

THE ENERGY SELF-SUFFICIENT CITY

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Abstract

The concept of an “energy self-sufficient city” involves a decentralised energy production system with energy extraction in neighbourhoods or villages which are interconnected in a “thermal smart grid”. Regional renewable energy sources are to be given priority for energy production (electricity, heat, cooling). Current energy provision on the basis of fossil fuels in centralised thermal power plants involves a considerable negative impact on the environment. Traditional concepts require energy to travel large distances to reach the consumers. A solution to this problem is the conversion of a centralised energy supply system to an integrated network of local or regional energy suppliers. Such a decentralised energy system results in a regional “thermal smart grid” which operates on the basis of renewable, local energy sources (biomass, refuse-derived fuels, solar power, geothermal energy, etc.). The objective is to devise a regional energy supply system which integrates decentralised energy plants in various types of settlement. The energy supply concept is assessed and developed on the basis of model cases. The settlement types chosen for in-depth study are “city”, “urban settlement”, “rural settlement” and “neighbourhoods with a specific type of use” (light industrial district, heavy industrial district, mixed-use zone). The principle of a “thermal smart grid” is potentially feasible for each of the settlement types mentioned above. The methodology developed enables spatial planners to make quantitative and qualitative statements about the potential energy self-sufficiency in a defined settlement area and to develop concepts for an optimisation of settlement and spatial utilisation structures. Investigations into the achievable levels of self-sufficiency for the four model cases shows energy self-sufficiency is strongly dependent on the surface available for biomass cultivation.

1. Definition of the problem and approach to a solution

At present, the Austrian energy sector is largely dependent on non-renewable fossil raw materials imported from abroad. In addition to this dependence, the use of fossil fuels entails a considerable negative impact on the environment. To date,

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the energy required in settlements has usually been generated in a centralised system of thermal and other power plants, which are frequently located on the periphery of settlements. Traditional energy concepts require energy to travel large distances to reach the consumers. In this context it is accepted that up to 20% of the energy generated is currently lost again. In Austria, a more pronounced environmental awareness has taken shape in the course of the Kyoto Protocol process and in response to the strong fluctuations in the price of fossil energy sources. For many years now, Austria has been pursuing a forward-looking course aimed at using renewable sources of energy.

One approach to solving the problem outlined above is to convert the centralised energy supply into a network of local or regional energy suppliers. This would bring the energy producer into the immediate proximity of the consumers, which means that energy would be generated at the place where it is needed. This integrated network of decentralised energy systems creates a regional "thermal smart grid" (the main focus being on management of thermal energy) which operates on the basis of renewable local energy sources (biomass, refuse-derived fuels, solar power, geothermal energy, etc.). This grid should be capable of covering the heating and cooling needs of the entire catchment area. The energy supply concept outlined entails a change from the centralised energy production practised to date to a decentralised energy supply tailored to local conditions and based on renewable energy sources. Regional resources such as biomass, solar power, refuse-derived fuels, hydropower, etc. should be used to operate small-scale power plants.

2. Objectives and methodology

The technical feasibility study⁴ on which this paper is based aimed to devise a detailed spatial energy supply concept which would establish the extent to which decentralised energy production facilities could be integrated into various types of settlement in different model regions in order to raise energy self-sufficiency to 95%. Within the framework of this feasibility study an intelligent thermal network, the "thermal smart grid", was to be developed on the basis of decentralised energy production plants using renewable energy sources, so-called energy hubs. The aim was to network the load graphs of the energy producers and consumers so as to amalgamate the daily, monthly and yearly load graphs. In addition, the study aimed to ascertain and evaluate options for achieving the highest possible level of self-sufficiency in the regional energy supply for each of the four defined settlement types. Possible regional and local energy sources for the production of heat and/or electricity are biomass (wood, maize silage, oilseed rape), solar power (solar thermal energy and photovoltaics), wind power, geothermal energy, small-scale hydropower plants and waste-to-energy plants. A further objective was to develop a combined energy and spatial utilisation concept

⁴ „Neue Energien 2020“ ("New Energies 2020"), a project funded by the Österreichische Forschungsförderungsgesellschaft mbH (Austrian Research Promotion Agency, FFG)

based on sustainable spatial energy planning taking account of the daily, monthly and yearly load graphs.

The energy supply concept posited as an approach to solving the problem was verified on the basis of a model case for each of four settlement types and then developed further. The settlement types chosen for in-depth study were "city", "urban settlement", "rural settlement" and "neighbourhood with a specific type of use" (light industrial district, heavy industrial district and mixed-use zone).

As a further focus of the technical feasibility study, the energy consumption for mobility in the various model cases was investigated. The mobility of the population essentially depends on people's individual needs and the options available. The mobility cost results from the distances that have to be covered in order to satisfy these needs and depends on the starting location and destination as well as on the availability and accessibility of transport infrastructure (transport networks).

3. Key terms

An "*energy self-sufficient region*" is a settlement structure – consisting of natural and open spaces, spatial infrastructure (incl. transport infrastructure) and settlement units ("energy self-sufficient cities") – which is capable of covering the energy requirement for heating, cooling and electricity, incl. mobility of the local inhabitants, for its area and population, based on the load graphs (daily, monthly and yearly) for the energy sources available within the boundaries of the spatio-functional system.

The "*thermal smart grid*" is fed by several basically independent, decentralised energy hubs based on renewable resources (biomass, refuse-derived fuels, geothermal energy, solar power, etc.). These are operated all year round (8,000 operating hours per annum) at optimum capacity, or as close to it as possible. This networking of consumers and producers ensures that all energy generation plants are used as economically and eco-efficiently as possible. Economically means continuous operation, and thus shorter amortisation periods than with the duty cycle and intermittent partial load operation used before. Continuous operation results in a longer service life due to the reduced corrosion rate of the boilers. In terms of eco-efficiency, the non-intermittent operation of waste-to-energy plants results in lower emissions of harmful substances, the reason being that in waste-to-energy plants the highest concentrations of pollutants are emitted during the warm-up and cool-down phase.

4. Quality criteria for settlement areas

Humanity and the natural world as an integrated system should be the benchmark for technological and economic development, not the other way round. The way we live should be geared towards securing a high quality of life for the human population through long-term preservation of natural resources.

In all activities, the burden on people's health and on the environment should be minimised by using processes which largely avoid production of harmful substances and exploitation of the Earth's natural resources (raw materials and energy) by establishing closed cycles wherever possible.

The utmost goal of spatial and urban planning must consist in creating conditions that foster people's well-being. Giving due consideration to the social impact of all technical solutions is an essential prerequisite for this. The built environment should foster the development of a form of community which encourages communicative coexistence and guarantees the highest possible level of safety and security (prevention of accidents, protection against violence). The interplay of a large number of individual measures within the framework of an integrated ecological structure should restore the settlement areas' attractiveness as a living environment.

- 1) The principles of spatial organisation for an energy self-sufficient urban and settlement structure are based on the following considerations:
- 2) Maximum possible preservation and further development of viable natural spaces and countryside forms the basis for sustainable spatial development.
- 3) The infrastructural framework for forward-looking, sustainable settlement development is a smoothly functioning public transport system.
- 4) The twin foci of natural spaces and public transport allow a settlement concept based on key areas along the existing and planned public transport axes. These key areas are designed in accordance with the "city of short distances" model in the form of an "EcoCity".

The functional mix forms the basis for the spatial distribution of all everyday activities. The optimum organisational form at supra-local and local level is decentralised concentration.

The "city of short distances" entails the creation of compact, space-efficient and hence energy-efficient settlement structures, a structurally balanced mix of compatible uses, and everyday amenities and recreational facilities that are within walking distance supplemented by less frequently used facilities that can be easily

reached by public transport. Careful, economical use of the non-renewable resource of land is the guiding principle.

In terms of population, the settlement units of the "EcoCity" are designed so that they allow the establishment of economically viable facilities for all essential functions (lower limit) on the one hand, while on the other hand guaranteeing that all these facilities are within walking distance (upper limit). The guiding principle of a "city of short distances" is thus the underlying spatial organisation principle of an "EcoCity".

The spatial quality criteria cited above, plus high energy efficiency and settlement units with low energy requirements together comprise an exemplary conceptual model of sustainable settlement development that can be referred to as a "smart city".

5. Model regions / cases

Two different patterns of settlement development can basically be distinguished, depending on topography and climate:

- A) those in valley locations (in both Alpine and non-Alpine regions) and
- B) those in lowland plains

The above giving rise to two different types of settlement development:

- a) ribbon development in the valley locations, and
- b) nucleated development in the lowland plains.

To allow an analysis of as many different permutations as possible, four model cases of settlement types in different model regions were selected for the present study:

- + the city in the lowland plain (Vienna Basin)
- + the urban settlement in an Alpine valley (Inn Valley)
- + the rural settlement in a non-Alpine valley (Pulkau Valley)
- + the neighbourhood with a specific type of use in the lowland plain (Vienna/Marchfeld)

The settlement types are based on Austrian parameters and comprise:

- + cities with a population of approx. 40,000 to 100,000,
- + urban settlements with a population of 1,000 to 5,000,
- + rural areas with fewer than 1,000 inhabitants per settlement, and
- + neighbourhoods with a specific type of use.

On account of the complexity of their structures and the low number of them in Austria, cities with populations of over 100,000 were not included in the study from the outset. The results for the settlement types "city" = medium-sized town or city and "urban settlement" should be transferable to small towns with populations of between 3,000 and 40,000 inhabitants, which make up the majority of urban settlements in Austria. Other energy supply concepts are – obviously - to be elaborated for isolated, entirely dispersed settlements.

6. Results and need for further research

The investigations into the achievable levels of energy self-sufficiency for the four model cases showed that energy self-sufficiency is strongly dependent on the surface available for biomass cultivation. Furthermore, the forms of an energy self-sufficient region in the various model cases investigated differ primarily in terms of topographical conditions, settlement structure and compactness and organisation of spatial functions and uses. In the present technical feasibility study, one of the criteria for defining regional energy self-sufficiency is a positive thermal and/or power balance for every month of the year. Calculating the thermal balance over the entire year does not appear useful for defining the concept of an energy self-sufficient region because there is only very limited potential for storing the surplus quantities of thermal energy obtained over several months in the summer.

Detailed analysis of a centralised energy supply concept permits the conclusion that it makes sense to keep any energy losses as low as possible. The energy loss of the thermal distribution network should not exceed a maximum of approx. 10%.

To summarise, a need for further research can be identified, particularly in the following areas:

A) "New" mixes of uses: definition of a concept for a balanced mix of uses for each type of region and settlement and a corresponding spatio-functional organisation of uses from the point of view of energy-conscious spatial planning;

B) Agriculture and forestry: elaboration of concepts for the reconciliation of competing needs (e.g. conservation of landscape ecology, food production, renewable energy sources) in the spatio-temporal use structure;

C) Inter-community and regional concept: inter-community and regional concept of energy supply as a spatio-functional partnership between predominantly urban and predominantly rural settlement areas;

D) Availability of geodata / spatial and usage data: comprehensive provision and availability of spatial geodata and data on usage behaviour to allow detailed

assessment of the status quo (volume of built-up area used for energy production and surface available for energy production) by urban area and elaboration of the necessary comprehensive energy concepts for specific regions or for Austria as a whole.

The research should focus on pilot plans for specific demo regions to explore the current findings in greater depth. In particular, the quantitative assumptions relating to settlement structures and structures of built-up areas should be reviewed, the energy and spatial utilisation concepts elaborated in more detail and the feasibility of implementing them tested by means of an appropriate study. Cooperation with planning practitioners (regional and local authorities, communities) and local and regional energy suppliers is a key prerequisite for this.

7. References

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