Energy Research & Social Science 14 (2016) 90–101

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

No pipes in my backyard? Preferences for local district heating network design in Germany

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ARTICLE INFO

Article history:
Received 24 August 2015
Received in revised form 15 January 2016
Accepted 20 January 2016

Keywords:
Local district heating
Social acceptance
Renewable energies
Conjoint analysis

ABSTRACT

In the context of urbanization and energy turnaround, local district heating (LDH) is one possibility to decentralize energy production and use environmentally friendly energy sources. When constructing an LDH network, planners have multiple possibilities concerning network design, security of supply, and choice of energy source. So far, little is known about users' preferences concerning these factors, which might have considerable impact on the acceptance of alternative energy systems. A two-step approach was pursued to investigate LDH network design preferences: first, a focus group on LDH systems from the users' perspective was run. Second, conjoint analysis was applied to analyze preferences for LDH characteristics (network design, security of supply, and type of energy source). Most relevant factors in the context of LDH systems were costs, source dependence, organizational issues, security of energy supply, environmental effects, and construction work. Results of the conjoint analysis showed that the energy source and its corresponding primary energy factor was the most important attribute for preferences, followed by network design. The preference for energy sources changed dramatically when introducing different prices for energy sources. Results further indicate that it is necessary to integrate users' requirements into LDH network planning processes and to improve communication about LDH.

1. Introduction

The upcoming scarcity of fossil fuels as well as climate change targets in terms of CO_2-emission reduction have led to a turn toward renewable resources for energy generation. In Europe, there is great potential for LDH, although it is currently not used [1]. With ongoing urbanization processes, district heating provides a solution for heating in densely populated areas by replacing individual boilers [1]. LDH has the advantage that renewable energy sources can be used for heating, which is not possible with conventional (boiler) technology [1]. Furthermore, it is also a more reliable option for CO_2 reduction targets than counting on heat savings in buildings, because there is more variety of technologies to choose from, more renewable energy sources, and, at the same time, it is more cost effective [1]. To diffuse this technology at a wide scale, as proposed in the Heat Map Europe [1], the support of the public will be essential. For this purpose, in the present study, technically feasible options are weighted against each other from an acceptance point of view, also considering costs and environmental impacts.

The German government announced ambitious aims concerning the use of renewable resources: by 2050, 80% of gross electricity consumption and 60% of gross energy consumption, respectively, should be based on renewable resources. Within the "Energiewende" (energy turnaround) the residential sector has to play a key role as it contributes significantly to energy consumption (in Germany, for example, 38% of the total consumption (without traffic) [2]). To enhance energy efficiency in the residential sector, several measures are available. This includes, e.g., the application of efficient heat and power generation units, storage systems, or energy-saving renovation measures. Furthermore, the application of LDH networks can increase the energy supply efficiency. They allow for the wide use of combined heat and power, renewable energies like solar or geothermal heat, or the utilization of various industrial surplus heat sources [3]. Compared to building-internal heat supply systems, the application of LDH networks can form efficient trade-off solutions between costs and environmental impact [4]. Besides, energy sources can be used that are often not available for single buildings, for instance, waste heat and wood chips.

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http://dx.doi.org/10.1016/j.erss.2016.01.008
2214-6296/

Therefore, district heating networks can contribute to reduce the costs for the transformation of the energy system toward more sustainability. This paper focuses on LDH networks that are defined as a form of small-scale district heating. In comparison to district heating as it is conventionally used, the number of connected houses is limited and the required generator capacities and flow temperatures are lower.

Models for the expansion planning of heat and power supply systems often integrate LDH (e.g., Refs. [5,6]). They focus on minimizing total annual cost as single objective. In other approaches, environmental objectives are included and the model is extended to a multi-objective optimization [7,8]. The preferences and resulting weighting factors of different objectives are often subjective and cannot be determined a priori. In these cases, Pareto efficiency is applied as evaluation criterion in order to find non-dominated solutions.

The application of multi-objective optimization methods already indicates the impact of acceptance behavior on the expansion planning of energy systems. However, a thorough empirical assessment of the acceptance of LDH from a user perspective is still lacking, although it has been identified as a major factor of influence on the success or failure of energy-related technologies [9].

New technologies, like district heating, are often met with resistance by the public, especially when they replace established technologies [10]. Moreover, not only the technology itself but also the underlying technical infrastructure raises concerns [11]. Perceived threats and risks as well as insecurity in dealing with the new technology further decrease public acceptance [12]. Aside from environmental objectives, previous models for the design of LDH do not include social dimensions, because user preferences for LDH are largely unknown. Studies exists on preferences of community representatives for single aspects of heating systems, such as choice of fuel [13], however, an approach to determine acceptability of entire designs of LDHs is still lacking.

Thus, in this study, perceived benefits and barriers of LDH are identified in an empirical approach to provide planners and policy makers with knowledge about possible pitfalls in the context of LDH beyond its technical challenges. Social acceptance, in this work, is thus understood as user or consumer acceptance (of possible future user of such a system) in a narrower sense according to Wüstenhagen et al. [9]. In close cooperation with planners, the relevant attributes for LDH planning are investigated using conjoint analysis. It allows to measure the relative importance of acceptance-relevant factors such as network design, security of supply, and type of energy source and how they are weighted against each other. Furthermore, the impact of economic factors such as energy costs on preference patterns are considered. This method has been applied successfully in other contexts of social acceptance research [11,14–17]. It has, however, not been applied to the context of heating infrastructure so far. The outcomes of our study are expected to provide valuable input for a socially acceptable implementation of LDH.

2. Acceptance of microgeneration technologies

When the implementation of “green” technologies started, social acceptance was largely ignored [9]. The consequence was local opposition [18]. However, for a successful and widespread implementation of innovative energy-related technologies, the knowledge of determining factors of social acceptance is a central issue. In addition, microgeneration technologies such as LDH require more than “passive acceptance” or tolerance, which is often observed for large infrastructure projects such as wind power stations [19]. Two different approaches of integrating social and political acceptance into the implementation- or construction process have been proposed: the ex-ante and ex-post approach [20]. In an ex-ante approach, political and social barriers are considered at the same stage as technical barriers. Thus, after this stage, only technically, politically, and socially feasible scenarios remain. In an ex-post approach, technically feasible scenarios are designed first and afterwards analyzed for their social and political desirability.

Previous research has identified a number of aspects which affect market acceptance by users in particular, i.e., motivators and barriers of microgeneration adoption. The main barrier of microgeneration adoption, which has been repeatedly identified in empirical studies across Europe, referred to economic aspects, i.e., capital cost [21–23]. Initial investments in microgeneration technologies were either unaffordable for people or, combined with maintenance costs, not profitable enough, because the savings did not warrant the investment [24]. Further economic concerns were related to a reduced resale value of property, which would not reflect the invested capital. Some microgeneration installations would even deter potential property buyers, e.g., in case of photovoltaic system installations on roofs [25]. In contrast to economic concerns, increased energy savings support microgeneration technologies, i.e., the reduction of heating costs increased support for waste process heat as source of district heating [26].

However, non-economic reasons also play an essential role in explaining community acceptance of energy systems. Because LDH is a technology that is not implemented for one household alone, decision making and integration of citizens in the decision process is a critical issue [27–29]. Inconvenience due to modifications in existing energy systems in a household [12] or concerns about contractual “lock-in,” i.e., giving up the option to switch between suppliers [26], were further reasons for rejection. Also, social aspects such as opportunities for dialogue between experts and laypeople or visible demonstrations as well as the fit of the heating project in the local context (for example, considering the local economy for the choice of fuel) need to be considered [30]. Further influential factors on the decision to choose a new heating system were related to the technology itself, i.e., its functional reliability [31]. Environmental attitudes [32,33] and perceived environmental benefits were found to be decisive for the preference of heating systems [34] as well.

Although a large body of literature on general motivators and barriers of microgeneration in general and LDH in specific exists, there is only little knowledge about the perception of design and implementation of LDH networks. Research on this topic has largely focused on technical parameters or on optimization models without taking user acceptance into account [35–38]. In cases in which user acceptance was covered, trade-offs between different aspects of LDH were not discussed. What is missing is a quantitative study to gain a better understanding of how the characteristics of an LDH network design relate to each other and which of them is most important for acceptance or rejection of such a project. Conjoint analysis provides the opportunity for users to decide which configuration of characteristics they prefer, so it is also possible to gain insights into which aspects of district heating are most important. Thus, it is possible to derive concrete design guidelines for planners and developers of local district heating infrastructure projects.

The research presented in this paper therefore aims to reveal users’ perspectives and acceptance-relevant aspects of LDH as well as users’ preferences for LDH scenarios. As methodological approach, a two-step-empirical procedure was applied: first, focus group interviews were carried out to gain a deeper understanding of the involved motives and barriers among users. Second, conjoint analysis was applied to determine relative preferences and trade-offs of LDH scenarios. By measuring preferences for different technically feasible scenarios, we follow the ex-post approach