Spatial planning of regional settlement structures in the energy transition

- Summary -

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Background

The settlement structures existing in Vorpommern and also in other countries and regions of the Baltic Sea Region have similarities, but also differ in some ways. One common feature, for example, is that solutions must be found everywhere for the increasing need to reduce energy and resource consumption and to adapt to climate change. One difference can be seen in the fact that in Vorpommern the settlement development since 1990 has been planned differently than before and that new settlements are still being built there, preferably in the form of single-family dwellings. This could be similar, for example, in the Baltic Republics. By contrast, settlement structures in Denmark, Sweden and Finland have been planned and developed for much longer in a system characterized by continuity. Figure 1 gives an impression about the dwelling types preferred in different urbanized areas within countries in the Baltic Sea Region.

However, there are also many differences between the individual forms of settlement that exist or are planned in a region today. For example, the quality of life that can be achieved in single-family house settlements is often rated higher than in other forms of settlement. However, the one-off and ongoing consumption of energy and resources, the costs and other burdens for single-family house settlements are also significantly higher than for other forms of settlement. It is therefore both necessary and worthwhile to examine settlement development and the essential connections between settlement structure and energy supply on a region-specific basis and to take the knowledge gained into account in the future design of settlement structures in the region studied. At the same time, this makes it possible to improve the controlling influence of spatial and regional planning on the development of settlement structures.

Motivation

In the report on spatial planning of regional settlement structures in the energy transition, this region-specific analysis - supported by the EU funding project BEA-APP - is carried out for the Vorpommern Region. The achieved results should contribute to strengthening the regional planning control of settlement development and implementation of the previously developed regional energy concept as well as the associated guiding principle of the Vorpommern Region. At the same time, they should also provide orientation on how the settlement structure and energy transition can be managed not only in the Vorpommern Region, but also in other regions of the Baltic Sea Region. Special attention should be paid to the requirements resulting from the continuation of the energy transition. On the other hand, the residential segment of single-family houses is to take centre stage, as it represents the most attractive form of living for a large part of the population, but at the same time also causes the highest consumption of energy and resources.

It is explicitly not a question of preferring certain types of buildings or housing that may be more sustainable than others. Rather, planning and decision-making leeway that exists at different levels of the design of settlement structures is to be demonstrated. Figure 2 shows manifold connections and interactions existing between regional conditions, settlement structures and the energy transition.

Analyses and selected results

First, in the introductory part of the report, the settlement structures are conceptually analyzed and a definition of settlement structures suitable for the following analyses is derived. Also some typologies described in the literature that include energy-related settlement characteristics are briefly presented.

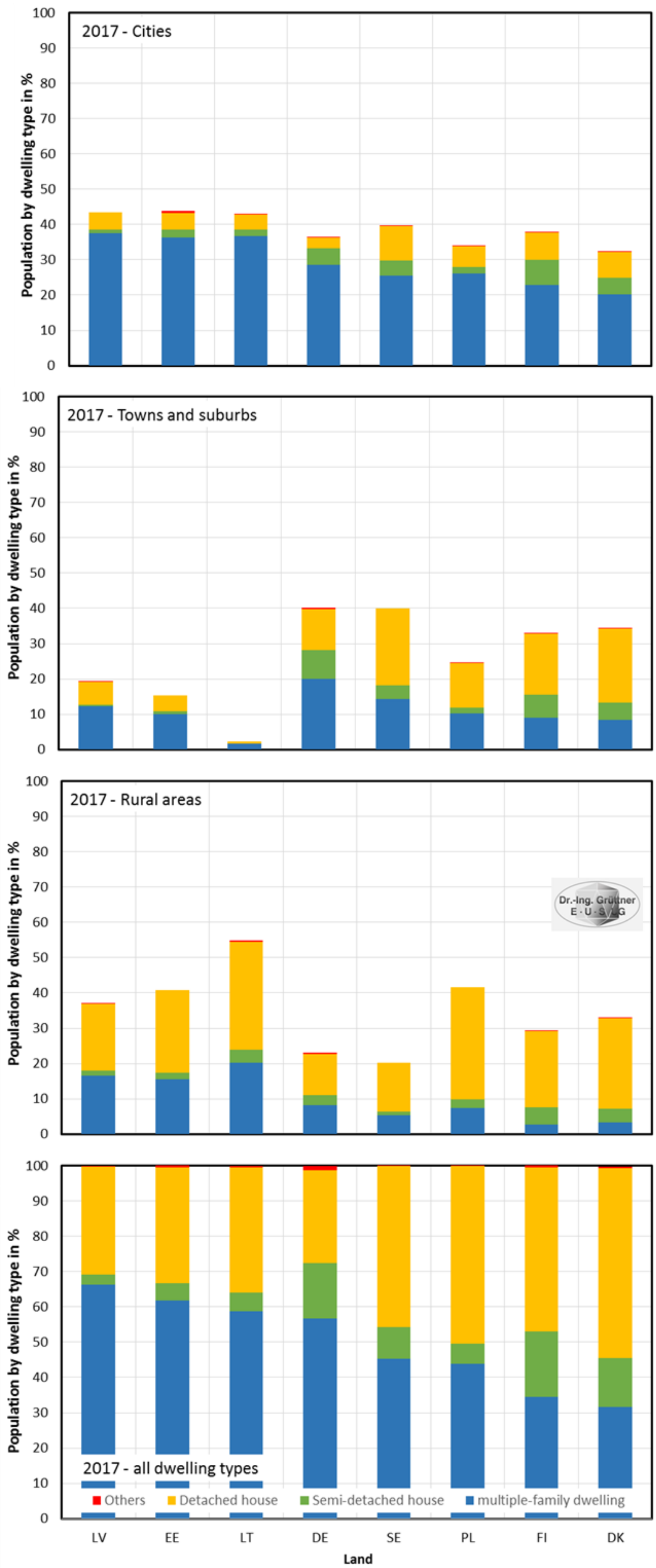

Figure 1: Population by dwelling type in BEA-APP participating countries

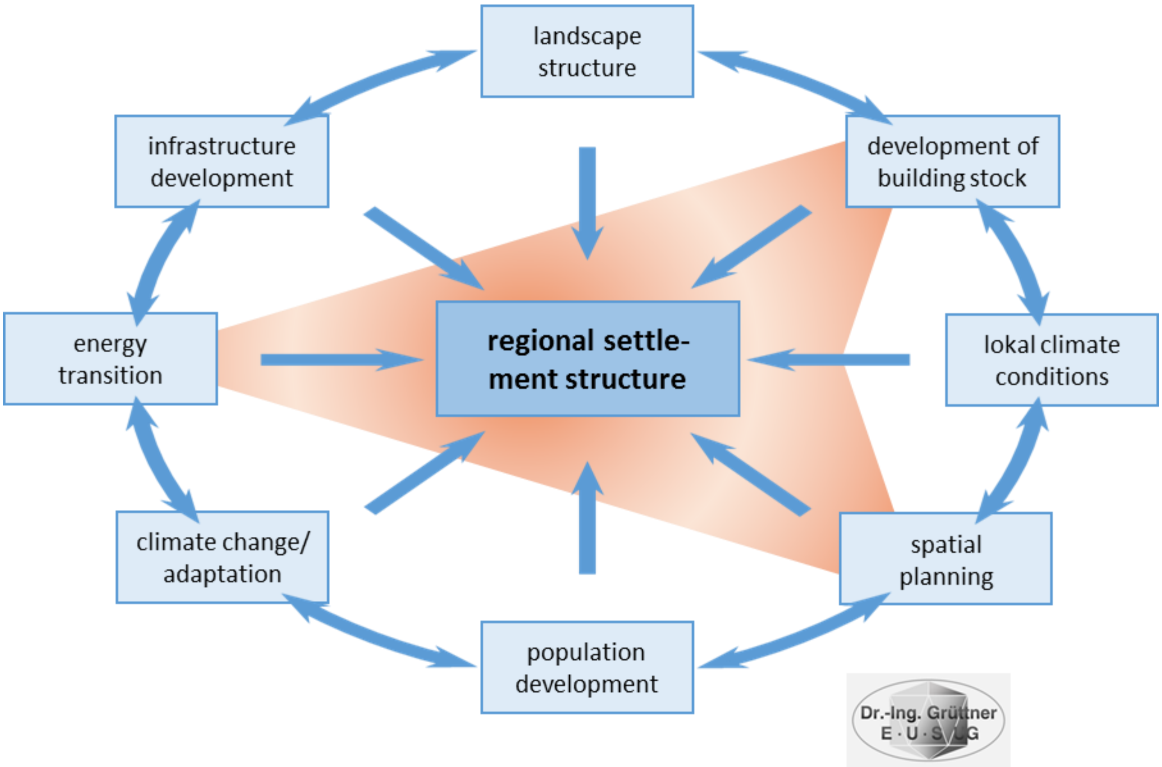

Figure 2: Interactions of regional aspects and settlement structure

The analyses were carried out at the three spatial levels of region, municipality and housing estate. A distinction was therefore made between the regional settlement structure (macro level), the settlement structure of a single municipality (meso level) and the settlement structure of the individual residential area (micro level). The regional settlement structure is defined as the size distribution of the cities or rural communities existing in the region, the location relationships between them and their typification, whereby this typification can refer, for example, to the number of inhabitants.

The settlement structure of a municipality is in turn defined by the size structure of its settlements (districts), their location and types. The types may, for example, refer to morphological characteristics. Finally, the settlement structure of a housing estate is indicated by the size structure and by the main characteristics of its buildings, their location relationship and by a typology that may refer to the predominant building types.

Subsequently, the essential relationships between individual building and residential area structures as well as their energy consumption are described and must be taken into account in the planning of such residential areas. A variety of possibilities are addressed for optimizing these structures in terms of energy efficiency by incorporating renewable energies, for example through the design and arrangement of buildings, through the active and passive use of solar energy or through surrounding planting. In addition, essential connections between the design of residential areas and the technical infrastructures necessary for their development are outlined here.

For example, there is a close correlation between building density of residential areas and their heat demand. Its density, in turn, determines whether a district heating system can be operated economic efficient. Table 1 shows exemplary heat demand densities of some different types of housing estate. The density of connected heat demand required for economic operation is from 25 to 30 MW/km^2.

As can be seen from a brief overview of the climatic conditions in the Vorpommern Region, there are differences within the region which must be taken into account when making recommendations for the planning implementation of the aforementioned connections between settlement structure and energy. Regional differences exist, for example, in the outside temperature. As figure 3 shows, the normal values observed for the period from 1961 to 1990 were in the 7.3 °C and 8.9 °C ranges. Although these differences in outside temperatures do not appear to be very large, they are measurably reflected in the heating degree day numbers of individual residential locations. This results, for example, in differences in the heating energy requirements of residential buildings, which ultimately also determine the economic efficiency of certain heating systems. Therefore, differentiated recommendations should be given for residential areas at different locations even if they are similarly built on and designed.

Table 1: Heat demand density of different settlement types /1/, pp.96/97

settlement type	floor area number	density of heat demand in MW/km²	suitability for district heating
1	2	3	4
old town	1,5 - 4,5	70 - 145	+
city > 19th century	1,0 - 3,0	35 - 75	+
apartment building	05 - 1,5	20 - 40	+
line building	0,4 - 0,8	25 - 35	+
compact line buildings	0,8 - 1,2	15 - 25	+
prefabricated slabs buildings	0,5 - 1,5	15 - 35	+
multiple-family dwellings	1,0 - 3,0	5 - 10	+
row house	0,2 - 0,4	15 - 25	o
detached houses	bis 0,18	5 - 10	-
compact detached houses		10 - 20	o
village	0,1 - 0,5	10 - 25	-

Legend: - less suitable, o suitability limited, + well suitable

The introductory part concludes with an analysis of objectives that must be taken as a basis for the regional management of settlement structures. It becomes clear that the *Regional Spatial Development Programme Vorpommern* from 2010 /2/ already contains a large number of objectives, guidelines and programme statements which are geared towards the management of regional settlement development.

For the analysis of the settlement structures in Vorpommern, the database is first described. In addition to municipal data from official statistics, data on energy consumption and energy production in the region and in the municipalities were provided. The results of the *Vorpommern Regional Energy Concept* /3/ and the *Vorpommern Storage Study* /4/ were also used and updated.

The settlement structure of Vorpommern is first subjected to a supra-regional comparison. According to this, there are no particularly large differences between the regional settlement structure and the settlement structure of the country. This finding further strengthens the statement already made in the Regional Energy Concept that in particular state data on energy consumption can be used to estimate the energy consumption of municipalities. These consumption data were needed here to calculate the state of energy transition at municipal level.

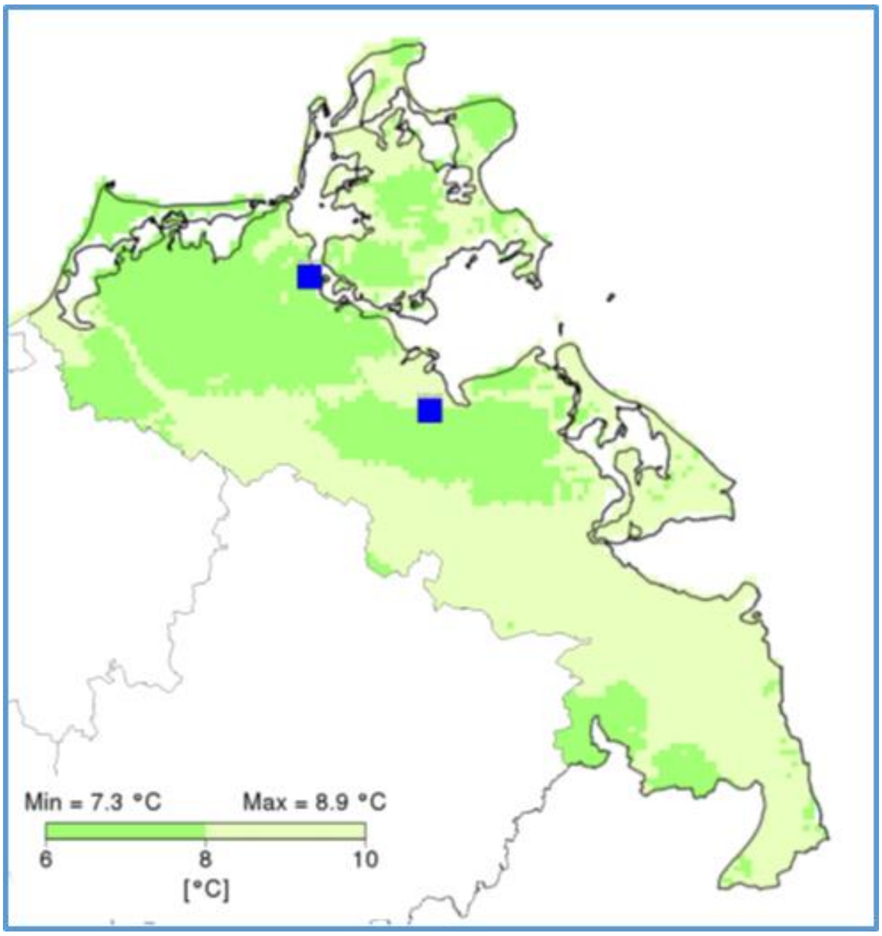

Figure 3: Spread of annual average air temperature in the Region Vorpommern[1]

The data obtained formed the essential basis for a typification of the municipalities in the Vorpommern region, which - after a preliminary examination of regional population and residential building developments - took place in three stages. In the first stage, the municipalities were typified on the basis of a basic dataset that depicts the municipalities on the basis of their socio-economic characteristics. The resulting typification of municipalities shows essential similarities with the central-location system, as it is significant in regional planning in Vorpommern and in the Regional Spatial Development Programme Vorpommern. The plausibility of these results enabled the continuation of typing in a second stage. For this purpose, the basic data set was extended to include data on municipal characteristics describing the state of energy system transition achieved in the municipalities. The community typing obtained with this extended dataset shows both similarities and differences to the typing based on the basic dataset. There are similarities between the two classifications, especially in the classification of cities. In the case of rural communities, on the other hand, there are greater differences, because municipalities using wind energy, for example, are now assigned their own type of municipality. Such communities generate much more electricity than they consume themselves, which clearly distinguishes them from other communities and their energy turnaround status in the electricity sector. The community types derived with this extended typification are subject to an interpretation in which this extended typification of the communities is to be made more comprehensible. On the one hand, the commonalities of the congregations are described, which led to their assignment to one and the same type of congregation. On the other hand, the differences that exist between the different types of municipalities become clearer. In a third step, this community typing is specified with a modified data set. The modification of the municipal data set consists in the fact that the wind energy is calculated out in the municipal characteristics related to the energy

1 Image source: Climate Atlas of the German Weather Service, available at www. dwd.de/klimaatlas.

transition. In many places, the use of wind energy is not primarily seen as a contribution to the local energy transition in the municipalities, but rather as a contribution to the supra-regional energy transition. The result is a community typing which is similar to the two previously derived typing, but which, in contrast to the second step, depicts the local energy turnaround more clearly. The results can be presented in schematic form as shown in Figure 4.

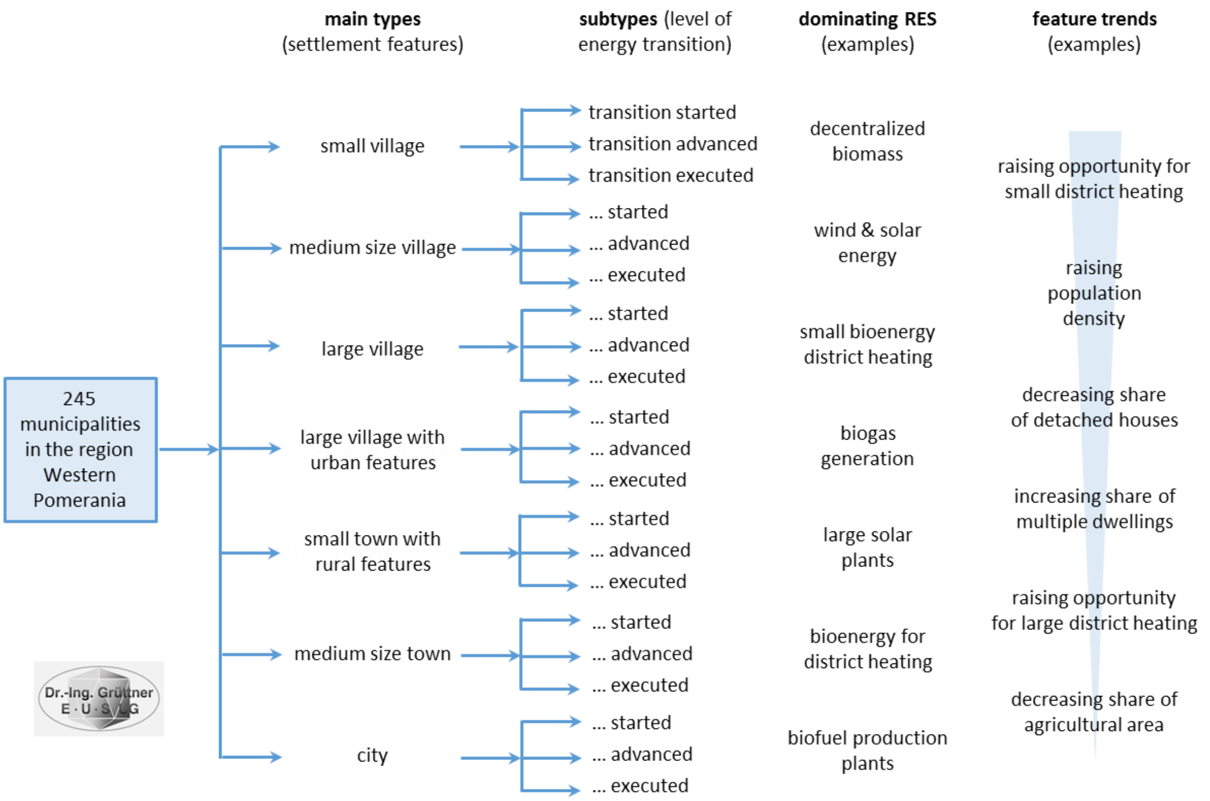

Figure 4: Types of settlements in energy transition and main features

An analysis of four exemplarily selected residential areas in the Vorpommern Region shows that the design variants implemented there can have both advantages and disadvantages. For example, residential buildings can be arranged and aligned to reduce wind inflow and associated heat losses for some of the buildings. However, this can also mean that these buildings are shaded more strongly against solar radiation. This reduces heat gains and the potential use of solar energy. A further example is the necessary compromise between a maximum use of solar heat gains in winter and the lowest possible absorption of solar heat in summer, as otherwise active air conditioning may be required.

This already results from the necessity that the planning of residential areas must always take into account the surroundings of the planning area as a framework condition for planning and design. Therefore, there are design aspects in every residential area that can be described as best practice, as well as those that do not (or cannot) fulfil this requirement. More far-reaching conclusions should, where appropriate, be reserved for further analysis, which can create and use a broader database. In order to consistently implement the energy and ecological planning and decision-making leeway described in practice, a planning approach is required that is geared to this from the outset and that is implemented in specifically designated eco-settlements.

The final part of the report on spatial planning of regional settlement structures in the energy transition is made up of considerations and recommendations for the spatial planning control of the settlement structure and the energy transition. To this end, the main planning and building law fundamentals of control are first analyzed. This is followed by the analysis of the control of settlement development and energy transition in urban land-use planning, which are important for settlement development at both residential area and community levels. It shows that preparatory and, in particular, binding urban land-use planning, in conjunction with informal instruments and energy law, has extensive possibilities for optimally shaping the above-mentioned relationships between residential area structures and energy consumption. These possibilities can be further extended by further instruments such as urban development contracts. Building on this, the regional level and the possible control of settlement structures will then be considered. It becomes clear that both direct and indirect control options are available to regional planning. Direct control is possible, for example, with regional plans and informal instruments such as settlement concepts. Indirect control can be achieved with the support of urban land-use planning in the energy- and infrastructure-optimized design of residential areas.

Finally, proposals for extending the control options of spatial planning for settlement structures and energy system transition are submitted. In addition to a more precise specification of the regional control objectives specified in the Vorpommern Regional Spatial Development Programme, the proposals aim, for example, at extending monitoring measures. These must provide the information and data needed for the implementation, further development and, if necessary, readjustment of the regional management strategies.

Benefits for other Regions

As has been shown in other studies also carried out in the BEA-APP project, there are region-specific differences between the countries in the Baltic Sea Region, between their spatial and regional planning systems and between their spatial planning objectives, but also many similarities and commonalities, including, in particular, common objectives. These findings lead to the assumption that the results achieved here for the region Vorpommern are also important for the other countries involved in the BEA-APP project. The possible uses are manifold and further approaches can be expected. This will only be mentioned briefly in the following:

The findings gathered and achieved here are transferable to all countries participating in BEA-APP (hereinafter referred to as BEA-APP countries). For example, the planning recommendations for housing estates are also valid in other Baltic Sea countries. This does not exclude the possibility that they may have to be reviewed and clarified on a case-by-case basis, for example due to varying climatic conditions, or adapted to regional conditions. Furthermore, the approach proposed here for the typification of municipalities, including energy-use-related municipal characteristics, can be applied in all BEA-APP countries and - if necessary jointly - further developed. Conversely, the typologies that already exist in the countries or may be developed in the future can be brought together in a typology that encompasses the entire Baltic Sea Region. It could identify both country-specific settlement structures and common settlement structures, i.e. those to be found in several or all countries. They could also be incorporated into common guidelines for the development of settlement structures to be developed, for example in the context of cooperation on transnational spatial planning or for VASAB, which could then be used and taken into account in all Baltic Sea countries.

Important starting points also exist with regard to the catalogue of general planning criteria that was developed in the BEA-APP by the Ministry of Energy, Infrastructure and Digitalization Mecklenburg-Vorpommern /5/. These general criteria are, for example, suitable for the search and evaluation of areas for the establishment of renewable energies as well as for the search and evaluation of locations and connecting routes of transnational projects. The general criteria cover the topics of planning, society, economy, technical aspects and conflict potential for 20 location categories, including residential areas in cities and rural areas. First of all, the consideration of the residential area-specific planning and design recommendations presented in the report can contribute to improving the social, economic and energy quality of residential areas in all BEA-APP countries. Secondly, the community typification may further specify the individual general criteria respectively the associated location categories.

Thirdly, they can be used as a prototype for further typing to other general planning criteria or their location categories. This would require the definition of appropriate site characteristics for each of the concerned site categories. These would then have to be quantified using appropriate data, equally available in all BEA-APP countries. This operationalization of the general criteria should preferably be carried out using INSPIRE data and at the same time accelerate the implementation of this EU Directive. Both the second and the third aspect would thus improve the manageability of the general criteria, support their uniform application in the BEA-APP countries and improve the database of joint transnational spatial planning.

Finally, possible uses of the above described findings for the implementation of regional energy concepts in the BEA-APP pilot regions can also be demonstrated. Regional energy concepts define goals and -based on the status quo of a region's energy supply - show ways to achieve them. When analyzing the status quo, it may be useful to structure the communities within the concept area according to settlement types on the basis of the types of communities developed. On the one hand, these can contribute to identifying and explaining the predominant forms of energy supply in the communities of the concept area. Conversely, certain forms of energy supply are more suitable for individual types of communities than others. This applies, for example, to district and local heating networks. Therefore, on the other hand, suitable community types or settlement structures can be assigned to the energy supply targets proposed in an energy concept. The comparison between the existing structures and the target proposed in an energy concept can thus provide information on how the existing settlement structure could be further developed in order to support the achievement of the proposed energy supply targets.

In order to use the general planning criteria for the implementation of regional or local energy concepts, the criteria must be operationalized. For this purpose, descriptive characteristics must be assigned to each criterion. These characteristics are subsequently to be specify by suitable data which should be available in the highest possible spatial resolution, e. g. as raster or cadastral data (parcels of land). These data describe and specify the main type of use for each raster or land parcel. For areas which include residential areas, this is particularly the type of residential area, the number and type of existing buildings, apartments and dwellings as well as the predominant type of energy supply. In addition, other aspects such as the proportion of green area, protected area/monument status etc. can also be taken into account. Assuming this operationalization, the general criteria can, for example, be used to analyze settlement structures. For this purpose, parameters such as population density are calculated for the raster or parcels of a region from the stored data. For coherent residential areas, i. e. for neighbouring raster or land parcels with the same use, the respective total area sizes and the spatial location in relation to each other (distances) are determined. Similarly, raster or parcels that are suitable for designating new residential areas can be searched. These must meet certain requirements to be defined for this purpose. For example, neighbouring raster or land parcels may not fall into certain location categories (industry, airfield, military, etc.).

For the implementation of an energy concept, general characteristics of the raster or land parcels can be evaluated by energetic indicators in order to proof their suitability for a particular type of energy supply or energy generation. For example, raster or land parcels that meet the general criteria “residential area" can be evaluated with energy demand indices specific to the type of settlement, as shown in Table 1. If this results in a sufficiently high energy demand density, the establishment of a district heating supply can be considered. If neighbouring raster or parcels include undeveloped areas, larger solar plants can be included in the planning. If neighbouring rasters or land parcels are used for agricultural purposes, the possibility of a bioenergy plant can be analyzed. Thus, there are two possible analysis directions: In one direction, given raster or parcel areas can be examined to determine which type of energy generation or energy supply could be suitable for them. In the other direction, it is possible to search for raster or parcel areas with certain characteristics that make them suitable for a particular type of energy supply or generation (location search).

The proposed approaches can also be tested and further developed, for example within the framework of the transnational, i. e. joint development of a transnational energy concept for the entire Baltic Sea region. This could be the subject of a follow-up project based on BEA-APP project results.

References

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