MATERIAL LANDSCAPE IBA PARKSTAD

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Abstract IBA Parkstad, part of the green metropolis, has a long history as an extraction landscape because of its location over an underground coal field. The closing of the mining industry led to socio-economic consequences and lumbered the region with an environmental legacy. This research paper explores new energy potentials for the region and specifically focuses on the Brunssummerheide. Local energy potentials can be utilized at the Brunssummerheide and contribute to the energy vision of IBA Parkstad as an autonomous energy region in 2040. An energy factory in the form of a sawmill, a biogas plant and a helophyte filter is the most promising synergy that could process local materials and uplift the area as an industrial region. This research sets the urban and architectural requirements for the sawmill factory based on a material analysis.

Keywords: production landscape, energy, sawmill factory, biogas plant, helophyte

Introduction

IBA Parkstad is part of the 'Green Metropolis', the triangle where The Netherlands, Belgium and Germany come together. *The big challenge for the Green Metropolis is to find ways of converting itself into a region that can get all its energy needs from renewable sources extracted in the region itself. Its unique history, underground potential and characteristic appearance above ground can inspire plans to develop the 'energy landscape of the twenty first century'* (Sijmons, 2016).

IBA Parkstad and the province of Limburg decided in 2013 to organize an IBA for the region. IBA stands for Internationale Bau Ausstellung. The term IBA originated in Germany and is a creative approach with a proven economic impulse for the concerning region (IBA Parkstad, n.d.). The decision to organize an IBA specifically for this region is certainly not a coincidence with the mining history of the region. Once, the eastern part of South-Limburg was the energy supplier of Holland. The mining industry resulted in a modern and prosperous area during the 20th century. After coal mining first declined and then stopped altogether, the region sank into an economic malaise, with all the attendant social problems (Sijmons, 2014). Up untill this day the unemployment and income of the region are far behind compared to the Randstad (NOS, 2014). The closing of the mining industry not only led to socio-economic consequenses for the region but also lumbered the region with an environmental legacy (Balsum, 2003).

Parkstad Limburg wants to be energy neutral in 2040. The report 'Parkstad Limburg energietransitie' states that no money can flow out of the region for the import of fossil fuels anymore. The objective is to retrieve all energy from wind, sun, water, geothermal heating and biomass by 2040. Also Dirk Sijmons studied these four energy potentials in his book Energy and Landscape. An ambitious vision for the region that became well known for its mining industry and its fossil fuel production during the 20th century. Now the former mining region wants to be inventive, innovative and ambitious again to create new jobs regionally and locally (Parkstad Limburg, 2017). These four energy potentials form the foundation for all local and regional projects that are part of the energy transition vision of Parkstad Limburg in order to become energy neutral in 2040:

1 Solar energy
2 Wind energy
3 Geothermal energy
4 Biomass

The studies of Dirk Sijmons and Parkstad Limburg explored the energy potentials for IBA Parkstad on a respectively urban scale and policy level. In order to understand the local and spatial consequences of the energy vision, a translation from the bigger scale to the smaller scale is required. Therefore this research will focus on the Brunssummerheide in IBA Parkstad. A shift and translation from the urban and policy perspective to the local and spatial perspective inevitably changes the framework of the energy potentials. It creates the opportunity to focus on the design solutions that facilitate the energy potentials. The problem statement of this paper is therefore formulated as:
Which local energy potentials of the Brunssummerheide can be utilized and which urban and architectural requirements does this set for a design intervention?

In order to address this problem statement this paper will first introduce the history of the material landscape of IBA Parkstad. The mining history left its mark in the landscape which creates challenges and opportunities for a new energy framework. The second chapter will first discuss the material and energy potentials that were introduced by Dirk Sijmons for the 'Green Metropolis'. Then the paper will elaborate on these potentials by adding the actors slag heap, the forest and landfills. These are existing actors that can be utilized for a new energy framework on the local and spatial scale. In the third chapter the energy potentials are explored on a smaller scale. A previous research by Superuse on the metabolic system of Heerlen is therefore introduced and discussed. In the following chapter a new energy framework for the location Brunssummerheide is proposed. In the conclusion the energy framework is translated to a set of urban and architectural requirements for the design of a material factory at the Brunssummerheide.

1 History of mining

The 'Green Metropolis', the triangle where the Netherlands, Belgium and Germany come together, has a long history as an energy extraction landscape because of its location over an underground coal field (Sijmons, 2014).The first coal mining took place during the 12th century in the Domaniale mine of Kerkrade. As of 1742 the abdij of Rolduc independently started to exploit a coalmine. The development of the mining process resulted into a profitable business during the 18th century. Around 1900 the first coal mines were established in the South of Limburg resulting in 12 privately and publically owned mines. The discovery of the gas field in Groningen and the relatively low production costs of imported oil and coal resulted in economically unsustainable mines. The shutdown of the 12 coal mines started with the historical speech of Joop den Uyl (minister of economic affairs) in theater of Heerlen in 1965. In the following nine years all mines were closed (De Mijnstreek, n.d.). After the closure of the coal mines in 1974, 45.000 mine workers and 30.000 employees of related businesses lost their jobs. Half of the labor force in the eastern mine region was unemployed towards the end of the seventies. Since the dismantling and closure of the mines the 'Green Metropolis' has become largely dependent for its energy needs on sources outside the region. From the twentieth century onwards, the numerous mines spread across the region had a profound spatial impact on their surroundings. Mining buildings, shaft towers, mining communities (garden villages) and slag heaps were the first landmarks in the landscape, followed by heavy industry complexes, concentrated urbanization and the attendant infrastructure (Sijmons, 2014)

In the mining period, pine trees were planted in large numbers on the former 'wastelands' of the sandy plateaus for the benefit of the mining industry (Sijmons, 2014). The pinewoods were planted in the Netherlands since the 18th Century. For the Brunssummerheide in particular this happened since 1730 (Eifelnatur, n.d.). Production woods with fast growing 'douglas-sparren' and 'grove dennen' where commercial wood factories that delivered construction wood for the mines, support for the railway tracks and sawdust for the paper industry. The mines demanded enormous quantities of wood and possessed large wood terrains. In general the woods were businesses that could take care of themselves. According to Jos Jansen (secretary of the Bosschap) the turning point must have been around 1954. The mines were closing, the railway company started to use reinforced concrete and the paper industry mostly used recycled paper. Also plastic was introduced and replaced wood in consumer products. The Dutch forests now have a mainly recreational function and during the seventies the notion of 'natuurwaarde' was introduced. Nature has to be protected from this point on and the Netherlands also has to deal with international agreements about nature quality. Jos Jansen is satisfied with the ecological quality of the forest but mentions a big disadvantage of the current situation. The financial situation of the forest is dramatic (Marijnissen, 2011).

Also the soil of the Brunssummerheide was heavily exploited during the 20th century due to three kinds of minerals. Lignite in the northwestern part, silica sand in the eastern and the southwestern part and coal in the perimeter of the Brunsummerheide. Most of the excavations were later filled with municipal solid waste or industrial waste and covered with a second layer (Natuurmonumenten, 2016).

2 Energy & Material potentials

In the book 'Energy and landscape' Dirk Sijmons points out four energy perspectives for the Green Metropolis. The underground coalfields with their elaborate systems of tunnels and shafts present opportunities for the construction of heat networks that could supply part of the region's energy needs. Secondly certain areas such as the high plateaus in the Belgian part of the region and the more open areas in Germany present an opportunity for wind energy. Further he argues that solar energy can be generated on a large scale in the more heavily urbanized parts of the Green Metropolis. At last the prospects of biomass are pointed out. Waste flows from the large pine forests on the plateaus could play a role in biomass en biofuel production. The stretches of landscape could acquire significance as 'energy gardens', which could be operated and managed by individual residents, collectives or local authorities (Sijmons, 2014). Basically these four energy perspectives resemble the energy potentials that Parkstad Limburg has formulated. This paper will elaborate on the energy potentials by adding the potential of slag heaps, forests and landfills.

3.1 Slag heaps

Slag heaps were left as a tangible memory of the mining industry in the landscape of the Green Metropolis. A report about minestone estimated that there is 150 million ton of minestone and mine sludge is hidden in the soil of Limburg (Balsum, 2003). The slags heaps are mostly re-vegetated to create recreational green spaces. In case a slag heap is excavated, the mine stone is preferably used for the same location or at a location with a similar soil composition (Parkstad Limburg, 2002). Slags heaps are accumulations of mine stone that were produced as a by-product of the underground mining industry. Mine stone is a collective name for all sorts of stones. The layers in which coal occurs have been formed in the geological Carboniferous period of more than 200 million years ago. In that period alternating depositions of peat, clay and sometimes sand arose. Under the influence of large loads on these layers, the peat changed into coal, the clay in clay stone (and slate) and the sandy deposits in sandstone. Transitional stones also formed between the different types (Bodemrichtlijn, n.d.). Mine stone mainly exists of sandstone and clay stone mixed with coal grit. Existing slags heaps in the landscape of Limburg represent a cultural value and are often closely situated to residential areas. Therefore the current plans for the excavation of the slag heap Oranje Naussau IV causes resistance from residents that are worried about cultural en ecological damage (Buursibelco, 2016).

The mine stone that is used in the Netherlands is largely (75%) imported from Germany. Currently only an importer of German mine stone is certified in the Netherlands. The imported mine stone is mainly derived from active production sites (Bodemrichtlijn, n.d.). Mine stone is mainly used for low value applications in hydraulic engineering and road construction. However recent research is promising about new applications for minestone. One of the possibilities is to process minestone to a fertilizer. Minestone contains organic material and minerals that can complement volcanic rock minerals in fertilizers. Other possibilities are minestone as soil base for viticulture or as pigment in construction materials (Hensels, 2015).

3.2 Forest

Wood

The development of the bio-based economy in The Netherlands will probably result in an increased wood consumption from 0.9 m3 per capita to 2 m3 per capita in 2030 (Nabuurs et al., 2016). This growth is the result of energy policy and more demand for sustainable materials in the construction sector. Other countries have similar ambitions and will contribute to this demand. The Dutch wood market is strongly dependent on import. The total wood consumption in the Netherlands in 2013 was 14.7 million m3 rhe (rondhoutequivalent, of which only 10,3 % is produced in the Netherlands (Nabuurs et al., 2016). It will be difficult for net import countries like The Netherlands to acquire enough wood and biomass (Nabuurs et al., 2016). As mentioned in the 'history of mining', pine trees were planted in large numbers for the mining industry. The current financial situation of the forest asks for new ways to think about its function. According to the Agriculture Economic Institute forests smaller than 5 hectare rely for 40% on subsidies where forests bigger than 50 hectare even rely on 50%. When the 'Ecologische Hoofdstructuur' is realized in 2018, a plan that connects different nature reserves, yearly subsidies of 300 million are required to maintain it. Currently the Dutch forest has mainly a recreational function. But it has the potential to become a production forest once again. According to Van den Ham (forest expert) there is a potential in traditional wood production. In the Netherlands there are currently about 58 million cubic meters of wood. Every year, 2.2 million cubic meters are added through fouling. But we only harvest 1.4 million cubic meters, while we could annually harvest 225.000 cubic meters extra. The Netherlands needs 16 million cubic meters per year, so that extra harvest is a drop in the ocean. But the use of indigenous wood can reduce the import and the pollution caused by transport. More importantly it generates income for the forest (Marijnissen, 2011). Since Parkstad Limburg is characterized by large stretches of landscape, the potential of wood should be included in the energy transition vision.

Arguments against the re-introduction of a production forest are the ecological consequences. Forester Wanda Zwart argues that it might be efficient to re-introduce the production forest but the ecology will suffer. The soil will be poor again; the structure and the nutrition that is built up will disappear.

The climate of the forest gets more extreme, hot in the summer and cold in the winter (Mulder, 2017).The balance between ecology, production and recreation is a real challenge. Yet Staatsbosbeheer advocates for an investment in the production forest, with an expansion of 100.000 hectare. The balance has to shift more to the production side. We need more wood from the Netherlands that contributes to CO_2 storage. Wood production is an essential part of a bio-based economy (Mulder,2017).

Biomass cultivation and biomass from waste flows

Biomass is a collective term for plant material that is considered suitable to serve as fuel (Sijmons, 2014). Biomass can be transformed into biofuel through chemical processes and fermentation or burned in a power plant to generate electricity. Biomass is considered a sustainable energy source for two reasons: it is 'renewable' and the CO_2 released during combustion is pre-converted into oxygen during the growth process via photosynthesis (Sijmons, 2014). Most of the green electricity that is consumed in the Netherlands is actually produced in countries that incinerate biomass on a large scale. This biomass often comes from rainforests that are demolished and replaced by palm oil and rapeseed plantations. These plantations then compete with agriculture land for food production. Further the biomass is often transported and shipped over large distances before being burnt. The use of imported biomass is therefore doubtful. In the Netherlands there are few energy companies that deliver locally produced energy (Parkstad Limburg, 2017). How come? In Western Europe the high land prices mean that currently there are not many prospects for cultivating energy crops. However the potential of the Green Metropolis is slightly better than other regions because of the relatively poor soil that is consequently less suitable for food production. Land that has been made fallow through mining can offer great potentials for biomass cultivation. Further the waste from forests, orchards, farmlands and domestic waste (groenafval) offers even more potential for biomass.

3.3 Landfills

But not only had the coal industry left its marks in the landscape. The excavation of clay, sand, gravel and marl left behind big holes in the soil. These were later filled with waste. According to director of Bodemzorg Limurg Dick Rootert this makes the landscape unique." Because these excavation holes are filled with waste you don't notice you are actually walking on a former landfill" (Zierse, 2017). But the dumping of waste materials is certainly not a unique phenomenon for Limburg. Since the earliest days of the Industrial Revolution, Europe has been dumping large quantities of its unwanted waste materials in landfill sites. Previous estimates have suggested that there are somewhere between 150,000 and 500,000 such sites, either closed or still operational, in the EU-28 (Hogland, 2013). This exercise also highlights that most of the still-operational landfills are "sanitary" landfills, which are equipped with state-of-the-art environmental protection technologies and methane collection systems. However, at least 90% of Europe's landfills are "non-sanitary" landfills, which predate the EU's Landfill Directive (1999) (EURELCO, 2017). Also in Limburg there are around 900 landfills covered in the soil. These result often in expensive after care for the municipality and unusable land. Many former landfills are covered with vegetation and nature. A new destination for a landfill always has to be planned together with the municipality. Activities that can damage the ground are not permitted and constrain the use. (Zierse, 2017).

A recent research shows the potential of landfills as significant source of secondary materials and energy. Landfills can be transformed from a major cost to society (contribution to global warming, groundwater pollution and occupation of valuable land) into a resource recovery opportunity (Jones, 2013). Landfill mining strategies can be divided into two strategies. In situ landfill mining refers to resource recovery activities which occur on the landfill site without excavating the stored waste streams. Ex situ landfill mining involves resource recovery by partially or fully excavating the waste materials for further treatment. Enhanced landfill mining is defined as: *'the safe conditioning, excavation and integrated valorization of (historic and/or future) landfilled waste streams as both materials and energy, using innovative transformation technologies and respecting the most stringent social en ecological criteria'*(Jones, 2013).

Landfill can be transformed into new material (WtM), into energy (WtE) or stored for future recycling. CO2 and low temperature heat (40-60 degrees) arising from a WtE plant can be used in local horticulture (EtC) to, respectively, fertilize the plants and heat greenhouses, avoiding the use of primary fossil fuels. Further a WtM plant can produce inert aggregates. These aggregates can substitute gravel in construction applications such as concrete. Therefore a WtM plant can have an off-site impact upon the local gravel extraction in Parkstad Limburg. Another substitute that can be derived from a WtM plant is the plasmarok. Plasmarok has the potential to be used as a direct substitute for cement (Jones, 2013).

The mining of landfill also has some barriers and downsides. Landfill mining will result in a temporarily loss of ecosystems. Secondly, potentially affected communities might react negative towards plans of performing landfill mining in their neighborhoods (Jones, 2013). However the implementation of landfill mining is an energy potential in the Green metropolis and can contribute to more autonomy for the region as production landscape.

3 Metabolic scheme for the Brunssummerheide 2040

The previous chapters gave a short introduction of the mine region and showed where the energy opportunities lie. In order to analyze the energy potentials that can be utilized for the Brunssummerheide this paper introduces a study that was done by Superuse in 2009. Part of the research of Superuse called '*Industrial Ecology applied in the urban environment'* analyzed the region of MSP Heerlen. One of the outcomes was a metabolic scheme for MSP Heerlen that envisioned an urban ecosystem for 2040 called Recyclicity. See appendix A1. The Brunssummerheide partially belongs to the municipality of Heerlen. The scheme therefore forms a starting point for the exploration of the spatial impact of the energy transition at the Brunssummerheide. A metabolic scheme for the Brunssummerheide 2040 was created based on new insights and extended with the energy potentials that were discussed in the previous chapters. See Appendix A2.

The metabolic scheme for the Brunnsummerheide 2040 shows some differentiations compared with the scheme for MSP Heerlen. The cyclifiers *chip production* and *solar cell production* are removed from the scheme since the factory of Solland Solar Heerlen went bankrupt in 2015 (Grol, 2017). Therefore the assumption is made that a solar cell facility is not an easy business case in this region. The metabolic scheme is extended with three existing actors: the *forest*, the *slag heap* (in msp Heerlen referred to as *hill with mining rubble*) and the *landfill* (Kreupelbusch). All three actors are present at the Brunssummerheide and can play an important role in the metabolic system. Further the *gasplasma plant* is added as a new cyclifier for the future. A *gasplasma plant* is a WtE and WtM plant that is able to process material from landfills into new construction materials and energy. It also adds the opportunity to locally process the municipal solid waste in the system. Secondly a *sawmill factory* is added as new cyclifier. In order to increase the revenue of the forest for its own maintenance the Brunssummerheide can be utilized in a different way. Currently it only functions as recreational space. Wood harvesting can increase the revenues but also asks for a production place. Thefore the *sawmill factory* is introduced in the metabolic scheme. Finally a *solar cell plant* is added as cyclifier. The unused surface of the landfill Kreupelbusch at the Brunssummerheide can be used to situate a *solar cell plant.*

The former landfill Kreupelbusch, situated in the Brunssummerheide, covers 40 hectare and is filled with 6.2 million m3 municipal and industrial waste (Bodemzorg Limburg, 2017). The landfill gas production decreased from 9 million KWh in 2003 to 3.5 million in 2015 and continues to decline. Although the potential of landfill mining is interesting and the gasplasma plant is a promising cyclifier some issues arise. First of all the data about the content of landfills are often not documented. This is also true for Kreupelbosch, which makes it difficult to estimate the benefits. Another issue that arises is the spatial impact of enhanced landfill mining, especially in an environment like Brunssummerheide. Finally the overcapacity on the market for waste incineration makes a small local gasplasma plant economically not viable (Kocken, 2015).

However the combination of the *sawmill factory*, *biogas plant* and the *helophyte filter* cyclifiers could form an interesting case study for the Brunssummerheide. These cyclifiers can locally produce energy and material from the direct environment. Therefore they can contribute to the vision for IBA Parkstad as an autonomous energy region. In figure 1 the three cyclifiers are shown in relation with one another. The helophyte filtering system can filter the waste water from the sawmill factory and biogas plant and deliver biomass at the same time. This can be done achieved with reed but also with willows (Otte, 2014). The spatial requirements for a biogas plant were discussed in the report Recyclicity of Superuse (Superuse, 2009) Therefore this paper will focus on the sawmill factory. The numbers in figure 1 show the annual potential of production in the Brunssummerheide based on the exploitation period 2017 – 2034. The sawmill factory cyclifier represents both the harvesting of wood and the processing of wood. For the convenience it is assumed that both activities (harvesting and processing) are executed by the same entity. To be able to shift to a spatial perspective, the urban and architectural requirements for the *sawmill factory* are set in the next chapter. The requirements are set based on the amount of material that can be harvested in the direct surrounding in case a sawmill factory is placed at the Brunssummerheide.

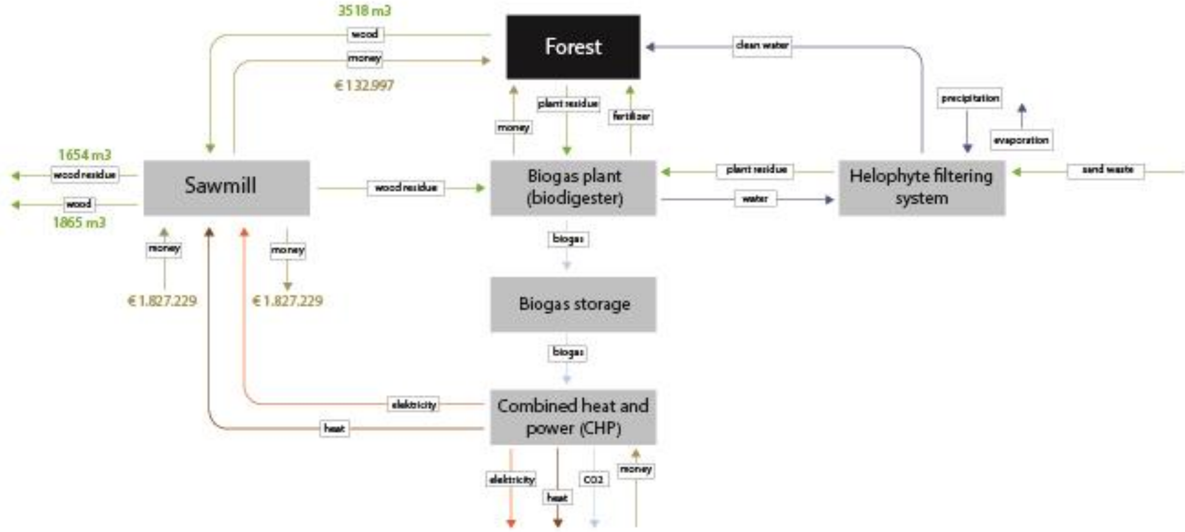

Figure 1. Synergy between the sawmill, the biogas plant and a helophyte filtering system.

4 The sawmill factory of Brunssummerheide

The Brunssummerheide (503 ha) is part of the Nature reserve Heidenatuurpark (3000 ha).Therefore two scenarios were set for the total potential of wood that can be processed. Scenario 1 only takes into account the Brunssummerheide, while scenario 2 covers the total Heidenatuurpark. The spatial requirements for the sawmill factory are dependent on the scenario. In this chapter scenario 1 will be the starting point. The total potential of wood that can be processed within the boundaries of the Brunssummerheide (scenario 1) depends on the following factors (Boosten, 2017).

- The annual forest growth.
- Sustainable harvesting limit (should not exceed annual growth).
- Costs of harvesting and transport (depends on: e.g. accessibility).
- Sales channels and the price of biomass/wood waste streams.
- Spatial quality and ecological value.

The Brunssummerheide covers an area of 503 ha of which 312, 62 ha consist of conifer-, oak- and beech trees (*Naald-, eiken- en beukenbos*). Natuurmonumenten gradually wants to bring this back to 180 ha in 2034 (Natuurmonumenten, 2016). This means that in the period from 2017-2034 a wood stock of 132,62 ha can be processed locally in a sawmill factory. Additionally the yearly forest growth can be harvested to an amount of 7 m3/ha. This amount of harvesting is acceptable while still maintaining a sustainable forest (Bosschap, 2013). In the period from 2017 – 2034 an estimate of 3518,44 m3/year wood can be processed in the local sawmill. After 2034 the processing of wood will be limited to the annual forest growth of 7 m3/ha which results in 1260 m3/year. Overviews of the wood quantity that can be processed are given in figure 2.

MATERIAL PROCESSING				
2017 - 2034 (reduction by policy)	**forest (ha)**	**wood (m3/ha)**	**transition phase (years)**	**wood (m3/year)**
Naaldbomen (grove den)	44,21	230	17	598,09
Loofbomen (o.a. eiken en beuken)	88,41	230	17	1196,18
TOTAAL	**132,62**			**1794,27**
2017 - 2034 (annual harvesting)	**production forest (ha)**	**growth (m3/ha/year)**		**wood (m3/year)**
Naaldbomen (grove den)	82,10	7		574,72
Loofbomen (o.a. eiken en beuken)	164,21	7		1149,45
TOTAAL	**246,31**			**1724,17**
> 2034 (annual harvesting)	**production forest (ha)**	**growth (m3/ha/year)**		**wood (m3/year)**
Naaldbomen (grove den)	60,00	7		420
Loofbomen (o.a. eiken en beuken)	120,00	7		840
TOTAAL	**180,00**			**1260**

Figure 2. Overview of the total wood harvest in the periode 2017-2034 and period >2034.

Now that we have found an estimate of the wood that can be processed, the potential net results (in terms of money) are estimated for the sawmill factory. Therefore the analysis should cover both the harvesting of wood and the processing of wood. Both activities are shown in figure 3. The potential revenues and costs for the two time periods (2017-2034 and >2034) were calculated based on the yearly production and reference numbers from Probos. The revenue of wood harvest per m3 are expected to increase from € 59,20 /m3 to € 61,40/m3 in 2030. The costs are expected to decline from € 23,60/m3 to € 21,40/m3. Since the exploitation of the sawmill factory approximately covers this period, the average of the reference numbers was used. These numbers are based on a scenario that assumes no change of policy and a continuing development of a bio-based economy (Nabuurs et al., 2016). Based on these assumptions a net result of € 37,80 /m3 is created with harvesting. After harvesting the wood will be brought to the local sawmill factory. The primary wood (rondhout) will be processed into construction wood (53%) and rest wood (47%). Rest wood is mainly used as strooisel in the dierenhouderij (50%) and as material for energy pallets (30%).The other 20% is utilized for the paper industry, plate industry and internal heat production of the industry (Nabuurs et al., 2016). Recent data of market prices for rest wood streams are not available. Therefore general reference numbers for wood and rest wood prices were used for the calculation. These are numbers from the report *Nederlandse houtstromen in beeld* by Probos. Based on a wood production of 3518,44 m3/year the revenue of processing is estimated to be € 519 /m3. The costs of processing the primary wood will mainly depend on the labor and capital of the sawmill factory. This calculation is not included in this research. However, based on the annual revenue of the sawmill factory, a budget for its construction and exploitation can be calculated.

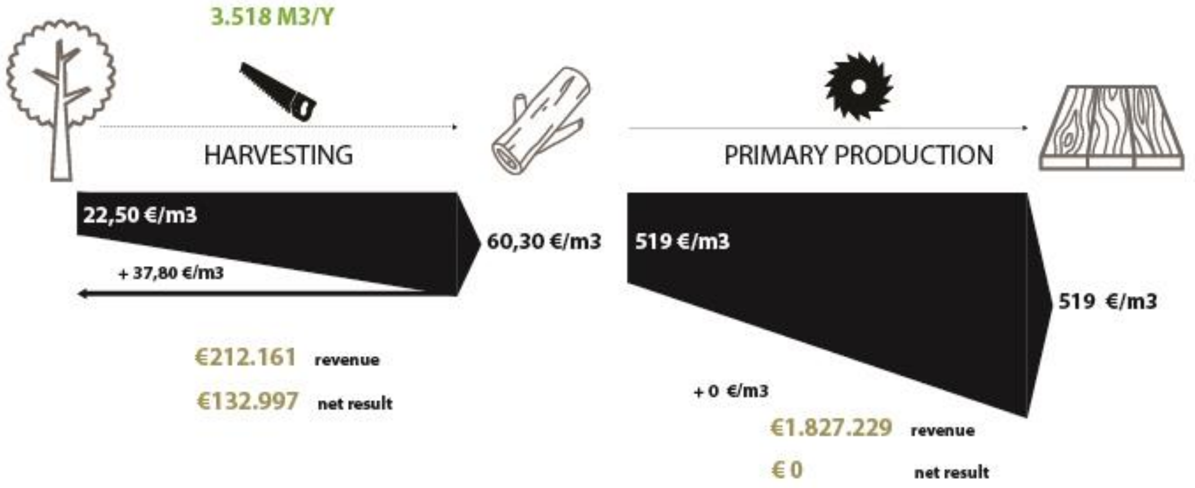

Figure 3. First two steps in the wood production chain of the Brunssummerheide 2017 -2034.

In figure 4 the revenues and costs for harvesting are shown based on the reference numbers and the calculated amount of wood that can be processed in the Brunssummerheide. The yearly net result after 2034 almost decreases by a factor 3. The net results are based on scenario 1 (only Brunssummerheide) but could be increased when Heidenatuurpark is harvested as a whole. In figure 5 the revenues of processing are shown. The yearly revenue for period 2017-2034 is estimated to be 1.827.229 euro. For the calculation it was assumed that conifer wood (grenen) and hardwood (eiken and beuken) yield 700 €/m3 and 1000 €/m3 respectively. The rest wood yields were assumed to be: strooisel €156/ton, woodchips €35/ton and pulp €400/ton.

REVENUES			
2017 - 2034	wood (m3/year)	revenue (€ / m3)	revenue (€ / year)
Naaldbomen (grove den)	1172,81	60,3	70720,66
Loofbomen (o.a. eiken en beuken)	2345,63	60,3	141441,31
TOTAAL	3518,44		212161,97
> 2034	wood (m3/year)	revenue (€ / m3)	revenue (€ / year)
Naaldbomen (grove den)	420	61,4	25788
Loofbomen (o.a. eiken en beuken)	840	61,4	51576
TOTAAL	1260		77364
COSTS			
2017 - 2034	wood (m3/year)	costs (€ / m3)	costs (€ / year)
Naaldbomen (grove den)	1172,81	22,50	26388,30
Loofbomen (o.a. eiken en beuken)	2345,63	22,50	52776,61
TOTAAL	3518,44		79164,91
> 2034	wood (m3/year)	costs (€ / m3)	costs (€ / year)
Naaldbomen (grove den)	420	21,4	8988
Loofbomen (o.a. eiken en beuken)	840	21,4	17976
TOTAAL	1260		26964
NETTO RESULT			result (€ / year)
2017 - 2034			132997,05
> 2034			50400

Figure 4. Net result of harvesting for both time periods (2017-2034 and >2034).

REVENUES (primary production)		
2017 - 2034	wood (m3/year)	revenue (€ / year)
Wood 53%	1864,77	1678296,16
Naaldbomen (grove den)	621,59	435113,82
Loofbomen (o.a. eiken en beuken)	1243,18	1243182,34
Rest wood 47%	1653,67	148933,39
strooisel (€ / m3) (50%)	826,83	80616,27
houtchips (€ / m3) (30%)	496,10	10852,19
pulp (€ / m3) (10%)	165,37	41341,68
plate (€ / m3) (10%)	165,37	16123,25
TOTAAL	3518,44	1827229,55

Figure 5. Revenues primary production of wood and rest wood streams for time period (2017-2034)

Now that we have an estimate of the material that can be processed and the revenues that can be created, the spatial requirements are discussed. To determine the spatial requirements for the sawmill factory in the Brunssumerheide, three reference sawmills were analyzed. These three sawmills are relatively small and process similar types of wood. The three reference sawmills are Houtzagerij Hengeveld, Houtzagerij Twickel and Limburg Hout. The sawmills process 4500 m3/year, 2800 m3/year and 350 m3/year respectively. The most important ingredients for a sawmill are the saw space (zagerij), the shave space (schaverij), the drying room and the storage space. In order to estimate the size of sawmill factory for the Brunssummerheide, the cubic meters of wood that are processed per m2 where calculated for the three reference projects. This number represents the efficiency. What is striking is the efficiency of the reference sawmills factories. Although the amount of data is very limited, it clearly shows that the amount of wood correlates with the efficiency. The spatial requirements for the Brunssummerheide sawmill factory are a derivative of the reference projects. The surface of the sawmill factory will then be 3152 m2 of which a large part covers wood stock space in the open air. See figure 5.

DESIGN 2017 - 2034			
spatial requirements	surface (m2)	m3/year	m3/m2
1 Zagerij			
2 Schaverij			
3 droogkamer			
4 opslag rondboomstammen			
TOTAAL	3152,34	3518,44	1,12
REFERENCES			
spatial requirements	surface (m2)	m3/year	m3/m2
Houtzagerij Hengeveld			
1 Zagerij	320		
2 Schaverij	300		
3 droogkamer	24		
4 opslag rondboomstammen (openai	1500		
TOTAAL	2144	4500	2,10
spatial requirements	surface m2	m3/year	m3/m2
Houtzagerij Twickel			
1 Zagerij	500		
2 Schaverij	160		
3 droogkamer	650		
4 opslag rondboomstammen (openai	2500		
TOTAAL	3810	2800	0,73
spatial requirements	surface m2	m3/year	m3/m2
Limburg Hout			
1 Zagerij	400		
2 Schaverij	0		
3 droogkamer	0		
4 opslag rondboomstammen (openai	500		
TOTAAL	900	350	0,39

Figure 6. Overview of reference sawmill factories.

5 Conclusions

This research paper explored the question which local energy potentials of the Brunssummerheide can be utilized. Therefore a metabolic scheme was introduced to build upon previous research. The sawmill factory, the biogas plant and the helophyte filter are the most promising within the Brunssummerheide. These cyclifiers can work in synergy and are able to process local materials and local energy. A project based on these cyclifiers can contribute to the vision of IBA Parkstad as autonomous energy region.

One of the issues that were discussed in previous research (Recyclicity) is the environmental progress that is made with the introduction of the proposed cyclifiers. The complete design should decrease resource use and improve the interaction between technosphere and the natural ecosystem (Goosens, 2009). Although the energy potentials were mapped in this research and the requirements were set for a sawmill factory, the environmental progress was only measured in terms of money flowing back to the forest. An actual design of a factory that combines a sawmill, biogas plant and helophyte filter on a specific location at the Brunssummerheide will give more answers to this issue. The relation of the design with its ecological environment then becomes very important. The location, materialization and logistics will be important topics to study in the execution of the design. A second issue is the technical feasibility of the overall designs of such a synergy. As the report Recyclicity advised, commercially used technologies were picked for this research. The technical feasibility of a synergy between the cyclifiers should therefore not cause too many difficulties. Finally the relation with the community (soft side) is equally important for the execution of an energy factory at the Brunssummerheide. Potentially affected residents might react negative to such a plan. Therefore it becomes important to use the energy factory not only as an industrial cyclifier, but also as a social cyclifier.

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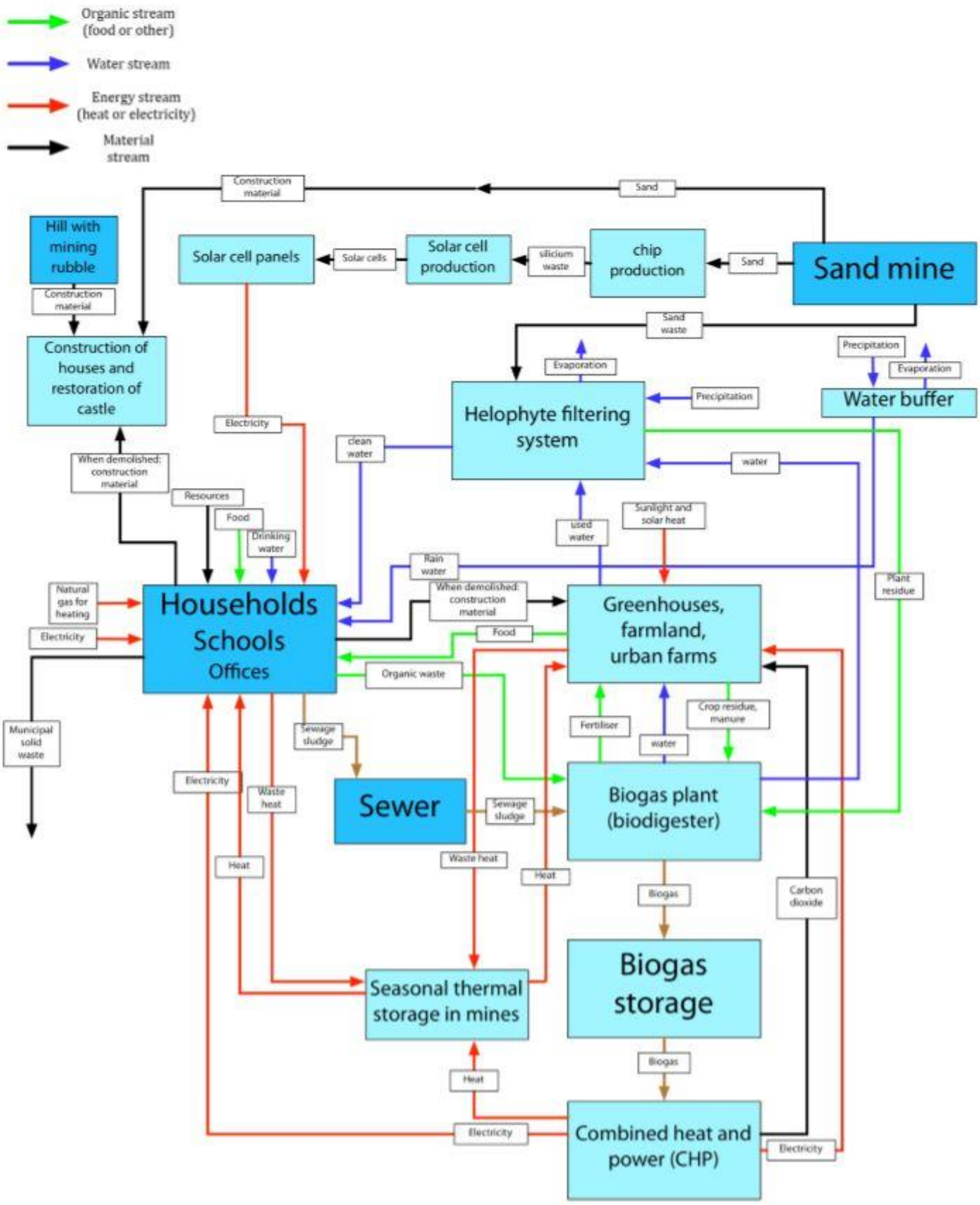
Appendix

Appendix A1 Metabolic Scheme Heerlen MSP 2040 (Superuse, 2009)



Appendix A2 Metabolic Scheme Brunsummerheide 2040