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Energy concepts for self-supplying communities based on local and renewable energy sources: A case study from northern Germany

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ABSTRACT

The reduction of GHG emissions in buildings is a focus area of national energy policies, because buildings are responsible for a major share of energy consumption. Policies to increase the share of renewable energies and energy efficiency measures are implemented at local scale. Municipalities, as responsible entities for physical planning, can hold a key role in transforming energy systems towards carbon-neutrality, based on renewable energies. The implementation should be approached at community scale, which has advantages compared to only focusing on buildings or cities. But community energy planning can be a complex and time-consuming process. Many municipalities hesitate to initiate such a process, because of missing guidelines and uncertainty about possible energy potentials. Case studies help to understand applied methodologies and could show available energy potentials in different local settings. The current case study presents a community energy concept for the inner-city of Elmshorn. By estimating the energy demand, consideration of local energy saving potentials, and available energy potentials within the community, it was possible to develop several energy system variants that virtually allow a heating energy and electricity supply fully based on local, renewable energy resources. The most feasible and cost-efficient variant is the use of local food production waste in a CHP plant feeding a district heating grid. The overall aim is to show that a self-sufficient heat- and electricity supply of typical urban communities is possible and can be implemented in a cost-efficient way, if the energy planning is done systematically and in coherence with urban planning.

1. Introduction

One of the biggest challenges in the coming decades for society will be to transform cities into sustainable and resource-efficient spatial structures. Climate protection, rising energy prices and the dependence on fossil fuel imports demand a shift towards renewable and decentralized energy systems. Up to 40% of primary energy consumption in OECD countries happens in buildings (Pérez-Lombard, Ortiz, & Pout, 2008) and up to 80% of this takes place in urban agglomerations (Kamal-Chaoui & Robert, 2009). Thus, energy – its efficient use and its GHG neutral provision – will be a central task for urban planning in the coming decades (Erhorn-Kluttig, 2011). The available building construction and communication technologies enable the development of smart and zero energy buildings. To approach this task at community scale has many advantages compared to a solitary consideration of individual buildings or at a broader city scale (Sharifi & Murayama, 2014).

The term "community", in an urban context, is understood as a specific geographic area, composed by similar physical characteristics and a set of social networks. A community has no fixed size and can range from a batch of physically similar buildings up to almost a district size area containing multiple uses, but connected by a shared identity. Overarching municipal energy strategies for city scale tend to be too general to have a direct influence on implementation and can only frame actions on a local level. In contrast, communities are distinguished by a higher grade of homogeneity that allows the development of customized energy strategies to happen. It is at the community scale that many technical synergies can be realized, promising that scale effects are reached, and decision makers are mobilized to act in their common interest (Petersen, 2013).

Community energy planning is the design process of finding techno-economically feasible variants to satisfy a community's future energy service needs. In the current study the community's energy demand is excluding transport, thus it is only referring to the operational building energy consumption aggregated to community scale. Usually, to begin, energy data to assess the current situation is collected, followed by targets for the future community

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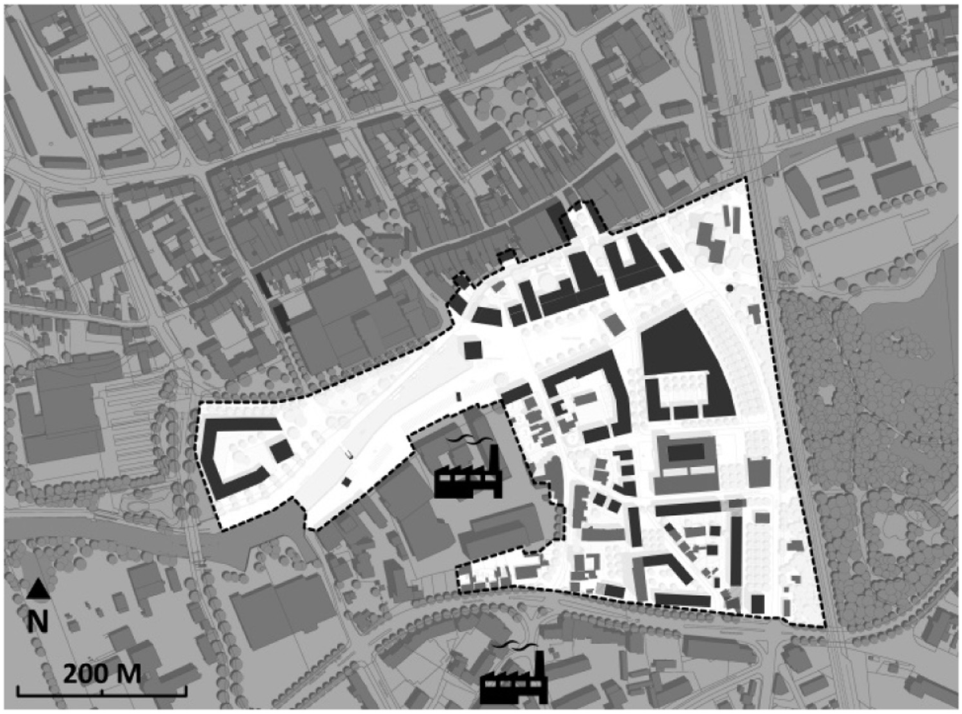

Fig. 1. Investigated area (light coloured) in Elmshorn with building stock (grey), new buildings (black) and waste heat sources (icon).

energy system. In the end, energy technology variants are developed to achieve the targets (Huang, Yu, Peng, & Liu, 2015). Besides cost-efficiency, multiple sustainability objectives were added in recent years as decision criteria, leading to a high degree of renewable energy being suggested (Neves, Leal, & Lourenço, 2015). The planning entities are often energy utilities, but municipalities could also play a central role: land-use planning, carried out at community scale, can have a significant impact on building energy consumption if synchronized with energy planning. The operational level of municipalities is communities; hence they could be the driver of community energy planning and key actors in the transition of cities towards sustainability.

Still, there are few examples apart from subsidized demo projects of energy-self-sufficient communities. Demo projects are often difficult to adapt to other communities because of differing financial or organizational conditions (Quitzau, Hoffmann, & Elle, 2012). Thus, the question is whether or not energy-self-sufficient communities are also applicable in an ordinary context without having an extraordinary financial support and under the use of conventional tools and technologies? Case studies can help to answer the question and elucidate the general planning strategies to achieve this, given that energy-self-sufficiency depends on linking energy demand and locally available energy sources, balancing and setting these in relation to a cost-effectiveness – thus, on drawing the right conclusions from local circumstances.

This is what the current study set out to do. The aim was to find out if in a more or less typical medium sized inner-city town, existing renewable energy potentials within the community can meet the communities' energy demand and whether it is possible to use these potentials in a cost-efficient way. The considered community is a mixed use area currently with a broad spectrum of building typologies, characterized by soon to be renovated buildings and new buildings; a setting that can be found all over Europe and is able to demonstrate barriers and opportunities for the energetic urban redevelopment. Heat demand was estimated based on building typology, age, gross-floor-area, geometry and renovation standard. The local energy potential was estimated in consideration of the local climate, the geologic and hydraulic setting, open space, building typologies, urban design and available waste heat sources. This data was combined with technical and economical characteristics taken from literature and supplemented with qualitative information, such as stakeholders, property information and other attributes related to the local setting.

2. Current state of community energy planning

Building energy performance is influenced by four main factors: urban context, building construction and shape, building energy system, and occupants (Ratti, Baker, & Steemers, 2005). While energy planning was mainly focusing on the middle two, practice has recently changed from building assessment and modelling to a wider scale that looks at communities and the interaction between all four factors (Petersen, 2013), (Sharifi & Murayama, 2014). After (Bourdic & Salat, 2012), energy-environment models and morphologic models are most commonly used for energy planning on community scale. While morphologic models use intermediate scales of aggregation, which allow insights on the wider urban scale, they are too unprecise and do not take the user into account, whereas energy-environment models have advantages in their usability. They describe the interaction between energy production, consumption and environmental impacts (normally via GHG emissions). The methodology is simple; the application does not cost much and is reproducible, but also based on aggregations. Thus, it is limited for stating evidence for single buildings – contrarily, a sufficient data set is not a prerequisite. Because of the simplicity of the methodology, morphologic models would allow municipalities to actively participate in community energy planning.

Municipal administrations are together with local politics and energy utilities important drivers of community energy planning. Energy used to be solely a matter for utilities. With the gas and electricity market in the EU being liberalized and open for different utilities, community energy planning is mainly focused on thermal energy. Energy utilities hold the concession for e.g. district heating or natural gas grids for communities, if granted by the