ANALYSIS OF THE ELECTRICITY CONSUMPTION BY THE URBAN LIVING AREA USING THE AGENT BASED MODELLING APPROACH

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1. Introduction

Electricity consumption in the residential sector is increasing continuously along with the population, the GDP growth, and the shift from gas and oil consuming devices to the electric analogues. Nowadays, most of the life activities are associated with the electricity demand that should be supplied. In order to develop the optimal supply strategy of this supply, the local electricity consumption need to be evaluated. To obtain the most accurate values the actual measurement of the demand may be pre-ceded, however in the case of a large group of households the actual measurement costs a lot and enormously complicated from organizational point of view. The good alternative to the actual measurement is to use the electricity consumption computer based model. Of course the model and its parameters should be verified to be accurate, but after the verification on the sample of households' electricity consumption - the result of the computer simulation may be extrapolated from the sample set of households to the wider area of the residential sector. Such end-use models have been already formulated and developed up to now by Shimoda (2004) and by Newshamn (2013), but obtained models have been formulated for other countries or for big cities.

The interest of the current research is to re-develop the end-use model in order to predict the electricity consumption of semi-urbanized areas and of a small Japanese town. The difference between a big city and a small town is in the types and sizes of dwellings, in the average number of inhabitants, in types of in-house electric appliance, and in other system parameters. The obtained model is planned to be applied in the optimization of the electricity supply of the local area, in the analysis of individual electricity consumption weight of electric devices in the total hourly energy demand, and in the analysis of the critical level of electricity supply that matches normal living activities in the residential sector.

2. Flowchart model

The flowchart model is adapted from the research about electricity consumption of an Osaka city conducted by Shimoda (2004). Figures. 1 and 2 depict the flowchart of the electricity consumption end-use model.

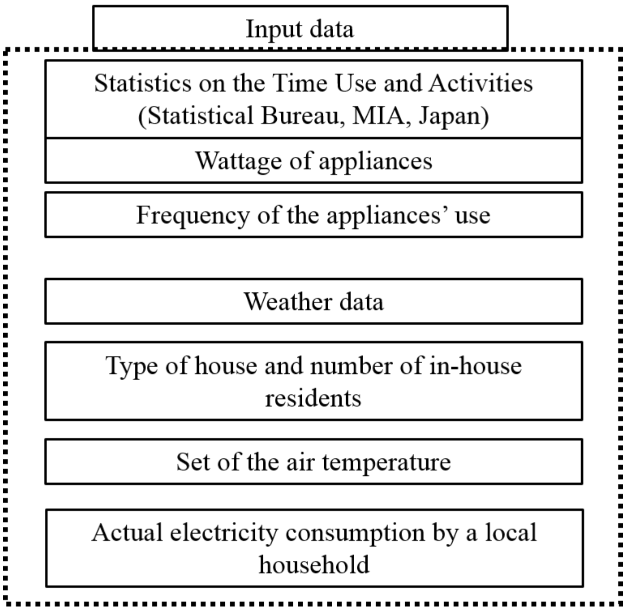

Figure. 1. The input part of a flowchart model of the household's electricity consumption calculation.

The input data may be divided by 3 groups: 1) statistical data about households' lifeschedule and appliance usage, 2) statistical data about the number and type of appliances, 3) data about environmental conditions, that affects the electricity consumption behavior.

The second part of the model depicts the distribution of a residents' interaction between each other and the interaction of residents with the in-house electric appliances. It includes the living appliance electricity-use model, correspondent to the shower, TV, lightening etc. –use; cooking appliance electricity-use model; heating/cooling appliance electricity-use and side appliance electricity-use models.

In this model the energy use of a household is calculated iteratively for every dwelling. Inhabitants life and time-use schedule, the electricity demand of electric appliances and the frequency of that appliances' use are taken from the open access sources such as Statistical Bureau of MIAC Japan, The Bureau of Labor Statistics of the U.S. and the market information taken

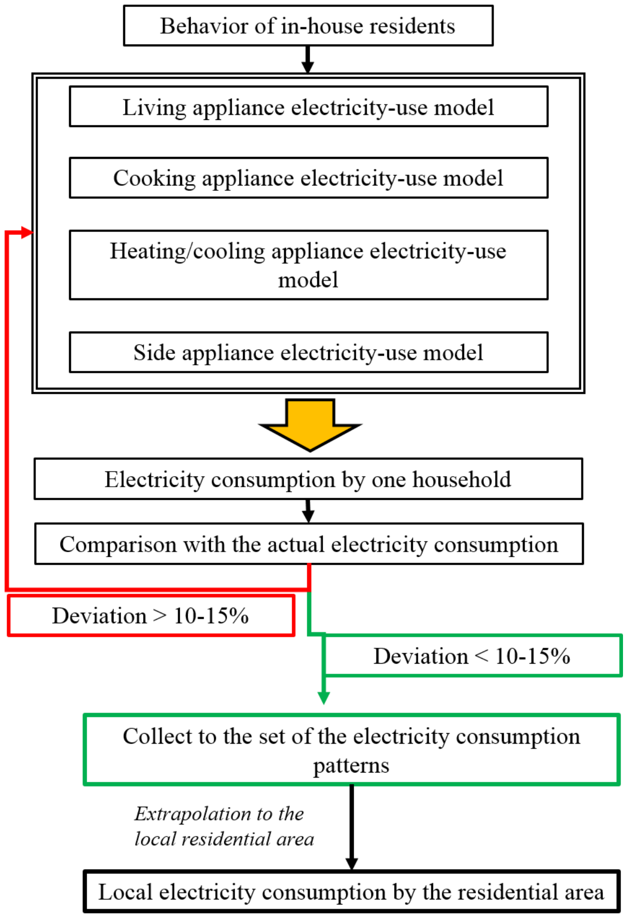

Figure. 2. The second part of a flowchart model, that depicts the system of sub-models of electricity consumption, that are necessary to be taken into account in order evaluate the electricity consumption by a household.

from Amazon and Wholesalesolar. The data about households' inhabitants, their age and the set of household's electric appliances is planned to be taken from the actual households located in a semi-urbanized area of Fukushima prefecture.

3. Modelling details

As a basis of the city model we have chosen the statistical data about more than 50 individual households, the information about which has been collected in a semi-urbanized area of Fukushima prefecture, and that has been partly presented in the work of Shiraki (2016).

The used set of households contains various types of dwelling, residenceship and used electric appliances. Table 1 matches the information about the electric appliances that were taken into account for calculating the individual electricity consumption of every individual household. Part of electric appliances has been taken from the statistical data collected in a real set of households, the second part has been approximated from the open market data and various statistics about the major in-home electric appliances (European committee of domestic equipment manufacturers; Tesco direct).

Table 1. Electric appliances that has been taken into account in most of households.

Type of the information	Appliances' title
Collected from the real households	Television, Refrigerator, Electric Stove, Electric heater, Air. Conditioner, Floor heater, Kotatsu, Electric carpet, Fan, Electric hot water dispenser, Lighting.
Approximated from the open market data	Kettle, PC, Cleaning devices, Ricecooker, Electric oven, Toaster, Washing machine, Desk/bed lamps.

The residents' distribution in a given set of households has been also very varied. The minimal number of residents was equal 2 and consisted on two working persons. The maximal number of residents corresponds to the family house that consists on 2 under elementary school, 1 junior school, 2 retired and 3 working age persons.

As for the basic conditions, we modeled the electricity consumption by a given set of household during the cold weather period. The air temperature has been assumed to be below 10 degrees, that enhance persons staying at home to use all the possible heating devices.

4. Tentative results

4.1. AVERAGE ELECTRICITY CONSUMPTION

We have constructed the set of individual electricity consumption for all the presented households. In order to avoid overburdening with graphs we would like to demonstrate an average electricity consumption dynamic (Figure. 3). The graph depicts an average electricity consumption of a living sector. Two visible peaks match most active in-home periods, that are assumed to be after breakfast and at the dinner time. The lowest level of the electricity consumption by a household is correspondent to the night time, when every resident is going to bed and use a personal bed electric carpet heater instead of a highly consuming air conditioner and oil heaters. The stable electricity consumption during night is forming by the side electric appliances that are permanently switched on, such as: refrigerators, standby modes of rice cookers and others.

This tentative result is showing that the obtained flowchart model and its numerical simulation provides rather reliable electricity consumption dynamics, however it still requests some additional calibration, in order to be capable to provide not just reliable but an accurate dynamics and to enable us to use it in order to predict the future electricity demand in a living sector of a city or country side.

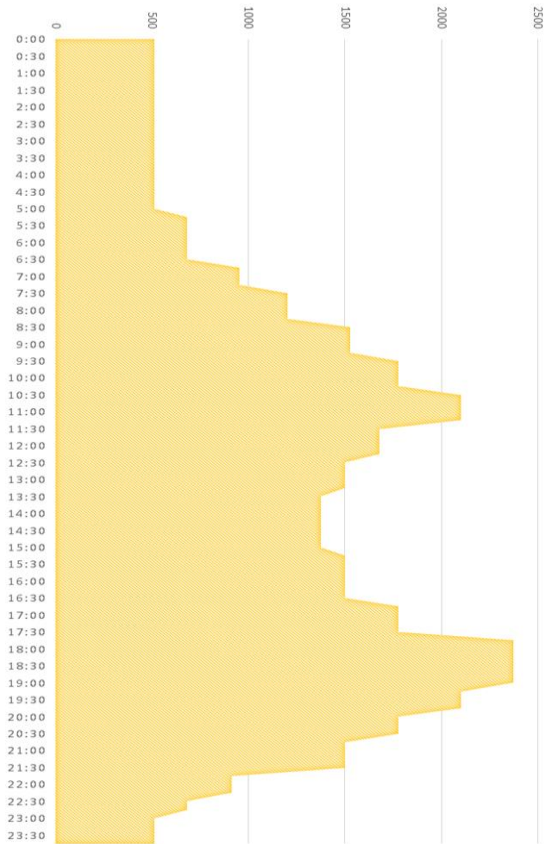

Figure. 3. Tentative result of the numerical simulation representing an average electricity consumption by a household. The X-axis corresponds to the consuming wattage of a household; the Y-axis matches the timeline.

4.2. ANALYSIS BY AN AGENT BASED MODEL

One of the key benefits of the usage of an agent based model is that the obtained results may be analyzed through the perspective of proportion in the integral electricity consumption. As an example of such a proportion we may demonstrate the figure 4. This figure depicts the proportion of electricity usage by individual sub-model. Side appliances use 21% of the daily wattage, living and cooking appliances use 43% and the heating appliances consumes the rest 36% of a daily electricity consumption by an average household.

Analyzing the time marks in the figure 3 and knowing the time of sunset and sunrise we may use the agent based model to evaluate the proportion of the consumed electricity during light (58%) and dark (42%) time (the time was chosen as a middle of march in Fukushima prefecture). This information may be very valuable in case of planning the electricity supply system in the way of planning the usage of solar, wind and the conventional power generators and its proportion in the system.

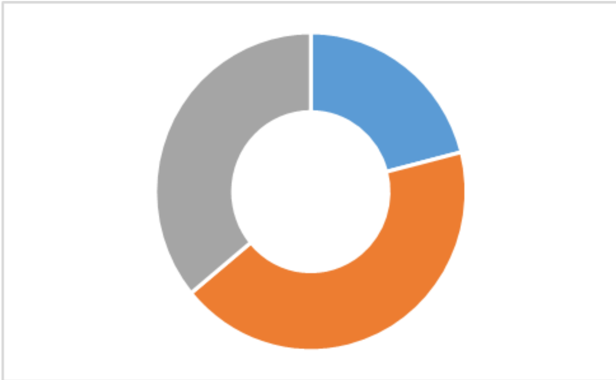

Figure. 4. The proportion of side appliances use (blue), living and cooking appliances use (orange) and heating appliances use (grey) in the integral electricity consumption.

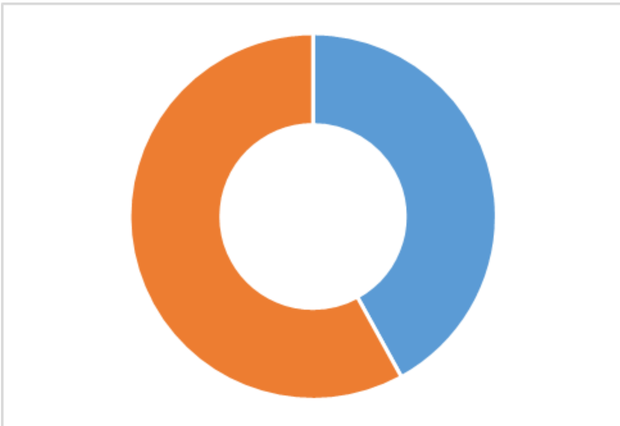

Figure. 5. The proportion of the electricity usage during day time (orange) and night time (blue).

5. Conclusion

The current work is devoted to the development of an agent based modeling approach of the electricity consumption profiling of a living area in city. As a basis we have choose the residential end-use energy model developed by Shimoda et.al (2004). This model has been overlapped and adapted to the local countryside semi-urbanized area. The input data about the countryside city has been partly taken from the set of 50 real households, taking into account the set of in-home electricity appliances and residents distribution. The householders' behavior and their lifestyles has been assumed according to the statistical information provided by “Statistics on the Time Use and Activities (Statistical Bureau, MIA, Japan)”.

The obtained information and data have been overlapped through the developed numerical model, the flowchart of which is presented on fig.1 and fig.2. The obtained result, represented by an average electricity consumption among the set of household is depicted on the fig.3. It corresponds to the expectable consumption dynamics, however still requires some verification by comparison with an actual electricity consumption data in order to de-fine the percentage of its accuracy.

The benefit of the used model is the possibility to analyze the individual and average proportion in electricity usage by households. One of such proportions is the proportion between the heating electricity consumption, that is very important during a cold period, living and cooking electricity consumption, that are correspondent to the integral satisfaction of residents, and the side appliances electricity consumption that may be less important but unavoidable.

The further usage of the developed model is planned as a tool to analyze the possible changes in the electricity consumption profile depending on the change in the population in the local area caused by migration or other reasons and on the shift of in-home appliance from its gas/oil based equivalents to more modern electricity based technologies. The second possible analysis by the developed tool is the analysis of the electricity consumption by a residential area through the prism of large-scale disaster vulnerability. The obtained de-tailed electricity consumption profile may be analyzed and the appliances in use may be classified though the criteria of “first”, “second” and “third” importance electric appliances and its consumption.

6. Acknowledgements

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