



How can heat pump-based demand management affect the future energy consumption in the residential sector?



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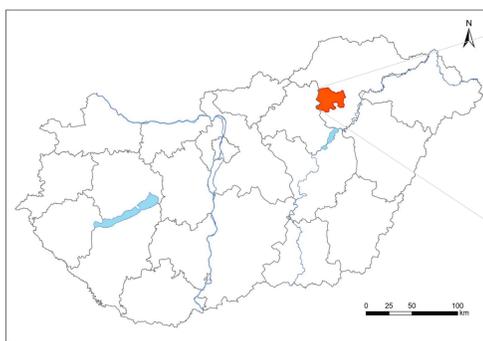
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Introduction

A particular problem of the Eastern-European countryside is the poor air quality often caused by the combustion of improper fuels as residential heating sources. Fuel switch (away from coal and other solid fuels) is a much-needed solution to this problem. Hybrid district heating networks can provide residential heating using clean energy (Schmidt 2017). Heat pumps are another alternative to air quality management, as electricity and ambient heat are used without local air pollution. This study focuses on the application of heat pumps with thermal storage. This technology is chosen because of the possibility of load flexibility, which is crucial for the integration of intermittent renewable energy sources and the optimal operation of the power grid. The aim is to design alternative energy scenarios to investigate the effects of energy efficiency measures and the potential for heat pump-based demand management.

Research area

The area is comprised of 20 settlements in the Bükkalja region, Borsod-Abaúj-Zemplén county in northern Hungary.



Area (km ²)	564.07
Population (in 2018)	36,296
Number of households (in 2018)	13,014
Population density (people per km ²)	64.3
Number of municipalities	20

Location of the research area in Hungary and its basic attributes

The energy poverty phenomenon is evident in the region with the residential building stock ranking low in the energy efficiency standards. It is not unusual to have residents appealing to illegal burning of household waste, wet firewood or the use of obsolete heating equipment.

Methods

The bottom-up approach was used to investigate residential energy consumption. A key aspect of the research was the development of a personal database used to fill the lack of data on the required scale.

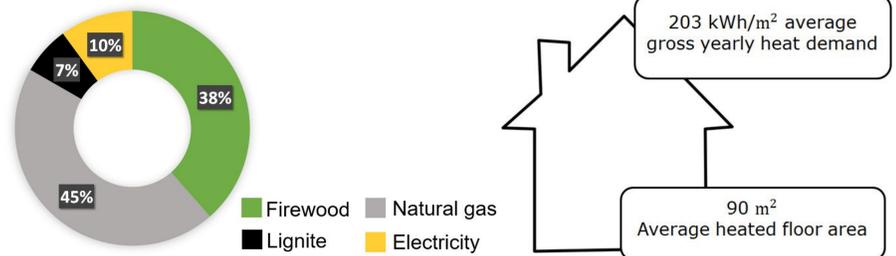
The methodology is summarized as following:

1. Consultation of official statistical data on the population composing the area;
2. Door-to-door survey reaching 1354 households between 2016 and 2019. Development of a household-level database on actual energy billing data, heated area, building thermal insulation conditions, stock of heating appliances, and usage patterns;
3. Assessment of fuel consumption and calculation of average annual heat demand (space heating and domestic hot water) of each settlement considering appliances used;
4. Estimation of the annual heat demand of a characteristic household of each settlement;
5. Design of four alternative energy scenarios comprehending the period from 2020 to 2040. LEAP (The Long-range Energy Alternatives Planning System) was used for this task. The scenarios are characterized by building energy retrofit and fuel switch;
6. Estimation of demand-side response potential achievable with the operation of heat pump coupled with thermal storage (TES).

Scenario	Heat demand reduction (%) (Harvey 2010)	Annual retrofit rate (%)	Air source heat pump - SCOP
Business-as-usual (BAU)	50	0.50	-
Standard Energy Efficiency (SEE)	50	1.25	5.6
Advanced Energy Efficiency (AEE)	67	2.50	5.6
Deep Energy Efficiency (DEE)	75	3.75	5.6

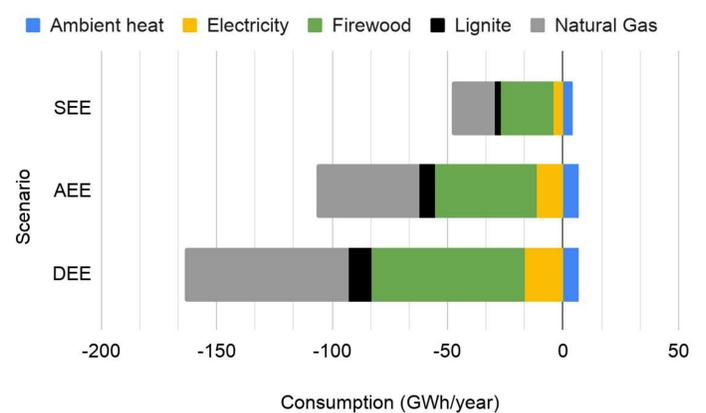
Results

The primary energy demand and electricity for residential heating in the research area is estimated at 239.9 GWh/year and 18.3 MWh/household.

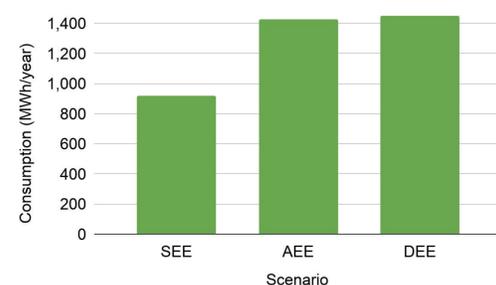


The estimated current energy mix for residential heating and characteristics of a typical household in the research area

Considering the area's current heat demand and population trend, the demand for the period between 2020 and 2040 was projected. The number of occupied households is expected to decrease by 3.1% in 2040 when compared to 2018, driven by the population movement. The survey shows that the current household retrofit rate is 0.5% per year. These factors are reflected in the projected 8.4 % heat demand shrinkage by 2040. This was the baseline (named BAU) for the comparison with the three alternative scenarios.



Projected gross energy demand in comparison with the BAU scenario for 2040



Estimation of demand-side response potential for the year 2040

Conclusions

A multidisciplinary method was used to design alternative strategies to reduce overall energy demand for residential heating. Moreover, technological solutions are considered to estimate the potential load flexibility with clustered uptake of heat pumps. The flexible consumption potential is estimated at 1450 MWh/year (or 34.9% of the area's electricity consumption for heating) with the actions described in the scenario DEE. Altogether primary fuel and electricity consumption can be reduced by approximately 20%, 46%, and 71% with actions in the scenarios SEE, AEE, and DEE, respectively.

References

- Harvey, D. (2010). Energy and the New Reality 1: Energy Efficiency and the Demand for Energy Services. London: Earthscan. DOI: 10.4324/9781849774918
- Schmidt, D., Kallert, A., Blesl, M., Svendsen, S., Li, H., Nord, N., & Sipilä, K. (2017). Low-temperature District Heating for Future Energy Systems. Energy Procedia, 116, 26–38. DOI: 10.1016/j.egypro.2017.05.052

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