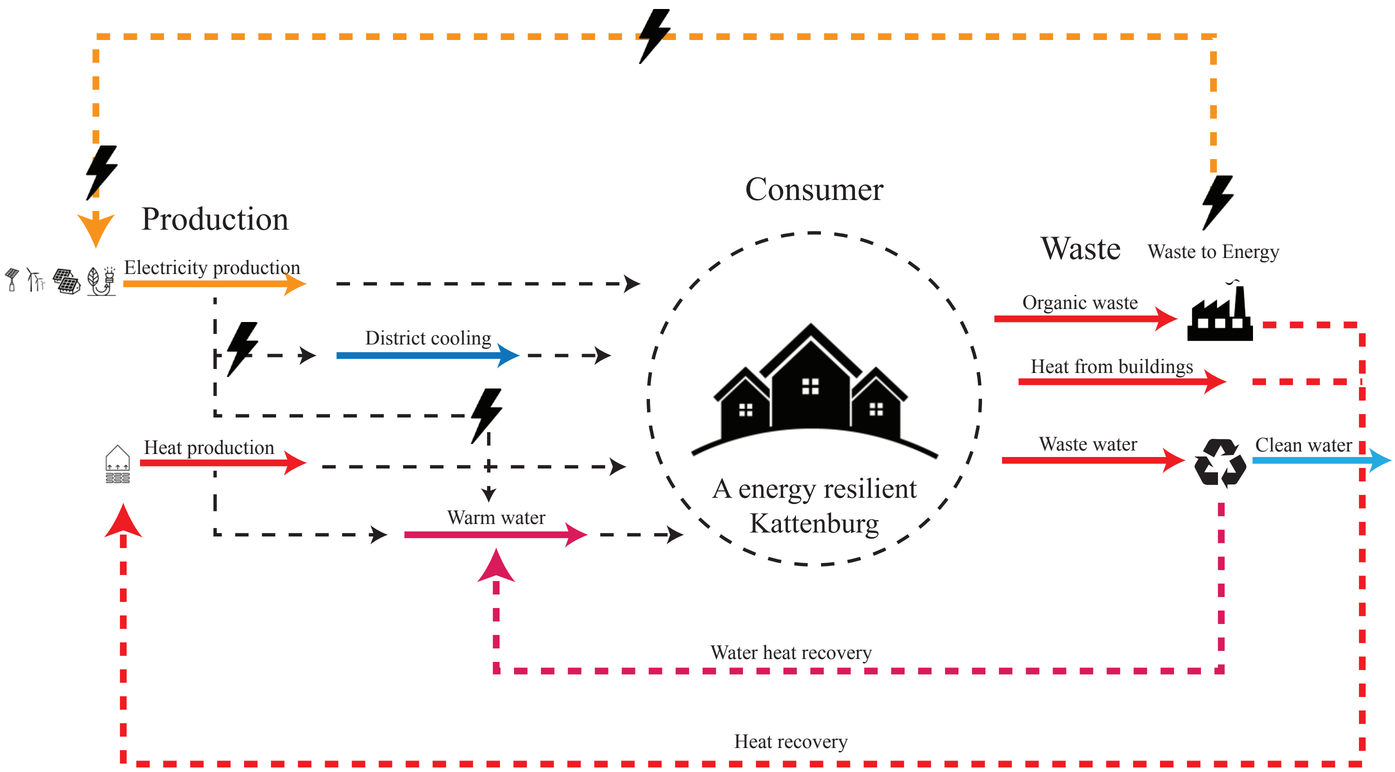
Annex figure 2: Katten burger linear metabolism
(own image)

Figure 3



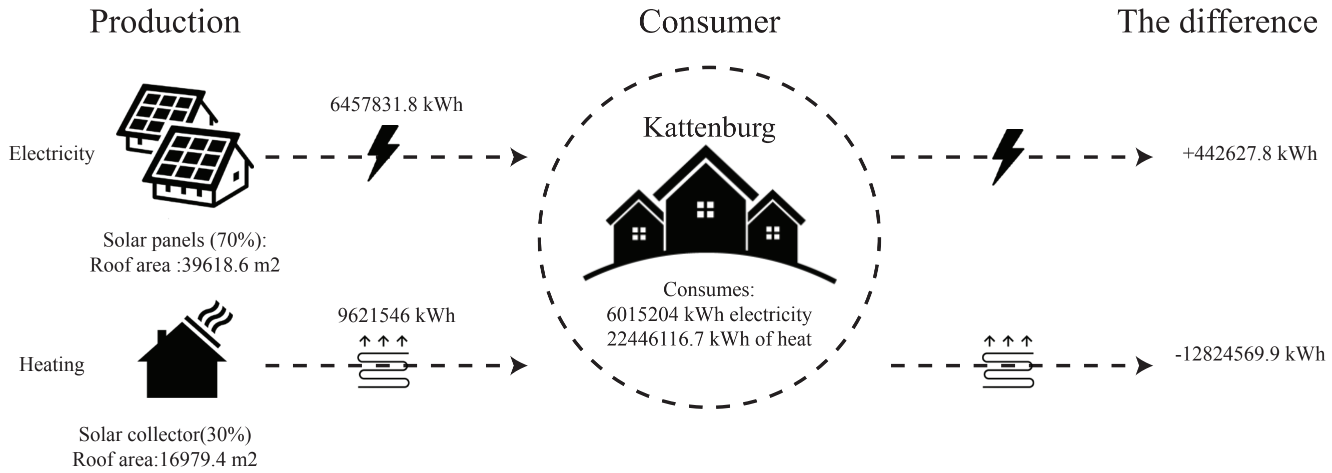
Annex figure 2: Katten burger linear metabolism
(own image)

Figure 4



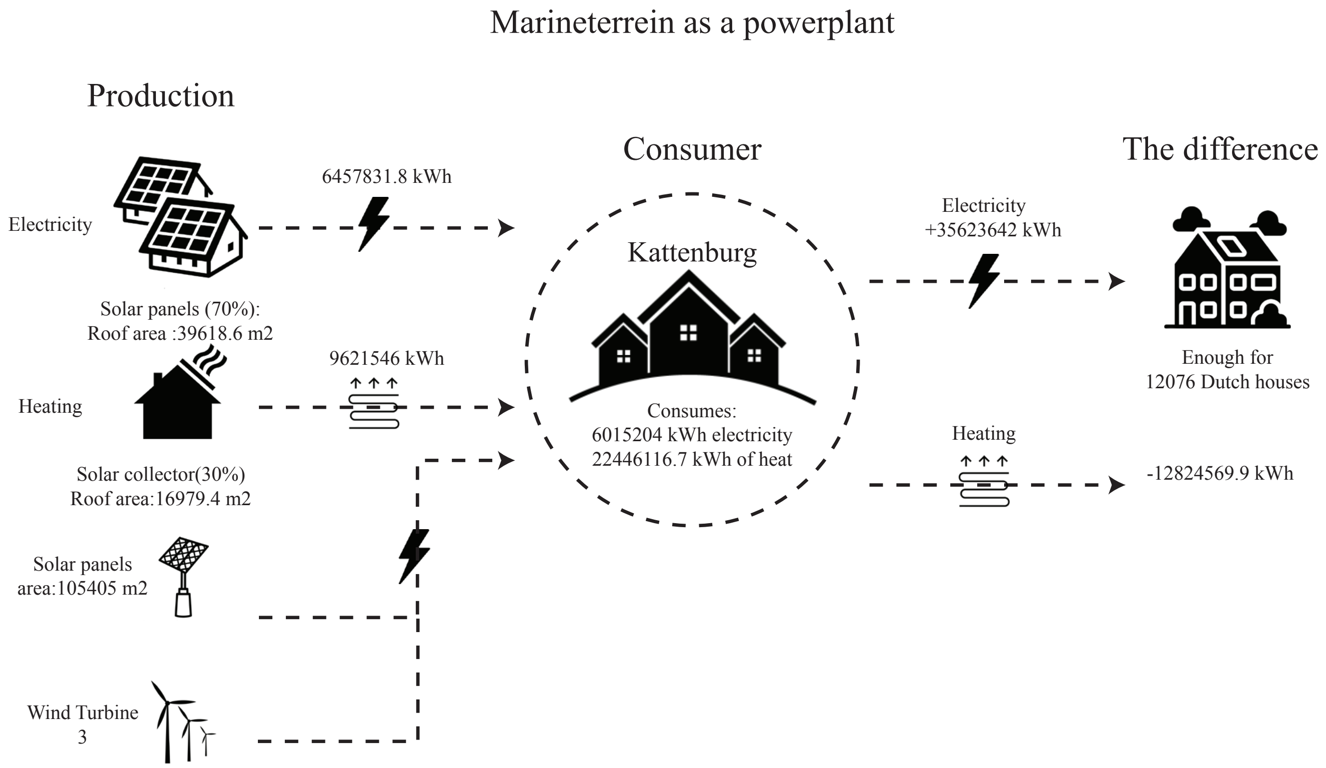
Annex figure 3: Katten burger Potential implications
(own image)

Figure 5



Annex figure 4: Katten burger minimum implications
(own image)

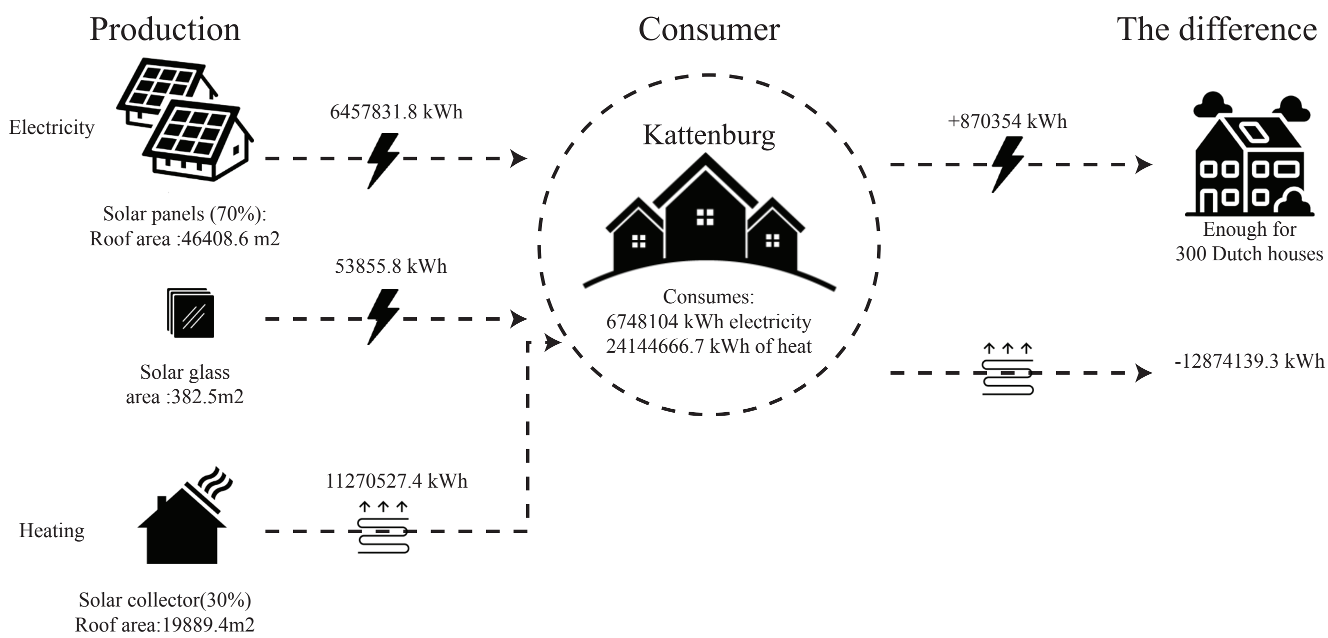
Figure 6



Annex figure 5: Marine terrein as a powerplant
(own image)

Figure 7

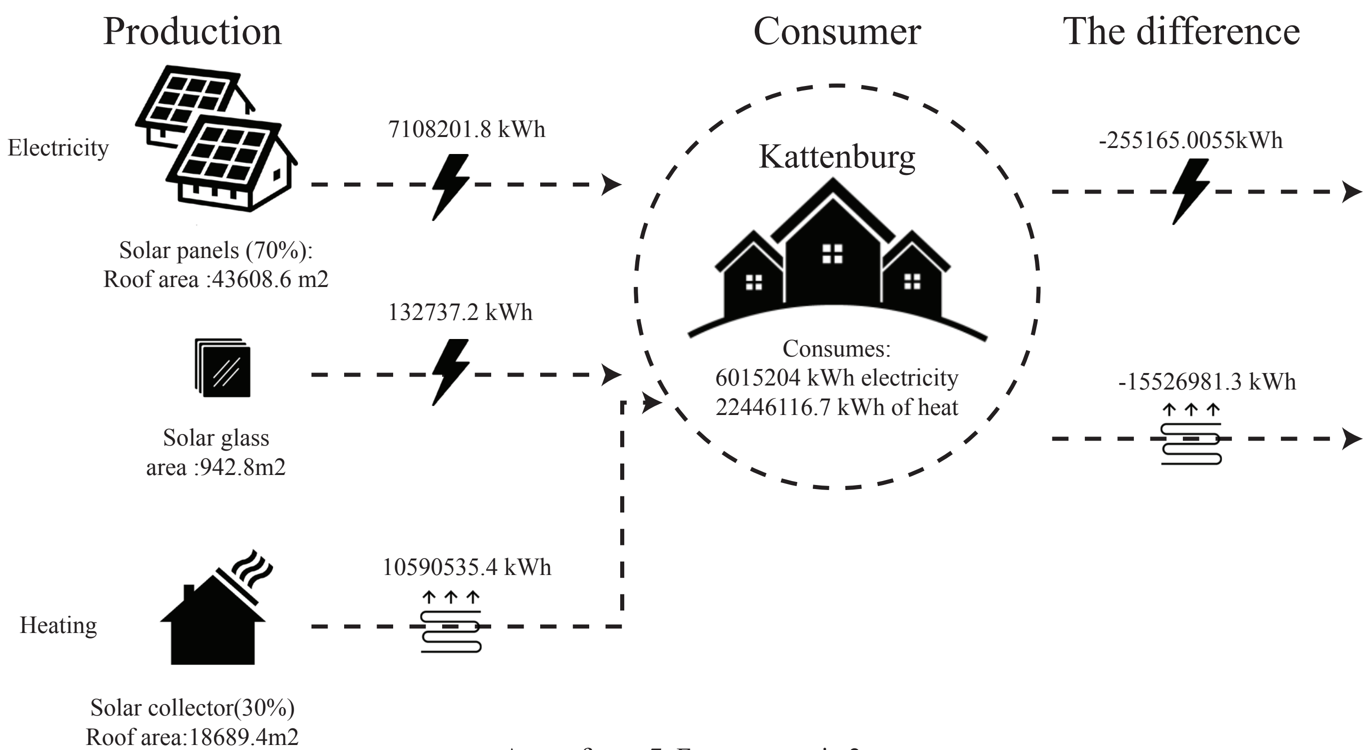
Future scenario 1 (1 floor)



Annex figure 6: Future scenario 1
(own image)

Figure 8

Future scenario 2 (5 floors)



Annex figure 7: Future scenario 2
(own image)

Electricity production

Technology	Applicability	Technology ready	Aesthethics	Production
Printable Photo Voltaic	Can be printed on anything	in 5 years	Built within materials/ invisible you can say	produces about 87.8 Kwh yearly per m2
E-Plant technology	Can be placed as green spaces. Can not be walked on	ready for small scale larg scale--> 10 years	Looks like greenery	3 W per m2
Waste water energy through microbial fuell cell	Waste water centers or building black water systems.	testing phase in 10 years	can't be seen , technology outside of public view	no info yet, speculations saying tha tits enough to produce energy for water treatment
Vivace hydro	Slow current streams	Tested market ready 10 years	on the bottem of rivers or channels	182815 kWh yearly per m2
Nemoi wind turbine	anywhere	Market ready	Very big , can be seen as obstructing someones view	Enough energy for one household
Pavegen	Walkways	Ready	easy to spot, and able to interact with people	each step produces around 0.00117 kWh yealy
Energy crops	Greenhouses	Ready	can be seen as agriculture	produces around 8.76 kwh yearly per m2
Wind power	open fields	Ready	Are accepted outside of city's. people sees them as obstructing their view	6000000 kWh yearly around 200 hous-es
Solar power (panels)	almost everywhere	Ready	Accepted	163 kWh yearly per m2
Solar glass	For glass stuctures	Ready	Cant break the barrier between the solar visibility	140 kWh yearly per m2

Electricity production technology "aesthetics" analyses
(own image)

Heat production

Technology	Applicability	Technology ready	Aesthethics	Production
Geothermal heating vertical	Combined with structure foundation	Ready	not visible	produces about 438 kWh yearly per foundation pile (30 meters deep)
Geothermal heating horizontal	minimum 2 meter deep, can be applied under someone's backyars	Ready	not visible	produces 219 kWh yearly per m^2
Solar collector	rooftops or ground	Ready	accepted within the sustainble world	produces about 566.66 kWh yearly per m^2
Biomass heating	anywhere	Ready	seen as a factory plant, nos as some-thing that pleases the eye	8.76 kWh per squaremeters based on energy crops.
Heat Recovery	from buildings,waste water,	REady	not visible	depends on the source

Heat production technology "aesthetics" analyses
(own image)

Cooling production

Technology	Applicability	Technology ready	Aesthethics	Production
District cooling	anywhere	Ready	are built like nearby buildings to fit within surrounding	30 % more efficient then conventional air conditioning
District seawater cooling	Near sea	Ready	are built like nearby buildings to fit within surrounding	70-90 % more efficient then conventional air conditioning
District deep water cooling	Deep lake or sea needed	Ready	are built like nearby buildings to fit within surrounding	70-90 % more efficient then conventional air conditioning

Cooling production technology “aesthetics” analyses
(own image)

Technology	Source
Printable photo voltaic	Kovalenko, Alexander & Hrabal, Michal. (2017). Printable Solar Cells. 10.1002/9781119283720.ch5.
E-plant technology	https://www.plant-e.com/en/informatie/
Microbial fuell cell	Omine, K., Sivasankar, V., & Chicas, S. D. (2018). Bioelectricity Generation in Soil Microbial Fuel Cells Using Organic Waste. Microbial Fuel Cell Technology for Bioelectricity, 137-150. doi:10.1007/978-3-319-92904-0_7
Vivace hydro	http://www.akenergyauthority.org/Content/Programs/EETF/Documents/Round_1/040.pdf
Nemoi wind turbine	https://semtive.com
Pavegen	http://www.pavegen.com
Energy crops	http://www.ee.co.za/article/biofuel-and-energy-crops-for-electricity-production.html
Wind Power	https://sciencing.com/much-power-wind-turbine-generate-6917667.html
Solar Power	https://www.energieleveranciers.nl/zonnepanelen/opbrengst-zonnepanelen
Geothermal heating vertical	https://warmtepompenadvies.nl/geothermische-warmtepompen-grondwater/
Geothermal heating horizontal	https://warmtepompenadvies.nl/geothermische-warmtepompen-grondwater/
Solar collector	https://www.energievergelijken.nl/nl/zonnepanelen/zonnecollectoren
Solar glass	https://www.onyxsolar.com/r-d
Heat recovery	Ebrahimi, K., Jones, G. F., & Fleischer, A. S. (2015). Thermo-economic analysis of steady state waste heat recovery in data centers using absorption refrigeration. Applied Energy, 139, 384-397. doi:10.1016/j.apenergy.2014.10.067
District cooling	06/01220 Efficiency analysis of a cogeneration and district energy system. (2006). Fuel and Energy Abstracts, 47(3), 183. doi:10.1016/s0140-6701(06)81224-5
Deep water cooling / seawater cooling	Rosen, M. A., Le, M. N. & Dincer, I., 2005. Efficiency analysis of a cogeneration and district energy system. Applied Thermal Engineering, 25(1), pp. 147-159. State of Hawaii Department of Business, 2002. SEA WATER DISTRICT COOLING FEASIBILITY ANALYSIS, Hawaii: Department of Business, Economic Development & Tourism Energy, Resources, and Technology Division.

Technology sources
(own image)