MINING FOR BLACK WATER:

AN IMPROVEMENT OF THE RESOURCE EFFICIENCY OF PARKSTAD

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ABSTRACT

'Mining for black water demonstrates how Parkstad can make use of its environmental deficit of the past to shape its future. By generating an overview of the input and output on energy, water and materials of the urban metabolism of Parkstad Limburg, a strategy is proposed to improve the resource efficiency. The aim of this paper is to determine guidelines and spatial requirements for the design of a raw material and water treatment park. This facility closes water and waste cycles and induces new possibilities to generate energy. All in all it will strengthen the social, economic and environmental structure of Parkstad.

KEYWORDS: *Urban Metabolism, Parkstad, Raw Materials, Waste Management, Water Cycle*

I. INTRODUCTION

Economic and social growth are strongly accompanied by an increasing amount of waste, causing unnecessary losses of materials and energy (Lema, Suarez, 2017, p. 325). As a society we have already consumed a vast amount of freshwater, fertile silt laden land and energy from fossil fuels. This rapidly altered our climate, depleted natural resources, disrupted ecosystems and severely damaged biodiversity (Zhang, 2013, p. 464). To this day, our energy and raw materials are still mainly sourced from oil reserves, fossil fuels and surface minerals. However with the worldwide growing population, these fossil fuel resources are depleting. In order to maintain our population, we have to change the relationship between people, energy and the environment in the coming decades. We need to understand the relation between the consumption of resources and the production products and wastes and learn to design in such a way that local resources are optimally seized before an demand is posed upon other areas. Moreover, to ensure a sustainable future, an urgent increase is required in energy generated through the use of renewable sources and circular waste streams. In order to build a better and more sustainable environment, it is important to take local available resources into account when designing and making plans (Dobbelsteen, Stremke and Broersma, 2012, p. 171). Jongert, Nelson and Korevaar (2015, p. 2) introduced the term *'cyclifier'* to identify a type of actor that improves the urban metabolic efficiency.

This context-led research aims to explore the current urban metabolism of Parkstad Limburg to understand if energy, water, materials and nutrients are used efficiently and to find out where a cyclifier could be integrated to decrease system-level inputs and outputs. By creating symbiotic systems that simultaneously increase the resource efficiency and incorporate the spatial characteristics, a sustainable solution is found for the whole region. In this research the past of Parkstad is the frame of reference. Exploring the existing qualities and describing the essential characteristics and weaknesses of the region formed a basis of the research.

II. FORMAT GUIDE

The research describes the urban metabolic dynamics of Parkstad in the sense of flow approach. In order to do so a Material Flow Analysis (MFA) is necessary that focusses on the flow of energy, water and materials. It generates an overview of inflow, outflow and accumulations of materials in the system and it provide an improved understanding of the functioning of Parkstad to react to present and future material stocks and flow issues. To carry out a MFA quantitative and qualitative data is collected by literature studies, interviews and a site visit. Next to that, Energy Potential Mapping is carried out to include local available opportunities and to quantify all different local potentials. This data is derived from several platforms such as Atlas Living Environment, PDOK and ArqGIS software.

The systematic approach of these two methods lead to a set of possible interventions and form a regional strategy. It also determines where in the urban metabolic system a cyclifier could improve the resource efficiency. The second step in this research is to formulate a program of requirements for one of the interventions. The spatial conditions are based on case studies and literature reviews.

1. Parkstad, a former Mining Area

To provide inspiration for the architectural design the first step of the research is to understand the cultural and socioeconomic context of Parkstad. This helps to determine the site-specific and unique characters and establishes the limits. Moreover it bridges the gap between the scientific model and the need of the city and its everyday users. The first chapter discusses the findings of the historical, spatial and demographical analysis. By establishing the dialogue between the past and the future, and utilize existing resources, sustainable architectural and social design solutions can be created.

1.1 History of Parkstad

The landscape of Parkstad underwent a high amount of spatial and organizational adjustments over the last centuries. During the 19th century this formerly agricultural area in the South of Limburg rapidly developed as the Dutch epicenter for coal mining. Coal mining did not only become the most economic and social facet of this region, it structured the landscape as well. By that time there was no clear regional expansion plan for the whole mining area. New mining colonies developed around the mines far away from the existing settlements and scattered across the rural area (Geest, 2013, p. 23). Due to the lack of transportation options and to avoid investments in new roads the mine workers needed to live within walking distance to their work. Fragmentation was and still is a result of it. This so called amorphous urbanization is a consequence of the regions history, which is heavily characterized by coal mining. Therefore it is an example of an energy landscape in which land-use and settlements are based on energy, more specifically fossil fuels (Gordijn, Verwest and Hoorn, 2013, 2003, p. 19).

The mining industry disappeared as quickly as it emerged. Due to the large-scale introduction of natural gas and the increasing labour costs, the viability of the mines decreased. In 1965 Den Uyl decided to close the mines and return the landscape to grassland. After closing the mines in 1974 the region underwent an unprecedented redevelopment program (‘from black to green’). To this day only a hand full of monuments memorises the mining industry (Jong, 2004, p. 231).

1.2 Current situation

With the disappearance of the mining industry in 1974 Parkstad is now suffering from environmental, economical and social issues such as changing demography, unemployment, low education levels, high vacancy rates, identity loss and a lack of social cohesion (Hoekeld, 2014, p. 63). Therefore Parkstad became more isolated and disconnected with the rest of the region. However if you take a closer look, one can see the quality of the area. The quality of Parkstad can be found in the landscape. As a result of the redevelopment program the greenery and natural elements offer a great living environment. (Dritty, 2011, p. 15). According to the

Parkstadmonitor, a platform where the inhabitants are asked to give their opinion about the current state of the region, they are overall very satisfied with the current conditions of their living environment, especially the high amount of greenery (Parkstad Stadregio Limburg, n.d.). Yet it is the mining past which is still deeply rooted in the social life that was taken away from them (Croé et al, 2005, p. 4). Moreover due to the mining past a scattered landscape was left behind which disrupted the ecological national network (Croé et al, 2005, p. 22).

2. Urban Metabolism Parkstad

Before one is able to understand the urban metabolism of this region and what interventions could improve the resource efficiency, a Material Flow Analysis is carried out. This paragraph describes the most important findings of the energy, waste and water flows. The image below displays an overview of the points of discussion.

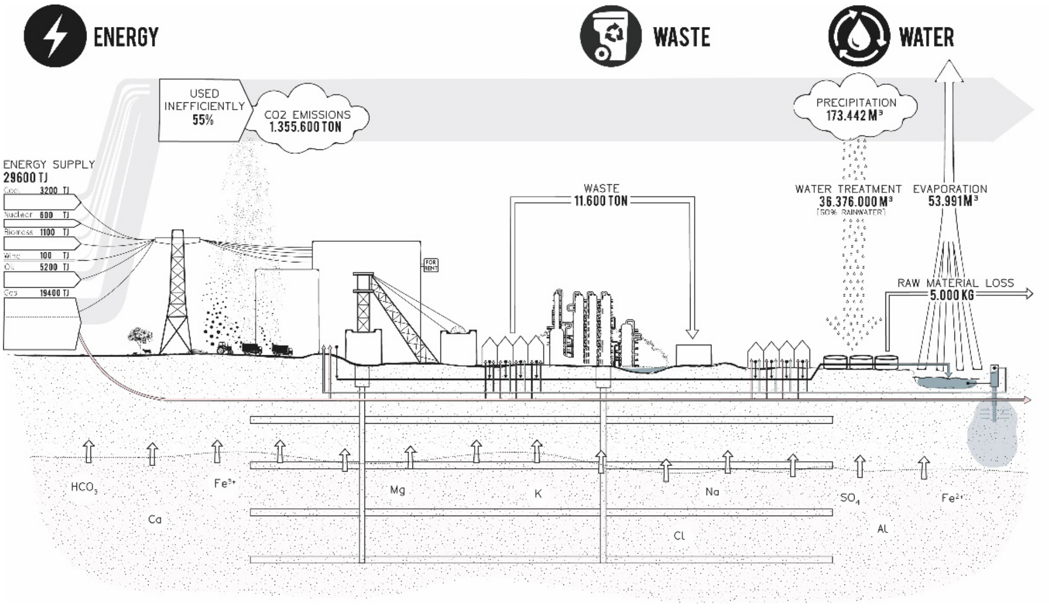

Image 1: Urban metabolism Parkstad, Own image

2.1. Energy

Parkstad is currently working on the transition of the energy supply. To this day the whole region is using a lot of fossil fuels to fulfil the entire energy demand just like they did in the past of the mining period. Therefore the board of the Parkstad region asked the University of Wageningen, Zuyd Hogeschool and H+N+S Landscape architects to explore the current energy demand, its consumers and how they could anticipate on the future using new types of renewable energy sources. According to this research the total amount of primary energy sources that is used in Parkstad is 29600 TJ per year (Delheij et al, 2016, p.10). Households and offices are the biggest consumers. The industrial and the agricultural sector are using a relatively small amount of the total energy demand. One of the main resources that is currently used is natural gas (65,5%). This energy source is mostly used for heating the houses, offices and industries, the rest is converted into electricity at the power plants. Appendix I displays an overview of the natural gas network in The Netherlands and the power plants. Another fossil fuel that is supplying the energy demand of Parkstad is coal (10,8 %). The coal is imported overseas from South-Africa, Colombia and Indonesia and shipped to the harbour of Rotterdam (Ministerie van VROM, 2008, p. 51). As the Netherlands mainly functions as a transit country for coal, only a small amount of the entire coal supply is used to generate electricity, the rest is transported to the Ruhr area (Ministerie van VROM, 2008, p. 53) (Appendix II). Looking at the energy flow of Parkstad, it becomes clear that a large part of the incoming energy is used inefficiently. The reason of this is probably the low efficiency of the power generation facilities. The heat that is released during combustion of the fossil fuels is party generated into electricity. The rest is lost to the surface water and the atmosphere (Delheij et al, 2016, p. 10). Furthermore nuclear energy, biomass and wind energy also contribute to the energy supply for a very small amount, 2,1 %, 3,7 % and 0,3% respectively.

Another primary energy source that is largely used is oil (17,6%). Motor vehicle engines are probably even less efficient than the power generation facilities. Only a quarter of the fuel is transposed in movement, the rest is going to waste in the form of heat as well. The usage of these fossil fuels comes with a price: air pollution. According to the Cluster Milieu Onderzoek en -advies (2016, pp. 26-58) the fine dust concentration PM2.5, hence the concentration of PM10, around Heerlen and Kerkrade is the highest in comparison with the rest of the Netherlands. The average value for the Netherlands is 12.5 $\mu g/m^3$, whereas in Rotterdam, Amsterdam and Heerlen/Kerkade this value is 14.1, 13.5 and 15.2 respectively. The higher value is mainly caused due to the fact that the air quality of Limburg is also influenced by foreigner countries such as Germany and Belgium Cluster Milieu Onderzoek en -advies (2016, p. 29). Nonetheless the limit value is not yet exceed (25 $\mu g/m^3$). However, according the Landelijk Meetnet Luchtkwaliteit (2019), who monitors the concentration of PM2.5 in the Netherlands, a value of 27 $\mu g/m^3$ was measured on 23th of May 2019 at the Looierstraat in Heerlen (Appendix III).

All in all it seems that a high amount of energy and heat is wasted, hence there is a huge potential for energy saving and benefits to transform the current energy demand into renewable energy sources such as wind energy, solar energy, geothermal energy and energy from biomass (Appendix IV).

2.2. Waste (incl. Nitrogen & Phosphate)

Understanding the flow of nutrients is vital for a successful urban sustainability. Nutrients may remain in the urban system through accumulation in the soil or groundwater by inadvertent losses or direct disposal through nutrient recycling. It shows which natural nutrient flows are altered in the human-dominated ecosystem (Kennedy, Cuddihy, Engel-Yan, 2007, p. 54). Therefore in this study the flow of nutrients is also included. There are two key nutrients: nitrogen and phosphorus.

Sewage sludge consist of a high amount of nutrients and other valuable raw materials. In Parkstad approximately 5.526 ton of sewage sludge is produced every year. In total 42% of the entire amount of sludge that is treated in Limburg, is dewatered and dried by a sludge-dryer in Susteren into granulate. After this, it is partly shipped to the concrete factory ENCI in Maastricht where the sludge is used to power the cement kiln. The ash that is left over after incineration is used as well. The other part of the sewage sludge is going to the sludge treatment company SNB in North Brabant where it is generated to energy (Waterschapsbedrijf Limburg, 2017, p. 24). The purification of wastewater and the treatment of sewage sludge is an energy consuming and complicated process. Therefore the market for the sewage sludge is shrinking. Within a few years the contract with ENCI and SNB end, which means that there is no market anymore where the sludge is used (Waterschapsbedrijf Limburg, 2017, p. 24). WML decided to process 75% of the entire sludge into biogas to power their facilities for the coming period until they find another solution. This process does not recover the valuable resources from sewage sludge. Therefore a lot of nutrients and other raw materials are wasted (Waterschapsbedrijf Limburg, 2017, p. 41).

Other than sewage sludge, there is household waste. There are four recycling centers where household waste is collected from underground containers by the company Rd4 (Rd4, n.d.). Moreover the company Afvalzorg is taking care of the waste treatment of demolition and construction waste (Afvalzorg, n.d.). Lastly the company Attero, situated in Landgraaf, recovers energy and raw materials from waste (Attero, n.d.). At this transfer station waste is dumped and treated. They are in possession of their own incinerator and waste water treatment plant (Rijkswaterstaat Ministerie van Infrastructuur en Waterstaat, 2019). Attero produces biogas, which is partly going to German households (Attero, n.d.). In appendix V an overview is displayed of the type waste and the positions of the waste companies in Parkstad (CBS, 2018).

2.3. Water

If we want to close our material loops we also need to look at the amount of waste water that is produced by households and factories. Water is an essential element for all life and many, if not all, industrial processes.

2.3.1. Mine water

Water is an important point of attention, especially in Parkstad due the mining history. After closing the mines water measures continued for many years at the Beerenbosch pump shaft to protect the Dutch territory against the mining activities in Germany. When the Germans finally closed the last German mine in 1992, the dewatering measures were halted in 1994. Meanwhile, all the abandoned mining corridors in the northwest and centre of the mining district have been flooded (Heitfeld et al, 2016, p. 118). Mine workers used several kind of lubricants and chemicals for the rock drills and machines. During a visitation to the Mine Museum in Heerlen, Martin Hermans mentioned that a high amount of machineries, cables and other tools where left underground after the termination of the mines. Also the coal layers are full of Pyrite (FeS_2). The reaction of Pyrite in combination with the mine water will form sulphuric acid and can have an impact on the environment in surrounding areas (Heitfeld et al, 2016, p. 92). One of these problems is acid mine drainage (AMD). AMD is the result of sulphide, typically pyrite in coal seams, where the pyrite is exposed to oxidising conditions in coal mining to produce sulphuric acid (H_2SO_4) and metal precipitates such as Fe (Dang, Dang, 2017, p. 1). The Mine Museum monitors the rising mine water and stated that the water is rising 2 centimetres per month. The chance that these polluting chemicals and lubricants will blend with the mine water is quite high (Dijk, 2017). Therefore rising mine water could be a threat for existing drinking water wells (Wolkersdorfer, Bowell, 2004, p. 168). To this day there infiltration of mine water into the drinking supply did not occur. The time it takes until the final state of the mine water level is reached is estimated to be at least 20 years from now (Heitfeld et al, 2016, p. 119). Therefore it should be noted that the main threat to groundwater quality will appear within this time frame.

The mine discharges have been sampled since the start of the mining activities at several monitoring locations and different layers underground. This data is available since 1970 for individual wells (WML, 1970-2014). Heitfield et al (2016) generated a composition of the mine water at different levels underground (Appendix VII). These show that sulphate and chloride are largest treat to groundwater quality in the impact area (Heitfeld et al, 2016, p. 124).

Unfortunately the after-effects of the mining activities do not end here. The rising water levels could also lead to sinkholes and mass shifting of the ground (Heitfeld et al, 2016, p. 14). Currently ground heave has been observed induced by mine water. It is measured that the level of the ground already raised with 300 to 350 mm around several mine concessions (Heitfeld et al, 2016, p. 26). In the future a maximum of further 100 mm to 170 mm is expected (Staatstoezicht op de Mijnen, 2014, p. 7). For the future 40 years it is expected that the impacts due to the rising mining water is restricted in terms of location and severity (Heitfeld et al, 2016, p. 122). Heitfeld et al (2016, p. 122) states that the most important risk arise from the mine shafts, which is independent from the future rise of mine water. Therefore it is necessary to monitor the water quality and the quantity of the ground. Currently there are only five monitoring points where the water is monitored. Heitfield et al. (2016) propose to construct new monitoring points and observation wells at the Maurits/Emma concession area, the Emma concession and the Oranje Nassau to measure the developing groundwater quality and to monitor the rising heads (Heitfeld et al, 2016, p. 122) (Appendix VII).

2.3.2. Fresh water

Fresh water is provided by the water company *Waterleiding Maatschappij Limburg* (WML). The water is derived from both ground and surface water. Currently the groundwater in Limburg is still of good quality and therefore 75 % of the drinking water exists of groundwater. In order to keep the underground water levels in balance, approximately (25%) of the drinking water is surface water (including rivers, lakes and rain water) (WML Limburgs Drinkwater, n.d.).

WML is responsible for the transport and the treatment of the waste water in the whole province of Limburg. In Parkstad the waste water is transported to four different waste water treatment plants: Kaffeberg (Kerkrade), Rimburg (Landgraaf), Hoensbroek (Heerlen) and Simpelveld (Simpelveld). The four waste water treatment plants use different techniques in order to purify the water. The water treatment facility of Simpelveld uses a relatively new technique: the Nereda technology, which is a sustainable and innovative way of cleaning the water. The benefits and advantages of this technology is further explained in chapter 4. The collected waste water that ends up in the sewage system is treated to a certain extent, before it is discharged to the surface water again. The points where the water is discharged are: Worm (Rimburg) Caumerbeek (Hoensbroek), Andselderbeek (Kaffeberg), Eijserbeek (Simpelveld) (Waterschapsbedrijf Limburg, 2017, p. 41) (Appendix VIII).

Regarding the water outflow, it is assumed that 50 % of the waste water does not end up in the sewage system (Appendix IX). The rest of all the rainwater is discharged on the waste water treatments plants. During long-term rainfall and heavy rain showers, the waste water treatment plants are overloaded with rainwater could lead to problems in the entire region.

To conclude this chapter this metabolic scheme shows the most important factors that are currently active in the field of water, energy and materials.

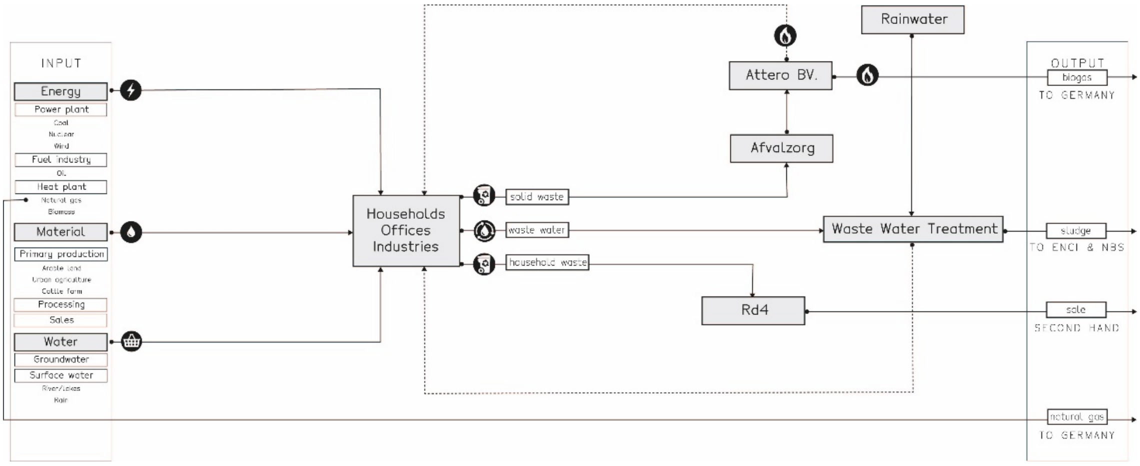

Image 2: Metabolic scheme Parkstad, own image.

The sum of the pains are mapped to see where in Parkstad interventions could be implemented.

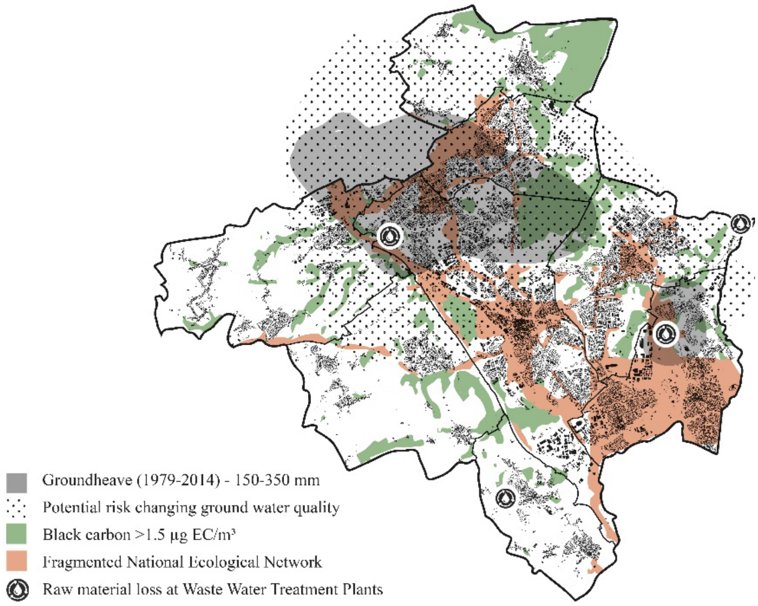

Image 3: Problem Map, own image. (Appendix X)

3. Opportunities & potential interventions

In this chapter potential interventions are explained to achieve a resource efficient urban metabolic system. Image 4 shows a future scenario, a strategy which incorporates 1) rechanneling energy 2) recollecting resources and 3) creating biotopes.

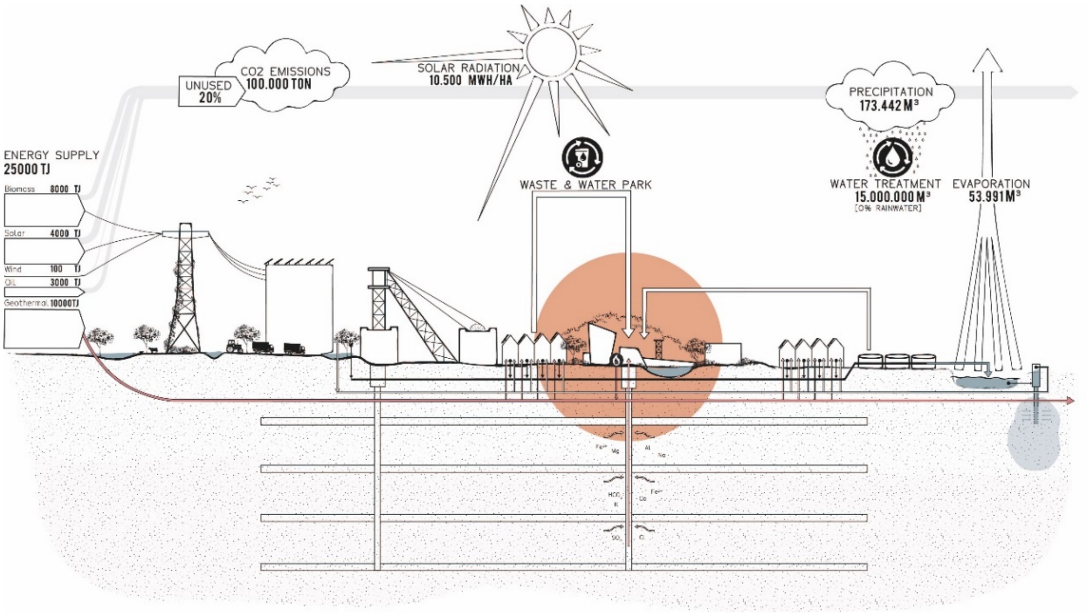

Image 4: Urban Metabolism - Future scenario after strategy, own image.

3.1. Energy – channelling energy waste

Parkstad is using almost 96% fossil fuels of the entire demand to supply the households and the industries. However with the ambition of Parkstad to be energy neutral in 2040, there has to be a drastic transformation (Delheij et al, 2016, p. 10). To this day there is no spatial planning of the subsurface. However the subsurface is the technical space which not only houses vital functions of water, electricity, sewers and drainage, but also the natural system that is crucial for a green, healthy and livable environment (Hooijmeijer et al, 2016, p. 1). Especially in Parkstad the subsurface offers a huge potential for energy saving due to the mining history and the rising mine water. Mine water BV is currently working on the development of abandoned mining corridors into low-temperature resources. Because of the geothermal heat of the earth the mining water is water: the deeper the mine, the water the water. Every 100 meters the temperature rise by 3°C. This means at the depth of 800 meters below the surface the temperature is about 30-35°C (Verhoeven et al, 2014, p.1). Currently there is one facility that uses the mine water to supply approximately 270 homes, various office buildings, schools, a sports hall and two supermarkets experience the comfort of the mine water (Mine Water, n.d.). Another opportunity is to make use of excessive heat of point sources such as supermarkets, swimming pools and hospitals and road collectors (Broersma, Fremouw and Dobbelsteen, 2013, p. 500).

According to Atlas Living Environment, biomass is highly available in Simpelveld due to the amount of agricultural establishments and the waste they produce. In the other municipalities it is mostly organic waste. Other forms of renewable energy sources, such as open fields for PV panels and wind mills are not taken into account as an opportunity, due to the negative impact of the valuable landscape of Parkstad. These findings are displayed in Appendix XI in the form of Energy Potential Maps.

3.2. Waste – collect resources

At regional level, raw materials can be obtained by harvesting nutrients from waste water and household waste (Tilly, Borsboom and Looije, 2014, p. 85). Blue Economy, the book of Pauli (2010), explains how humans can learn from models in natural ecosystems and how this forms the solution to both the environmental challenges (pollution) and the economic challenges (scarcity). According to him: '*In nature, the waste of one process is always a nutrient, a material, or a source of energy for another* (p. 6)*'.* On that account in this research sewage sludge is not seen as a by-product, but as a valuable source of renewable energy, raw materials and clean water. There are different options and priorities regarding the recovery from sewage sludge. Currently water boards mainly focus on the recovery from phosphate, bioplastics, cellulose and bio-ALE. Phosphate is recovered as struvite and can be applied as fertilizer in agriculture. Bioplastics could be formed by the use of a process in which volatile fatty acids (VFA), that are created in the first stage of the process, are fed to microbes that later will turn into building block plastics. Cellulose is recycled from the toilet paper and can be applied in road construction. And at last bio-ALE, a material that is extracted from aerobic granular sludge. This process can be seen as up-cycle due to the fact that a more valuable product is recovered from waste (Leeuwen et al, 2015, p. 788). After recovering valuable resources from the sewage sludge it can be digested into biogas. Sewage sludge ash is then left over and has the potential to be used in various construction applications as well. Sewage sludge ash (SSA) can be described as physically a free-flowing, fine grained material. The color depends on the sludge and varies from yellow, to red brown. The SSA mainly consist of silt and fine sand size fractions and is therefore suitable as a fine aggregate component (Johnson, Napiah and Kamaruddin, 2014, p. 567). Due to the fact that the contracts end with sludge treatment companies ENCI and SNB there is a need of a facility that recovers the valuable resources from the sewage sludge.

3.3 Water – create biotopes

The current sewage systems and waste water treatment plants in Parkstad do not have sufficient capacity to transport the increasing amount of waste water. The waste water treatment plant in Hoensbroek is already overcharged by 12,1 % for the last few years (Waterschapsbedrijf Limburg, 2017, p. 43). The energy that is needed to purify the rainwater is used inefficiently due to the fact that the rainwater is discharged on the waste water treatment plants. Especially with heavier rainfall caused by climate change, more rainwater needs to be drained quickly. Buffering the water or delaying the runoff are two possibilities. Other than that capturing the rainwater and using it will in the end also save on drinking water (Urban Green-Blue Grids, n.d.). Therefore it would be wise to integrate more buffers in the landscape to capture the rain water in order to avoid the water going to waste. This means to detach the rainwater from the sewage system

(Urban Green-Blue Grids, n.d.). By creating biotopes in the landscape, it improves the urban nature by local use of freshwater. Storing water at sites around the region water can be brought back again during dry periods and urban green areas can be given freshwater (Tilly, Borsboom and Looije, 2014, p. 99). Regarding the polluted mine water, the purification of mine water and the removal of the toxins can be achieved through passive and active treatments. Over the past 20 years, a variety of passive treatment systems have been developed that do not require continuous chemical inputs, because they are based on naturally occurring chemical and biological processes. Passive methods require more land area than active treatment methods, but use less costly reagents and are easier to operate and maintain (Hedin, Nairn, Kleinman, 1994, p. 1). Primary passive treatment technologies include aerobic and anaerobic wetlands, sulfate reducing bioreactors, anoxic, limestone drains and vertical flow wetlands, slag leach beds and open limestone channels (Ziemkiewicz, Skousen and Simmons, 2003, p. 118). Applying new storage areas for both rainwater and mine water has a positive influence on the landscape. It has a recreational and ecological value that recovers the fragmented landscape of Parkstad.

3.8 Selection of location

Together the above mentioned interventions form a strategy for a future scenario of the whole region to improve resource efficiency. By adding constructed wetlands, water buffers, renewable energy sources, mine water pumps and a raw material park, resources could potentially be used more efficiently. These cyclifiers are shown below.

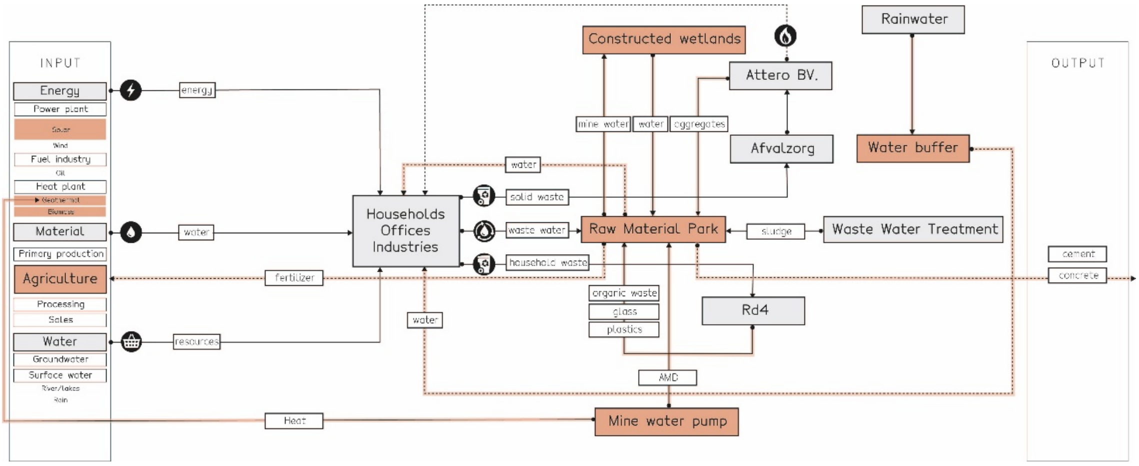

Image 5: Metabolic Scheme - Future scenario after strategy, own image.

However there is a need for a solution that takes into account the lost identity of Parkstad as well. Therefore the raw material park not only buffers rainwater, purifies waste water and mine water and recollects raw materials, but also functions as an energy and raw material production facility. The waste water is a sustainable version of the black gold that could lead to a new character for Parkstad. Based on GIS software and the information of the previous section of this research, a location is selected.

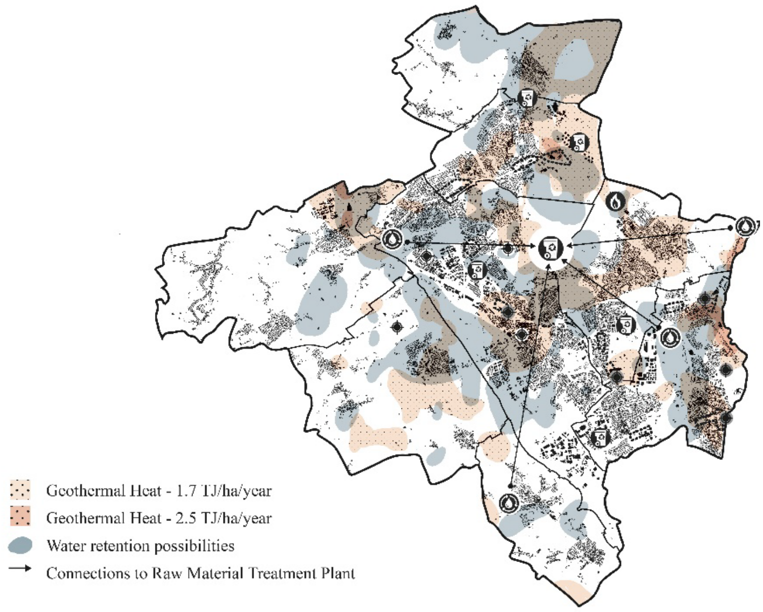

Image 6: Positioning Raw Material & Water Treatment Park (Appendix XII)

As the image above shows, the most suitable location for the facility is the Sibelco Sand Quarry in Heerlen. The quarry is situated on the former terrain of the Oranje Nassau IV and is spread over 110 ha (BuurSibelco, n.d.). The cultural and historical value of the site is quite high, since the last intact slag hag (mining waste) mountain is situated here (Stiching Behoud Brunssummerheide, Stichting Behoud Mijnsteenberg ONIV, Bewonerscollectief BuurSibelco, 2018, p. 4) Due to the central position within Parkstad this location is accessible for all inhabitants. Moreover this site falls within the risk zone of the after-effects of the mining activities. Lastly, there is space available to buffer rainwater. All in all, it the sand quarry has a high potential for the transformation of a raw material and water treatment park. (Appendix X)

4. Towards the design: waste water treatment park

The previous section mainly focussed on the potential interventions which could improve the resource efficiency in Parkstad and where to locate these. In this section the focus will shift to the architectural implications of the raw material and water treatment park. First the selected location is described in further detail, which in the end could help to determine the program of requirements. To gather information about the program of requirements and their spatial requirements, case studies and technical literature studies are carried out. Essentially the ‘orange boxes ’that are connected with the raw material park, shown in image 6, is specified.

4.1 Sibelco Sand Quarry: the new raw material treatment park

Coal was not the only thing that was extracted from the soil in this region. There was also the availability of brown coal, clay, loam, loss and sand. To this day there is still a company that excavates sand. Sibelco in Heerlen extracts and refines silver sand, also referred to silica sand, for already 100 year (BuurSibelco, 2016, p. 5). For several years local inhabitants are trying to stop the sand mining activities due to nuisance and destruction of the landscape. In 1988 there was already a plan for redevelopment made by GS (the Provincial Executive). However Sibelco was allowed to continue with the excavation of sand for another 30 years (until 2020). Yet it seems that Sibelco will get a permit again for another fifteen years (BuurSibelco, Stiching Behoud Brunssummerheide, Stichting Behoud Mijnsteenberg ONIV, 2018, p. 4). Hence in this research it is opted to find a solution that aims to restore the identity and the fragmented landscape of the

Sibelco quarry while closing the material and water loops of the region. To facilitate this idea the site requires a mine water treatment facility that pumps up the water, neutralizes it and purifies it. Moreover there is the need of an extra water treatment facility that recovers the valuable resources from the sludge. The optimal scenario would be to build the facility made with a material which contains mining residues/sewage sludge. Image 7 gives an overview of the processes that are integrated in the raw material & water treatment plant. The following paragraphs elaborates further on these processes. The system exists of three cyclifiers: a mine water treatment facility, a waste water treatment plant and a concrete production LAB.

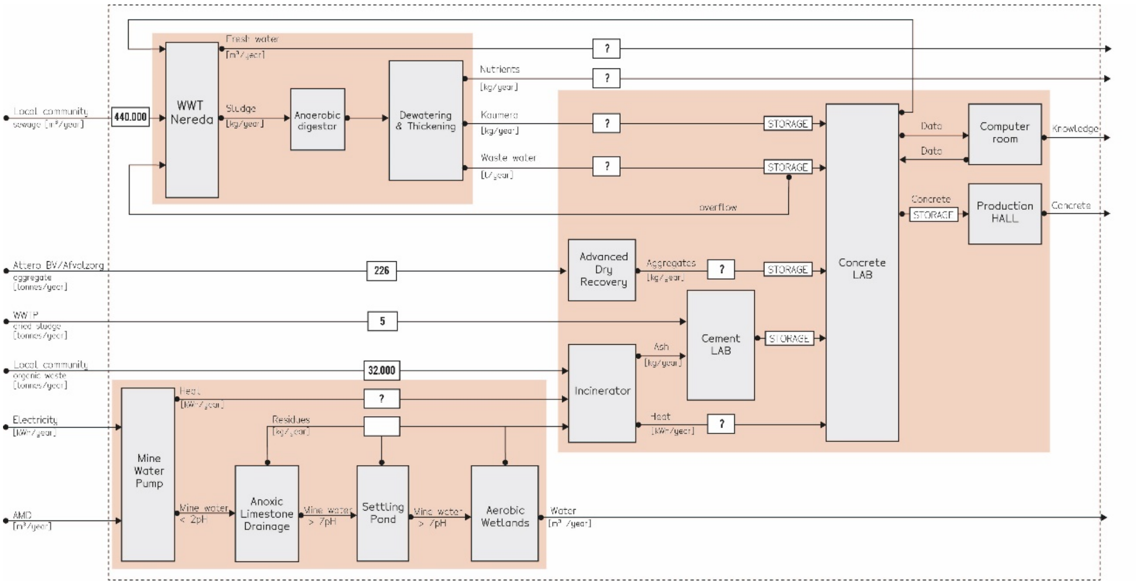

Image 7: Processes Raw Material & Waste Water Treatment Park, own image.

4.2 Building with sludge – The Concrete Production LAB

At this moment there are already several bricks and concrete blocks made with recycled waste materials such as sewage sludge (Addis, 2006, p. 65). Concrete is one of the main materials used in the construction industry. Concrete consumes high energy and has a negative impact on the environment. Especially the cement industry emits a high amount of carbon dioxide (Lee, Lee and Kim, 2018, p. 2). Concrete from secondary raw materials, such as sewage sludge, is a way to contribute to a more sustainable world. Using secondary raw materials does not only reduce the waste pressure on the environment, it also reduces CO_2-emissions and the energy demand (Visser et al, 2016, p. 60). This concept is interesting for Parkstad to apply due to the high amount vacant buildings and demolition waste. According to Wim Fleuren, Project coordinator at the Infrastructure department of Heerlen about 4 million tonnes of concrete is wasted (Atanasova et al, 2014, p. 14)

Various studies revealed the potentials of using waste water, sewage sludge, metal sludge, household waste and mining residues in the concrete production as a replacement for the main ingredients for concrete: aggregates, cement and water (Monkman and MacDonald, 2017, pp. 365-375). According to Vouk et al (2017, p. 168) up to 20 % of sewage sludge ash could be used in cement mortars and concrete, without detrimental effects on the final product· Another way to integrate waste streams is the use of post-consumer plastics as aggregates for concrete. It offers potential benefits for innovative lightweight concrete products. Attanasio et al (2015, p. 24) state that applying post-consumer plastics results in the development of lightweight concrete (density 1050-1130 kg/m³ and mechanical properties 2.6-9.3 MPa). Lastly by using end-of-life concrete streams into prime-grade aggregates and cement concrete can be recycled. The C2CA project, a research ground that focusses on the mineral processing and recycling industry, uses of Advanced Dry Recovery in their technology that leads to higher quality coarse recycled concrete aggregates for their use in concrete. This technology removes moisture fine fractions and contaminants more effectively from the coarse fractions. This can lead to superior compressive strength that opens up new opportunities for the construction industry. The resulting concrete hardens much faster than concrete made from natural aggregate, while the same amount of cement is being used (Lotfi, et al, 2017, p. 85). Research shows that these recycled aggregates are comparable with natural aggregate in terms of workability and compressive strength of the new concrete. Replacement levels are typically allowed up to 20% or 30% of the coarse fraction of the recycled natural weight concrete aggregate, with acceptable negative effects on visual quality, workability, compressive strength and durability of the mortar and concrete (Lotfi, et al, 2017, p. 90). Although there are several opportunities for the recycling of concrete, the biggest challenge is the gap in know-how of possibilities and procedures of recycling concrete. As a consequence only 20 % of recycled concrete in housing construction is used (Atanasova et al, 2014, p. 15). With the help of research institutes, different ways of waste material applications could be tested in producing a new concrete.

The materials that are processed in the raw material and waste water treatment park are harvested from the mine water purification facility and the waste water facility on site and collects sewage sludge of the other waste water treatment plants, aggregates of Attero BV/Afval Zorg and household waste, such as organic waste and plastic from the rest of Parkstad. The mining residues and sewage sludge, including the granular sludge, will finally be collected in a production facility where it is converted into a new building material. Activated sludge and metal sludge are treated in an incinerator which will form into ash. To manufacture the sustainable concrete, storage is needed to collect the raw materials: water, bio-ale, aggregates and ash. Also there is a need of a computer room to control the amounts of raw materials that are going in and out. Because the recycling and renewing of concrete in the building industry is still experimental, a laboratory is required to experiment with these techniques and analyse technical parameters on site.

Finally these materials are collected and processed in the Production Hall. The software database CES EduPack is used for the selection of the right shaping process for the production the new building material, which is in the end suitable as a panel for the façade. Also the mechanical properties are determined (Appendix XIII). Lightweight structural concrete is the most suitable for the façade panels, which are shaped by the ceramic extrusion process. The total amount of space that is required for this Concrete LAB is 400 – 500 m². These findings are based on a case study of the concrete factory in India (Appendix XIV).

4.3 Waste water treatment facility – The Kaumera generator

The waste water treatment facility that is proposed in this research makes use of the same technology as in Simpelveld, the Nereda technology. This technology uses bacteria to treat the water. These bacteria clump into granules and therefore settles significantly faster than activated sludge (Giesen et al, 2014, p. 2). By applying granular sludge technology, the Nereda wastewater solution is a natural process that purifies water 50 % more cost-effectively, without using chemicals. The system is easy operate, sustainable, cost-effective and the application needs a small physical footprint (RoyalHaskoningDH, 2019). 25-75% reduction in treatment system footprints as a result of higher reactor biomass concentrations and the non-use of secondary settling tanks. Aerobic granular sludge can even achieve biological nutrient removal in a single tank without the need for separate compartments (Giesen et al, n.d). The first stage involves feeding and displacing treated water from the top of the reactor. The second stage is aeration and finally settling. After settling, the granular sludge is removed and the water is ready to be discharged again. All these stages occur in one reactor (Oliver, Thomposon, 2016, p. 1). The removed sludge goes to an anaerobic digestor for further stabilisation of the organic matter (Andreoli, Sperling, Fernandes, 2007, p. 48). This treatment is widely used to release organics from sludge to methane and simultaneously valuable resources such as nutrients are removed. The second stage of resource recovery is thickening and dewatering of primary and biological sludges (Andreoli, Sperling, Fernandes, 2007, p. 78). The main purpose of thickening and dewatering is reduction of the water content in the sludge to reduce its volume. But there are more benefits that the Nereda technology has to offer: the recovery of Kaumera Nereda Gum (formerly neo-alginate). Researchers at the TU Delft discovered that a this new type of raw material can be extracted from the granules. Kaumera is an alginate like exopolymer (ALE) and can be applied numerous industries, such as agriculture, horticulture ad the concrete industry (Kaumera, n.d.). In the concrete industry it can be used as a coating to give concrete a longer life through better curing (Koemans and Kleyhorst, 2017, p. 13).

The overall spatial requirements of the Nereda water treatment depend on the amount of households that are connected with the waste water treatment plant. The focus of the design is to supply the water for residents that live around the sand quarry, mostly the former mine colonies. That would be approximately 10.000 people including the production facility (Appendix XV). This means that the treatment plant has to have the capacity of 20.000 p.e. (54 g BOD) and treats 1.200 m^3/day (Appendix XVI).

4.4 Mine treatment facility – Mining for black water

Lastly the mine water facility For the mine water a mine water pump is required that pumps up the water. The treatment technology that should be applied in Parkstad depends on different factors. The most important aspects are target quality, chemical composition, topography and available land (Trumm, 2010, p. 2017). The target quality of the water in Parkstad is that it could be discharged to surface water and used in industries. After analyzing the mine water chemistry it is recommended to neutralize the water first by Acid Lime Drainage (Hedin, Nairn and Kleinmann, 1994, p. 26). In the second stage the water will go to a Settling pond for further pH adjustments and metal precipitation (Hedin, Nairn and Kleinmann, 1994, p. 27). Finally the water flows into Aerobic Wetlands where the metal concentration can be further adjusted. In appendix XVII a more detailed explanation of these stages is available.

III. CONCLUSIONS

The aim of this research was to discover the current situation of the urban metabolism in Parkstad and find out where a cyclifier would be beneficial to improve the liability and resource efficiency in Parkstad. Due to the mining past of this region the subsurface was integrated in the urban system as well. After closing the mines the mine water has risen the whole area in South Limburg and reached a hydraulic equilibrium. This could eventually lead to problems regarding the quality of the groundwater. However it seems that there is a high potential of using the mine water as a renewable energy sources to lower the use of fossil fuels.

This paper revealed several interventions that improve the current situation: rechannelling energy, creating biotopes and collecting resources. The latter is discovered in further detail. Criteria for a raw material and waste water treatment park including a raw material production facility are explored. The park requires a mine water treatment facility that pumps the mine water from underground and purifies the water in three different stages. Moreover there is a waste water treatment facility that makes uses of aerobic granular sludge, that could be harvested after cleaning the water. This is a valuable resource which could be beneficial for the production of concrete. Lastly the sludge of both the mining residues and the waste water is collected in a incinerator where it is converted into energy. The ash that is then left over is an ingredient for the bio cement. These three cyclifiers are located on the Sibelco Sand Quarry. This turns out to be the most suitable location due to the central position within Parkstad and the fact that this is one of the risk zone for the after-effects of the coal mining activities. The aim of this research was to determine a program of requirements including the spatial characteristics. These findings are shown below:

Process / Space	**Building**	**Space requirements**	**Surface area [m²]**	**Input (Flow rate)**	**Output (Flow rate)**
Mine water facility					
Pump mine water	II	-	10	Electricity	Waste
Anoxic Limestone Drain	II	-	60	Acid mine water	Alkaline mine water
Technical Area	II	High ventilated	20	Electricity	Waste
Heat exchanger	II	High ventilated	10	Electricity	Heat
Settling Pond	Outside		100	Alkaline mine water incl. metals	Mining residues Mine water
Aerobic wetland	Outside		200	Mine water	Water
Waste water treatment facility					
Nereda technology	Outside		200	Waste water Electricity	Kaumera
Material production facility					
Lobby	III	Insulated/ ventilated	10	Electricity Heat	Waste
Toilets	III	Insulated / ventilated	20	Water Electricity	Waste water
Cement LAB	III	Insulated / ventilated	30	Dried sludge Ash	Biocement
Concrete LAB	III	Insulated / ventilated	30	Water Kaumera Biocement Aggregates	Data Concrete raw materials
Computer room (VMC area)	III	Insulated / ventilated	60	Data Electricity	Knowledge
Loading/Unloading	III	-	30	-	-
Storage	III	-	120	Raw materials	Raw materials
Production hall	III	High ventilated	60	Concrete raw materials Heat	Concrete
Incinerator	III	-	10	Organic waste Mining residues Electricity	Heat Ash
Total	III		400-500		
Total	I+II+III		1000		

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