SHORT-TERM ELECTRICITY CONSUMPTION IN NORWEGIAN HOUSEHOLDS - DRIVERS AND PROFILES

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Overview

Due to large hydropower capacities and relatively low prices electricity has been the most important energy carrier in Norway over the last decades. In contrast to heating customs in most European countries electrical energy in Norway is widely used for space heating and domestic hot water heating. Since mostly only one electricity meter is installed total metered electricity consumption cannot be split into *electro-specific* consumption (i.e. for lighting and white goods) and electric heating energy consumption. In addition to direct electrical space heating firewood is used in most residential buildings for space heating purposes. Hot water based central heating systems are relatively rare in Norwegian dwellings. However, due to cheap electricity and relatively low investment costs air-to-air heat pumps are quite common.
Forecasts on energy consumption are an important part of planning and maintaining an energy system. While long-term perspectives mostly are important for long-term resources management short-term forecasts provide useful data for grid management. In order to make assumptions on future demand a basic understanding of the relevant drivers is necessary. Knowledge of how much electricity is actually used for thermal purposes enables the design of substitutional energy systems (e.g. district heat networks).
In this study electricity meter data and survey response data of several hundred Norwegian households is analysed in order to identify the main drivers of residential electricity consumption used for electro-specific and space heating purposes on a daily level. Further, average hourly profiles of absolute and relative metered consumption are estimated and roughly analysed.

Methods

A web based survey on household specific data has been carried out among electricity customers of two system operators in southern Norway (sample 1 and 2). Only customers that had advanced metering systems installed in their homes have been invited to participate. Altogether about 1.600 customers have answered the questionnaire containing about 30 different items (questions). Both technical data (e.g. floor space, dwelling age and standard, number of household members, heating system, wood firing customs) as well as information on attitudes and behaviour have been inquired. Since mainly dwellings of type detached houses with direct electrical space heating and electrically heated hot water tanks are represented in both samples only these observations are included. However, electrical space heating is mostly complemented by wood firing and/or air-to-air heat pumps. About 300 observations remain after excluding observations with missing or defect response or meter data. The large majority of all included households use wood firing in addition to electrical heating and about 50% use air-to-air heat pumps. Since only total electricity consumption is metered a simple decomposition method is used to estimate *basic* and space heating electricity consumption. In theory the basic component includes consumption of electrical appliances and electric hot water tanks. Basic consumption per day is assumed to be temperature-independent and constant. The actual space heating component is assumed to include only electricity consumption caused by electric heaters and heat pumps used for space heating. It is assumed that variations in outdoor temperature (represented by heating degree days) are most relevant for explaining variations in daily space heating consumption of each observation. Further assuming a linear relationship between space heating consumption and heating degree days a parameter called *space heating rate* serves as proportionality constant. Thus simple linear regression of heating degree days on daily electricity consumption yields basic consumption as intercept and space heating rate as slope estimate for each observation. Basic consumption and space heating rate assumed to be constant for each observation. However, these two parameters vary from observation to observation. It is assumed that household-specific factors (e.g. the number of residents) mainly affect basic consumption while dwelling-specific factors (e.g. dwelling age and heated floor space) mainly affect space heating rate.
Hourly electricity consumption is analysed using average diurnal profiles for different seasons, weekdays and consumer groups. Both absolute and relative hourly profiles are estimated. Relative profiles are calculated by dividing

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hourly consumption by the daily mean consumption per hour. Hourly consumption is thus standardized, i.e. corrected for differing consumption levels while the basic pattern is retained. Relative hourly consumption is also called *load factor*.

Results

Simple linear regression yields basic consumption and space heating rate for each observation. Since only observations using direct electrical space heating a relatively high correlation between consumption and heating degree days seems feasible. Median coefficients of determination are 0.76 for sample 1 and 0.86 for sample 2. Since several years lie between survey and metering period for sample 2 the following regression analyses have been carried out only for data from sample 1.
Results of multiple linear regression of different factors on basic consumption and space heating rate are shown in tables 1 and 2.

Tab. 1: Regression results, basic consumption

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	15.05	1.666	9.0344	0.0000
EI-applic [TRUE]	3.1	1.29	2.4030	0.0175
space:1p	-0.01492	0.0172	-0.8675	0.3871
space:2p	0.05282	0.01363	3.8765	0.0002
space:3p	0.06057	0.01545	3.9198	0.0001
space:>3p	0.09642	0.01066	9.0442	0.0000
—				
adj. R squ.	0.4543			
p-value (F-stat.)	1.151e-18			

Tab. 2: Regression results, space heating rate

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.678	0.3057	8.7598	0.0000
woodf[yes_main]	-1.631	0.2942	-5.5449	0.0000
woodf[yes_suppl]	-1.101	0.2946	-3.7386	0.0003
heatp_air [TRUE]	-0.5691	0.1545	-3.6847	0.0003
space:<1970	0.01261	0.001284	9.8168	0.0000
space:1970-1979	0.01181	0.001701	6.9466	0.0000
space:1980-1989	0.01051	0.001622	6.4802	0.0000
space:1990-1999	0.009119	0.001714	5.3199	0.0000
space:1999<	0.005364	0.002743	1.9557	0.0525
—				
adj. R squ.	0.4412			
p-value (F-stat.)	1.6454e-16			

Adjusted coefficients of determination are about 0.45 for both regressions and low p-values of the F-statistic indicate high overall significance.
Heated floor space as interaction with number of persons per household is a significant factor for explaining the variance in basic consumption. Except for 1-person households basic consumption is increasing with each square meter of heated floor space. The increase (slope estimate of the interaction term) is smallest for 2-person households and largest for households with more than three persons. The use of electricity-intensive applications on average leads to an increase in daily basic consumption.
The interaction of heated floor space and dwelling age, wood firing customs (three intensity levels) and the use of air-to-air heat pumps (yes/no) are the most important factors explaining the variance in space heating rate. Increase per square meter heated floor space is highest for dwellings of the oldest age group (built before 1970) and decreasing with decreasing dwelling age. On average the use of air-to-air heat pumps and wood firing (*supplementary* or *mainly* as opposed to *little* which represents the base group) leads to significant reductions in space heating rate.

Analysis of hourly load and load factor profiles is work in progress.

Conclusions

Based on some general information provided by residential consumers daily electricity consumption used for electro-specific and space heating purposes can be roughly estimated. Simple linear regression yields that on average heating degree days can explain about 76-86% of the variance in daily electricity consumption. Intercept and slope parameters are interpreted as basic consumption and space heating rate and are assumed to be constant for each observation. About 45% of the variance in basic consumption (from observation to observation) can be explained by heated floor space and number of persons as well as the use of electricity-intensive applications. About 44% of the variance in space heating rate can be explained by heated floor space and dwelling age, wood firing customs and the use of air-to-air heat pumps. On average wood firing leads to a larger reduction in space heating rate than the use of air-to-air heat pumps.

The results of this study can be used to modify or extend existing models of regional residential electricity demand and transmission capcacity requirements. Further, estimated consumption for space heating purposes can be used to evaluate the use of substitutional energy carriers.