Electricity consumption profiling of a city using the agent based modelling approach.

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Understanding of an hourly electricity consumption by a living household is an essential issue in various research directions. Electricity consumption profiles and its changes depending on season, weather, some social factors may one of the key parameters that should be known for the energy-saving strategy, for the planning of eco- electricity generator usage, and for other purposes. The electricity profiling is the topic that is under discussion for a relatively long time and there are many developed methods. Most of it can be classified as engineering method **[4,8,9]**, conditional demand analysis (CDA method)**[5,6,7]** and hybrid method. However, these methods still request an actual measurement of electricity consumption at the house. Present research is devoted to the modelling of an electricity consumption by a large group of living households combining principles of developed methods, computer based modelling and statistical data. The goal of such approach is to predict the energy consumption profile not of the one household, but the wide group of it, such as a city block, village of a middle size or bigger area. This model enables us not only to evaluate the current state of electricity profile in the area, using some local data, but to predict the further dynamics of electricity consumption depending on the changes of population number, changes on the market of electric devices, aging of the local community.

Key Words : *electricity consumption, aget based modelling, computer based modeling.*

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 analogs. 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 preceded, 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 **[1, 2]**, but obtained models have been formulated for the other country or for the big city. The interest of the current research is to re-develop the end-use model in order to predict the electricity consumption of rural, semi-urbanized areas and of a small Japanese town. The difference between a big city and a small town is in the types and size of dwellings, in the average number of inhabitants, in types of in-house electric appliance, and in other system parameters.The obtained model is planed 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 [1]. Figs. 1 and 2 depict the flowchart of the electricity consumption end-use model.

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 appliences, 3) data about environmental conditions, that affects the electricity consumption behaviour.

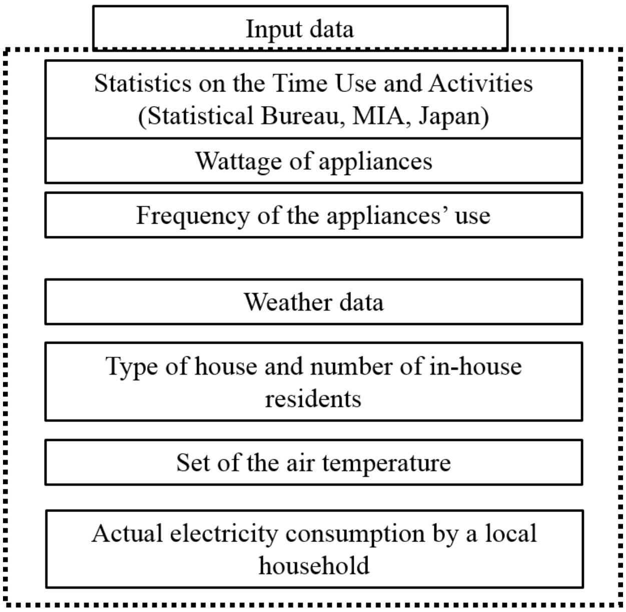

Fig. 1. The input part of a flowchart model of the household's electricity consumption calculation.

The second part of the model depicts the descti-btion of a residents' interaction between each other and the interaction of residents with the inhouse electric appliences. It includes the living appliance electricity-use model, correspondent to the shower, tv, lightening etc. –use; cooking appliance electrici-ty-use model; heating/cooling appliance electrici-ty-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 appli-ances' use are taken from the open access sources such as Statistical Bureau of MIAC Japan, The Bu-reau of Labor Statistics of the U.S. and the market information taken from Amazon and Wholesaleso-lar.The data about households' inhabitants, their age and the set of household's electric appliances is planed to be taken from the actual households lo-cated in a semi-urbanized area of Fukushima pre-fecture.

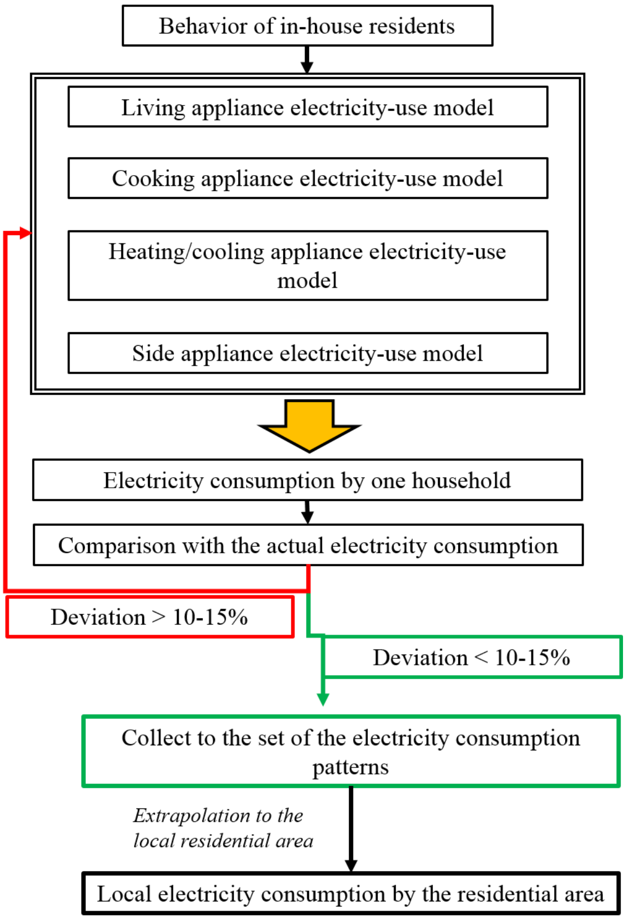

Fig. 2. The second part of a flowchart model, that depicts the system of sub-models of electricity consumption, that are nessesary to be taken into account in order evaluate the electricity consumption by a household.

3. MATHEMATICS

The following equations demonstrates how the integral electricity consumption is calculated:

$$C_{h,t_0} = \sum_{i=0}^{n} \mathrm{Tapp}_{i,t_0} \times \mathrm{Max}(\mathrm{X}_{t_0}) + \sum_{i=0}^{n} \mathrm{Sapp}_{i,t_0} + \sum_{i=0}^{n} \mathrm{Papp}_{i,t_0} \quad (1a)$$

$$C_{h,daily} = \sum_{i=0:00}^{24:00} C_{h,i} \quad (1b)$$

C_{h,t_0} - is the electricity demand of the entire house-hold at the time t_0, Tapp_{i,t_0} is the electricity demand of the appliance if it is in use, Sapp_{i,t_0} - electricity demand of the standby appliance if it is not in use, Papp_{i,t_0} - electricity demand of the appliance that is permanently in use. X_{t_0} - is the set of inhabitants who is at home and use the appliance: usage of an appliance corresponds to $X_{t_0} \geq 1$; $\mathrm{Tapp}_{i,t_0} \times \mathrm{Max}(\mathrm{X}_{t_0}) = \mathrm{Tapp}_{i,t_0}$, if the inhabitant do not use the appliance - $X_{t_0} = 0$; $\mathrm{Tapp}_{i,t_0} \times \mathrm{Max}(\mathrm{X}_{t_0}) = 0 \cdot$

Some of electricity demands depend on the weather factors. The usage of the air conditioners and other temperature control devices is set to be depended on the air temperature outside of the household. Parameters of such dependence are taken from the other researches **[3]** and **[2]**.

Cooling appliances switchs on if:

$$\mathrm{Max}(0, \mathrm{T} - 22) > 0$$

Heating appliances switchs on if:

$$\mathrm{Min}(0, \mathrm{T} - 18) < 0 \cdot$$

4. DATALES OF THE SIMULATION AND ITS RESULTS

(1) Modeling details.

As a basis of the city model we have choose the statistical data about more than 50 individual households, the information about wich has been collected in a semi-urbanized area of Fukushima prefecture, and that has been partly presented in the work **[3]**.

The used set of households contains variouse types of dewaling, residenships and used electric appliences. **Table 1** matches the information about the electric appliences that were taken into account for calculating the individual electricity consumption of every individual household. Part of electric appliences 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 variouse staticistics about the major inhome electric appliances (**European committee of domestic equipment manufacturers; Tesco direct**).

The residets distribution in a given set of households has been also very varied. The minimal number of residens was equal 2 and consisted on two working persons. The maximal number of residens 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 degree, that inhance persons staying at home to use all the possible heating devices.

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

Type of the information	Applience title
Collected from the real households	• Tlevision, • Refrigerator, • Electric Stove, • Electric heater, • Air.conditioner , • Floor heater, • Kotatsu, • Electric carpet, • Fan, • Electric hot water dispenser, • Lighting.
Aproximated from the open market data	• Kettle , • PC, • Cleaning devices, • Ricecooker, • Electric oven, • Toster, • Washin machine, • Desk/bed lamps.

(2) Tentative result.

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 dynamics (**Fig.3**). The graph depicts an average electricity consumption of a living sector. Two visible peaks matches most active inhome 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 appliences 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 accurater 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.

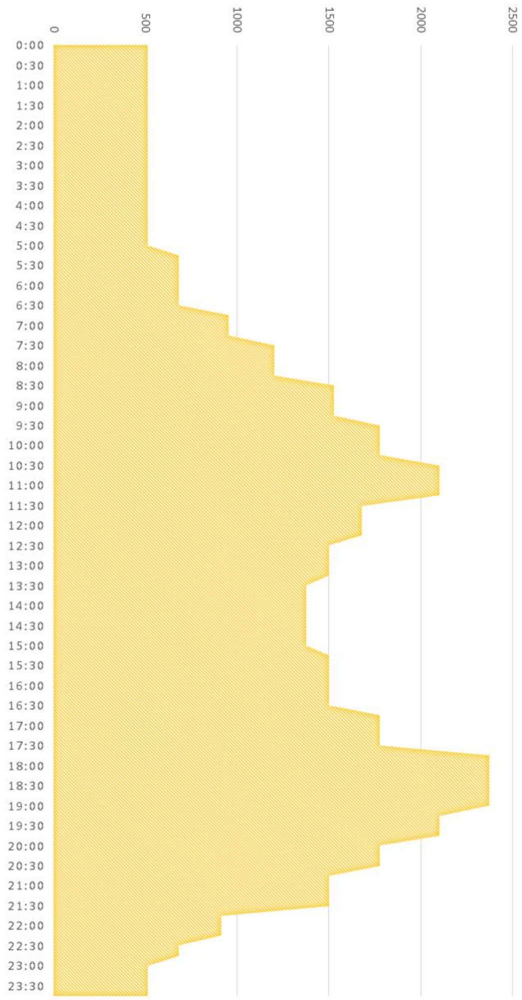

Fig 3. Tentative result of the numerical simulation representing an average electricity consumption by a household. The X-axis corresponds to the consuming wattage of the household, the Y-axis matches the timeline.

(3) Usage of an agent based model

One of the key benefits of the usage of an agent based model is that the obtained results may be analized through the perspective of proportion in the integral electricity consumption. As an example of such a proportion we may demonstrate the **fig.4**.

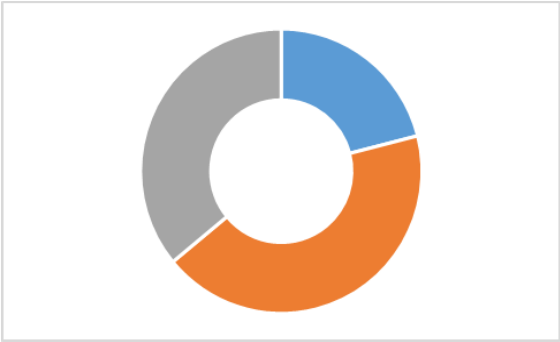

Fig 4. The proportion of side appliences use (blue), living and cooking apliances use (orange) and heating appliances use (grey) in the integral electricity consumption.

This figure depicts the proportion of electricity usage by individual sub-model. Side appliences use 21% of the daily wattage, living and cooking appliances use 43% and the heating appliences consumes the rest 36% of a daily electricity consumption by an average household.

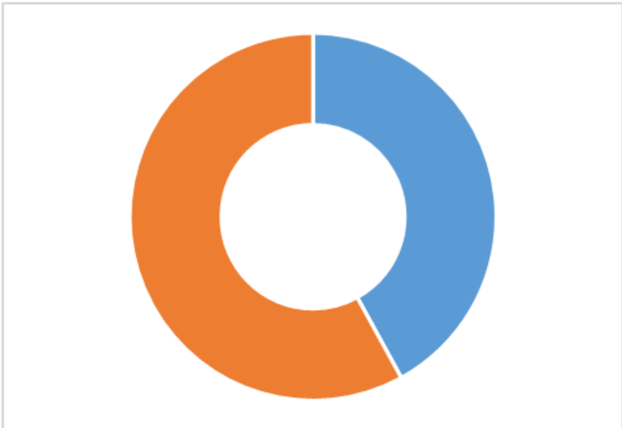

Fig 5. The proportion of the electricity usage during day time (orange) and night time (blue).

Analizing the time marks in the **fig.3** and knowing the time of sunset and sunrise we may use the agent based model to evaluate the the proportion of the consumed lectricity during light (58%) and dark (42%) time (the time was choosen 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.

5. RESULT

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 **[1]**. 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 inhome electricity appliences and residents distribution. The householders' behavior and their lifestiles 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 wich is presented on the **fig. 1** and **fig. 2**. The obtained result, represented by an average electricity consumption amoung 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 define the percentage of its accuracy.

The benefits of the used model is the possibility to analize the individual and average proportion in electricity usage by a households'. One of such propotions 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 satisfatction of residents, and the side appliances electricity consumption that may be less important but unavoidable.

The further usage of the developed model is planed as a tool to analize 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 inhome appliance from its gas/oil based equivalents to more modern electricity based technologies. The second possible analizis by the developed tool is the analizis of the electricity consumption by a residential area through the prism of large-scale disaster vulnerability. The obtained detailed electricity consumption profile may be analized and the appliences in use may be classified though the criteria of "first", "second" and "third" importance electric appliences and its consumption.

ACKNOWLEDGMENT: This research was supported/partially supported by National Institute for Environmental Studies, Fukushima Branch Encouragement Research Support (支部奨励研究). We thank our colleagues from National Institute for Environmental Studies who provided insight and expertise that greatly assisted the research, although they may not agree with some of interpretations/conclusions of this paper.

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(Received August 25, 2017)