

# Survey on Household Wood Biomass Use and Energy Consumption in the Oku-Aizu Region

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## Abstract

We surveyed and analyzed the current status of household energy consumption and use of firewood and other wood biomass in the town of Mishima, Fukushima Prefecture for the purpose of building a supply chain model for forest resource use in mountainous regions. The number of questionnaires returned was 341, with a response rate of 48.6%. The survey results revealed that approximately 9% of households were using wood biomass combustion devices. Annual firewood consumption per household was 3 m<sup>3</sup>, and over 90% of the raw logs used were procured inside the town. The difference in the ages of the houses of firewood users and non-users suggests that building structure may have influenced this result.

**Key words :** firewood, household energy consumption, mountainous area, questionnaire survey, wood stoves

## 1. Introduction

Ascertaining the status of wood biomass utilization for household wood stoves and other wood-burning is important from the perspective of utilizing regional forest resources and tackling climate change. Although cold mountainous regions tend to be sparsely populated, per capita energy consumption for heating is likely to be high and, therefore, deserves detailed investigation.

Several studies have already been conducted on the use of wood biomass from the viewpoint of solving environmental problems simultaneously. Nemoto et al. (2017a, b) investigated household use of wood biomass combustion devices from a nationwide view. Regionally, Hatanaka et al. (2011, 2012) surveyed household use of wood-burning devices in 10 municipalities in Nagano Prefecture from the viewpoint of effects of carbon emissions reductions. From the viewpoint of promoting usage of unused biomass, Ogasawara et al. (2017) investigated the use of firewood in fruit-producing areas and found higher use of wood stoves and other wood-burning devices than in other areas owing to the ready availability of tree prunings. Many case studies at a local scale have also been conducted, for example, Izumi et al. (2018) conducted a random electoral-register-based sampling survey to ascertain the level of firewood use in Shiwa Town, Iwate Prefecture. Harashima et al. (2014) researched the utilization of wood stoves and other wood-burning devices and firewood consumption in the Minowa district of Ina, Nagano Prefecture, through a visual survey and questionnaire. Uezono (2018) also

conducted a questionnaire survey on household energy consumption in both mountainous and urban areas of the San'in region in western Honshu. These studies indicated that currently the consumption of firewood is stable in both mountainous and urban areas, but the amount of firewood consumption is very limited compared to the rich potential of this resource from domestic forests. The role of woody biomass energy should be reconsidered compared to other energy (electricity, gas, and so on) based on reliable field surveys with promotion to a suitable environmental policies such as transformation to a decarbonized society.

With regard to energy consumption in the residential sector, the Ministry of Internal Affairs and Communications' Family Income and Expenditure Survey (2018) includes data on household expenditures for electricity, kerosene, gas and other energy sources broken down by city classification, drawn from a subset of the survey sample. Data on household energy consumption by city classification nationwide are also available in the form of estimates for the residential sector in the Agency for Natural Resources and Energy's *Energy Consumption Statistics by Prefecture* (2018) and the Ministry of the Environment's *Statistical Survey of Residential Sector CO<sub>2</sub> Emissions* (2018).

Few studies, however, have looked specifically at the level of wood biomass use in relation to household consumption of various energy resources in mountainous regions. The town in Fukushima Prefecture that was selected as our studied area decided to promote usage of woody biomass and started to survey the current situation

of forest and biomass consumption inside and near the town. In this study, in collaboration with the town, we conducted a questionnaire survey of all households in a mountainous district to shed light on the trends and characteristics of household energy consumption and use of wood biomass, which is a forest resource. This study provided the town the basic information on instituting environmental policy regarding woody biomass as energy.

## 2. Survey and Analysis Methods

### 2.1. Study Area

The mountainous location chosen for this study was the town of Mishima in the Oku-Aizu region of Fukushima Prefecture (Fig. 2 in Ooba *et al.*, 2020). The Oku-Aizu region is colder than Aizuwakamatsu City and other locations at the same latitude, with mean temperatures approaching those of northern Tohoku, the northernmost region of Japan's main island of Honshu. Depending on the year or month, Oku-Aizu can receive more than double the snowfall of Aizuwakamatsu. Mishima is a small municipality with a population of about 1,600 people living in approximately 750 households scattered among 18 villages. Its elderly ratio (percentage of the population aged 65 or older) is 54.1% (Fukushima Prefecture, 2020). At its peak during the development of the Tadami River hydroelectric dam, Mishima's population topped 7,700; since then, however, the population has steadily declined, prompting the town to launch various initiatives to attract young residents from other parts of Japan and otherwise curb depopulation. Given that it has a forest coverage of 88% (Forestry Agency, 2018), the town is also considering measures for exploiting its forest resources, including the

use of wood biomass energy in public facilities and subsidies for using firewood.

### 2.2 Survey Method

We conducted a questionnaire survey of 702 households, representing all of the households in Mishima except occupants of homes for elderly people requiring special care. The survey was conducted from October 20 to November 6, 2017, with questionnaires being distributed to each household by the town through ward chiefs and returned by postal service. The number of questionnaires returned was 341, with a response rate of 48.6%.

The questionnaire, which was to be filled in by the head of each household, asked about type of house, use of heating equipment, use of wood biomass combustion devices, consumption of electricity, kerosene, and other sources of energy, and household attributes. Table 1 shows the items surveyed in the questionnaire. We went through these by hand, and based on the questionnaire responses, identified the characteristics of households using wood biomass combustion devices and compared them with households not using such devices.

For converting the amount of firewood used into wood biomass consumption, we assumed that 1 m<sup>3</sup> of firewood = 800 kg and that one bundle = 13 kg.

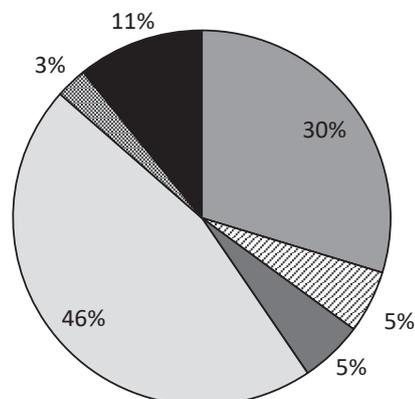
## 3. Results and Discussion

### 3.1 Use of Wood Biomass Combustion Devices

Figure 1 shows a breakdown of devices owned by households using wood biomass. Approximately 9% of the households were using wood biomass combustion devices (wood stoves, fireplaces, cookers, boilers) at the time of the survey. Although this was lower than values found by previous studies (13.5%: Izumi *et al.*, 2018; 27.4%: Yasumura *et al.*, 2011). Wood stoves and boilers (firewood-heated baths etc.) accounted for most of the wood biomass combustion devices being used, with 11%

**Table 1** Items surveyed in the questionnaire.

Category	Item
House	Type of house, building structure, age, total floor area, number of buildings, number of rooms, owned/rented, renovation/rebuild history, building structure at rebuilding
Number of heating devices	Kerosene stove/kerosene fan heater, electric stove/oil heater, gas stove, heated floor, kotatsu, air conditioner
Households that use firewood	Number of devices, annual firewood consumption, procurement method, purchase price, source, raw wood production location, intention to continue using equipment, problems, reasons for quitting, desired support measures
Households that stopped using firewood	Type of equipment, reason for quitting, conditions for using firewood again
Energy consumption status	Monthly electricity, kerosene, and LPG costs, electricity billing plan, installed energy-saving equipment, number of people at home during the day (weekdays, holidays)
Attributes	Family age/gender composition, occupation, residential district name, confirmation of respondent's family relationship



■ Wood stove    ▨ Fireplaces    ■ Cooker    □ Boiler  
 ▩ Other    ■ Compound

**Fig. 1** Breakdown of household wood biomass combustion devices.

of firewood-using households using more than one type of device.

The number of years since households started using firewood combustion devices varied from several decades to several years prior; of these households, 28% started using these devices in 2010 or later. Looking at the relationship with house renovation/rebuilding and wood biomass utilization, although 17% of firewood-using households installed devices when renovating or rebuilding, no such relationship was observed in most households. Among households not currently using wood biomass, approximately 19% of all respondents indicated that they intended to use firewood combustion devices in the future subject to availability of cheap firewood and subsidies for installing devices. This indicates that, combined with existing users, a potential 27% of households may use firewood combustion devices given the right conditions.

Most existing users obtained their firewood either by producing it themselves or procuring it for free from acquaintances rather than purchasing it from vendors. Over 90% of the raw logs used were procured in Mishima Town, either from the users' own forest plots or from the plots of acquaintances.

### 3.2 Number of Heating Devices

Table 2 shows heating device ownership of households in Mishima Town. The percentage of households equipped with air conditioners was relatively low in Mishima, with most households using kerosene stoves and fan heaters for heating purposes. A comparison of the number of other heating devices owned by users

and non-users of wood stoves and fireplaces shows that users of firewood for heating purposes owned fewer kerosene stoves and fan heaters than non-users. However, ownership of other heating devices such as kotatsu or heated floors was higher among firewood users than non-users, albeit only slightly. Among households using wood stoves, all but one household owned only one stove. This suggests that almost all of the households using wood biomass also used fossil fuels or grid electricity for heating purposes. The percentage of household energy consumption used for heating is a matter for future investigation. The sample size of firewood users for this question was small, and statistical tests found no significant differences in mean values.

### 3.3 Household Energy Expenditure

Table 3 shows the mean household energy expenditure in Mishima and other locations in Japan's Tohoku region in 2017. Energy expenditure in Mishima was high compared with mean values in the Tohoku region, indicating high energy consumption for heating purposes. Kerosene and electricity consumption tended to be lower among firewood-using households (Table 4), while consumption of LPG (Liquid Petroleum Gas) was almost double compared to the amount consumed by non-users. These differences, however, were not found to be statistically significant (*t*-test,  $p < 0.05$ ), and a more detailed statistical analysis would be needed such as factor analysis (covariance structure analysis or statistical causal analysis) according to the building age of the house related to the performance of thermal insulation.

**Table 2** Heating device ownership and mean number of devices owned.

Device type	Ownership as a percentage of all households (%)	Mean number of devices owned by firewood users	Mean number of devices owned by firewood non-users
Kerosene stove/fan heater	93.8	2.23	3.10
Kotatsu	80.4	1.31	1.08
Air conditioner	42.2	0.62	0.75
Electric stove/oil heater	26.4	0.15	0.39
Heated floor	6.2	0.08	0.07
Wood stove	3.5	1.08	–*
Gas stove	1.8	0.00	0.03

\*This question was not asked of firewood non-users

**Table 3** Mean annual household energy expenditure (unit: JPY/year)

	Electricity	Mains gas	LPG	Kerosene
Mishima Town	130,656	–	65,418	58,585
Fukushima City*	127,437	19,088	33,389	25,386
Morioka City*	100,629	18,248	37,177	31,723
Tohoku region*	114,770	15,516	36,026	40,113

\* Source: Family Income and Expenditure Survey 2016 (Ministry of Internal Affairs and Communications, 2018)

**Table 4** Firewood use and energy costs (JPY).

Energy (per month)	Firewood use	Number	Mean	Standard deviation
Kerosene	User	13	9,700 (94.8%)	16,000
	Non-user	278	10,000 (100%)	9,900
LPG	User	11	8,900 (172%)	15,000
	Non-user	254	5,200 (100%)	5,400
Electricity	User	13	9,800 (89.7%)	5,300
	Non-user	306	11,000 (100%)	9,300

### 3.4 Wood Biomass Consumption and Substitution Effect

Annual firewood consumption per household was 3 m<sup>3</sup>. Assuming this firewood was used in wood stoves, the amount of heat generated by burning this amount is 6.55 GJ, which is equivalent to 208 L of kerosene or 31.5% of mean annual household kerosene consumption (660 L) in Mishima. In terms of costs, almost all firewood in Mishima was either self-procured by felling trees or obtaining logs for free from acquaintances. Only one household surveyed purchased firewood, but at the extremely low price of JPY 200/m<sup>3</sup>. Assuming that the firewood used in Mishima households lowered kerosene use by 208 L at the prevailing price of JPY 89/L and that no costs were incurred in firewood procurement, use of firewood reduced annual household heating costs by approximately JPY 18,500.

### 3.5 Wood Biomass Use and Energy Expenditure

We conducted independent sample t-tests to compare energy expenditure for kerosene, LPG, and electricity between firewood-using households and non-using households (Table 4). Although mean energy expenditure between the two groups differed, this difference was not

statistically significant. The lack of differences may be due to other factors such as the small sample size, differences in usage of heating and hot water supply, or differences in household attributes.

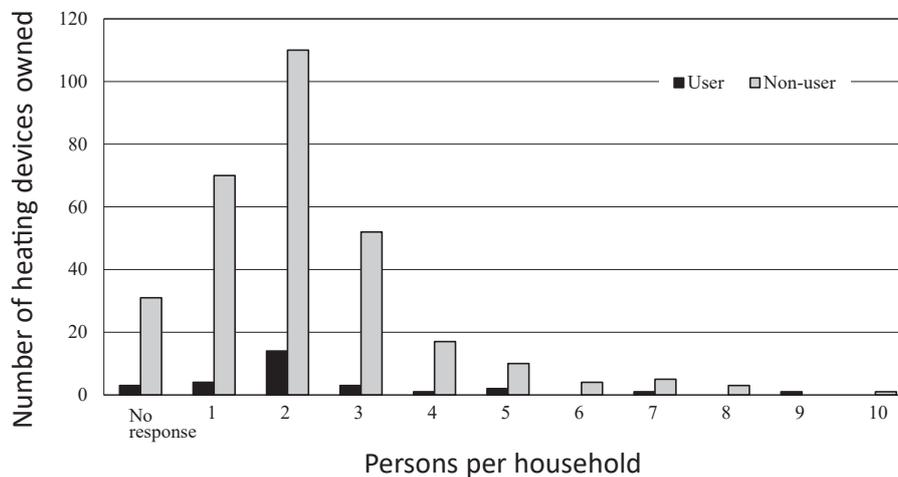
### 3.6 Wood Biomass Use and Household Characteristics

To investigate the reasons for no statistically significant difference being found between the energy costs of firewood-using households and non-using households, we conducted independent sample t-tests on the difference in means with building age, floor area, number of buildings, number of rooms, renovation/rebuilding history of the households surveyed as separate dependent variables and use/non-use of firewood as the independent variable. The homes of firewood-using households tended to be older (Table 5).

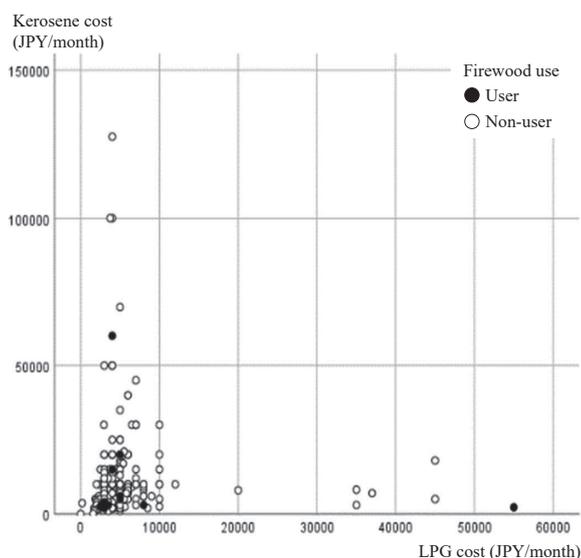
As shown in Fig. 2, we also compared the number of people per household. Only mean building age was found to differ between firewood-using and non-using households at the  $p < 0.05$  level (Table 5), with the homes of firewood-using households tending to be older. Owing to poor insulation and other factors related to house structure in firewood-using households, energy expenditure would likely be even higher than in

**Table 5** Use/non-use of firewood and household attributes

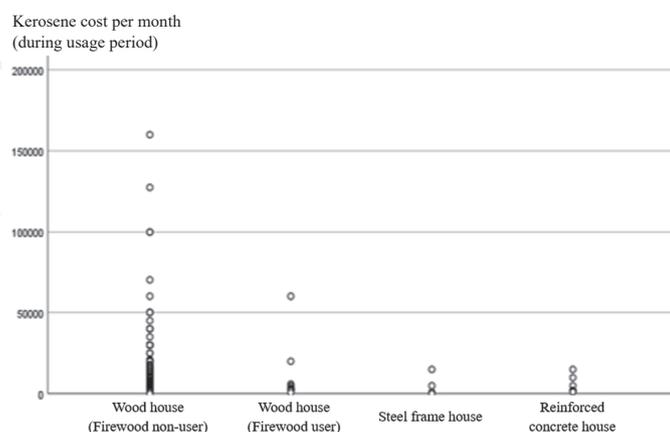
	Firewood use	Number	Mean	Standard deviation
Building age (years)	User	12	110	69
	Non-user	303	71	55
Floor area (m <sup>2</sup> )	User	13	190	210
	Non-user	328	160	179
Number of rooms	User	12	7.8	3.7
	Non-user	314	7.5	2.8
Persons per household	User	12	2.8	1.9
	Non-user	293	2.4	1.5
Persons at home during the day (weekdays)	User	12	1.8	0.75
	Non-user	299	1.6	0.97



**Fig. 2** Persons per household in relation to number of heating devices owned for use/non-use of firewood.



**Fig. 3** Use/non-use of firewood and energy expenditure per month.



**Fig. 4.** Energy expenditure in relation to building structure.

households where firewood was not used, but further research and analysis would be required to identify exactly which factors are important.

Figure 3 shows the relationship between firewood use and energy expenditure. Although we found no decrease in energy consumption as a result of firewood use, the relationship between building structure and firewood use shown in Fig. 4 indicates that firewood use may be effective in reducing energy consumption in wooden houses, which require higher energy consumption.

#### 4. Conclusions

We conducted a questionnaire survey of all households, the town of Mishima, Fukushima Prefecture to shed light on wood biomass use and household energy consumption in a mountainous region. The survey results revealed that approximately 9% of households were using wood biomass combustion devices, with most such

households procuring their own firewood for free. Annual firewood consumption per household was 3 m<sup>3</sup>, assuming this firewood was used in wood stoves, the amount of heat generated was equivalent to 31.5% of the mean annual household kerosene consumption in the town. Usage of firewood is economical, bringing a reduction in annual household heating costs of approximately JPY 18,500. These findings showed firewood still to be major heat resource in this town, and this trend is the same as was seen in previous studies (e.g., Izumi et al., 2018). Total demand for firewood inside the town can be self-supplied from the forest resources (Ooba et al., 2020).

In 2019, Mishima Town installed a new air conditioner system using fire-wood boilers in one of the town's public facilities, *Seikatsu Kogei-Kan* (Mishima Local Crafts Museum), referring to our policy suggestion based on this study and other studies conducted by our project team (e.g., Ooba et al., 2020). This boiler system was coupled with the startup of a new small-scale firewood supply chain inside the town. Local companies in the town with the potential to provide more firewood intend to expand the biomass supply (personal communications). In the future, suppliers need to be matched with consumers of firewood at the local scale. Additionally, to transform this heat resource from a depletable to a renewable energy to achieve a decarbonized town, more detailed field surveys and analyses of related policies for not only biomass but also house building and renovation should be conducted.

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