7.9 Transition to sustainable energy system in South Limburg: a regional case-study, Sven Stremke M.A.

1. Introduction

1.1 Energy trends

Examining recent developments in the European energy system, three major trends can be observed: Firstly, energy consumption has been rising more than 20 percent since the oil crisis in the late 1980's. Secondly, extraction of primary energy resources in Europe has been decreasing significantly (EIA, 2006). Thirdly, the amount of energy provided by renewable means remains limited in comparison to conventional energies. Across Europe, renewable sources contribute only 6.8 percent to the energy provision (CBS, 2007). In order to bridge the widening gap between energy supply and demand, Europe is importing more and more energy. Consequently, the share of imported resources has risen to almost 50% of the total consumption and is expected to increase in the future (EIA, 2006). For many reasons, this situation can not be considered sustainable; neither in economical nor ecological terms. The importing of energy from outside of Europe increases dependency on foreign economies. Above all, scientific studies have revealed a significant correlation between the excessive combustion of fossil fuels and global warming, leading to changing climate and precipitation patterns as well as rising sea levels (e.g. IPCC, 2007).

1.2 Sustainable energy transition

Sustainable development represents a paradigm shift, also in the "energy world". The Royal Netherlands Academy of Arts and Sciences emphasizes in one of their latest publications on energy transition that "research must focus on a system approach to the entire [energy] chain, from primary sources of energy to end-user" (KNAW, 2007, p.xiii). Cambridge University Professor Susan E. Owens emphasizes that spatial organization of the built environment affects more than half of the total energy consumption (1990). Integration of energy-conscious thinking in spatial planning and design can (and must) contribute to sustainable energy transition.

Transition to sustainable energy systems is by no means limited to the provision of renewable energy; improving energy efficiency is just as important. Both aspects, efficiency (step one) and renewables (step two), have been described in the three-step-strategy referred to as 'Trias Energetica' (Lyssen, 1998). Step three, using fossil-fuels as "cleanly" as possible may be beneficial during the transition from one energy regime to another. Long-term objective, however, is to establish sustainable energy systems which are self-sufficient on the basis of renewable energy sources.

1.3 State-of-affairs

The discussion on sustainable energy transition is not a new one. In the aftermath of the first and second oil crisis, Howard and Elisabeth Odum, among other scholars, argued for a "steady-state economy" where "inflows of energy balance the outflows" (1976, p.241). Energy transition, however, remains a rather vague objective for spatial planning and design disciplines. Increasing efficiencies in energy conversion and assimilation of renewables have become key concerns of sustainable development; many ideas circulate and newspapers discuss energy issues regularly. Yet, we are still depending, to a large part, on fossil-fuels and the appetite for energy continues growing across the globe. Disciplines concerned with the planning and design of the built environment are only beginning to understand the magnitude of sustainable energy transition.

1.4 Knowledge gap

While envisioning evolution of entire regions from fossil-fuels dependency towards a sustainable energy system, we have encountered a number of constraints. One question we were facing was how to store wind energy so it becomes available in times of need. It appears that many of the constraints can not be solved by mere spatial allocation of land-uses such as housing areas, industries and greenhouses. That is why this paper centers on the key differences between resource-based (fossil-fuels) and renewable energy systems. With renewable energy systems, we refer to energy systems entirely based on renewable energy sources, primarily solar irradiation. Nature and (some) ancient societies offer a number of examples. Experiences from a regional case-study in South Limburg (NL) will help to clarify the differences between the two energy regimes and illustrate possible solutions.

2. Method of Inquiry

This paper presents findings of a multidisciplinary research project conducted by spatial planners, landscape architects and engineers investigating potential synergies between spatial planning and exergy. Throughout the research project, case-studies help to identify and test energy-conscious interventions in the physical environment. For the case-studies, we employ a method referred to as 'research-driven design'.1 In 2006, we were asked to envision possible pathways for energy transition for the region of South Limburg (Netherlands).

2.1 The area: Margraten in South Limburg

South Limburg is located in the South of the Netherlands and comprises an area of approximately 660 square kilometres with a population of about 617.000 inhabitants. The region has a long history as energy provider to the entire Netherlands. With the closing of the coal mines in the early 1960's, however, the region not only suffered thousands of job losses but also became highly dependent on energy imports from other parts of the Netherlands and abroad.

Margraten, the focus of this paper, is a rural municipality in South Limburg (see figure 3) consisting of two large villages and seven smaller settlements. The size of the municipality is 58km2 and land-uses are distributed as following: 42% arable land, 36% pasture, 10% forest and approximately 7% settlements. Margraten is part of the Heuvelland 'national landscape' [hilly land] which is protected by law. The Heuvelland (see figure 2) is unique because of its open plateaus and closed valleys, which can only be found in this part of the Netherlands. At present, about 98 percent of the energy demand is provided from outside the municipality. Remaining two percent of energy is renewable; primarily second generation biomass (CBS, 2006).

Fig.1: Former 'Oranje Nassau' coal mines, South Limburg, 1920's (photographer unknown)

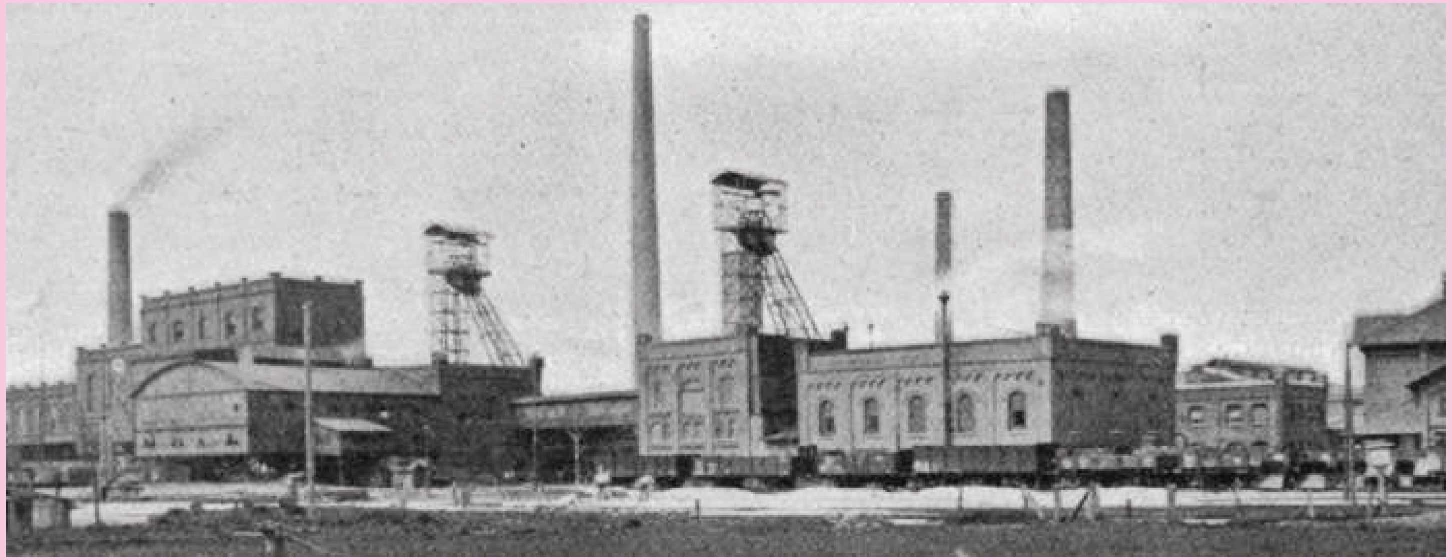

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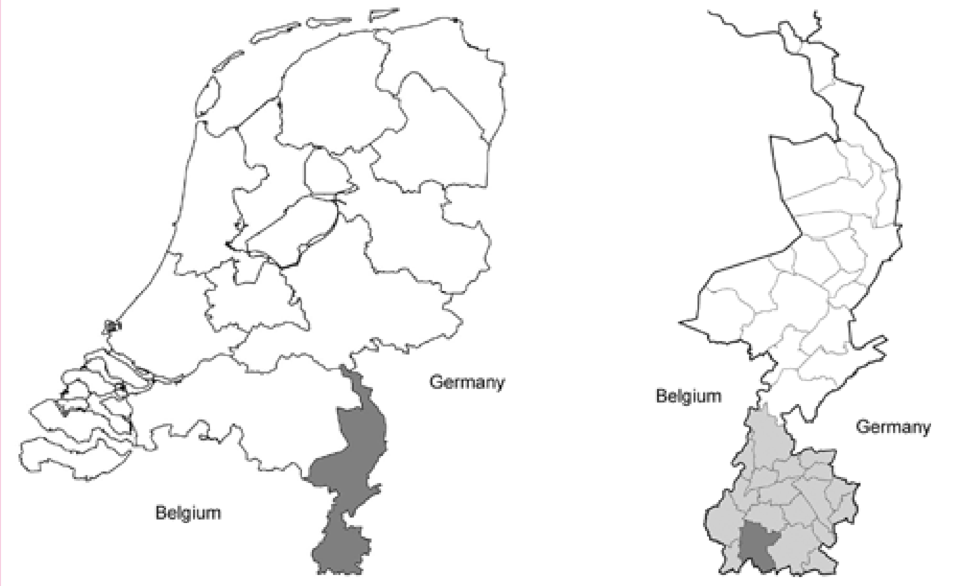
Fig.2: View through one of the valleys cutting through the Heuvelland plateau.

2.2 The team: Researchers and Master thesis students

In January 2007, we invited a group of international master students to envision a sustainable future for the region of South Limburg. The assignment of the Regional Atelier was to design sustainable landscapes which could increase regional self-sufficiency in terms of energy. The scope-of-work included a wide range of energy related issues ranging from potential energy savings, assimilation, storage, transportation, consumption and re-use of energy to the exploration of added values on a regional scale (e.g. preservation of cultural landscapes and improved flood control). During the design process, the group split up into smaller working units investigating the Maasvallei, Heuvelland and Parkstad. Each team composed strategic landscape visions articulating robust strategies and design guidelines. The

Fig.3: Province of Limburg in the South of the Netherlands (left figure). Region of South Limburg indicated in light grey and municipality of Margraten indicated in dark grey (right figure).



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findings were visualized and presented to the public (Etteger and Stremke, 2007).
In 2008, two of the Regional Atelier participants approached the author asking for supervision of their Master thesis project. The proposal was to continue working on the Heuvelland and to concretize energy-conscious spatial interventions for the municipality of Margraten. This paper presents parts of this collaboration between graduate students (Boekel and Neven, 2008) and researchers (Stremke and Koh, 2008).

3. Sustainable energy transition in Margraten

Energy and the built environment influence each other in many ways. Available resources and conversion techniques shape urban and rural landscapes (e.g. Ruhr area in Germany). However, physical realities may also support or constrain energy assimilation (e.g. Hoover dam, Black Canyon, United States). Human energy systems are primarily resource-based and differ in many aspects from sustainable energy systems. Differences between the two energy regimes are of major relevance to planning and design of the built environment. Subsequently, we compare rate of assimilation, temporal availability and energy density of the two energy regimes and illustrate strategies to evolve a sustainable energy system in the municipality of Margraten.

3.1 Rate of assimilation

Resource-based systems can flourish (for a limited period of time) based upon fossil-fuels stored underground. Due to the exploitation of accumulated resources, system output can exceed system input. Systems based on renewables, in contrast, can only appropriate as much energy as is being assimilated; system input exceeds output.
Solar energy, the main source of renewable energy, is available abundantly (e.g. Willet, 1977). A major constraint of renewable energy systems, however, is their limited capacity to capture and store inorganic energy. If present societies were to rely on renewable sources exclusively, relative inefficiency in energy assimilation and conversion would increase land-use pressure; large areas would be needed to assimilate sufficient renewable energy (see figure 4).

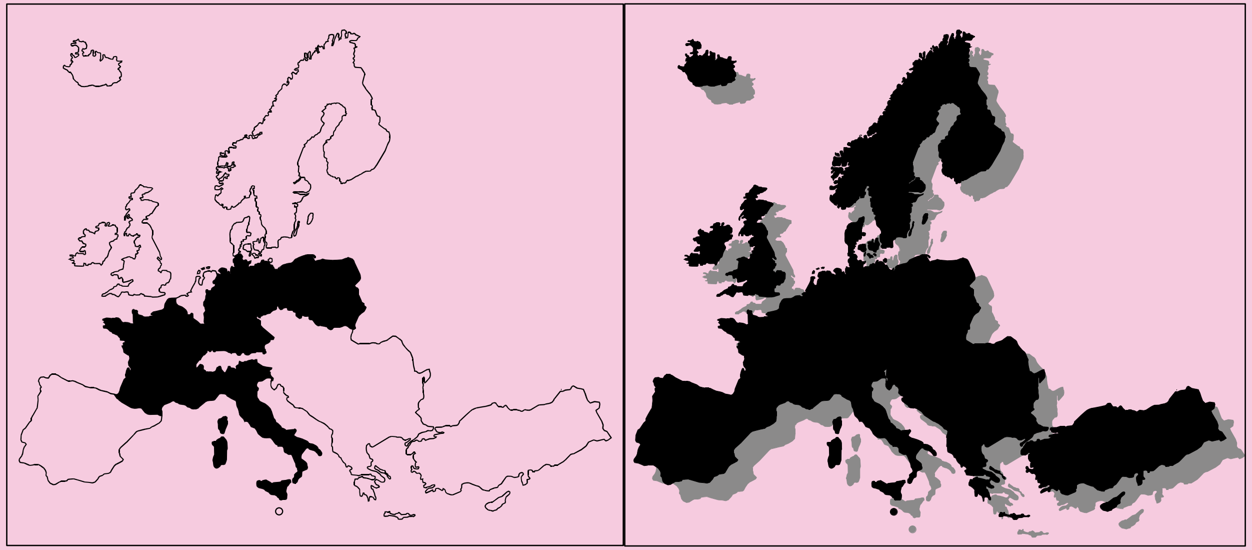

Fig.4: Area required to substitute natural gas consumption of Europe by first generation biomass (left figure). Area required to substitute natural gas consumption by second generation biomass (right figure).

Margraten: Potential self-sufficiency has been estimated on the basis of land-use characteristics, renewable energy potentials and present day energy consumption. Energy consumption of the 13.500 inhabitants amounts to approximately 110 TJ of natural gas and 50TJ of electricity per year2. Due to the relative low density of 230inhabitants/km2 (compared with Dutch average of 397 inhabitants/km2), the municipality could become self-sufficient on the basis of wind turbines and fermentation of second generation biomass (Stremke et al., submitted).

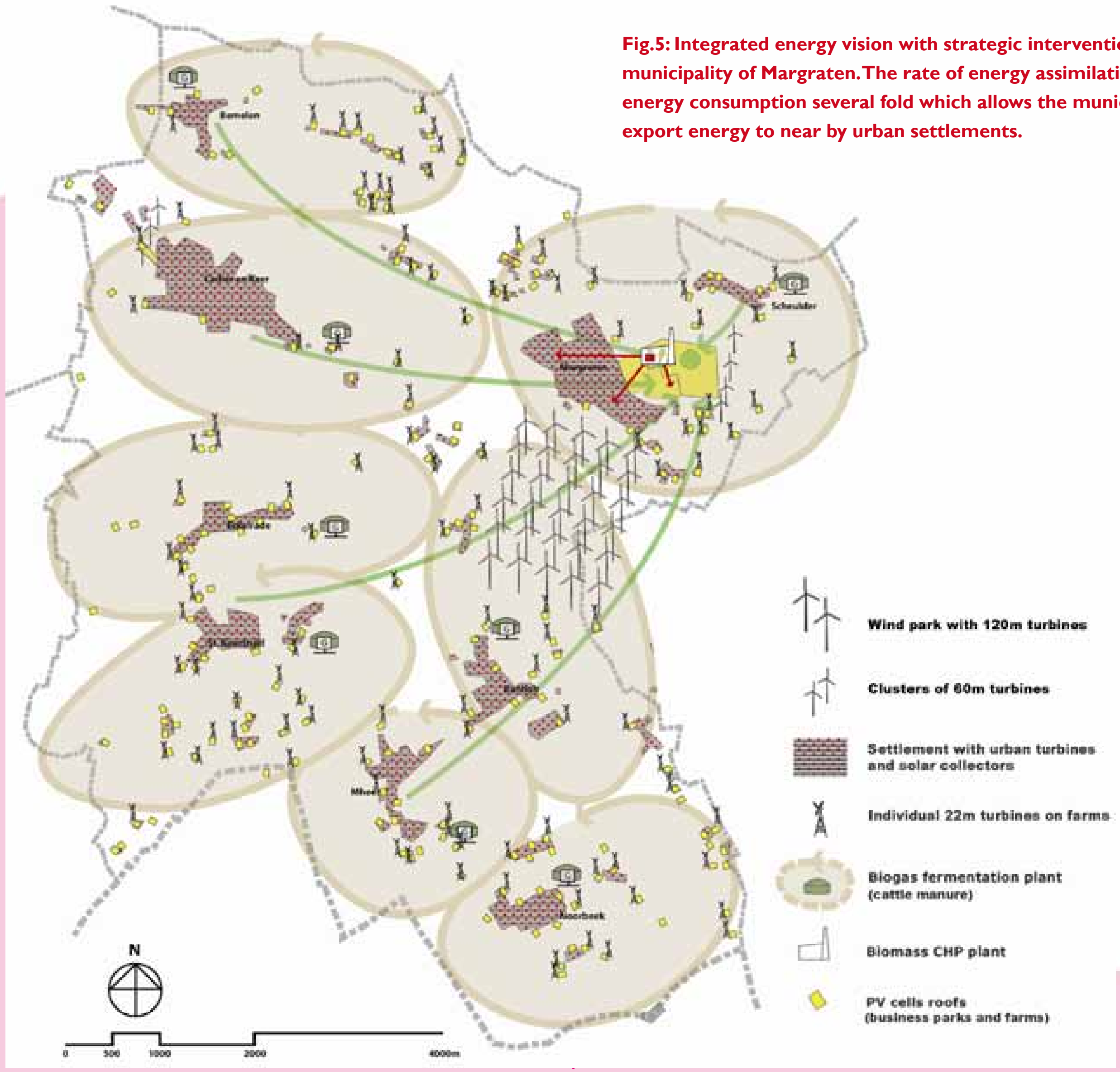

Fig.5: Integrated energy vision with strategic interventions for the municipality of Margraten. The rate of energy assimilation exceeds energy consumption several fold which allows the municipality to export energy to near by urban settlements.

For densely populated regions, however, the degree of self-sufficiency relies heavily on the criteria established for the utilization of renewable sources. Assuming that landscape quality and biodiversity have to be (at least) maintained, energy consumption in densely populated areas must be decreased significantly in order to increase self-sufficiency.

3.2 Temporal availability

One great advantage of accumulated resources such as natural gas and coal is that they are available 24/7 and throughout different seasons. Resource-based systems influence not only the rate of resource extraction but also energy conversion; for instance power plant capacities. Price variations, political unrest or extreme weather conditions (e.g. hurricanes) may influence resource extraction to some degree. However, they result only in minor fluctuations in supply (on global scale). Temporal availability of fossil-fuels is considered continues.
Renewables are indeed available for an indefinite period of time; the 'supply' of most sources, however, is not constant. Sun, wind, water and biomass are only accessible during certain periods of time. The supply of renewables may fluctuate between day and night, between summer and winter, rainy seasons and dry seasons (see figure 6). Periodic changes in the environment do and will continue to constrain the transition to renewable energy sources.

Margraten: If the municipality is to rely on renewable sources, periodic fluctuation in supply must be anticipated. Seasonal energy storage can be accomplished by means of biomass or biomass derivates such as biogas, bio-ethanol and biodiesel. Strategies include storage of solid biomass (for incineration in CHPs), storage of cattle manure (for fermentation) and storage of biogas in containers and the local gas network (see figure 7). Capacities for CHPs and mini CHPs have to be designed to be able to generate sufficient electricity in times without wind and solar irradiation.

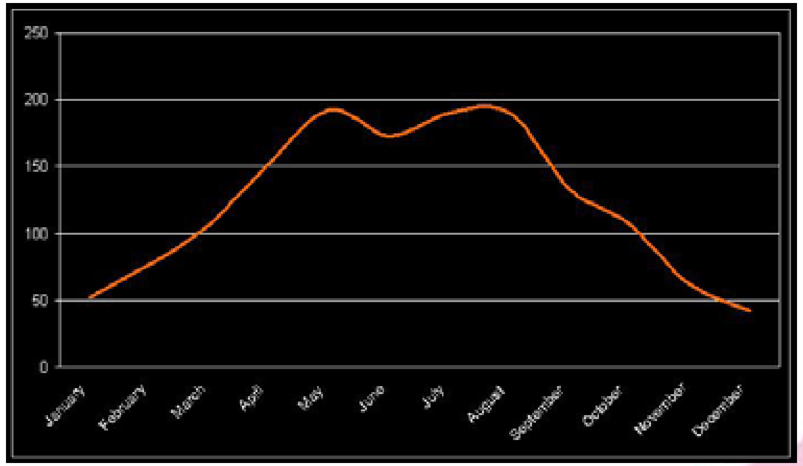

Fig.6: Periodic fluctuation of solar irradiation (here in hours of sunshine/month) throughout the year.

3.3 Energy density

Energy density, that is the amount of energy stored in a given unit of mass, varies considerably between the different energy carriers. Generally, fossil-fuels have a significantly higher energy density. Gasoline, for example, has an energy density of 47 MJ/kg. This is because fossil-fuels have been exposed to high pressure and heat over millions of years. Renewable energy carriers, in contrast, have a much lower density (e.g. bulky biomass with 10 MJ/kg). Renewable energy systems appropriate diverse energy sources and carriers with relatively low energy density (e.g. solar radiation, geothermal heat and biomass). Density of bulky biomass, for instance, is low due to the large water content in fresh plant material. It is possible to increase energy density; such "upgrading", however, is energy intensive.
Density of energy carriers influences the spatial distribution thereof. How far geothermal heat can be cascaded, for example, is a function of monetary and material investments. Laws of physics, however, prevent cascading of warm water over longer distances.
Margraten: Different strategies can be employed to mitigate

relatively low densities of renewable energy carriers. One option is to minimize distances between places of energy assimilation (i.e. source) and consumption (i.e. sink). Spatial extent of energy (sub)systems should reflect the density of the respective energy carrier. Liquid biomass, for instance, should be used within the municipality in order to minimize transportation. The number and location of conversion plants in the region (e.g. fermentation plants), is then a function of how much energy is available at which density. Another option is to "pre-treat" energy carriers.

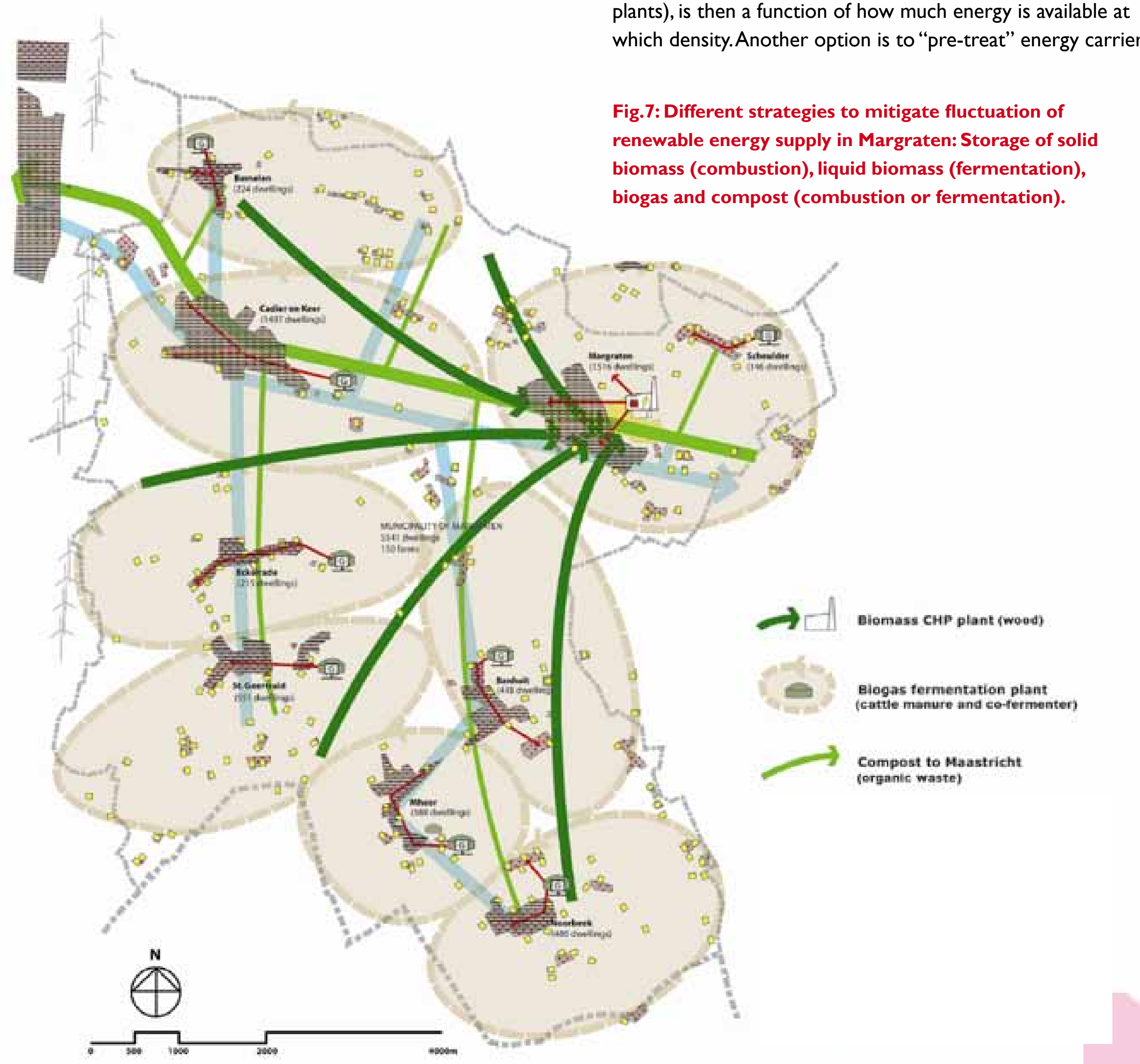

Fig.7: Different strategies to mitigate fluctuation of renewable energy supply in Margraten: Storage of solid biomass (combustion), liquid biomass (fermentation), biogas and compost (combustion or fermentation).

In the case of by-products from landscape maintenance, just to name one example, biomass can be dried before transportation. Increasing energy density is, to some degree, also beneficial for seasonal storage as it reduces the volume of energy carriers.

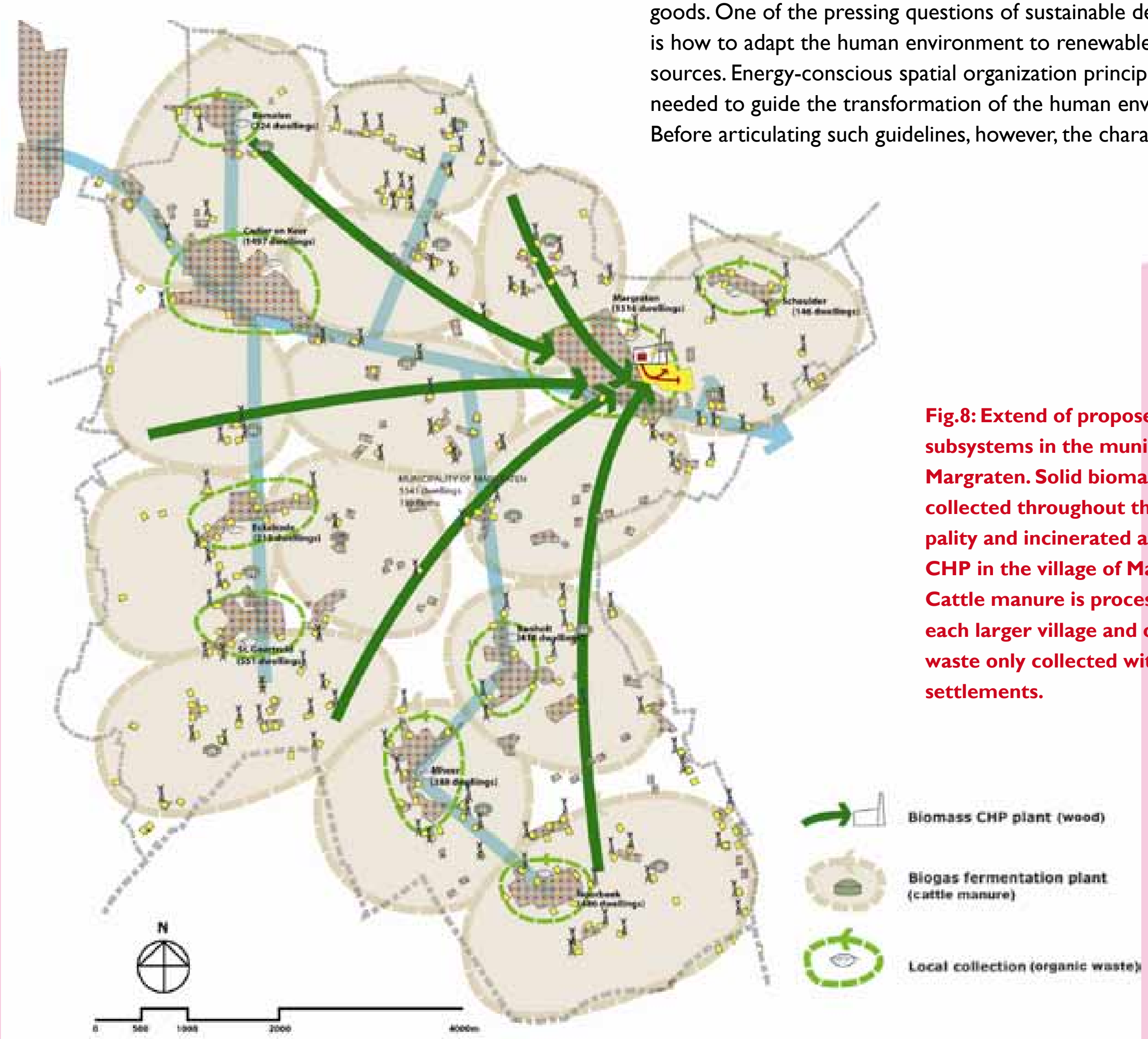

Fig.8: Extend of proposed energy subsystems in the municipality Margraten. Solid biomass is collected throughout the municipality and incinerated at the CHP in the village of Margraten. Cattle manure is processed in each larger village and organic waste only collected within the settlements.

4. Conclusion

The discovery of fossil-fuels, in conjunction with invention of the combustion engine, not only stimulated unprecedented economic growth but also resulted in spatial patterns which are highly dependant on vast amounts of energy (e.g. Sieferle, 2001). Excessive amounts of energy are needed for construction and maintenance of the built environment, for transport of people and goods. One of the pressing questions of sustainable development is how to adapt the human environment to renewable energy sources. Energy-conscious spatial organization principles are needed to guide the transformation of the human environment. Before articulating such guidelines, however, the characteristics

of regenerative energy system must be explored. This paper discussed key differences between resource-based (fossil-fuels) and renewable energy systems with special focus on possible implication to energy-conscious planning and design.
Comparative analysis of the two energy regimes has shown that they differ significantly. In resource-based energy systems, rate of energy extraction (fossil-fuels) and conversion meet energy demand. For renewable energy systems, in contrast, rate of assimilation may not exceed (present-day) demand. Not enough energy is available! Another constraint of renewable energy sources is their limited temporal availability. They are not available all the time! Moreover, this paper has highlighted that energy density of renewables is relatively small compared with fossil-fuels. Energy does not have the right quality! In spite of the many advantages of renewable energy sources, above constraints need to be addressed while discussing sustainable energy transition. Through research and (case-study) design, different mitigation strategies have been identified and illustrated in this paper.
One may conclude that sustainable energy transition appears to have more implications to the human environment than previously assumed (also see Stremke and Koh, forthcoming).
The properties and constraints of renewable energy systems discussed in this paper, illustrate the manifold relations between spatial planning, landscape design and energy transition. We invite landscape architects, planers, designer and engineers to join in the exploration of innovative strategies towards a sustainable human environment. This way, spatial planning and design disciplines can remain relevant and face their responsibility for other places and future generations.

Acknowledgments
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1 RESEARCH-DRIVEN DESIGN INVOLVES THE CREATION OF A LOCALIZED DESIGN BASED IN PART ON THE RESULTS OF SCIENTIFIC RESEARCH (KLAASEN, 2004).
2 CALCULATIONS FOR ENERGY CONSUMPTION IN MARGRATEN ARE BASED ON DUTCH PER CAPITA AVERAGE CONSUMPTION PUBLISHED BY STATISTICS NETHERLANDS (CBS, 2008).