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Analysis of Household Energy Consumption of Lighting and Electric Appliances and Predictions for 2020

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Abstract: The increase in household energy consumption has been more apparent than such increases in the industrial and transportation sectors. The sources of household energy consumption can be classified into heating and cooling, cooking, hot-water supply, and lighting and electric appliances. In particular, energy consumption for lighting and electric appliances has been significantly increasing. In order to consider energy-saving measures in the home, we should trace the tendencies of increasing energy consumption due to lighting and electric appliances in recent years. In this paper, we analyze the current level of energy consumption for lighting and electric appliances and, moreover, attempt to predict the level we can expect in 2020. Consequently, it is estimated that the energy consumption of lighting and electric appliances will decrease by 16% from the 2010 level, mainly due to the energy savings expected for refrigerators and lighting.

1. Introduction

Energy consumption in Japan has been increasing since 1965. The increase in household energy consumption is more significant than that in the industrial sector. Household energy consumption is broken down into major demands: cooling, heating, hot-water supply, lighting and electric appliances. Of these, the energy consumption of lighting and electric appliances has shown the biggest increase in recent years. The increase in household energy consumption depends largely on how residents use lighting and electric appliances such as televisions and refrigerators.

To ensure the efficient and effective use of energy in residences, it is necessary to clarify the factors behind the increase in the energy consumption of lighting and electric appliances and to predict the level of energy consumption in the future. Household energy consumption depends on the number of households, individuals' lifestyles, and so on. Therefore, to predict the household energy consumption of the future, it is necessary to analyze the trends in household energy consumption over the past 10–15 years based on the number of households, population, changes in lifestyle, the influences of the aging society and low fertility, and the number of electric appliances in each household.

In recent years, ways to achieve energy savings have been taken seriously throughout the world, and several studies on household energy consumption have been conducted. However, few studies have analyzed the changes in household energy consumption or have attempted to predict future changes in the energy consumption of lighting and electric appliances. Accordingly, the aims of this paper are to analyze energy consumption of lighting and electric appliances between 1998 and 2010 and then to predict the energy consumption of 2020. The trend of the household energy consumption changes in a time span of a decade. Thus, it is necessary to predict the short term energy consumption to develop concrete energy saving policies.

2. Analysis data and approach of this study

The changes in household energy consumption for lighting and electric appliances are analyzed based on existing data in this

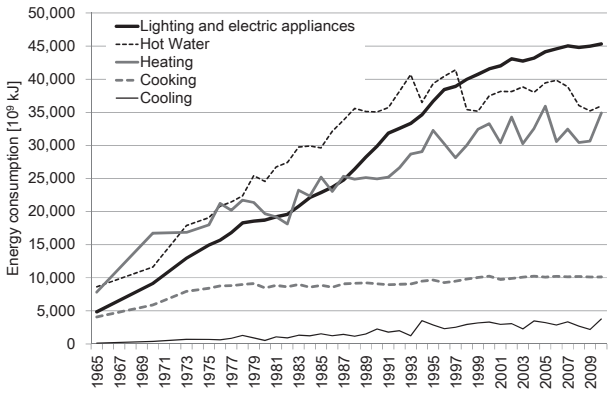

Figure 1 Household energy consumption [i)]

field. Then these data are used for the prediction of future energy consumption in 2020.

Several types of data were analyzed: 1) energy consumption of each electric appliance, 2) population and number of households in Japan, 3) number of electric appliances owned by an average household, 4) number of clothes washers sold that are equipped with a dryer function, 5) hours of watching TV, 6) number of lighting fixtures in houses, and 7) efficiency of electric appliances.

3. Results of data analysis

3-1. Energy consumption of lighting and electric appliances

Figure 1 shows the levels of household energy consumption by cooling, heating, hot-water supply, cooking, and lighting and electric appliances between 1975 and 2009. The energy consumption levels of heating, hot-water supply and lighting and electric appliances together account for a large portion of total household energy consumption. While the energy consumption levels of heating and hot-water supply have remained steady from the 1990s, those of lighting and electric appliances have been increasing.

The energy consumption per household unit and that per person are shown in Figures 2 and 3, respectively. The energy consumption per household unit has been flat since 1995, while that per person has been increasing in recent years. It is clear that the amount of energy consumption depends on the energy consumption by each person. As mentioned below in section 3-3, the sizes of households have been decreasing in recent years, and it is predicted that the number of households will increase. Thus the increase in the number of households will lead to an increase in household energy consumption.

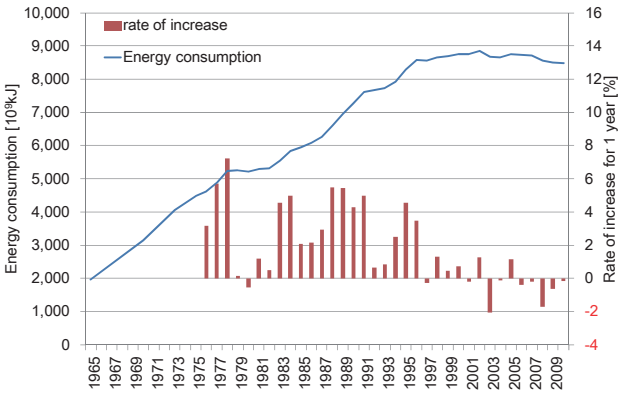

Figure 2 Annual changes and rate of increase in energy consumption for lighting and electric appliances per household unit (Created from i)

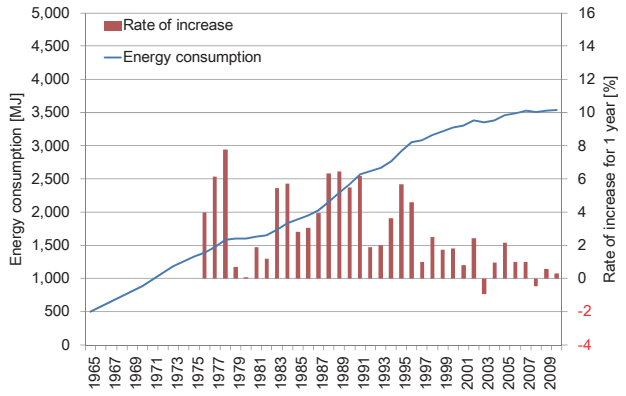

Figure 3 Annual changes and rate of increase in energy consumption for lighting and electric appliances per person (Created from i)

3-2 Population

Figure 4 shows Japan's population between 1970 and 2011 and estimated population from 2010. The population is decreasing from its peak in 2008, and the decline of the population is predicted to continue after 2010. The decline of the population has led to a decrease in household energy consumption, even though the amount of household energy consumption per person has not changed.

3-3 Number of households and average size of household

While the number of households has increased, the size of each household has been decreasing (Figure 5). Bachelor's establishment and two-person households have been increasing in recent years and account for about 50% of the population, at 23.4% and 27.2%, respectively. The size of the average household is predicted to decrease after 2019.

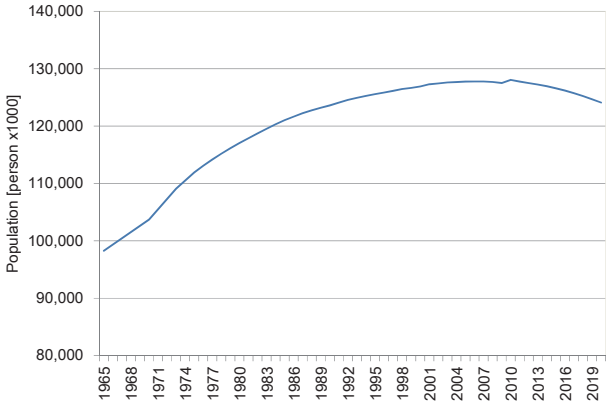

Figure 4 Population [i), ii)]
Created from *Estimated population in Japan* by National Institute of Population and Society Research, and The Institute of Energy Economics' *EDMC Handbook of Energy & Economic Statistics in Japan*

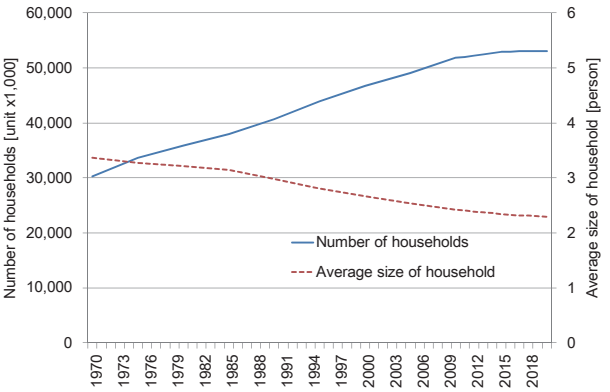

Figure 5 Annual changes in number of households and size of household
Created from *National Population Census* by Ministry of Internal Affairs and Communications, and *Future estimation of number of households in Japan* by National Institute of Population and Social Security Research (2010)

3-4 Energy consumption of lighting and electric appliances and numbers of products owned by a household

Figure 6 shows the numbers of electric appliances owned by an average household. The increase in the number of TVs owned by a household has been most rapid: 1 per household in 1975, 2 in 1992, and 2.3 in 2012. The number of TVs owned by a household has come to approximate the size of an average household, that is, 2.42 in 2012. Consequently, the TV has essentially become a "personalized" item.

The number of refrigerators and clothes washers owned by a household was nearly one in 1974 and 1.1 and 1.2, respectively, in 2004, which shows a slight change. The number of toilet seats with a warm-water bidet has also been increasing gradually. The number of PCs has also been increasing, especially from the 1990s

3-5 Household energy consumption of electric appliances

Figure 7 shows the amount of electric energy consumed (kWh) by lighting and electric appliances in Japan. The energy consumption of almost all electric appliances has been increasing. The energy consumption of refrigerators is the largest among the electric appliances. The energy consumption of lighting and TVs has been increasing year by year, and that for TVs was the same as that for refrigerators in 2003.

The levels of energy consumption of clothes dryers and toilet seats with a warm-water bidet are no larger than those of other appliances, since the number of these appliances owned by a household is smaller than others. However, the energy consumption per appliance is large. The third-largest energy consumption is that of electrical carpets for floor heating. These three appliances will become some of the main factors affecting household energy consumption.

Other appliances account for large portions of energy consumption: clothes washers with clothes dryers, rice cookers, electric pots, etc. These appliances consume vast amounts of energy, and thus they should be considered in predicting the amount of electric energy expected to be consumed in the future.

In this paper, we predict the energy consumption of 2020, focusing on the top five energy-consuming appliances: refrigerators, TVs, lighting, electric carpets, and toilet seat with a warm-water bidet.

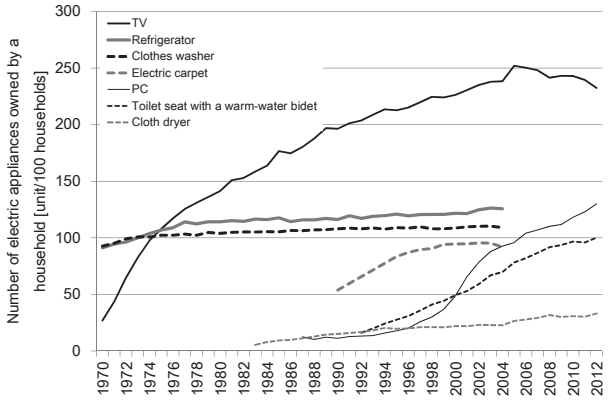

Figure 6 Number of electric appliances owned by a household
Adapted from *Monthly Consumer Confidence Survey covering all of Japan* by Cabinet Office, Government of Japan

4. Prediction of energy consumption in 2020

4-1 Refrigerators

The diagram in Figure 8 shows the calculation of the energy consumption of refrigerators. The amount of energy consumption of refrigerators in 2020 (A-2020 in Figure 8) is calculated from the energy consumption per unit in 2020 (B-2020) and total number of units in 2020 (C-2020).

The total number of units in 2020 (C-2020) is calculated from the data of number of units owned by a household in 2020 (D-2020) and the number of households in 2020 (E-2020). The number of units owned by a household in 2020 (D-2020) is assumed.

The number of refrigerators owned by a household in 1998 was 1.25, and this did not change until 2004. The number of refrigerators owned by a household in 2020 (D-2020) is estimated as 1.3, because when aging persons live together with their families, they continue to use their own refrigerator as a spare one.

The numbers of households in 1998, 2003, 2010 and 2020 (E-2020) are based on the data in Figure 5.

The energy consumption per unit in 2020 (B-2020) is calculated from the energy consumption per unit in 2003 (B-2003) and the efficiency of a refrigerator in 2020 based on that in 2003 (F-2020), which is assumed. The efficiency of refrigerators based on the value in 2020 (F-2020) is assumed from the data that show the annual change of energy consumption per capacity of one litter and the capacity of sold refrigerators. The efficiency of refrigerators in 2020 based on that in 2003 can be assumed as 0.28.

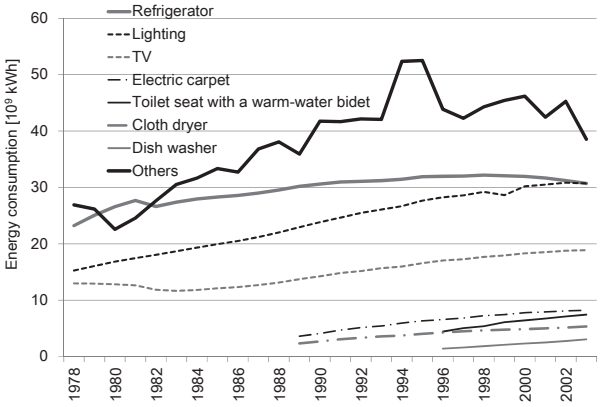

Figure 7 Annual changes in energy consumption of electric appliances[iii)]

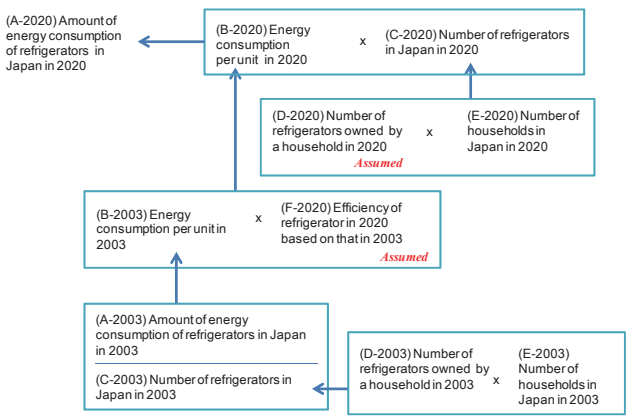

Figure 8 Calculation of energy consumption of refrigerators in 2020

The amount of energy consumption of refrigerators in Japan in 2010 is also calculated in the same way as that in 2020. The efficiency of refrigerator in 2010 based on that in 2003 is 0.45 from the existing data on efficiency of refrigerators between 1991 and 2005.

For the above estimations, the amounts of energy consumption of refrigerators in 2010 and 2020 are calculated as 14.889 billion kWh and 9.813 billion kWh, respectively. The amount of energy consumption of refrigerators in 2010 decreased by 52% from that in 2003, and that in 2020 will decrease by 7% from that in 2010.

4-2 TVs

The calculation diagram of the energy consumption of TVs is shown in Figure 9. The amount of energy consumption of TVs in 2020 (A-2020) is calculated from the rated energy consumption per unit in 2020 (B-2020), total number of units in 2020 (C-2020), and viewing hours (G-2020).

The number of TVs is estimated to depend on the population rather than the number of households. The number of TVs owned by a person can be calculated as the ratio of the number of TVs owned by a household (Figure 6) divided by the family number (Figure 5). The number of TVs owned by a person in 2003 and 2010 were 0.92 and 0.99, becoming nearly 1.0. Even if a person owned more than one TV, the number of TVs that person could watch at one time would still be one. Thus, the number of TVs owned by a person in 2020 (D-2020) is assumed as 1.00.

The population levels in 2003, 2010 and 2020 (H-2020) are shown in Figure 4.

The viewing hours in 2020 (G-2020) are assumed from the values in 2003 and 2010[iv]. The viewing hours depend on the economic and social background of the user, and thus viewing hours cannot be estimated in this paper; therefore, the value of 2010 is used.

The energy consumption by a TV in 2020 (B-2020) is taken from the values of the most recent popular type of TV in 2010, the 32-in. liquid plasma type, whose energy consumption is 98W. In 2020, since TVs have generally been used for 8.9 years recently, the lowest energy-efficiency value for common TVs is expected to be higher than that for the latest models of 2010.

From the above results, the amount of energy consumption of TVs in 2020 is estimated to be 17.5 billion kWh, which is 8% less than this level in 2003 and 7% less than that in 2010.

4-3 Lighting

The energy consumption of lighting is calculated by the number of lamps and the energy consumption of the lamps in 2010 and 2020. The number of lamps is referred to in a previous study [v]. In this paper, it is assumed that the incandescent lamps used in 2010 will have been changed to LEDs by 2020, since the product lifetime of incandescent lamps is 2–3 years, incandescent lamps have not been produced from 2011, and the prices of LEDs have drastically declined.

Considering all of the above data and findings, the energy consumption of lighting is expected to decrease by 43% from 2010 to 2020.

4-4 Toilet seat with a warm-water bidet

The energy consumption of toilet seats with a warm-water bidet is calculated in the same way as that of refrigerators.

The increase in the efficiency ratio from 2003 to 2020 is estimated as the same value of the increase in the efficiency ratio from 1998 to 2003.

The numbers of toilet seats with a warm-water bidet per household in 1998, 2003 and 2010 are based on the data in Figure 6. The number has been increasing gradually year by year, and it became over one in 2012. Thus, this number is assumed to increase gradually and become 1.1 in 2020.

From these results, the amount of energy consumption of toilet seats with a warm-water bidet in 2020 is calculated as 10.8 billion kWh, an increase of 43% and of 2% over that in 2003 and 2010, respectively.

4-5 Electric carpet

The energy consumption of electric carpets is calculated in the way same as that of refrigerators.

Because there is only slight potential for increased efficiency of electric carpets, not by improving the coefficient of performance (COP) of electric carpets but by the change in usage depending on the user, no large improvement in efficiency is expected for this product. Therefore, the efficiency of electric carpets in 2020 is estimated to be 0.95 based on the efficiency in 2003.

The numbers of electric carpets owned by a household in 2010 and 2020 are estimated to be the same as that in 2003, since the number of electric carpets has not changed in recent years and the shipment rate is also unchanged.

As a result, the amounts of energy consumption of electric carpets in 2003, 2010 and 2020 are calculated as 8.207 billion kWh, 8.655 billion kWh and 8.591 billion kWh, respectively. There is a 5% increase from 2003 to 2010 as well as a 1% decrease from 2010 to 2020.

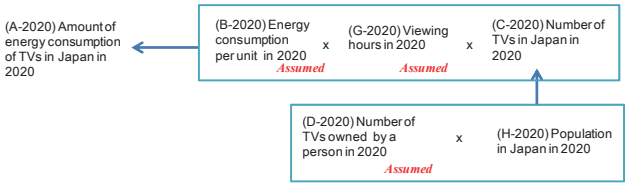

Figure 9 Calculation of energy consumption of TVs in 2020

Table 1 Energy consumption of lighting (upper: 2010; lower: 2020)

	Fluorescent lamp	Bulb-type fluorescent lamp	Incandescent lamp	Subtotal
Energy consumption per unit [W]	40	15	80	135
Number in Japan [million]	480	150	250	860
Amount of energy consumption [billion kWh]	18.4	2.25	20.0	40.65
			Total energy consumption in 2010	38.2

	Fluorescent lamp	Bulb-type fluorescent lamp	LED	Subtotal
Energy consumption per unit [W]	40	15	10	65
Number in Japan [million]	480	150	250	860
Amount of energy consumption [billion kWh]	18.4	2.25	2.5	23.15
			Total energy consumption in 2020	21.8

4-6 Others

A variety of electric appliances used in the household are considered "others" in Figure 1. Because clothes washers and rice cookers consume large amounts of energy and thus significantly affect household energy consumption, it will be important to estimate the impact of these appliances in the future. However, due to the lack of data on the number of these owned by a household and their energy consumption, the energy consumption of "others" in 2010 and 2020 is assumed to be the same as the value in 2003, which is 38.556 billion kWh.

4-7 Energy consumption of lighting and electric appliances

The levels of energy consumption for lighting and electric appliances in 2003, 2010 and 2020 are shown in Figure 10. From our results, a 6% decrease in household energy consumption in 2010 from 2003 is calculated. However, in fact the energy consumption in 2010 increased from 2003 (Figure 1). A possible reason for this difference is the increase in the energy consumption of other appliances, which is not estimated in this paper. Compared to the energy consumption given in Figure 1, the 12% increase in the energy consumption of other sources of demand can be estimated.

The energy consumption in 2020 is estimated to decrease 16% from that in 2010. The main factor of the decrease from 2010 to 2020 is the improved efficiency of refrigerators. In addition, the second factor of this decreases is the change in lighting from incandescent lamps to LEDs.

The miscellaneous "others," lighting, and TVs have become large factors of household energy consumption. However, while the energy-consumption levels of TVs and lighting are decreasing, "others" still accounts for over 30% of household energy consumption.

In this paper, the energy consumption of "others" cannot be considered due to the lack of information; however, this factor should be considered in future work.

5. Conclusion

In this work, we analyzed the energy consumption of lighting and electric appliances, which account for a large percentage of household energy consumption. Furthermore, we attempted to predict future energy consumption in 2020. From our results, energy consumption in 2020 is estimated to decrease from the current level.

Though this study, we found that these data on household energy consumption are insufficient for predicting future changes in energy consumption.

In order to understand and predict household energy consumption, it is necessary to store and analyze the various data related to household energy consumption. Such knowledge will be invaluable in promoting measures for energy conservation.

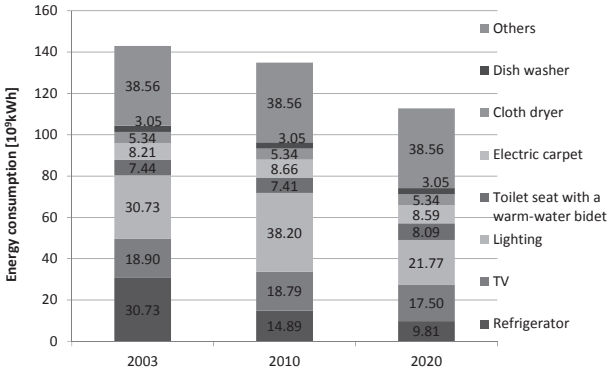

Figure 10 Household energy consumption and its breakdown in 2003, 2010 and 2020

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