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Heat supply planning for the ecological housing community Munksøgård

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ABSTRACT

Munksøgård is a housing community near the city of Roskilde, Denmark. In 2014, Munksøgård's residents have agreed to change the existing heat supply system. The choice of future heat supply was narrowed to heat pumps, new biomass boilers and connection to nearby district heating network. The choice was additionally narrowed as a result of the voting at the general assembly.

The present paper presents results from techno-economic energy system analysis, simple private-economic analysis and assessment of externalities related to the heat supply, compares them with the voting results and discusses the differences. The potential inconsistencies between economically rational solutions and choices of end-users are highlighted.

The techno-economic energy system analysis is performed by TIMES-DK model, which optimizes over all sectors in Denmark until 2050. The connection to district heating proved to be optimal from the system perspective. A spreadsheet model has been developed to perform the private-economic analysis and the evaluation of externalities. New biomass boilers proved to be the cheapest from the private-economic perspective; district heating came close. At the voting, heat pumps and biomass boilers received the most votes. One of these two solutions will be implemented. Why district heating received the least votes calls for detailed investigation.

1. Introduction

Danish energy system is heading towards a renewable energy based future in 2050. A few other national targets should be met along the way [1,2]: renewable energy should account for more than 35% of final energy consumption in 2020, while approximately 50% of Danish electricity consumption needs to be produced from wind power in 2020. Furthermore, the intention of the Danish Government is that electricity and heat generation has to be 100% renewable by 2035, and the power plants should not burn coal from 2030. Despite established and clearly defined national targets, lower administrative units such as regions and municipalities are not obliged to have their own targets for transition to renewable energy. For example, Central Denmark Region has set a goal for renewable energy share to 50% in 2025 [3]. Zealand Region aims for 18% of wind power and 27% of regional biomass in region's energy consumption in 2020 [4]. North Denmark Region decided to annually reduce CO_2 emissions by 2% until 2025 [5]. Different goals can be seen on municipal level as well – Samsø's net balance over a year is 100% renewable for 10 years [6], Rinkøbing-Skjern expects to be 100% self-sufficient with renewable energy in 2020 [7], while the municipalities Copenhagen and Aarhus are planning to be CO_2 neutral in 2025 and 2030, respectively [8,9]. Below the municipal level, specific renewable energy targets are not set. On that level, district heating companies are deciding on the type of fuel, while private consumers are the ones making decisions on type of heating supply (district heating, heat pumps, oil boiler, etc.), mean of transportation (bicycle, train, gasoline car, etc.), heat and electricity savings, etc.

Energy system analysis has received a lot of attention at the national level. Different aspects of the Danish energy system were analysed within several studies. The Danish energy system as a whole was analysed for the years 2030 and 2050 in Ref. [10]. The specific role of district heating was addressed in Refs. [11–13], the role individual heat pumps in Refs. [14,15], profitable heat savings in Refs. [16,17], while the optimization of waste treatment was

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Abbreviations

TIMES	The Integrated MARKAL-EFOM System
DK	Denmark
GIS	Geographic Information Systems
CEEH	Centre for Energy, Environment and Health
ETSAP	Energy Technology Systems Analysis Programme
DKE	Denmark East
DKW	Denmark West
DRY	Design Reference Year
DH	District Heating
CHP	Combined Heat and Power
HO	Heat Only
DKK	Danish Kroner
RSS	Residual sum of squares
MSE	Mean squared error
FRIDA	A model for the generation and handling of solid waste in Denmark
HVDC	High Voltage Direct Current
IntERACT	Integrated Economic eneRgy Applied Computational Tool
O&M	Operation and Maintenance
BBR	Danish Register of Buildings and Dwellings
SF	Single-family
MF	Multi-family
WLP	Wind Lower bound on Production
WLP-NFE	Wind Lower bound on Production – Non-Fossil Energy
DREAM	Danish Rational Economic Agents Model

analysed in Refs. [18,19]. At a municipal level, district heating in Copenhagen was analysed in Ref. [20], while low-temperature district heating and competition between district heating and heat savings in Frederikshavn was addressed in Refs. [21,22]. A renewable energy scenario for Aalborg municipality was addressed in Ref. [23] while the integration of renewables for the same municipality was analysed in Refs. [24,25].

When it comes to smaller geographical areas such as groups of buildings or a housing community, energy system analysis is usually not applied. At such geographical scales, results from demonstrations or measurement projects are usually reported or operational aspects of a specific technology are discussed. In accordance with this, Bøhm presented results of measurements of consumption, efficiency and losses in domestic hot water systems in 15 residential and public buildings [26]. Harrestrup and Svendsen [27] have performed measurements of heat consumption before and after the renovation of a multi-storey building in Copenhagen with heritage value and have reported reduction of heat consumption of 47%, which proved to be within expected values. Morelli et al. [28] used a multi-storey building in Copenhagen from 1896 as a case-study for three types of energy retrofit measures and concluded that the reduction of energy consumption by 68% is achievable, but renewable energy sources are needed to achieve a “nearly-zero” energy building. Mørck et al. [29] have investigated cost-effective, low-energy buildings within the demonstration project Class 1 in housing community Stenloese Syd. They have done measurements of gross energy consumption and discovered that it is 180% higher than the expected. They have identified several possible explanations for the discrepancy, such as the weather conditions, smaller internal heat gains, higher indoor temperature, etc. The choice of heat supply system or whether to renovate a group of buildings largely depends on private-economy and private preferences.

There is a consensus among residents of the ecological housing community Munksøgård that the existing heating system needs to be changed. The present paper presents three views on the question “Which heat supply system should be chosen by Munksøgård?". First, national energy system analysis until 2050 is performed with TIMES-DK model. The results from this analysis represent the optimal solution seen from the Danish energy system as a whole; Munksøgård is not explicitly modelled, but results can be extracted from the model representing that type of buildings. Hereafter, analysis of Munksøgård's local energy system is performed with a spreadsheet model. These results include private-economy and externalities such as local pollution, noise or stability of supply (the two latter only as a qualitative evaluation). Thirdly, the new heat supply system will be chosen in the democratic voting process at the general assembly in the community. Finally, the differences between solutions will be presented and the challenge in making socio-economically suitable solutions attractive to private consumers will be discussed.

The present paper offers two sets of contributions:

- Heat supply systems on local/communal scale are usually analysed by consultants, while in scientific publications heat supply systems are usually analysed on a very detailed level (single building or a specific heat supply unit, etc.) or on a more aggregated level (municipal, regional, national). In the present paper, our geographical scale is positioned in between very detailed and aggregated level – we analyse new heating system on a level of a housing community with 100 houses in total.
- New heat supply systems are usually analysed from one point of view – purely technical, private-economic, socio-economic, private preferences at end-user level, etc. In the present paper, we analyse the new heating system from three perspectives and discuss the similarities and differences.

However, Munksøgård is just used as a case to illustrate the challenge between planning from a socio-economic and private-economic point of view and realising these investments at end-user level.

1.1. The Munksøgård community

Munksøgård is an eco-village built in year 2000 [30]. It is located on the periphery of Roskilde city, which is 40 km west of Copenhagen, as presented in Fig. 1a. It consists of 5 groups of buildings constructed around an old farmhouse, as presented in Fig. 1b. The idea was to create a village-like community with focus on resources, environment and local involvement. To create a mixed community of people, the apartments have different sizes and are a mix of rental, share owned and private owned apartments. One group is reserved for younger people, one for older and three for families. Each of these five groups consists of 20 apartments and the total number of people is around 250.

The special solutions applied at Munksøgård are local district heating based on wood pellet boilers supplemented with solar heating, local waste water treatment system, separation of urine in the toilets, relatively efficient buildings, use of rain water for washing machines and a big green area for gardens and animals (sheep, cattle, pigs, etc.). The village is placed on the edge of Roskilde city having land-zone area on one side and city-zone on the

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