The Energy Consumption Reduction Effect Due to Lifestyle Changes

Asaki Chiba *1, Takashi Akimoto *2, Takeshi Kondo *3, Yasuko Adachi *4

* Shibaura Institute of Technology, Japan
1 me15068@shibaura-it.ac.jp
2 akimoto@sic.shibaura-it.ac.jp
* Nikken Sekkei Research Institute, Japan
3 takeshi.kondo@nikken.jp
4 satoko.adachi@nikken.jp

Abstract
This paper presents the results of a project analyzing the difference in energy consumption based on building properties and resident lifestyle behavior to determine potential energy saving measures in the future residential sector. Six models were created with different household compositions as well as building properties. All models showed a decrease in energy consumption but the most significant effect was observed in the models including the “efficient household appliance” component. The results indicate that primary energy consumption was reduced by 30.1% in these models as compared with the standard model. It was also found that primary energy consumption changes with the insulation efficiency of a residence, and other factors such as household composition. To optimize energy savings in the future, it will be necessary to take into account these factors while ensuring energy saving measures do not invade on a resident's healthy life.

Keywords - lifestyle; energy consumption; household size; home appliance; insulation performance

1. Introduction

The Kyoto Protocol’s first commitment period (time during which parties who have ratified the protocol must have fulfilled their commitments to limit greenhouse gases) ended in 2012. Emissions of greenhouse gases from the Japanese residential sector have increased by 48.1% compared with that in 1990. This is because of the nuclear power station accident during the Great East Japan Earthquake, after which increased thermal power generation was necessary.

Other factors, believed to have contributed to the increase in energy consumption, include increased total number of households and single-person households. Figure 1 shows the transition of the number of households and family members per household in Japan between 1960 and 2010, and Figure 2 shows energy consumption in kilocalories (kcal) for different uses and per household in Japan.
The work presented in this paper focuses on differences in lifestyle behavior and the effect this has on energy consumption. With the unstable energy prices and after the Great East Japan Earthquake, which led to a shortage of electric power supply and an increased power demand, the need for energy self-support of a residence as well as the need for power saving efforts were recognized. Previous research indicates that when low power consumption lifestyle behaviors are adopted in a household, energy consumption can be decreased by as much as 37.3%. (Akihito et al., 2014) However, many studies on energy-saving actions lack details that clearly show the characteristics of these actions as well as the effects. There is little preceding studies about energy saving which gave detailed parameters, such as people's action and a driving schedule.
of the various apparatus accompanying it. We approached and examined about such research. The purpose of this paper is to present results of a project analyzing the difference in energy consumption based on building properties and resident lifestyle behaviors to determine potential energy saving measures in the future residential sector. Six models in which household composition and building properties differ were created. Simulations were run to determine thermal environment and energy consumption for the different models.

2. Model Simulation Parameters

It analyzed using the warm temperature environment simulation tool "AE-Sim/Heat". "AE-Sim/Heat" builds and analyzes the model called a "Thermal Network" in the heat performance and heat environment of a building.

A total number of 36 simulations were conducted to clarify the thermal environment and the energy consumption with different building properties and lifestyle behaviors of the occupants. Model simulations for this project were based on building properties from an existing apartment building located in Tokyo, Japan. This building was completed in January 2011 and has reinforced concrete construction. The total area of the building is 3,745 m² and the total number of households is 43. One household unit, located on a middle floor (in between adjacent units), was simulated for this study. Figure 3 shows the floor plan for this unit.

![Fig.3 Floor Plan](image)

The building parameters in the model reflected building material characteristics. Table 1 shows insulation efficiency parameters of a selected model scenario. Lifestyle behavior parameters included in the model were the schedules of each resident and home appliance settings, such as air conditioner settings and hot water heater settings. (Masaaki et al., 2004) The appliance settings were set the same as the target dwelling
unit. AMeDAS (Automated Meteorological Data Acquisition System in Japan) data was used for weather condition parameters in the simulations.

Table 2 shows the household parameters used in the simulations. The four-person household case was considered as the general case. However, recently the resident number/household has been decreasing in Japan. With this in mind, the one-person household case and two-person household case were studied as well. Six analysis models were established in total. These included Standard model, High insulation model, High efficiency home appliance model, High insulation and High efficiency home appliance model and Energy saving action model 1 and 2.

Home appliance user schedules were set the same in all models. The total number of home appliances included in the simulations were 19. The capacities of home appliances such as refrigerator, washing machine and so on, were different depending on the number of residents. Therefore, the energy consumption of home appliances differed depending on simulation model cases.

### Table 1 Insulation efficiency parameters included in each model scenario

<table>
<thead>
<tr>
<th>Insulation parameters</th>
<th>Coefficient of heat transmission [ W/(m^2 K) ]</th>
<th>Solar heat gain coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior wall (south)</td>
<td>0.65</td>
<td>0.79</td>
</tr>
<tr>
<td>Exterior wall (north)</td>
<td>2.63</td>
<td></td>
</tr>
<tr>
<td>Roof</td>
<td>0.42</td>
<td></td>
</tr>
<tr>
<td>Window</td>
<td>4.65</td>
<td></td>
</tr>
<tr>
<td></td>
<td>*reference value 2.70</td>
<td></td>
</tr>
<tr>
<td>Heat loss coefficient</td>
<td>2.51</td>
<td></td>
</tr>
<tr>
<td>Envelope average U-value [ W/(m^2 K) ]</td>
<td>*reference value 0.87</td>
<td>0.49</td>
</tr>
</tbody>
</table>

### Table 2 Household parameters

<table>
<thead>
<tr>
<th>Household Number</th>
<th>Family Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>one person</td>
<td>an office worker</td>
</tr>
<tr>
<td>two persons</td>
<td>a young couple</td>
</tr>
<tr>
<td>four persons</td>
<td>a couple, children</td>
</tr>
<tr>
<td></td>
<td>an aged person</td>
</tr>
<tr>
<td></td>
<td>an aged couple</td>
</tr>
<tr>
<td></td>
<td>a couple, a child, grandmother</td>
</tr>
</tbody>
</table>

### 3. Results

#### 3.1 Standard Model

Annual heating and cooling load in megajoule (MJ) for every household composition in the simulations are shown in Fig. 4. There was no big difference in heating load between the one-person-household and two-person-household. However, when comparing the heating load of the young couple case with the office worker case, the latter's load is larger (50 megajoule). Similarly, the single elderly person’s load is larger (622 megajoule) than the aged couple’s. In general, when the number of persons...
per household is the same, heating load is larger than the cooling load (including for elderly people).

When comparing per person heating and cooling load, heating loads are reduced by approximately 50%, and cooling loads are reduced by approximately 40% in a two-person household, compared with a one-person household. Similarly, with a four-person household, heating loads are reduced by about 70%, and cooling loads are reduced by about 45% compared with a one-person household.

The annual primary energy consumption in gigajoules (GJ)/year per household is shown in Fig. 5. The amount of electricity used for air conditioning and hot water supply differs greatly between the different household configurations. The per person annual primary energy consumption is shown in Fig. 6. Compared with the energy consumption of a one-person household, a two-person household consumed approximately 60%, and a four-person household consumed about 43%.

![Fig.4 Annual Cooling and Heating Load](image)

![Fig.5 The Primary Energy Consumption per Household](image)
The monthly primary energy consumption of our standard model is illustrated in Figure 7. It is clear that more energy is consumed for heating purposes rather than air conditioning. The model can confirm energy usage for high demand seasons and years.

Fig.7 The Monthly Primary Energy Consumption of the Standard Model
3.2 Results for Each Model Scenario

The annual primary energy consumption for each model scenario of the four-person household (a couple, children) is shown in Fig. 8. This household configuration showed the highest annual primary energy consumption in the standard model.

![The primary energy consumption chart](image)

Fig.8 The Annual Primary Energy Consumption for each Model Scenario

Compared with the Standard model, the High insulation model (better window insulation) reported a reduction in primary energy consumption primarily related to the decrease in power consumption from less air conditioning. In total, the primary energy consumption decreased by 3.9 gigajoules/year (4.8%) with the High insulation model.

When insulation efficiency does not change but an efficient household appliance is introduced (High efficiency home appliance model), the primary energy consumption of heating is reduced by 2.6 gigajoules/year and the primary energy consumption of air conditioning is reduced by 0.6 gigajoules/year. The annual primary energy consumption for air-conditioning is reduced by 3.3 gigajoules/year (4.0%). For other household appliances, primary energy consumption is reduced by 9.9 gigajoules/year (12.1%). Overall, total reduction in primary energy consumption for the High efficiency home appliance model was approximately 29.3%.

When both efficient household appliances and building insulation are introduced (High insulation and High efficiency home appliance model) the reduction effect in energy consumption was the largest. This model resulted in a reduction of 24.6 gigajoules/a year (30.1%) as compared with the Standard model.

The Energy saving action 1-model, which uses a heat-insulating curtain during heating and cooling, resulted in a 0.6 gigajoules/year reduction of primary energy consumption for heating and a 3.8 gigajoules/a year reduction for primary energy
consumption for air conditioning. In total, a reduction in primary energy consumption of 3.2 gigajoules/year (3.9%) was calculated using this model as compared with the Standard model.

The Energy saving action 2-model, which specifies use of household appliances, resulted in a 30% reduction in primary energy consumption for lighting and cooking appliances. A reduction for heating of 0.9 gigajoules/year and for air conditioning of 5.4 gigajoules/a year was also reported. In total, primary energy consumption decreased by 6.9 gigajoules/year (8.4%) using this model.

4. Discussion

The models which introduced efficient household appliances displayed the greatest reduction in primary energy consumption. The energy consumption was reduced by 29.3% as compared with the standard model. However, although heating load decreases by improvement in the insulation efficiency of a residence, cooling loads do not necessarily decrease. This result is consistent with previous findings. Since energy consumption changes with the insulation efficiency of a residence, and factors such as family configurations, optimal energy-saving strategies will be different in each case. Furthermore, sufficient verification is required to ensure that those strategies do not invade on a resident's healthy life.

In conclusion, although all the analyzed models had an energy-savings effect, the High efficiency home appliance addition had the largest effect on reduction of energy consumption.

5. Conclusion

The purpose of this paper is to present results of a project investigating the difference in energy consumption based on building properties and resident lifestyle behaviors to determine potential energy saving measures in the future residential sector. All of these results take into consideration detailed parameters, such as people and a schedule of apparatus. The energy consumption of the Standard model was reduced by 7.3% when introducing better insulation and by 29.3% in the case of introducing high efficiency household appliances. When adopting both of these changes, energy consumption was reduced by 30.1%. In addition, when thermal barrier curtains were used during air conditioning operation, the energy consumption was reduced by 2.0%. From the simulation results, we can conclude that:

1) In a case where a residence is sufficiently insulated, the introduction of an efficient household appliance would produce energy savings.
2) The heat load was reduced considerably using the High insulation model. When insulation repair is difficult, turning the light off frequently and closing curtains during air conditioner operation will result in similar energy savings.

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References
