Identifying Electricity Demand for Residential Consumers: A social, economic and technical analysis at the local level

Mathieu Bordigoni, ENEDIS, Phone +33 181 97 53 93, E-mail: mathieu.bordigoni@enedis.fr
Thomas Verderi, ENEDIS, Phone +33 670 47 26 75, E-mail: verderithomas@gmail.com

Overview

For all stakeholders involved in the electricity system, a clear understanding of consumption behaviours is essential to face new challenges related to the energy transition. Residential sector is a major contributor to overall electricity consumption. However, in order to establish relevant energy policies or investments planning, an evolving overview of the underlying causes of energy demand is often missing. With further electrification of mobility and heating, the design of a rapid and updateable estimation method is a major issue.

However, most current studies are based on costly and time-consuming surveys of households. Building a representative survey without sampling bias, at a national scale, may be a demanding task. In addition, such a methodological approach may not be appropriate to capture new 'weak signals', as the increase of electric vehicles, heat pumps or self-consumption of electricity. We suggest a new method to estimate drivers of residential electricity consumption, whether social, economic or technical, based on a cross-sectional semi-individual design analysis of local consumption.

Combining information on individual annual consumption of consumers with social, economic and technical data at the neighbourhood scale, it is possible to identify relationships between electrical demand and explaining variables as electrical heating, building age, household composition or social category. This analysis can be performed every year to follow trends in energy consumption, or energy efficiency. In addition, this approach may be adapted to target new energy demand behaviour with a substantial development in only few local areas, as PV production or electric vehicles.

Methods

The methodology proposed is based on the statistical analysis of two combined set of data established at a local scale (neighbourhood level):

- Distribution of individual annual electricity consumption for residential customers in the local area
- Aggregated information at the local level characterizing households
    - Incomes / Poverty
    - Composition of the population (age, household size)
    - Technical description of housing (type, size, building age, heating, secondary residence)
    - Socio-professional categories (executive, farmers, blue-collar workers…)
    - New electricity uses (electric vehicles, distributed generation)

Distribution of individual annual electricity consumption is divided in a variable number of quantiles[1] for each local area. Then, a system of regression equations is defined; each quantile of annual consumption is explained by a common dataset of social and technical information at the local area. Regression equations are then estimated using variations in local conditions among thousands of areas at the national level, for a specific year. In that sense, we are using a cross-sectional analysis with a semi-individual design; measurement level of outcome is individual and explaining variables are aggregated[2] (Künzli N. & Tager IB., 1997).

A set of coefficients is then obtained for each explaining variable; one set for each quantile. Coefficients for a same variable may be significantly dissimilar for different quantiles of annual electricity consumption. For instance, the

[1]The number of quantiles analysed is the result of an iterative analysis. In the first run, demand distribution for a specific group may be very tight, between two pre-defined quantiles. To avoid problem of sampling and loss of information, the number of quantiles is then adaptively increased.

[2]N. Künzli and IB. Tager (1997) have assessed semi-individual design in comparison with ecologic studies for air pollution epidemiology studies. They concluded that the semi-individual study shares its methodological and inferential properties with typical individual-level study designs and that the strong inferential limitations of ecologic studies do not apply to the semi-individual multisite design.

local proportion of secondary residences, with generally a low level of consumption, impact mainly low quantiles of local consumption, less higher quantiles. By differentiation, it is consequently possible to estimate the distribution of annual consumption for all residential consumers belonging to a specific group, e.g. the distribution of individual annual consumption for households with an electrical heating system or for those living below the poverty line.

The robustness of the proposed methodology is tested in two different ways:

- Comparison with existing surveys on residential customers demand.
- Uncertainty analysis of the semi-individual design with simulated consumption individual data.

Results

The proposed methodology has been applied to analyse electricity consumption of French households, in 2015, including about 45.000 local areas. The objective is first to test the proposed methodology using technical determinants with well-known effects on electricity consumption, as well as some social characteristics. Selected variables are:

- Median incomes
- Proportion of households using electricity for heating
- Proportion of apartments
- Number of pieces by households
- Proportion of secondary or vacant residences
- Socio-professional activity of residents

As a result, a distribution of individual annual electricity consumption is obtained for each group, with potential interactions between selected variables. For example, a national distribution of electricity consumption for two-room or one-room apartments with electrical heating, owned by an executive, may be estimated, as illustrated in the following figure:

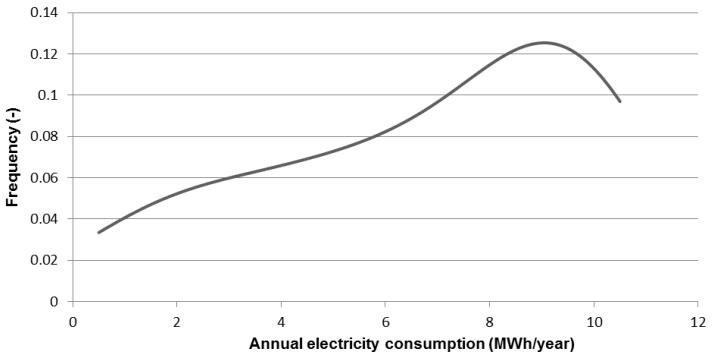

Figure 1: Estimation of the individual annual electricity consumption distribution for households living in two-room or one-room apartments with electrical heating, owned by an executive.

Further analyses are underway, to study electricity consumption behaviours for specific group of consumers as for people in situation of fuel poverty.

Conclusions

Understanding electricity consumption behaviours for different groups of residential consumers is essential for energy policy and investments planning, as residential consumers may have a very heterogeneous demand. This can help to target incentives more accurately or to anticipate potential distributive effects. This is especially relevant for local decisions as some neighbourhoods or cities may have very different drivers of residential electricity consumption.

In addition to complex surveys, the proposed methodology makes it possible to realise annual studies at the national level on many different variables, and therefore to capture main trends in residential electricity consumption. The methodology may also be applied for other energy products, as gas consumption.

References

Künzli, N., Tager, T.B. (1997): "The Semi-individual Study in Air Pollution Epidemiology: A Valid Design Compared to Ecologic Studies", *Environmental Health Perspectives*, 105(10):1078-1083.