AN EXERGY PLANNING APPROACH FOR THE REGION PARKSTAD LIMBURG (NL

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Abstract

In the Senter Novem-financed research project “synergy between regional planning and exergy” opportunities are studied to implement strategies to improve regional exergy flows in Parkstad Limburg. Parkstad Limburg is a collaboration between seven municipalities in Zuid Limburg, who are making an active effort to realise economic growth. New energy is one of the primary targets that Parkstad works on, and construction of a ring road connecting the municipalities is an important measure to support further integration. In this paper we consider possible ways to do exergy planning for the Parkstad Limburg, using the ring road as a transport facility and the deserted coal mines as storage for energy.

Exergy planning is defined in this study as the realisation of spatial conditions necessary for the effective use of hitherto unused energy flows (residual energy). Studies have been made charting the spatial distribution over the region of the quality of the energy demand. Sources of residual energy and of residual material flows have also been surveyed, and new potential sources approached. In view of the fact that spatial and temporal mismatch of supply and demand of energy is not uncommon, possibilities for its storage, conversion and transport have also been invented. Thus, studies have been made for the transport of organic waste material from agricultural processes to a methane digester to yield methane gas. The methane is to be purified and added to the natural gas grid or converted to electricity and heat in a CHP (Combined Heat Power) plant. The electricity may be delivered to the electricity grid and the heat energy may be used for space heating.

To prevent mismatching, a heat distribution network and storage facilities are essential. Businesses with waste heat can supply heat to this network (and realise cooling for themselves) while parties with an energy demand can extract heat. This exergy approach can provide new opportunities for reducing the primary energy use of the Parkstad region.

1. Exergy planning

Until now the reduction of the energy use has been mainly studied at the single-building scale. Despite the fact that Dincer and Rosen (2005) argue that exergy is essential in order to understand sustainable development, the thermodynamic aspect of exergy is sometimes left out. Given the potentials of the total energy chain, we argue for using exergy as a principle to be implemented on a regional scale. It gives new opportunities for energy-savings, by making better use of different qualities of energy. In order to achieve this, energy connections are suggested between various spatial functions. Thereby spatial structure and it’s planning or intervention, become relevant and gets related to energy savings by means of applying exergy principles. This method of planning is referred to as exergy planning; the realisation of spatial conditions for improved use of unused (residual) energy flows.

Exergy planning has to lead to:
- A better use of the quality of energy (understanding exergy);
- The realising of spatial energy cascades (using different qualities of energy)
- The better use of residual flows (waste = food, or output = input)

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- The realising of a low exergetic (residual) energy demand (LowEx)
- A more efficient use of high exergetic (residual) energy supply

Residual energy flows and the way they are spatial and temporal linked, are important aspects of exergy planning. We have to identify what we mean by residual energy flows and how we can link these flows. The present residual energy flows are potentials that an area or region has and is energy that is locally available, but (still) not yet used for energy purposes. We can consider:
- Not used solar energy in heat from indoor air, soil or water;
- Unused solar light, solar radiation, wind-, hydro- or wavepower;
- Accessible geothermal heat from the interior of the earth;
- Cold from the ground or groundwater;
- Residual heat from manufacturing or cooling, greenhouses and sewer;
- Residual cold from manufacturing, heating (with heatpump);
- Organic waste from manufacturing processes (food-industry), agricultural production or municipal waste (especially green waste and garden waste), and sewer drain from the built environment;
- Biomass from maintenance of parks and natural areas and construction waste;
- Waste from fossil sources such as oil, plastics, etc.

2. The energy demand and residual potentials in the Parkstad Region

A large part of the energy demand in Parkstad region consists of heat demand (low-exergetic), that is mainly produced with fossil fuels (high-exergetic). The use of fossil fuel has to be reduced drastically and by applying exergy principles, fossil fuels have to be used for high quality energy applications. Moreover, we can make use of solar and wind energy and biomass can be used as a fuel. That could be biomass that is specifically grown to produce fuel, or a residual product. In paragraph six we will both identify and locate these residual energy flows for case in Parkstad Limburg. These residual flows are interesting because they are already available without any extra claim for use of land, in contrary to energy crops.

When waste is used for fuel production, we need to ensure that the residue from this energy production, can be used for other purposes in the carbon dioxide cycle. Heat (energy with low exergy) can be a residual product, thus used locally to cover the heat demand for buildings in the Parkstad region. Other residual flows can also be used locally. Biomass waste from the urban or rural areas can be converted to methane gas and fertilizer - a residue from the production of this gas. We can use the fertilizer in agriculture for growing crops and the methane gas utilised as fuel to produce electricity. Heat is a by-product of electricity production, and is also supplied to cover (part of) the heat demand for buildings in the urban area. A lot of residual heat is also produced from the industry, which can be applied for (part of) the heat demand for buildings.

The overall amount of heat demand for all houses in the Parkstad region is approximately 6 PJ and is produced using two billion m^3 of natural gas. Most of this heat has a temperature of 65 ^{o}C or less and can easily be obtained from low-exergy residual heat has opposed to high-exergy natural gas. This residual heat can be available in the surrounding areas or can be realised, using biomass-residual. These kind of cascading principles lead to better use of energy potentials. Eventually provision has to be planned to transport or store these residual flows or we can use the existing provision for transport and storage, to match demand and supply of energy. Besides the inventory of energy demand and potentials, the inventory of the possibilities for energy conversion, transport and storage, to deliver the most suitable form of energy in the right place and at the right time, is an important part of exergy planning (Gommans and Van den Dobbelsteen, 2007-103).

3. The location of energy conversion

Converting biomass residual to methane or other fuels from the Parkstad region, is difficult to accommodate in the urban environment. This being due to potential hazards, nuisances and additional traffic. Converting biomass in the rural areas may be desirable because there are sources of agricultural residual flows. The Bio plants currently operating in rural areas, use the biogas that is produced, to generate electricity by Combined Heat Power (CHP) plants.

The electricity grid in rural areas often has insufficient capacity. When using many or large CHP-plants, the electricity produced, cannot be supplied to the grid. Often the residual heat cannot be used, so it is lost. If there were greenhouses in the surroundings, the heat and the CO2 from the CHP-plants could be used for crop production - a reason for CHP-plants to be combined with greenhouses. Biogas transportation via pipelines can be a possibility to deliver the gas where it is required. Another possibility is biogas purification and deliver the gas to the local natural gas grid (green gas). The last mentioned alternative has the advantage that there is also a storage option for the gas, provided it is not a large quantity of methane gas.

In view of the fact that there is considerable space available on farms in rural areas, this can be utilised towards storage and drying of residual biomass on these farms. The biomass flows can subsequently be transported to urban locations at a later stage, instead of processing them in rural areas. As such, we can plan the bio digester plants on one of the industrial sites in the Parkstad region. Alternatively we can plan the bio digester plants in locations where there is already residual biomass collected, such as sewage treatment plants, or the waste collection locations. Dustbins where methane is often already collected, can be an excellent location for bio digester plants, as these sites are generally accessible. The question is whether we should use the gas directly for production processes, make electricity and residual heat, or purify the gas to supply it to the local natural gas grid. One can also think of supplying the biogas to nearby residential areas where CHP can generate heat and electricity. Thus, the existing heat network of "'t Loon" in the centre of Heerlen, can be heated with a CHP, driven on biogas instead of natural gas (as it occurs at present).

The production of electricity and heat (CHP) from biogas in an industrial site can take place at a larger scale. The percentage of electricity (with much exergy) produced, can be higher than in small. Industrial areas usually have an electricity grid with a high capacity, where production of large amounts of electricity is less of a problem for the grid. In this variant, the heat is transported to places where there is heat demand. Naturally there is a heat demand on the industrial site itself, but the CHP delivers much more. Moreover, there is often residual heat production on the site, which makes it interesting, as the heat from the CHP, including residual heat from production processes, can be exploited. In this way the energy demand for cooling is limited. In the Parkstad Region, the industrial sites are not far from locations with heat demand (especially housing). In view of this, there is little lost for transporting the heat. A main pipe for heat transportation may be conside-red to connect industrial and residential areas, thereby delivering, as well as obtaining heat from the pipe.

4. Distribution and storage of energy, grids and cascades

In the prior paragraph, residual biomass was converted into biogas (methane). This residual flow can also be converted into other fuels such as bio-ethanol or can be incinerated immediately. The conversion technique used depends on the nature of the present and the requested residual energy. Electricity, ethanol and methane is energy that is usable and not that difficult to transport. Pipelines and roads are available as channels for this transport. This is very different for heat (and cold), which is the main part of energy demand in the built environment. Specific heat distribution networks have to be built, and require a considerable amount of money. In the existing built environment it is more difficult to achieve a thermal grid than for newly constructed areas. The temperature level of the heat is also determined by the type of buildings (insulation, ventilation, function, etc.) and the applied services (low or high temperature heating, heat pump etc.). The demand also determines the extent of the temperature level and it determines if cascades can be realised to use the energy from residual heat more effectively (figure 1).

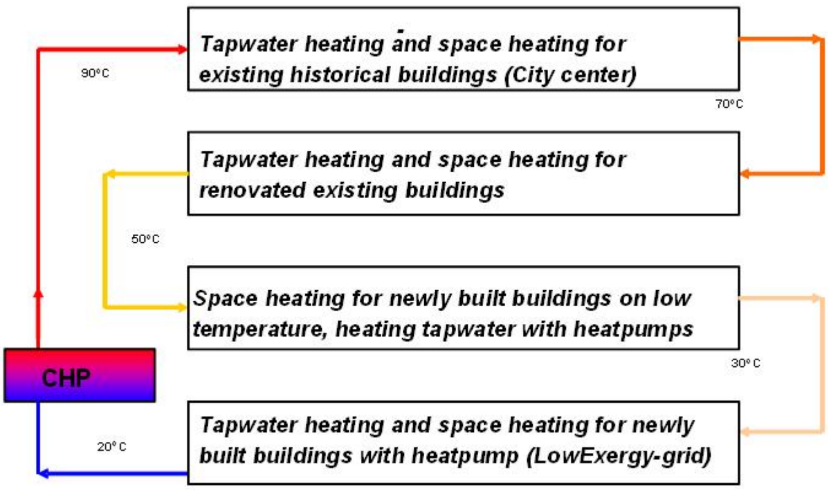

Figure 1: Residual heat from one district is the source for another district.

Sometimes it is necessary to store energy. Biomass or other organic residual flows are already a form of (chemical) energy storage. Residual heat, in the form of hot water is also a form of energy storage, but quickly loses its exergy when it is not insulated properly. The degree of heat and cold that can be saved depends on the insulation and the ambient temperature. When electricity from wind turbines or photo-voltaic cells is available, it should be utilised immediately or stored away. With the current techniques , storage of electricity is not easily obtainable in the Netherlands and requires a considerable amount of money. Currently the need for electricity storage is not large, but it will increase when the demand for electricity will be covered more and more by solar and wind power.

With regards to storage of exergetic low-valued cold or heat, there are local opportunities for storing them. For example vertical heat exchangers in the ground or groundwater-aquifers', sometimes accompanied by a heatpump, can store this low exergy energy. The old coal mines are specific in this region. They can be used for the storage of heat at higher temperatures, because 500 meters below the earth´s surface, the temperature is between 35 and 40oC. Currently, there are bore holes that are drilled for the withdrawal of heat - a sort of geothermal source. The geothermal temperature is relatively low. The potential for geothermal energy from deep and hot soil layers is unknown in the Parkstad region. Seasonal storage of residual heat in the coal mine galleries is a possibility.

In the Parkstad Region a specific heat and cool grid (LowEx thermal network) with heat pumps and heat exchangers is proposed (figure 2). Heat and cold is converted to / from a 3-pipe network and transported to locations where it is required at that moment or immediately after it is released. If there's no demand for heat or cold for a long time, it will be stored in the storages connected to this grid. This is locally possible in the ground. Regarding the district Stadspark Oranje Nassau, this heat can be stored in the old coal mine galleries (Gommans, Minewater 2008). Through realising the demand for heat on a low-temperature level as much as possible, and the demand for cold at a high-temperature level as much as possible, a minimum addition of (electric pump) energy is needed. This is referred to as "low exergy" designing (LowEx). It is difficult to implement this for existing buildings because these buildings normally require a high temperature for heating and a low temperature for cooling. With reference to newly built districts, where buildings are equipped with heating or cooling in walls, floors and ceilings or specific air heat exchangers (for example Fiwihex), a LowEx thermal network applies.

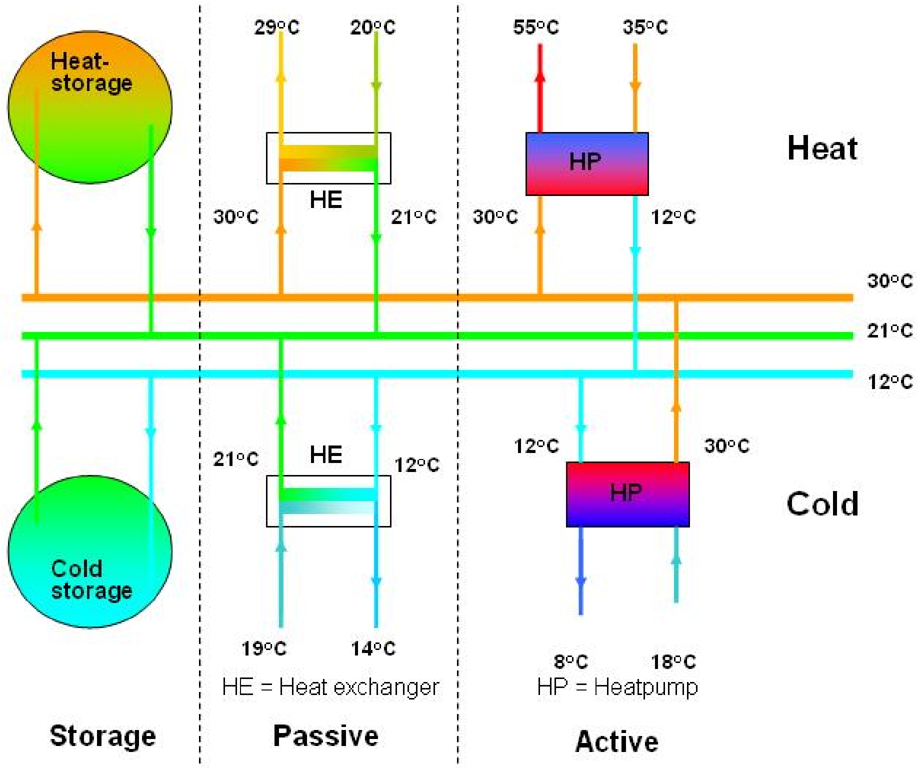

Figure 2: LowEx thermal grid for the Stadspark Oranje Nassau district Heerlen (L. Gommans - TUDelft)

5. Parkstad seen through exergetic glasses

Up until now we have focussed on principles of exergy planning. The question is if it is possible to link those principles in specific areas? In this case, Parkstad Limburg is a real playground for exergy planning. Is it possible to create plans for a more energetic sound Parkstad Limburg given the historical developments of the region and the specific circumstances. In the fourth paragraph we discussed the characteristics of a general applicable LowEx thermal grid, adapted to an area with specific opportunities. What opportunities are available? Can they emerge themselves, or is intervention required? These questions, are guidelines in this paragraph. First let us give a brief introduction to the region itself.

Parkstad Limburg refers to an area in South Limburg, previously known as the "Mijnstreek" or in English "Mine Area". The province of Limburg is situated in the south east of the Netherlands and borders Germany and Belgium. At present Parkstad Limburg is an official regional government authority, as it is a so called 'plusregion'. That means it is a region in which municipalities have common interests in economic and spatial

developments. Therefore the plusregion Parkstad Limburg deals with regional planning. This region can be described as a fragmented one. This fragmentation does not only refer to the institutional aspect (the seven municipalities) but also to the physical aspect of small villages existing within (approximately) one large rurban (rural and urban) area. This so called amorphous urbanisation is a consequence of the regions history, which is heavily characterized by coal mining. Fragmentation was and still is a result of it, as illustrated in figure 5. Therefore it actually is an example of an energy landscape in which land-use and settlements are based on energy, fossil energy (Gordijn, et al. 2003). Nowadays it is a region with 238,000 citizens and with both an urban and rural appearance. The region also became a significant player in tourism next to large industrial sites. Analysing the spatial structure of Parkstad Limburg we should state:
- urban area with sometimes very high building densities, but also green areas;
- rural area with a natural landscape and agriculture and with also a high level of services nearby;
- a mix of spatial functions;
- historically it was an energy supplier and currently it is an energy demander.

Understanding a regions spatial structure is helpful when identifying exergy planning opportunities. Aware of the energy potentials in Parkstad Limburg, makes it simpler to look for spatial features with accompanying exergetic options. The energy potentials we have here are residual energy flows both from city and countryside, like already mentioned in in the second and third paragraph. On one hand those residual flows contain high exergetic values, like biomass. On the other there are also low-exergetic valued waste heat flows. Based on the preliminary inventory data on energy demand, the supply of residual energy, and the options for energy conversion, transport and storage, we looked through ”exergetic” glasses at the Parkstad Limburg Region. Spatial plans are suggested for this region to obtain a better use of energy based on exergy principles and therefore the need for fossil energy may decrease. Let us first introduce chances there are in two examples on a smaller scale in the Parkstad Limburg Region: referred to as Park Gravenrode and Brunssumerheide East, prior to making the step towards general concepts on a large regional scale,

6. Brunssumerheide East and Park Gravenrode

The area of Brunssumerheide East, as shown in figure 3, is an example to start with. It is an area characterized with heath, a land fill site, a forest in construction, various housing areas, and some services like a swimming pool and a nursing home. On the one hand we see locations as sources of energy, and on the other hand there are spots where energy is used. A basic idea of exergy planning is to connect those areas in order to make improved use of unused (residual) energy flows. A relevant design principle is using a source-sink concept. This concept can be understood as an inclusive concept considering all kinds of landscape flows including organisms and non-living matter such as biomass and other forms of energy (Stremke, Koh and Van Etteger, 2007-28). Koh (2005) describes the need to integrate urban and rural areas as one complementary, mutual aiding and self-sufficient system on the regional scale. It actually means that we identify spatial functions as a source of non-used energy, that subsequently can be used in a more exergetic sound way like illustrated in figure 1, or a sink for energy. For the case Brussumerheide East, the heath in the north can be seen as a source in terms of manure, like urban waste (landfill related) and landfill gas as well. The woods in the south are a source of biomass waste (wood) as well.

Sinks, understood as spatial functions that can make use of low-exergetic energy flows, for instance low-temperature heat, are both the swimming pool, the nursing home, and the housing areas. In order to connect sources and sinks there is a need for distribution, storage, and conversion techniques, like discussed in paragraph three and four. Both the energetic characteristics of the sources as the spatial distribution of the sinks give arguments for an energy-space system. Waste, especially biomass, with a low-energetic value can from an efficiency point of view better be converted on spot in biogas or maybe oil (see f.i. Breuer and Holm-Müller, 2006-58). This is also true for the low-energetic manure in this case. Together with the reality that landfill gas is already produced in the north, we suggest to gasify low-energetic sources in the north (green open circle). The opposite is true for the wood from the woods in the south. As it contains more energy, it is more efficient to transport it. Therefore we argue for a CHP in the center of the area (red open circle), burning the transported gas from the north, wood from the south and distributing both electricity and heat to a grid. As the CHP is likely to be the spot with heat at the highest temperature (exergy comes in again), it should be seen as the top of a local heat cascade. Users of the heat are various housing areas (black open boxes, greyscales refer to population densities). Differences in age of the houses, therefore their technical constructions, make it possible to heat the houses with different temperatures. The total picture looks schematic wise like figure 3 on the next page. *The area of Park Gravenrode* can be described as an area with a dual look, both industry and leisure determine this subregion within the bigger look-alike Parkstad Limburg (see figure 4). Spatial elements of importance for our energy-space storyline are the industrial site Dentgenbach with some chemical factories and also for instance bakeries, a sewage treatment plant, a large ice hall (Snowworld), a zoo, and again some housing areas.

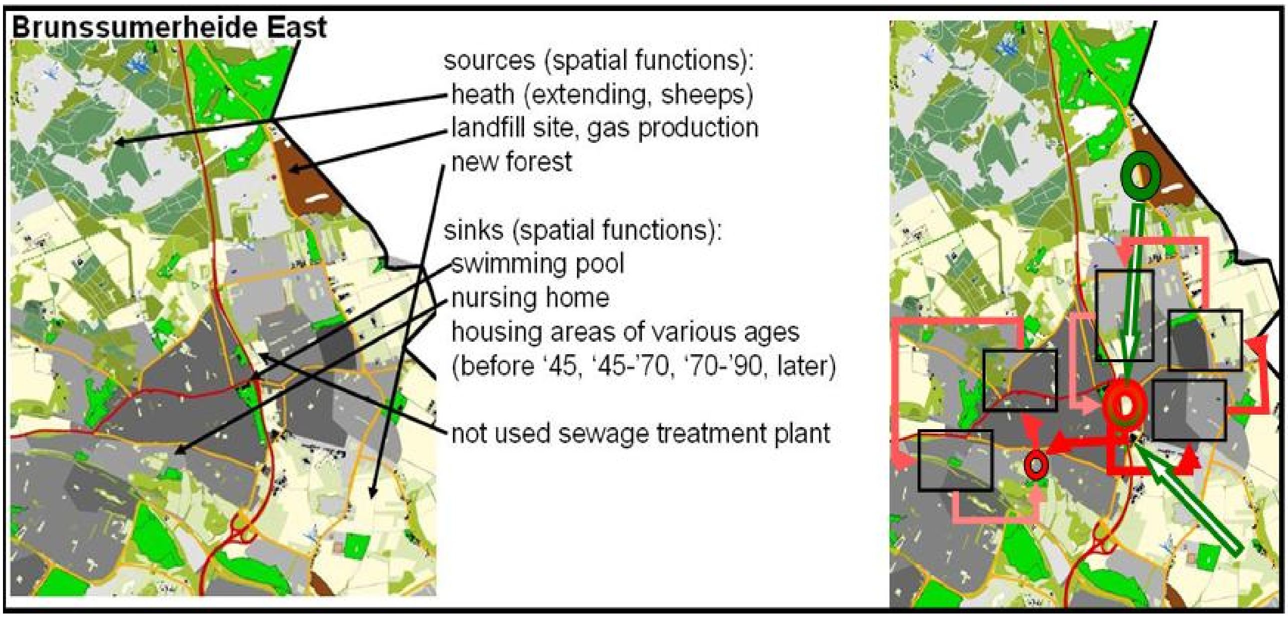

Figure 3: Brunssumerheide East as example of exergy planning – both geography and design shown

First, we begin by defining some sources and sinks for energy like in the Brunssumerheide East example. The large energy users (a sink) of high exergetic valued energy, chemical factories and bakeries, for exergy planning reasons, can also be seen as a source of residual heat. Further the sewage treatment plant is a source for biogas after conversion of electricity and heat. Moreover we identify the local zoo as a producer of manure and food waste. As sinks for energy we see the business park, tropical greenhouses (world gardens), energy exchange on the industrial site itself, various housing areas, and the zoo for accommodation of tropical animals in greenhouses. In this example the energy-space system also depends on distribution, storage, and conversion, as discussed in paragraph two and three. The sewage treatment plant can be seen as an energy roundabout, or central spot to combine regional biomass flows and convert it into gas, electricity, and heat. It is a remote location for obvious reasons, air pollution and spatial restrictions, and might be useful in this case for collecting biomass from the zoo and sewer. Subsequently the produced gas can be transported to the local industrial site where factories can use the gas for producing processed heat (high temparture heat). Then residual heat can be used in other sinks in the surrounding. Another heat source is Snowworld (a large fridge, kind of heatpump). Its waste heat can subsequently be used in housing areas, the business park, and the tropical greenhouses. A link is suggested between both systems to make them more robust and efficient. Figure 4 illustrates the overall picture.

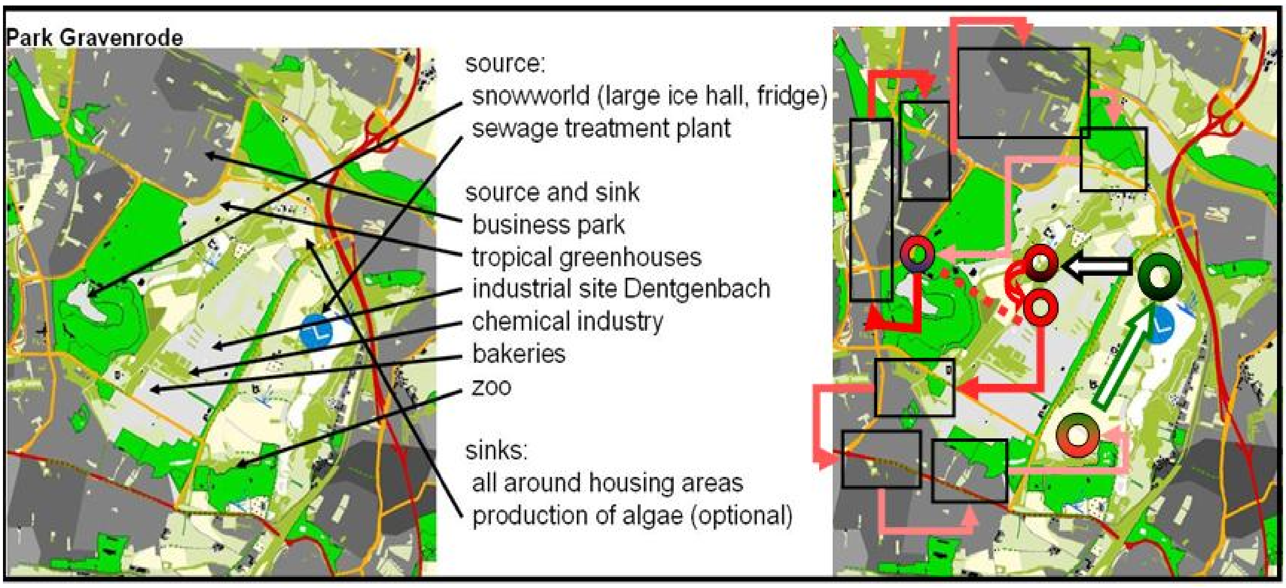

Figure 4: Park Gravenrode as example of exergy planning – both geography and design shown

In this example the sewage treatment is referred to as an energy roundabout (green-grey open circle on the right). Due to its relatively remote location, it can be argued for energy efficiency reasons to produce only biofuels (in casu gas) at this spot. In addition it is an argument that heavy industry is nearby for a biowaste to gas conversion. It is assumed is that those heavy industries can use high temperature heat, which is easier to produce in the industrial location itself by means of combustion, rather than to transport steam from another location. This more sustainable shift from natural gas to biogas is not that difficult due to already available natural gas infrastructure. Subsequently, the spatial structure of the Park Gravenrode makes it possible to use waste heat more often by means of a heat cascade, like illustrated in figure 1. That is an extra reason for not combining biowaste collection and combustion. In that case it would be harder to reuse the same amount of heat more often, due to the distances to spatial functions with a range for temperatures of their heat demand. The used example provides in the left part of the design scheme an option to cascade heat grids, related to the idea of using different qualities of heat in neighborhoods with various dates of construction. As such it can be concluded that the way in which energy sources (like biowaste) are used depends on spatial issues like variety of functions, and distances.

7. Parkstad complete

After briefly discussing two examples it becomes apparent, that there are several interesting options for the combination of energy and space by means of exergy planning in Parkstad Limburg. The kind of energy-space system depends on how the area is cropped or defined. This does not argue with the fact that for each option security of supply, back-up system, and flexibility are key features of the system. In each case where we think of a connection between spatial functions, you can raise the question – why isn't there a link already? A plausible explanation is that people / companies do not want to commit to long-term agreements. At the same time those long periods are necessary to recover investment costs in extra needed infrastructure. A company does not know whether it will be on that same spot in ten years. This makes it hard for each spatial function to become both a supplier of energy and user of energy. That is a consideration on the micro scale. A scale on which everyone would choose for a good option that saves money. Can we think of a more robust system? And does the spatial structure of an area provides some suggestion? Let's again have a look at Parkstad Limburg.

As stated before, Parkstad Limburg can be characterized by means of a lack on a clear structure. This observation is also done by the regional planning authority in it's spatial plan. It is even used as an important argument for one of the main desired spatial interventions, a new ring road. That new road is seen as a structuring component for the region, not as a ring road does in most of other urban areas, where it is a circle around the city center. But the road structures in Parkstad Limburg is like a string of beads. The beads here, are housing areas, and (especially) industrial sites. Connecting industrial sites and making them easily accessible by road, is done in order to attract companies from outside the region. Remembering our design principle in the examples, the road connects therefore various sources of energy like sinks for energy, as well. The idea to use this to built ring road also as the backbone of a heat grid is an interesting one. Adding some extra pipes like shown in figure 3 is relatively easy and not very expensive during construction works on the road. Figure 5 shows the region Parkstad Limburg and in black the alternative routes for the planned ring road. That ring connects also our two examples, that are on the right side of the figure. Two other examples, that are not mentioned here, would become connected as well.

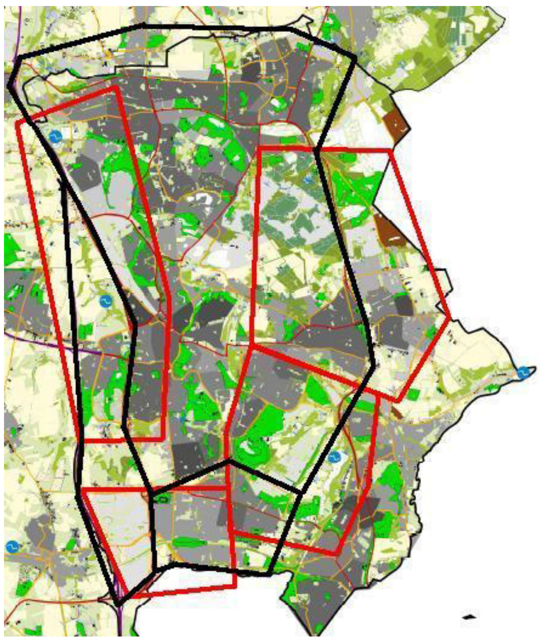

Figure 5: Parkstad Limburg an interesting spatial structure for an energy ring

Referring to the ring road as an energy ring means that we have a real spatial concept, a ring. It obviously has some advantages with respect to security of supply from a system theory point of view. In case an energy company would run the system then spatial functions (as sources and sinks) should be able to earn or save money with a connection to the main grid. It should be possible to deliver and acquire heat from the grid. In such a situation a company has a contract and a relationship with an energy company, that probably doesn't differ from the current situation. It could also be an argument for both developing new industrial sites (creating sources) and for instance warehouses (sinks) along the energy ring. Maybe it is even a strong argument for attracting new companies, as is also a goal of the ring road itself. If an energy ring has the same amount of attraction as a ring road has for spatial functions, then there is no doubt about new developments. Synergies between the energy ring and the ring road might even evolve in a stronger argument for spatial development. In addition a large heat ring network is a backup system itself, but can relatively easy be linked up to other storing facilities. The closed coal mines can be used as a source for heat-cold storage in the Parkstad Limburg case energy (Gommans and Van den Dobbelsteen, 2007-103). It means that it is also possible to link a general concept like an energy ring to areas with specific circumstances like the existence of a natural storing facility. Here we conclude that for a more exergetic sound design of Parkstad Limburg the concept of an energy ring perfectly applies

8. Concluding remarks

It is important to plan developments of spatial functions in such a way that they can make optimal use of the present regional energy potentials and residual energy flows. The place where, the time when and the nature of these sources provide beside the place, time and nature of the energy demand, to what extent there is a match between demand and supply. Exergy planning can help in order to come up with interesting area specific spatial concepts or plans to connect sources and sinks in a more sustainable way. Opportunities for transport, storage and conversion of energy, play an important role in obtaining a better adjustment of energy flows in time, place and form. Especially when we like to use the different qualities of energy flows.

To do this, it is necessary to have a look at the spatial structure of both the built (urban) and non-built (rural) environment and its energy demand and supply, at a more detailed scale. In this phase of the research, making plans and coming forward with a useful concept for the Parkstad region, we had an overall view. The use of residual energy also demands for a more detailed inventory with potential suppliers of residual energy involved. Otherwise it will be difficult to get a picture of the quantity and quality of the residual energy and the form in which it occurs (for example heat in waste gases, air or water). That is why it is necessary to consider the current plans with the knowledge that they should be refined at a later stage in the research. Collecting data on energy flows and on spatial structures is an iterative process together with making plans based on regionally applied general concepts. Research is also necessary for the suggested heat ring for Parkstad Limburg to get more detailed information about the demand and supply of energy and the form, time and place it is acquired respectively supplied.

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