227: Energy-Conscious Regional Design: Synergy between Ecosystem Thinking and Spatial Planning

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Abstract: Energy-Conscious Regional Design
In the coming years, we must not only invest in 'climate proofing' of our environment but also address another key aspect of sustainable development: A regenerative and self-sufficient energy system. This paper explores possible pathways for a transition to sustainable energy landscapes at the regional scale. The presented Landscape Approach is based upon the integration of ecosystem thinking and creative spatial design. A number of energy-related ecosystem concepts are identified and described. Based upon the understanding of these descriptive concepts, a number of prescriptive strategies are defined. They can facilitate a transition from fossil-fuel to sustainable energy systems. A regional case-study, finally, illustrates the application of energy-conscious strategies and estimates the potential self-sufficiency of South Limburg (NL).

Keywords: energy transition, landscape approach, sustainable energy landscape, regional planning, sustainable design

1. Sustainable Energy Transition

Throughout past decades the share of fossil-fuels imported from outside Europe has risen significantly. For many reasons, this situation is considered unsustainable, both in economical and ecological terms. Obviously, more and more energy can be imported to accommodate increasing demand and substitute depleting European stocks. Importing energy, however, increases dependency on foreign economies. Above all, scientific studies have revealed significant correlations between excessive combustion of fossil-fuels and global warming, leading to changing temperatures and precipitation patterns as well as rising sea levels. This is why we must not only invest in 'climate proofing' but simultaneously address another key aspect of sustainable development: a regenerative and self-sufficient energy system. The sustainable design paradigm allows spatial design disciplines to remain relevant and face responsibility for other places as well as for future generations.

This paper explores possible pathways for a transition to sustainable energy systems integrating ecosystem knowledge and creative spatial design. Based on the many similarities between natural ecosystems and the human environment, an innovative approach to energy-conscious spatial design emerges and is consequently explored. The Landscape Approach is then elucidated with the help of three relevant ecological concepts. Finally, a case-study at the regional scale will estimate the relative self-sufficiency that can be achieved by applying the Landscape Approach for the region of South Limburg in the Netherlands.

2. Energy Landscapes: Past and Present

The exploitation of fossil-fuels results in costs transferred to the environment (i.e. air pollution) and to future generations (i.e. energy scarcity). Being aware of the stress that human energy consumption induces upon the environment, we have begun questioning the excessive use of fossil fuels. Looking into the history of human energy systems, it becomes clear that the access to inexpensive fossil-fuels has suppressed renewable energy provision throughout the past two centuries. Before that period, however, humans have relied on renewable energy sources. Only a few of these sustainable energy landscapes remained untouched, illustrating the implications of renewable energy assimilation to the environment. Although technologies have advanced, (historical) energy landscapes remain inspiring, illustrating that the assimilation of renewable energy requires more space than the utilization of fossil-fuels.

Fig 1: Historical energy landscape near Kinderdijk, the Netherlands. (Photo by Wiiinston/Flickr)

Energy consumption in Europe has increased by more than 20% over a period of two decades; an ongoing trend that is accompanied with a significant drop in coal and crude oil production. This is why Europe today, relies to nearly 50% on the import of fossil-fuels from other regions in the world. [1] Clearly, Europe is no longer (energy) independent. The current debate on energy security, ethnical aspects of global trade as well as climate change reflect a growing awareness of these issues both in the public and scientific community.

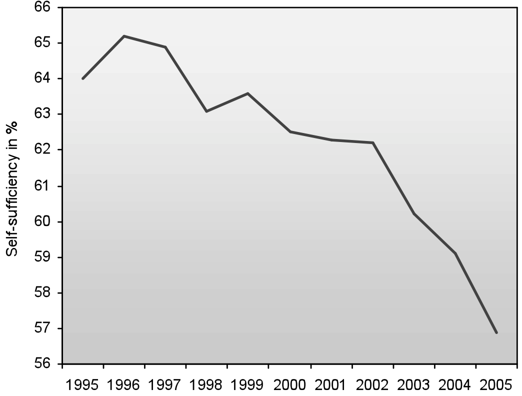

Fig 2: Declining energy self-sufficiency in Europe, period from 1994-2005 [based on 1]

The capacity for providing renewable energy is limited and influenced by geographical location, climate and geology. [2] If we are to depend on regenerative energy sources, we must not only address provision of energy but, simultaneously improve energy efficiency. This seems especially important, as we are competing more and more with other regions of the world for remaining resources. A sustainable energy transition, therefore, focuses on assimilation of renewable energy and energy efficiency. Designing sustainable energy landscapes is to envisage an environment which effectively assimilates, stores, cascades and saves energy.

So what are the key characteristics of a sustainable energy system with the sun as the main source? First of all, solar radiation, wind, biomass and other derivatives of the sun have a lower energy density than fossil-fuels. This is why assimilation of solar energy requires space and time. Secondly, solar radiation is distributed homogeneously across the landscape. This is why solar energy needs to be converted, concentrated and stored. The graphics below illustrate how much space would be needed to substitute today's natural gas and conventional electricity consumption by renewable means. The area required is a function of how we assimilate and converse solar energy.

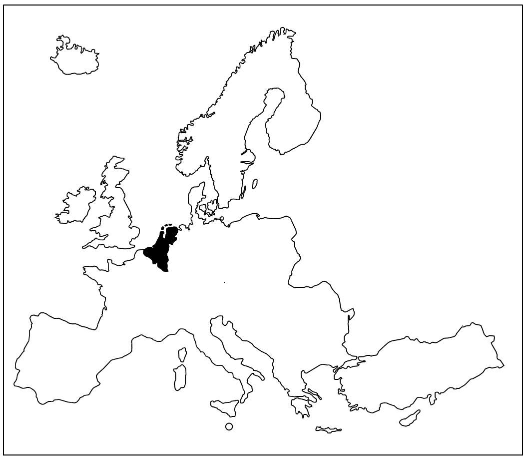

Fig 3: Area required replacing conventional electricity power plants in Europe by 5MW wind turbines. Calculations based on [1] and [3]

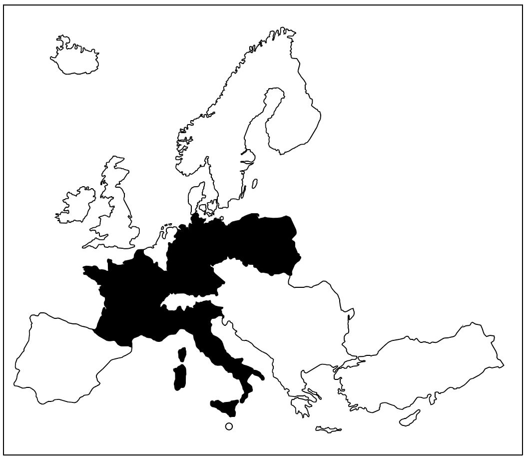

Fig 4: Area required replacing natural gas consumption of Europe by 1st generation biomass; here rapeseed as energy crop. Calculations based on [1] and [3]

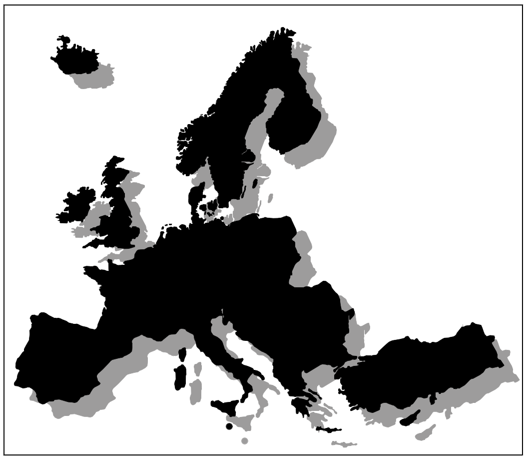

Fig 5: Area required replacing natural gas consumption of Europe by 2nd generation biomass; here extensive meadows. Calculations based on [1], [4] and [5]

3. Landscape Approach to Design

Energy is indispensable for life, both in the human and the natural world. The lack of resources and/or the inability to utilize available sources increases stress and results in fierce competition for remaining resources. Energy scarcity has triggered many ingenious solutions both in the technosphere and the biosphere. The hypothesis here is that nature offers powerful strategies for optimizing an energy system and coping with resource scarcity.

Ecology constitutes one of the relevant natural sciences guiding the path towards a sustainable world. Ecology is not only relevant because it deals with the environment, energy and resources, but also because of its integrative and regenerative approach, reflected in 'system thinking' and 'process ordering'. Due to long-term evolution, nature has designed effective ecosystems integrating energy flows and material cycles. Because ecological systems are selforganizing and regenerative systems, the very processes that take place in nature can offer a starting point for the design of sustainable energy landscapes.

The emerging Landscape Approach is one way of learning from our environment. Landscapes are understood as overlapping patches, each with numerous indispensable natural processes such as water purification and energy conversion. The Landscape Approach aims to alter human environments in a way that facilitates natural processes in combination with technological solutions. The understanding of ecosystem processes and creative spatial thinking forms the very basis of the Landscape Approach, a symbiosis between “natural” and “human” innovation.

4. Energy-Conscious Regional Design

So how can one articulate (prescriptive) design strategies based upon the understanding of (descriptive) ecological concepts and theories? In order to answer this question, we subsequently illustrate the findings of our latest research activities. Based upon literature studies, interviews, questionnaires and our experiences during two design studios at the regional scale, we have identified a number of *ecological concepts* which are of great value for energy-conscious landscape design. These concepts describe key properties of the natural world with respect to energy; they can help increase energy efficiency as well as provide renewable energy. In order to articulate concrete energy-conscious design criteria we have, in this paper, begun to translate three of the descriptive ecological concepts into more prescriptive *landscape strategies*. The list of strategies presented here does not claim completeness; rather it invites further exploration and articulation of concrete energy-conscious design criteria.

4.1 Source-Sink Relationship

By definition, renewables cannot be exhausted. However, only limited amounts can be utilized at any point in time. In natural ecosystems, many strategies exist optimizing the utilization of available energy. The concept of source-sink relationship originated as a demographic model describing the flow of organisms between different habitats. The local reproductive success of a population in a *source area* is greater than its local mortality; in a *sink area,* the local mortality is greater than local reproductive success. [6] It is suggested here, understanding the source-sink relationship as an inclusive concept embracing all kinds of landscape flows, including energy. The spatial allocation of areas supplying energy (the sources) and consumers (the sinks) has been neglected in the past, partly due to the abundance of fossil-fuels.

At first, the concept is helpful in discriminating and mapping present energy sources and sinks in a region. However, the source-sink concept is not only of special value during inventory and analysis. This is because source-sink relationships are dynamic; they can be altered by natural forces. Temporal changes in source-sink relationships are especially pronounced in regions with distinct seasons, as it is the case in most of Europe where temperature and precipitation change throughout the year. Based upon the characteristics of the source-sink relationship, we have articulated the following strategies to advance present-day energy systems.

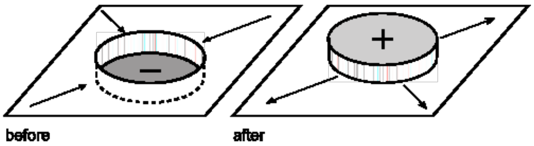

Fig 6: Reversing energy sinks into energy sources, e.g. energy harvest in rural settlements

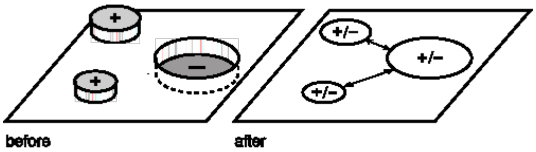

Fig 7: Reconnecting nearby energy sources and sinks with the help of existing infrastructure

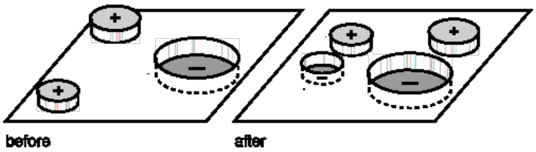

Fig 8: Clustering of sources and sinks; allocating sources close to sinks or vice versa

4.2 Differentiation of Niches

Differentiation of niches is driven by external influences such as shortage of resources and competition between organisms. Ecosystems differentiate into niches by means of vertical stratification, horizontal zonation and time zonation. [7] Differentiation of niches is one ecosystem strategy optimizing energy utilization at the same time reducing competition between organisms. In nature, highly differentiated ecosystems are able to sustain a higher population density as well as species diversity compared with less differentiated ecosystems.

A further differentiation of spatial niches in the human environment can improve utilization of available resources and thus reduce competition between different land-uses as well as economies. Geothermal energy, heat-cold storage in the underground and layering of land uses are among the possible applications. The following strategies have great potential in the light of resource depletion and should be accommodated in designing sustainable regions.

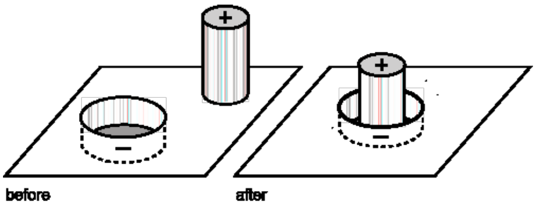

Fig 9: Vertical differentiation of niches; e.g. energy assimilation integrated in the urban fabric

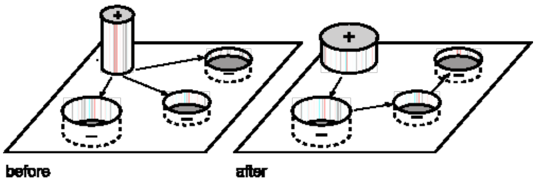

Fig 10: Differentiated use of resources; e.g. cascading of residual heat from power plant to offices & dwellings

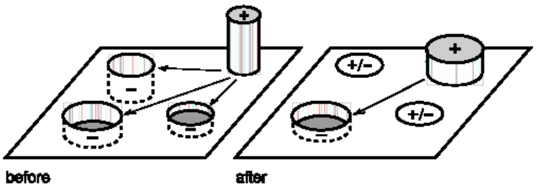

Fig 11: Optimum levels for multiple functions; e.g. ecological waste water treatment replacing energy intensive conventional water treatment

4.3 Biorhythm: Temporal Scale

Periodic changes in the environment constrain the assimilation of renewable energy, for instance wind and sun. Storing energy is one strategy to buffer fluctuations in supply between seasons and throughout the day. In addition to energy storage, a number of adaptive ecosystem strategies can help to cope with periodicity. Biorhythm is the pattern of physiological and behavioral responses to periodic changes in the physical environment. Plants growing seasons, animal's periods of hibernation and migration are just a few examples. Biorhythm allows organisms to survive through less favorable periods; it further increases resource utilization and allows ecosystems to recuperate. Human organization of life, in contrast, has gradually become aperiodic. This is due to cultural evolution and more specifically, the advancement of technology, shelter and clothing. This (relatively new) freedom, however, can only be sustained at the expense of energy, for instance natural gas to heat and illuminate our houses.

The following landscape strategies can help adapting sustainable energy systems to periodic changes in the environment.

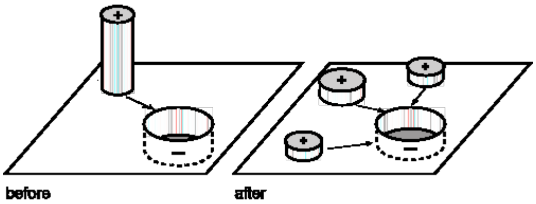

Fig 12: Mix of different renewable energy sources can create robust energy system

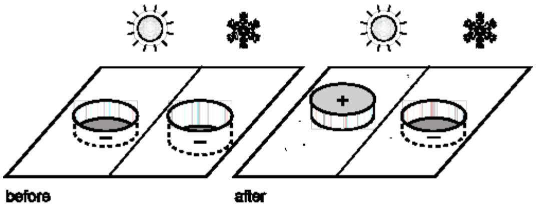

Fig 13: Physiological and behavioral adaptation can help coping with seasonal changes in supply

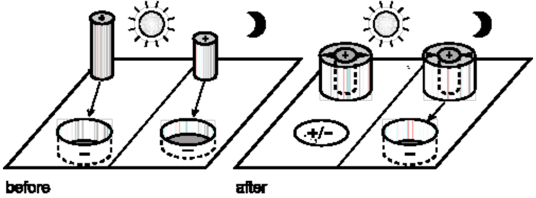

Fig 14: Matching energy supply and demand in time (biorhythm) and space (source-sink)

5. Case-study South Limburg

The region of South Limburg has a history of being an energy provider for the Netherlands and abroad. With the closing of the coal mines in the early 1960's, however, the region suffered thousands of job losses and became highly dependent on energy imports from other parts of the country and abroad. At present, about 98 percent of the energy consumption of South Limburg is provided from outside the region. [8]

During the initial phase of the case-study, we noticed that South Limburg, as administrative region, comprises three different landscape types: (A) The 'Heuvelland', a hilly landscape with strong rural character, (B) the 'Parkstad', a park-city as remnant of the mining period with the second highest population density in the Netherlands, and (C) the 'Maasvalley' on both sides of the rives Meuse. Throughout the case-study design, it became clear that the different characteristics of the three landscapes also imply different strategies towards energy transition; a rather fortunate coincidence since the objectives was to explore a wide range of possible strategies and design guidelines.

Fig 15: View across the Heuvelland, South Limburg, NL

Fig 16: View across the Maasvalley, South Limburg, NL

In short, it can be said that the greatest potentials for sustainable energy provision exist in the rural areas. Here, agriculture and cattle farming provide many residues which can be converted into different energy carriers; each conversion technique results in different efficiencies. Next to energy assimilation, conversion and storage were of great importance in the process of decision making. The concept of *biorhythm* allowed the exploration of possible solutions in how to anticipate periodic fluctuations in energy supply.

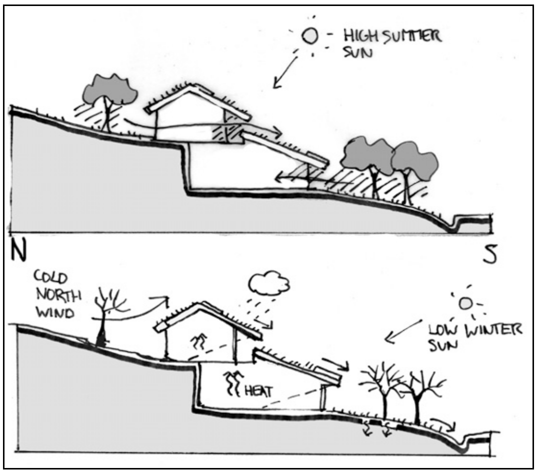

Fig 17: Energy-conscious building design and location anticipates periodic changes in the environment and allows for energy savings [9]

Urban areas, in contrast, are the greatest consumers of materials and energy in South Limburg. After investigating the distribution and characteristics of *energy sources and sinks*, different ways of optimizing existing material cycles and energy flows have been explored. Due to the limited availability of space, energy assimilation should be realized in the underground and/or integrated with existing infrastructure, dwellings and office buildings. The energy ring road is one example (Figure 18).

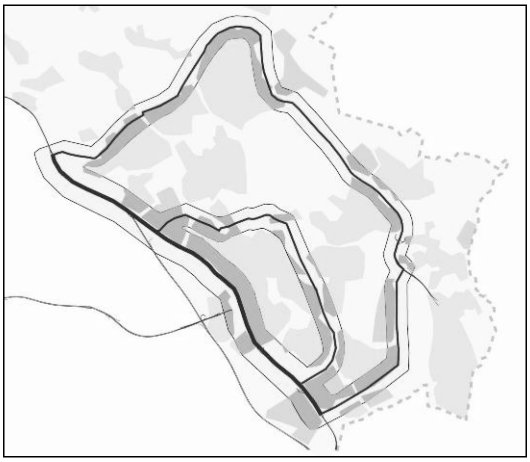

Fig 18: Energy assimilation, storage and transport with the help of a new energy ring road [9]

The river valley in South Limburg allows for further *differentiation of niches*, for example first generation biomass and larger wind parks. This can be achieved when growing seasons of chosen plant species correspond with the seasonal flooding of the river banks. For the river Meuse, these periods are known and short rotation coppice can be cultivated in-between floods. The very same river banks and other plane parts of the valley, which lies only a few meters below the surrounding plateaus, can be used for the assimilation of wind power. Here, the choice was to concentrate a new wind park near existing electricity lines away from ecologically valuable areas in the valley.

In the case of South Limburg, it has been estimated that more than 50 percent of the energy demand can be provided by renewables from within the region by 2035 without compromising food production or biodiversity. [9]

All designs for sustainable energy landscapes in South Limburg recognize and strengthen the unique landscape qualities of the region. In addition, the proposals illustrate how to realize added values such as improving flood control and minimizing soil erosion in the transition process.

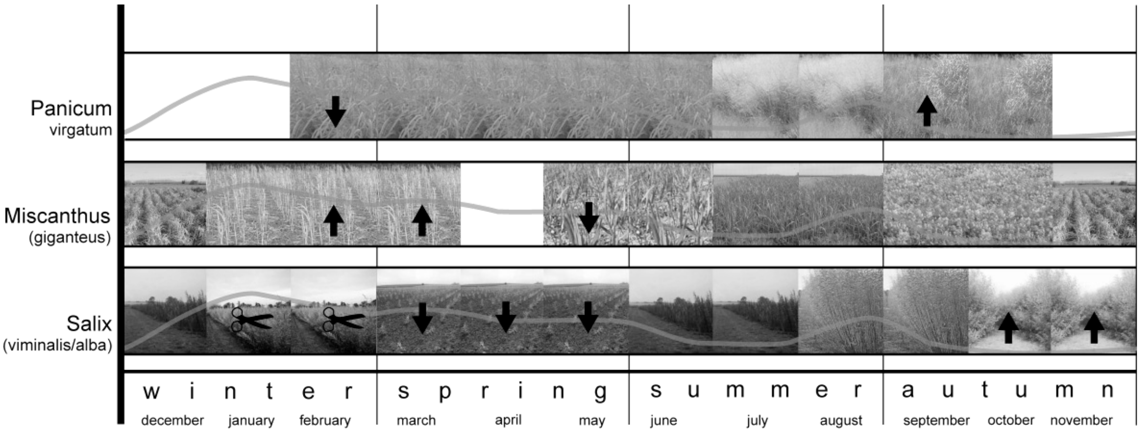

Fig 19: Planting schemes of three energy crops and water level of the river Meuse, indicated as grey line [9]

6. Conclusion

Ecosystem strategies have great relevance for a transition to renewable energy and with it the design of sustainable energy landscapes. The Landscape Approach to energy transition describes and illustrates possible synergies when ecosystem thinking meets creative spatial design. In doing so, we intend to expand and advance existing planning and design approaches to be more energy-conscious. Ecological concepts and theories can be an inspiration. At the same time they provide a conceptual framework, within which one can organize landscape strategies and explicit design guidelines.

Certainly, innovative design ideas are needed to transform entire regions, which now depend on fossil-fuels, into sustainable energy landscapes. For our case-studies, we have chosen to form strategic energy visions which, as shown in this paper, incorporate ecological knowledge rather than practicing ecological determinism. We propose embracing ecosystem strategies in combination with state-of-art technologies and experiences from existing projects at all scales. The Landscape Approach seeks to reduce the impact of mankind on the environment and renders pathways to take responsibility for people elsewhere as well as future generations.

7. Acknowledgements

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