CHAPTER III

HOUSEHOLD ENERGY UTILIZATION IN COMMUNITIES AT DIFFERENT LEVELS OF URBANIZATION IN NORTHEAST THAILAND [1]

1. Introduction

The diminishing supply of oil is becoming a very serious problem worldwide. Some economists predicted that the world oil reserve will begin to decline within 10 years (Aleklett, 2004; Laherrere, 2005; Kerr, 2007) and will be used up by 2050 (Laherrere, 2005). The consequence has been a continuous upward trend in crude oil prices in the world market. High oil prices have greatly affected developing countries, especially in Asia, because most of these countries are heavily dependent on oil imports (Bentley, 2002; Roubini and Setser, 2004; IEA, 2007). Thus, all countries have given high priority to strategies for mitigating this problem, one of which is developing new and renewable energy sources (Senelwa and Sims, 1999; Omer, 2005; McKay, 2006; Prasertsan and Sajjakulnukit, 2006; REN21, 2006; Wald, 2007; REN21, 2008). It is widely anticipated that renewable energy sources, including hydro-electric, geothermal, wind, solar, and biomass, will play more important role in the future (BP p.l.c., 2008).

Biomass is often viewed as an especially promising type of renewable energy because it is cheap, abundant, and widely available. It has high potential as a fuel source, and is considered to be a type of "green" energy that can be derived from a variety of sources (e.g., forest products, wood products, energy crops and agricultural residues). Biomass can also be locally produced in most rural communities so its supply is directly connected to the management of agricultural and forest lands in these communities. Its increased use may also reduce the use of expensive fossil fuel

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which will be a significant communal benefit and may also contribute to a healthier environment (Bartuska, 2006).

According to the International Energy Agency (IEA), 77.3 % of the energy consumed worldwide in 2005 came from fossil sources (43.4 % from oil, 15.6 % from gas, and 8.3 % from coal) whereas renewable energy sources provided about 12.9 % (IEA, 2007). Biomass energy accounted for only about 2.2% of total global energy consumption (REN21, 2006), but it is disproportionately important in developing countries in which 70 % of it is used by the residential sector, especially in rural areas where 2.4 billion people live (RWEDP, 2002) and people traditionally use biomass for cooking and heating. Asian countries consume more than 80 % of the total biomass energy. There is evidence that biomass energy consumption has been increasing lately in many countries. For examples, from 1991 to 2000, biomass energy consumption increased from 66.9 to 199.8 mtoe in India, and from 47.8 to 152.9 mtoe in China (IEA, 2007; REWDP, 1999, 2002). In Thailand, biomass energy consumption in 1981 was 11.5 mtoe, increased to 12.5 mtoe in 1991, then decreased to 8.5 mtoe in 2000, but increased again to 9.5 mtoe in 2004, when it accounted for 15.8 % of the total energy consumption in the country (DEDE, 2006). Biomass is, thus, a potential source of alternative energy that is worth exploring. It has been shown that an increase of biomass energy use is possible in many countries (Parikka, 2004) but whether or not this is the case in Thailand is still an open question.

Generally, in the course of development, people choose to switch from biomass fuels to more convenient energy sources such as Liquefied petroleum gas (LPG), electricity, and petroleum products. Several factors, both within and outside the household, have been found to influence these shifts in household energy consumption, both the amount consumed and the types of energy sources used. The main factors are levels of urbanization, economic development, and living standards. Of these factors, the level of urbanization has been found to have the greatest influence on the pattern of household energy consumption. For example, Cai and Jiang (2008) reported that, in China, people living in more urbanized areas tended to use energy sources that are more convenient, cleaner, and more efficient. Studies of Indian households by Pohekar et al. (2005) and Dhingra et al. (2008) showed that households shifted from use of fuelwood to modern types of energy due to the recent rapid increases in the levels of urbanization, economic development, and living standards, which are accompanied by changes in the style of living and the increased access to different sources of energy with the shift toward urbanization. Even in rural areas, changes in types of energy used by households and a relative decline in the share of energy provided by biomass have been observed (Mahapatra and Mitchell, 1999; Senelwa and Sims, 1999; Dube, 2003; Xiaohua and Zhenmin, 2005; Ouedraogo, 2006).

These studies all appear to support the conventional assumption that the role of biomass energy will diminish, and even completely disappear, as rural communities become more urbanized. However, in several countries in Africa the vast majority of rural households still rely extensively upon fuelwood as their energy source, and this has changed only little over the past few decades despite increasing population pressures and changing socio-economic and environmental conditions (Madubansi and Shackelton, 2006). In the Asia-Pacific region, the share of woodfuel production in total round wood production in 2005 was still high (74.6 %) and only slightly declined from the share in 1980 (75.3 %), indicating that woodfuel still plays a vital role in meeting energy demand in most of the countries in the region (Gumartini, 2009). In some countries, i.e., Lao PDR, Nepal, Pakistan and Vietnam, consumption of woodfuel even increased in absolute terms (Gumartini, 2009). Even in the developed country like Australia, 23% of households still used fuelwood for domestic purposes with an average of 4.5-5.0 million tons per year (Paul et al., 2006).

In Thailand, a study of energy consumption by urban households carried-out in 1989-90 found that in Bangkok 23.3 % of households used charcoal and 1.2 % used fuelwood while in Chiang Mai 63 % used charcoal and 16 % used fuelwood (Pongsapich et al. 1994). A recent study on charcoal utilization in Khon Kaen province of Northeast Thailand (Nansaior et al., 2006) revealed that a substantial amount of charcoal is still consumed in the highly urbanized parts of the Khon Kaen municipality. Moreover, stacks of firewood under the houses are still commonly observed in suburban villages in Northeast Thailand, and biomass energy seems to still be relied on by many households in these semi-urbanized villages. Such evidence should call into question the conventional assumption that biomass energy has no continuing importance for the national energy budget of Thailand and other developing countries. What is needed, therefore, is empirical research to establish the extent to which biomass energy still plays an important role as a source of energy for household consumption across the urbanization spectrum of the communities in terms of absolute quantity used, relative share of total energy used, and functional roles for which it is used, as well as to identify factors causing the differences in energy sources used among these communities.

This study aimed to investigate the above questions. The study was conducted in three villages in Khon Kaen province of Northeast Thailand that represent different points along the rural-urban continuum of communities, i.e., rural, suburban and urban. As the role of biomass energy cannot be studied in isolation from other energy sources, these three communities were examined for overall patterns of energy utilization. The objectives were (1) to compare utilization of energy (biomass and non-biomass) among communities at different levels of urbanization in terms of absolute quantity, relative share and functional roles, (2) to identify factors causing the differences in utilization of energy (biomass and non-biomass) among households in communities at different levels of urbanization, and (3) to elucidate the causes for the differences in utilization of energy (biomass and non-biomass) among communities at different levels of urbanization. Information obtained should help clarify the extent to which biomass energy still plays an important role as communities becomes more urbanized. An understanding on this issue will have significant implications for the formulation and implementation of the national policies on renewable energy promotion, not only in Thailand but also in other developing countries, particularly in some neighboring countries in Southeast Asia, e.g., Cambodia, Laos, and Vietnam, where rural villages can be expected to undergo a similar process of urbanization to that already being experienced by villages in Thailand.

2. Materials and Methods

2.1 Conceptual framework

Figure 1 illustrates the conceptual framework for energy utilization in the present study. The sources of energy are classified as biomass and non-biomass. The biomass sources are firewood, and charcoal, and the non-biomass sources include electricity, LPG, and gasoline. Household energy uses are for cooking, living, transportation, agriculture and other income generation activities. Different households are expected to differ in energy utilization, both in the absolute quantity and the relative shares of the different energy sources. Possible factors causing the differences in household energy utilization include size of household, size of land cultivated, occupation of household members, and level of income. These factors can be used to classify households into groups that may have distinctive patterns of energy use, including the total amount and the type of energy they use. Communities

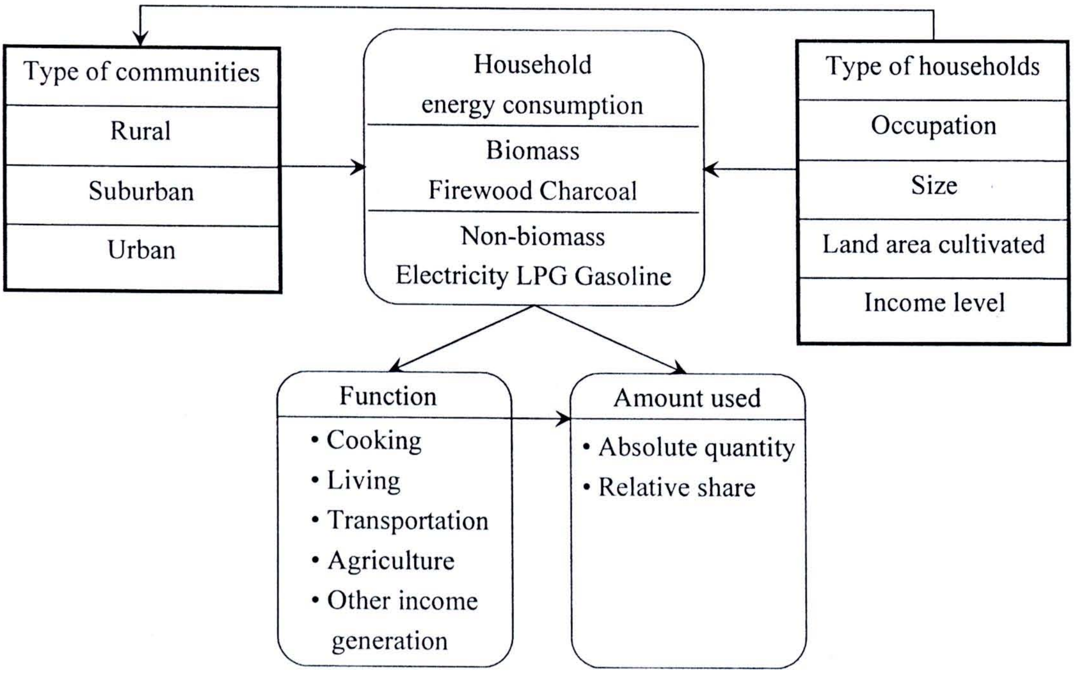


Figure 1 Conceptual framework for the study of household energy utilization in communities at different levels of urbanization.

at different stages of urbanization are expected to display different proportions of different types of households which will contribute to the differences in energy utilization patterns among these communities.

2.2 Study approach

The study was conducted in three villages in Khon Kaen province in Northeast Thailand that represent different points along the rural-urban continuum of communities, i.e., rural, suburban and urban, to assess changes in energy use associated with urbanization. Ideally, it would be best if changes in energy use in rural villages over many years could be monitored as they gradually undergo urbanization. However, such a longitudinal study is time consuming and very expensive and does not provide useful results in a timely fashion. Instead, this study substituted space for time by employing a design based on studying current energy use patterns in selected communities located at different points along the rural-urban continuum. This research strategy (sometimes called the "folk-urban continuum") has been used in many studies by anthropologists (Redfield, 1947), rural sociologists (Miner, 1952), and geographers (McGee, 1964). This approach is based on the assumption that there is a developmental lag between urban and rural communities so that changes begin to appear first in urban areas and then gradually are adopted by nearby suburban communities before finally becoming evident in more remote rural villages. The city, thus, represents the most advanced state of development, while the suburban village represents the area that has already undergone some changes in the urban direction, and the rural village represents more traditional patterns of energy use. In future years, it can be assumed that the suburban communities will continue to shift toward being more like the city while the rural villages will come to resemble the current state of the suburban ones.

2.3 Selection of study sites

Khon Kaen province was selected for this research because it includes communities ranging from quite rural to highly urban. The provincial capital, Khon Kaen city, is the sixth most populous city in Thailand (DPA, 2008) and displays a high level of urbanization. Khon Kaen city is large enough that its impact is strongly felt in surrounding villages, with many having developed a strongly suburban character in recent years. However, some villages, which are located in more remote districts, and enjoy less easy access to the city, still retain a rural character.

In selecting the three study sites that represent three points along the spectrum of urbanization in the province, the village database of 2007 (RDIC, 2008), the Khon Kaen geo-database of 2006 (Anonymous, 2006) and the aerial photograph of Khon Kaen province in 2006 (Point Asia Public Company Limited, 2007) were used. Twenty candidate villages were initially selected based on the distance from Khon Kaen city and the proportion of agricultural land to the total area of the community. This was followed by preliminary surveys and ground checking in candidate communities with informal interviews of key informants, selected villager groups and members of some households. Finally, Ladna Piang, Nongbua Deemee and Srijan communities were selected to represent the rural, suburban and urban communities, respectively (Figure 2). Additional criteria used in selecting these villages were the number of households (100-400), population density, total community area, level of infrastructure and diversity of occupation of households within the community.

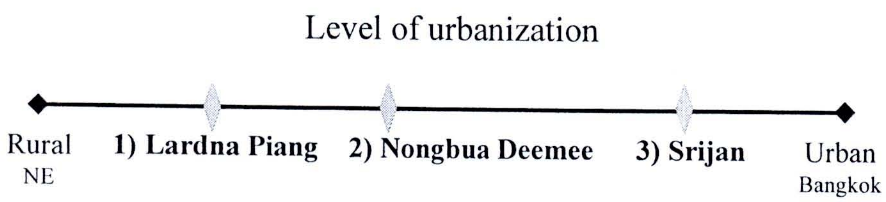


Figure 2 Positions of the three study communities along the rural-urban continuum.

2.4 Data collection

Data were collected on energy uses at the household level using a formal questionnaire survey, field observation and field measurements. For Ladna Piang and Nongbua Deemee, the rural and suburban communities, randomly selected samples of 50 % of the households were interviewed and observed to record their uses of different energy sources. The 50 % sample was employed to make sure that the sampled households represented all of the different types of households living in the communities. In the case of the urban community of Srijan, which has a smaller number of households, data were collected for all the households. The questionnaire was pretested before conducting the actual survey.

The questionnaire consists of three parts. The first part comprises information on the household, which includes name of the household head, address, number of members and their sex, age, occupation, and income earned. The second part covers number of fields they farm, area and crop grown in each field, numbers of different types of electrical appliances they use, and numbers of stoves, agricultural machines, motorcycles, and cars or trucks they own. The third part deals with the amount of energy used from each source and the activities for which that energy source is used. The sources of energy are divided into biomass, which includes firewood, charcoal, and others, and non-biomass, which includes electricity, LPG and gasoline (including diesel oil used for tractors and some trucks). The uses of energy are divided into cooking, living, transportation, agriculture and other income generation activities.

The amount of firewood and charcoal consumed by each household were measured by asking the appropriate member of the household to make a separate pile of the amount of wood or charcoal that he or she anticipated that it would be used in the following seven days. That amount was weighed and kept separately from the main supply. After five days, the household was re-visited and any unused wood or charcoal was weighed and recorded.

The amount of electricity which consumed by individual households were determined from their monthly electricity bills. The numbers and wattages of all electrical appliances were also observed and recorded.

The amount of LPG used by each household was obtained by asking the appropriate member of the household on how long a tank of LPG would normally last.

The amount of gasoline used for motor vehicles (automobiles and trucks) and motorcycles were obtained by the interview, asking how much money was spent for gasoline in a month for each motorcycle and for each car or truck, and then converting to volume using the average price of the month.

The amount of gasoline used for agricultural production by a household was derived by determining the standard amount of gasoline used by farm machinery per hectare for each crop, i.e., rice, cassava and sugarcane, and then multiplying the amount used per hectare with the corresponding planted area of that crop. Determination of the amount used per hectare for each crop was done by interviewing tractor operators and tractor dealers for each type of operation, i.e., plowing, harrowing and combine harvesting, and then summing all operations respective to the crop. The average figure over those obtained from all key informants was used as the standard amount of gasoline use for a particular crop.

The amount of gasoline used for other income generating activities was collected by interviewing appropriate household members.

All the data obtained were converted into a standard energy unit (Mega Joules, MJ) for further analysis, using conversion factors as shown in Table 1.

2.5 Data analysis

The absolute quantities of the different types of energy and their relative shares of the total energy mix used by each household were computed. These were used to calculate the average absolute quantities and their relative shares of the different types of energy used by all households in each of the individual communities. Comparisons were made among the three communities on the amount and share of energy used from different sources, and the changes in functional roles of different sources of energy with increasing urbanization were assessed.

Table 1 Conversion factors used in converting measurements from different energy sources to a standard energy unit (Joule, J).

Source of energy (Unit)	Joule (J)
Gasoline (litre)	31.48
Kerosene (litre)	34.5.3
Diesel (litre)	36.42
Electricity (kWh)	3.60
Fuel wood (kg)	15.99
Charcoal (kg)	28.88
General	
1 m^3 of solid wood = 600 kg.	
1 m^3 of charcoal = 250 kg.	
5 kg of fuel wood = 1 kg of charcoal.	
1 litre of LPG = 0.54 kg.	

Source: Thailand energy situation 2006, Department of Alternative Energy Development and Efficiency (DEDE, 2006), Thailand Ministry of Energy.

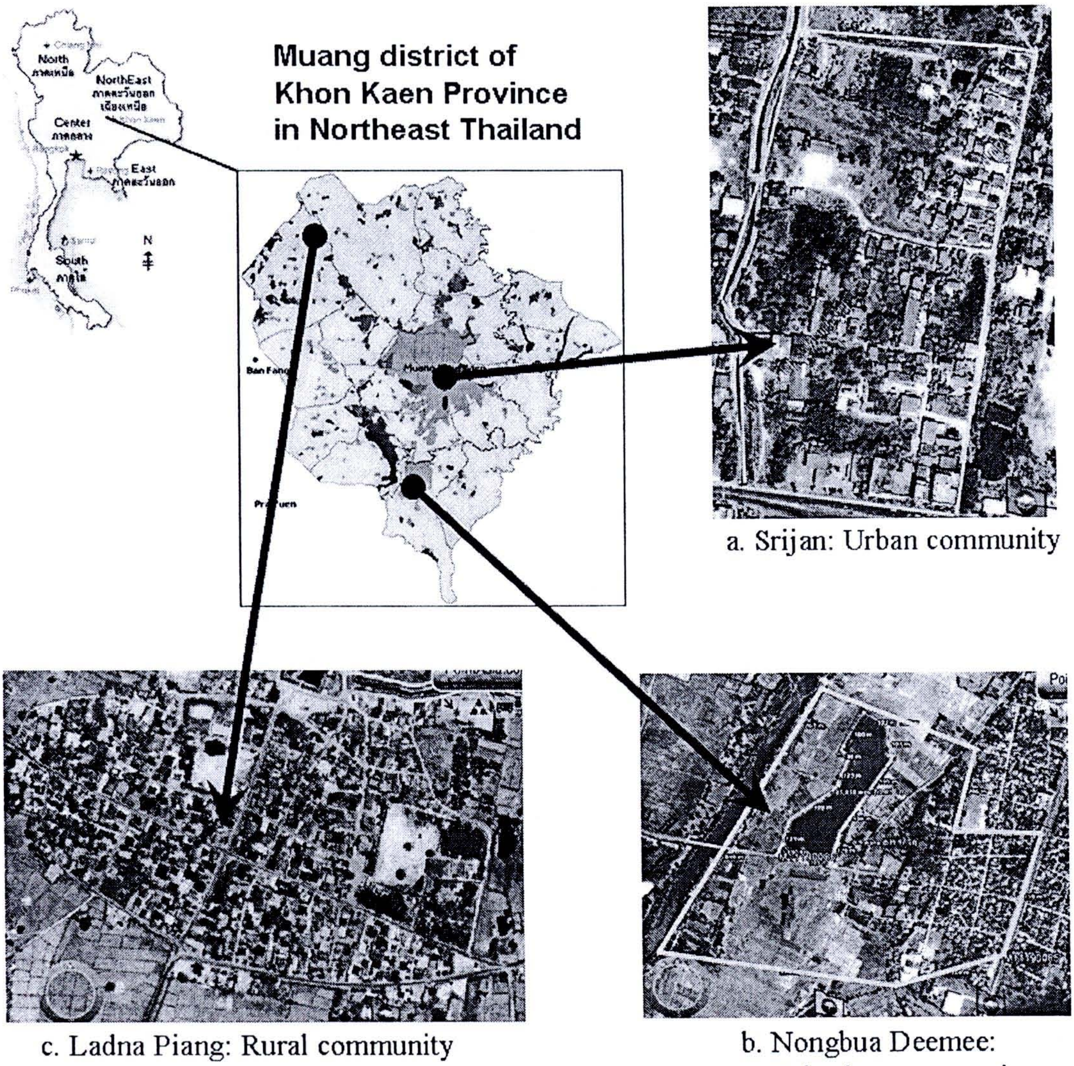
Variations among individual households in energy uses were examined and households were classified into different groups, both within the community and across the three communities, based on occupation, size of household, level of income and area of fields cultivated. Four occupational groups were identified, i.e., households having regular income, having their own business, having irregular income, and making their living from agriculture. Regular income households have members who receive a monthly salary as employees of government offices or private enterprises, while irregular income households have members who work for daily wages when employment opportunities are available. The households were grouped according to size, i.e., small (<3 persons), medium (3-5 persons) and large (>5 persons). Households were also assigned to groups according to income, i.e., below poverty line (<439 US$/yr), medium (439-3,864 US$/yr) and well-off (>3,864 US$/yr). The latter two groups were separated by two standard deviations from the poverty line. Households were also assigned to four groups based on the area of land they cultivated, i.e., very small (0-1 ha), small (1-2 ha), medium (2-4 ha) and large (>4 ha). For each type of classification, differences among groups in their consumption of the different types of energy were assessed, from which the effect of the grouping factor on household energy utilization was determined. One-way analysis of variance (ANOVA) and Duncan multiple range test (DMRT) were performed using SPSS software (SPSS, 2008) to analyze and test for statistical differences in average household energy consumption among the three communities and among the types of households in different classifications. The results were used to determine the factors that caused the differences in energy consumption among communities at different levels of urbanization.

3. Results

3.1 Characteristics of the study communities

The three study villages, Ladna Piang, Nongbua Deemee, and Srijan, are located in Maung district of Khon Kaen province (Figure 3). Their characteristics are given in Tables 2 and 3.

Ladna Piang, the rural village, is 32 km from Khon Kaen city, and is 15 km from the main highway but connected to it by a paved road. It has the largest land area (832.5 ha), but the lowest population density (2 persons/ha) among the three villages. Most of the area (97 %) is agricultural land used to grow rice, cassava, sugarcane and vegetables (Table 2). Most (93.8 %) of the household heads are farmers, the rest are laborers (4.6 %) and government or private enterprise employees (1.5 %) (Table 3), thus, the community has low occupational diversity. The village has a day-care facility for pre-school children, primary school and junior high school, but has no health service center. All households have access to electricity, mobile telephone service, and tap water provided through the community managed system. Most of the houses are typical rural Thai wooden houses built on stilts, but there are also a few modern style masonry houses in the village. Most houses have an adjoining rice storage barn, also built on stilts, around which firewood is stored. The life style in this community is typically rural; women still engage in making handicrafts, such as silk weaving, when they are free from farm work.



a. Srijan: Urban community

c. Ladna Piang: Rural community

b. Nongbua Deemee: Suburban community

Figure 3 Aerial photographs of the three study communities.

Table 2 Characteristics of the three study communities.

Characteristics	Rural: Ladna Piang	Suburban: Nongbua Deemee	Urban: Srijan
Distance from Khon Kean city (km.)	32	12.5	0
Total households (no.)	343	240	118
Total population (person)	1620	1624	895
Total community area (ha)	832.5	75.2	6.8
Population density (persons/ha)	2	22	132
Proportion of agriculture land	high = 0.97	medium = 0.72	very low
Occupation diversity	low	medium	high
Infra-structure	low	medium	high

Sources: Khon Kaen geo-database, Anonymous, 2006; RDIC, 2008.

Table 3 Percentages of households types for the individual classifications in the three study communities.

Household type	Rural: Ladna Piang (130 hh)	Suburban: Nongbua Deemee (93 hh)	Urban: Srijan (65 hh)
Occupation*			
Regular income	1.5	10.8	49.2
Having own business	0.0	4.3	26.2
Irregular income	4.6	36.6	24.6
Agriculture	93.8	48.4	0.0
Household size			
Small (< 3 persons)	13.8	18.3	33.8
Medium (3-5 persons)	63.8	68.8	49.2
Large (> 5 persons)	22.3	12.9	16.9
Average household size (person)	4.2	3.8	3.5
Household income**			
Below poverty line (< 439 US$/yr)	7.7	16.1	3.1
Medium (439-3,864 US$/yr)	65.4	60.2	40.0
Well-off (> 3,864 US$/yr)	26.9	23.7	56.9
Average household income (US$/yr)	3,584.4	3,821.5	7,265.3
Land operating			
Very small (0-1 ha.)	16.9	75.3	100.0
Small (1-2 ha.)	15.4	15.1	0.0
Medium (2-4 ha.)	36.2	8.6	0.0
Large (>4 ha.)	31.5	1.1	0.0
Average land operating (ha.)	3.6	0.7	0.02

*Regular income = household with monthly income from public or private organization; Irregular income = daily-paid worker.

**1 US$ =33.64 Thai Baht.

At the opposite end of the rural-urban continuum is the village of Srijan inside Khon Kaen city. It has the smallest land area (6.8 ha), but the densest population (132 persons/ha) of the three communities (Table 2). There is no agricultural land in this village, but there are few unused vacant plots, belonging to rich investors, that are used by some villagers to raise cattle and collect firewood. The community has easy access to all the facilities and infrastructure available in Khon Kaen city, e.g., transportation, electricity, telephone, tap water, public and private schools from primary to university level, public and private hospitals, supermarkets, shopping centers, public services, etc. Houses are of modern style, made from concrete, in the form of detached houses, townhouses and apartments. Almost half of the households (49.2 %) have members who are employees of public organizations or private enterprises with regular income; the rest are more or less equally divided between business owners (26.2 %) and daily-paid workers (24.6 %); no households have agriculture as their main occupation (Table 3). The life style is typical of residents of provincial cities in Thailand.

Nongbua Deemee, the suburban village, has characteristics that are intermediate between Ladna Piang and Srijan with regard to urbanization. It is 12.5 km from Khon Kaen city, to which it is connected by a good all weather road. The villagers, thus, can have access to all the facilities and infrastructure available in Khon Kaen city although using these services is less convenient for them than it is for households in Srijan village. Total land area (75.2 ha) and population density (22 persons/ha) is intermediate among the three communities (Table 2). Agricultural land accounts for 72 % of the total community area, but many plots are not used because their owners either have other occupations or are rich people living outside the community. There are fewer agricultural households (48.4 %) but more households with daily wage workers (36.6 %), government and private employees with regular salaries (10.8 %) and business owners (4.3 %) in this village than in Ladna Piang (Table 3), so that occupational diversity was considered as medium. There are also more houses of modern-style than in Ladna Piang, and more people follow an urban life style.

The mean size of households tended to decrease with urbanization from 4.2 persons in the rural community to 3.9 persons in the suburban one to 3.3 persons in the urban community. The distribution of households of different sizes differed to some extent among the three communities. While households of medium size (3-5 persons) were the most numerous class in all of the communities (63.8 % for the rural community, 68.8 % for the suburban community, and 49.2 % for the urban community), the rural community had a greater share of large size (>5 persons) households (22.3 %), followed by the suburban community (18.3 %) and the urban community (16.9 %). The share of small size (<3 persons) households was greatest in the urban community (33.8 %) compared to 13.8 % in the rural community and 12.9 % in the suburban community (Table 3). Income increased with urbanization with average household incomes for the rural, suburban and urban communities being 3,611, 3,384 and 6,279 US$/year, respectively. The distribution of households with different income levels was similar for the rural and suburban communities, with the majority (> 60 %) being in the medium income class and around 25 % classified as well-off. Poor households were more numerous (16.1%) in the suburban community than in the rural one, where they made up only 7.7% of the households. More than half (56.9 %) of the households in the urban community were well-off, while 40 % had medium income, and only 3.1 % were poor (Table 3). Differences in the area of land cultivated per household among the three communities were quite clear, with the area decreasing with urbanization. Not surprisingly, over 90 % of the households in the urban community had only small or very small plots of land (Table 3). The average areas were 3.62, 0.63 and 0.02 ha per household for the rural, suburban and urban communities, respectively. In the rural village, the majority of the households cultivated large and medium sized areas of land (31.5 and 36.2 %, respectively), but most of the households in the suburban community cultivated small (15.1 %) or very small (75.3 %) areas of land.

Percentages of households that used firewood were quite high for the rural (94 %) and suburban (80 %) communities, but much lower (46 %) for the urban community (Table 4). The percentages of households that used charcoal also declined with urbanization but more gradually, being 88, 83 and 74 % of households in the rural, suburban and urban communities, respectively. Conversely, use of LPG increased with urbanization, with the percentages of households that used LPG being 48, 69 and 71 %, for the rural, suburban and urban communities, respectively. All households in the three communities used electricity for their living activities. Most of the households had motorcycles, but the percentage declined with urbanization, being 91, 88 and 71 % for the rural, suburban and urban communities, respectively, while the share of households owning cars or trucks increased with urbanization, being 22, 25, and 42 % for the rural suburban and urban communities, respectively.

Table 4 Percentages of sampled households that used different sources of energy in the three study communities.

Characteristic	Rural: Ladna Piang (130 hh)	Suburban: Nongbua Deemee (93 hh)	Urban: Srijan (65 hh)
Using firewood	94	80	46
Using charcoal	88	83	74
Using LPG	48	69	71
Using electricity	100	100	100
Using gasoline for Agriculture	88	43	0
Using gasoline by motorcycle	91	88	71
Using gasoline by car	22	24	42

3.2 Differences in energy consumption among communities

Total average energy consumption per household increased with urbanization, from 46,042 MJ/hh/yr in the rural community to 52,465 MJ/hh/yr in the suburban community to 55,076 MJ/hh/yr in the urban community (Table 5). The share provided by biomass energy markedly decreased with urbanization, from 47.1 % of the total energy consumed by households in the rural community, to 35.4 % in the suburban community, to only 9.9 % in the urban community. The amounts of biomass energy used also decreased from 21,691 to 18,557 to 5,433 MJ/hh/yr for the rural, suburban and urban communities, respectively. At the same time, the amount of non-biomass energy used progressively increased from 24,351 MJ/hh/yr for the rural community to

33,907 MJ/hh/yr for the suburban community to 49,643 MJ/hh/yr for the urban community (Table 5).

Similar patterns were observed for quantities and shares of different types of energy consumed on a per capita basis (Table 5). The urban villagers used more energy per capita (19,396 MJ/person/yr) than those in the suburban and rural communities (16,219 and 11,952 MJ/person/yr, respectively), although the difference between the urban and suburban communities was not statistically significant. The average per capita share of biomass energy consumed declined from 46.2 % in the rural community, to 37.4 % in the suburban community to only 10.2 % in the urban one. The amount used, however, was slightly more for the suburban community (6,064 MJ/person/yr) than for the rural community (5,521 MJ/person/yr), and both were significantly higher than the average amount consumed in the urban community (1,977 MJ/person/yr).

In all of the communities, total energy consumption varied greatly among different households, ranging from 10,602 to 167,278 MJ/hh/yr for the rural community, from 11,289 to 217,354 MJ/hh/yr for the suburban community, and from 19,339 to 191,942 MJ/hh/yr for the urban community (Figure 4). Overall, 62.5 % of all sample households used less than 50,000 MJ/hh/yr, while 94 % used less than 100,000 MJ/hh/yr, and only 6 % used more than 100,000 MJ/hh/yr (Table 6). The percentage of households using less than 50,000 MJ/hh/yr was roughly similar in all three communities whereas the percentage using more than 100,000 MJ/hh/yr increased with urbanization.

Table 5 Absolute quantity (± standard error) and relative share of biomass and non-biomass energy consumption per household and per person in communities with different levels of urbanization.

Community	No. of sampled households	Biomass Quantity*	± SE	%	Non-biomass Quantity*	± SE	%	Total Quantity*	± SE	%
Average energy consumption per household (MJ/household/yr)										
Rural	130	21,691 [a]	± 1,570	47.1	24,351 [c]	± 1,510	52.9	46,042 [a]	± 2,187	100
Suburban	93	18,557 [a]	± 1,996	35.4	33,907 [b]	± 3,307	64.6	52,465 [a]	± 3,842	100
Urban	65	5,433 [b]	± 990	9.9	49,643 [a]	± 4,662	90.1	55,076 [a]	± 5,769	100
Overall average	288	17,010	± 1,051	33.9	33,145	± 1,739	66.1	50,155	± 1,913	100
Average energy consumption per person (MJ/person/yr)										
Rural	130	5,521 [a]	± 355	46.2	6,432 [c]	± 513	53.8	11,952 [b]	± 651	100
Suburban	93	6,064 [a]	± 1,164	37.4	10,155 [b]	± 1,118	62.6	16,219 [a]	± 1,734	100
Urban	65	1,977 [b]	± 359	10.2	17,419 [a]	± 1,869	89.8	19,396 [a]	± 1,884	100
Overall average	288	4,896	± 425	32.6	10,114	± 650	67.4	15,010	± 779	100

*Different letters in the same column indicate statistical difference at $P = 0.05$ by DMRT.

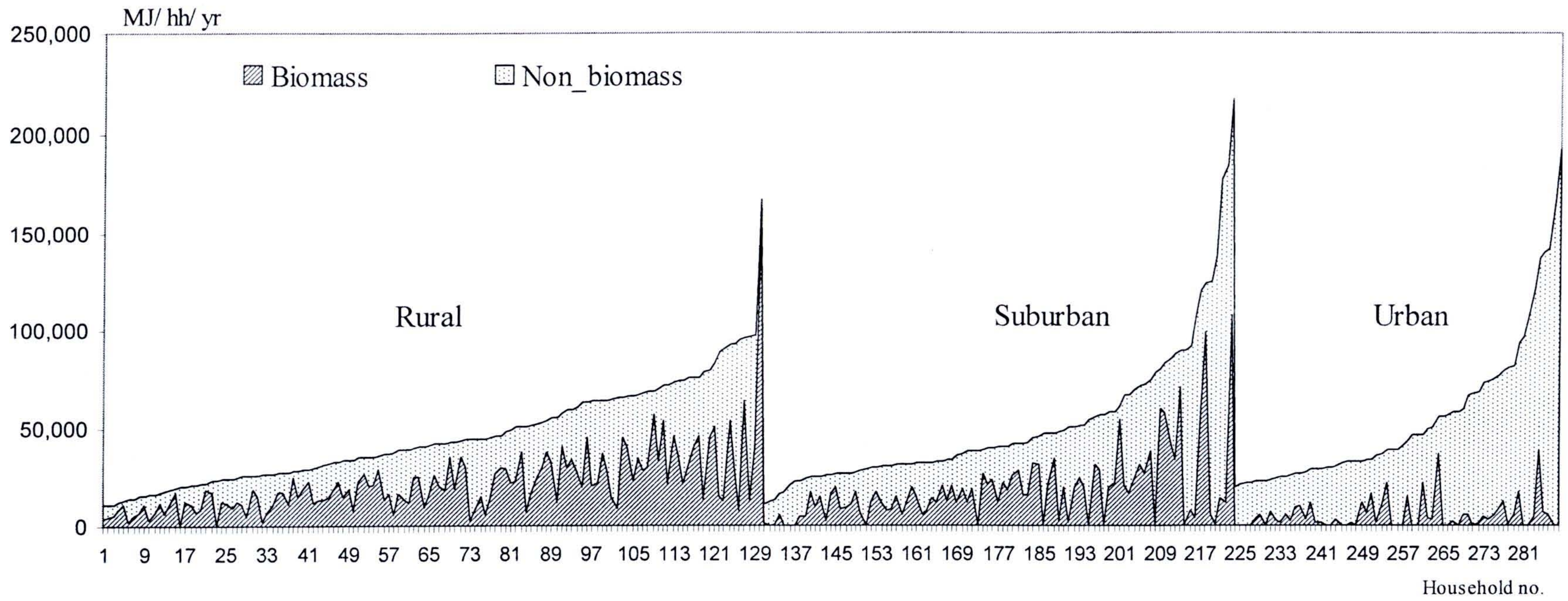


Figure 4 Distribution of biomass and non-biomass energy consumption of households in rural, suburban and urban communities.

3.3 The roles of different types of energy

Household activities that use energy were divided into living (cooking, lighting, cooling and entertainment), transportation (motorcycles, cars and trucks), agriculture and home industry (silk production, blacksmithing, and mushroom production). Averaging over all households in the three study communities, energy use for living amounted to 55.5 % of total household energy consumption, while transportation accounted for 39.2 %, agriculture for 4.0 % and home industry only 1.2 % (Table 7). Living activities used all types of energy except gasoline, while transportation and agriculture used only gasoline and home industry used only biomass.

The results in Table 7 clearly show that different types of energy are utilized for different roles. Both firewood and charcoal were used primarily for living, i.e., cooking, with a small amount used for home industry. The amounts of firewood and charcoal used for living were 9,066 and 7,344 MJ/hh/yr respectively, compared to 94 and 506 MJ/hh/yr, respectively, used in home industry. LPG and electricity were used entirely for living. Gasoline was mostly used for transportation (19,674 MJ/hh/yr) while a much smaller amount (2,020 MJ/hh/yr) was used for agriculture. Overall, biomass accounted for 34.0 %, gasoline 43.3 %, electricity 15 %, and LPG only 7.8 % of total household energy consumption.

Table 6 Frequency distribution of households at different levels of energy consumption in the three study communities.

Type of community	HH (no.)	<50,000 MJ/hh/yr		50,000- 100,000 MJ/hh/yr		100,000-150,000 MJ/hh/yr		>150,000 MJ/hh/yr	
		HH (no.)	%	HH (no.)	%	HH (no.)	%	HH (no.)	%
Rural	130	81	62.3	48	36.9	0	0.0	1	0.8
Suburban	93	60	64.5	25	26.9	5	5.4	3	3.2
Urban	65	39	60.0	19	29.2	5	7.7	2	3.1
Total	288	180	62.5	92	31.9	10	3.5	6	2.1

Table 7 Average energy consumption (± standard error) (MJ./hh/yr) by activity over the three study communities.

Activity	Biomass (MJ./hh/yr)		Non-Biomass (MJ./hh/yr)			Total	
	Firewood	Charcoal	LPG	Electricity	Gasoline	MJ/hh/yr	%
Living	9,066 ± 582	7,344 ± 536	3,909 ± 360	7,542 ± 320	0	27,860 ± 967	55.5
Transportation	0	0	0	0	19,674 ± 1,547	19,674 ± 1,547	39.2
-Motorcycle	*0*	*0*	*0*	*0*	*8,721 ± 464*	*8,721 ± 464*	*17.4*
-Car	*0*	*0*	*0*	*0*	*10,952 ± 1,487*	*10,952 ± 1,487*	*21.8*
Agriculture	0	0	0	0	2,020 ± 191	2,020 ± 191	4.0
Home industry	94 ± 39	506	0	0	0	601 ± 508	1.2
Total - amount	9,160 ± 586	7,850 ± 723	3,909 ± 360	7,542 ± 320	21,694 ± 1,547	50,155 ± 1,913	100
- percent	18.3	15.7	7.8	15.0	43.3	100	

The roles of different types of energy were the same in the three communities, but their relative shares of total energy used varied among the three communities. For the rural community, energy used for living accounted for 55.8 % of total household energy consumption; most of this (44.4 %) was provided by biomass, with 24.4 % of firewood and 20 % charcoal providing (Table 8). The shares provided by LPG and electricity were only 5.2 and 6.3 %, respectively. A slightly greater share of energy (59.0 %) was used for living in the suburban community, but the share provided by biomass was slightly less (35.2 %), and more firewood was used than charcoal. More LPG and electricity were used than in the rural community, and their shares increased to 9.5 and 14.4 %, respectively. For the urban community, energy for living was about half (50.3 %) of total energy use, with electricity providing the largest share (30.6 %) while biomass provided only 9.9 %

These results clearly show that as communities become more urbanized people tend to change the types of energy they use for living activities from biomass to cleaner sources (LPG and electricity). However, the changes were relatively slight when moving from rural to suburban, but were quite pronounced when moving from suburban to urban. The use of gasoline for transportation also increased in both absolute amount and relative share with urbanization, with the share being 33.1, 39.1 and 49.7 % for the rural, the suburban and the urban communities, respectively. In the rural community, gasoline was used for motorcycles more than for cars and trucks (20.7 % for motorcycles vs. 12.4 % for cars and trucks), whereas in the suburban community 18.3 % was used for motorcycles vs. 20.8 % for cars and trucks. In the urban community, much more gasoline was used for cars and trucks (39.1 %) than for motorcycles (10.6 %). The amount and share of energy used for agriculture and home industry both rapidly declined in the course of urbanization (Table 8).

3.4 Factors influencing household energy consumption

Apart from the type of community (rural, suburban and urban) in which they reside, household energy consumption may also be influenced by occupation, size of household, area of land cultivated and level of income of different households.

For purposes of our analysis, all of the households in our sample were assigned to four occupational categories.[1] These categories are: regular income, own business, irregular income and agriculture. On average, the households with regular income and the agricultural households used more or less the same amount of energy (47,233 vs. 46,662 MJ/hh/yr). The business owner households used slightly less energy (41,883 MJ/hh/yr), and the irregular income households used the lowest amount (36,620 MJ/hh/yr) (Table 9). The shares of different types of energy used by households varied considerably according to their main occupations. The regular income households and the business owners used much less biomass than the irregular income and the agricultural households, with the shares of biomass being 14.9 and 5.6 % for the regular income households and the business owners, respectively, as compared to 38.1 and 43.7 % for the irregular income and the agricultural households, respectively.

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[1] In the three study communities together, there were 16 households (6 % of the total sample of households) that used exceptionally high quantities of energy (>100,000 MJ/hh/yr). Detailed examination revealed that each of these households engaged in income generation activities that used exceptionally high amounts of energy, e.g., doing blacksmithing, cooking ready-to-eat foods for sale, operating a truck for hire. As it was not possible to separate energy used for these activities from energy used for living, we excluded this group of households from the analysis of factors influencing household energy use. However, these households do clearly show that occupation has a major influence on household energy consumption.

Table 8 Average energy consumption (± standard error) (MJ/hh/yr) and relative share by activity and source in rural, suburban and urban communities.

Activity	Rural community		Sub-urban community		Urban community	
	Amount* ± SE	%	Amount* ± SE	%	Amount* ± SE	%
Total living	25,714 ± 1,219	55.8	30,956 ± 2,239	59.0	27,722 ± 1,392	50.3
-Living-Biomass	*20,434 ± 1,156*	*44.4*	*18,454 ± 1,999*	*35.2*	*5,433 ± 990*	*9.9*
-Firewood	*11,243 ± 739*	*24.4*	*10,760 ± 1,269*	*20.5*	*2,287 ± 544*	*4.2*
-Charcoal	*9,191 ± 761*	*20.0*	*7,695 ± 1,086*	*14.7*	*3,146 ± 748*	*5.7*
-Living-LPG	*2,393 ± 313*	*5.2*	*4,962 ± 800*	*9.5*	*5,436 ± 852*	*9.9*
-Living-Electricity	*2,888 ± 52*	*6.3*	*7,540 ± 351*	*14.4*	*16,853 ± 1,188*	*30.6*
Transportation-Gasoline	15,241 ± 1,345	33.1	20,502 ± 3,053	39.1	27,354 ± 4,416	49.7
-Motorcycle	*9,544 ± 699*	*20.7*	*9,599 ± 832*	*18.3*	*5,820 ± 847*	*10.6*
-Car	*5,697 ± 1,116*	*12.4*	*10,902 ± 2,855*	*20.8*	*21,534 ± 4,417*	*39.1*
Agriculture- Diesel	3,829 ± 340	8.3	904 ± 176	1.7	0 ± -	0.0
Home industry	1,257 ± 1,122	2.7	103 ± 103	0.2	0 ± -	0.0
-Firewood	*135 ± 44*	*0.3*	*103 ± 103*	*0.2*	*0 ± -*	*0.0*
-Charcoal	*1,122 ± 1,122*	*2.4*	*0 ± -*	*0.0*	*0 ± -*	*0.0*
Total	46,042 ± 2,187	100.0	52,465 ± 3,842	100.0	55,076 ± 4,691	100.0

*Unit = MJ/hh/yr.

Households cultivating larger areas of land tended to use more energy than those farming smaller land areas. Means for total energy uses were 53,373, 46,174, 40,216 and 41,966 MJ/hh/yr for the households cultivating large, medium, small and very small areas of land, respectively (Table 10). Although energy used for living accounted for the major share of household energy for all the groups, its share of total energy use was slightly less for households with medium and large land areas (54.1 and 56.1 %, respectively) than for households with small and very small areas of land (63.2 and 63.7 %, respectively). However, the patterns of energy use for living were similar for households having small, medium and large areas of land, in that for these households biomass, mostly firewood, constituted the major share of the energy they used for living. In contrast, households having only very small areas of land used slightly more non-biomass energy for living than biomass energy (34.2 vs. 29.5 %), with electricity being the predominant type of non-biomass energy. In all four household types, more gasoline was used for motorcycles than for cars and trucks, but the difference declined among households with larger areas of land. Households with smaller areas of land used less energy for agriculture than those with larger areas. The effect of household size on energy consumption was clearly shown by the increase in total energy consumption as the household size increased. Means for energy consumption were 33,532, 45,269 and 53,503 MJ/hh/yr for the small (<3 persons), medium (3-5 persons) and large (>5 persons) households, respectively. Energy for living accounted for more than 60 % of total consumption for the small and large households, but slightly less (58.0 %) for the medium households. Use of biomass energy increased with increasing household size, while electricity use decreased with increasing household size (Table 11). The medium and large households used more gasoline for transportation than the small households, and used more gasoline for motorcycles than for cars and trucks. The small households, however, used more gasoline for cars and trucks than for motorcycles. The use of energy for agriculture also increased with increasing household size, reflecting the fact that on average agricultural households are larger than non-agricultural households.

Income levels also have a significant influence on household energy consumption. Households with higher income used more energy than households with lower income, as shown by the average energy consumptions of 32,058, 43,020 and 50,593 MJ/hh/yr for the low income, medium income and well-off households, respectively (Table 12). The share of energy for living, however, declined with the increasing level of income; the share was quite high (80.7 %) for the low income households, and declined to 64.3 % for the medium income and to 49.7 % for the well-off households. Although the share of biomass decreased with increasing income level, the actual amount used did not differ between the low income and the medium income households (16,990 and 17,993 MJ/hh/yr, respectively) but was somewhat lower for the well-off households (11,907 MJ/hh/yr). Richer households used more gasoline for transportation than poorer households, while the amounts of energy used for agriculture and home industry were small and did not differ very much among households with different income levels.

Table 9 Average energy consumption (MJ/hh/yr) and relative share (%) by source for the different occupations of the sampled households in the three study communities.

Source of energy	Regular income (38 hh)		Own business (18 hh)		Irregular income (55 hh)		Agriculture (161 hh)	
	MJ/hh/yr	%	MJ/hh/yr	%	MJ/hh/yr	%	MJ/hh/yr	%
Total living	25,159	53.3	22,084	52.8	27,573	75.3	27,331	58.6
-Living-Biomass	*7,015*	*14.9*	*2,337*	*5.6*	*13,968*	*38.1*	*20,385*	*43.7*
-Firewood	*2,953*	*6.3*	*1,232*	*2.9*	*8,123*	*22.2*	*11,410*	*24.5*
-Charcoal	*4,062*	*8.6*	*1,105*	*2.6*	*5,845*	*16.0*	*8,975*	*19.2*
-Living-LPG	*3,986*	*8.4*	*4,963*	*11.9*	*3,864*	*10.6*	*2,902*	*6.2*
-Living-Electricity	*14,157*	*30.0*	*14,784*	*35.3*	*9,742*	*26.6*	*4,044*	*8.7*
Transportation-Gasoline	22,075	46.7	19,750	47.2	8,967	24.5	15,616	33.5
-Motorcycle	*6,274*	*13.3*	*8,978*	*21.5*	*6,465*	*17.7*	*9,757*	*20.9*
-Car	*15,800*	*33.5*	*10,771*	*25.7*	*2,502*	*6.8*	*5,859*	*12.6*
Agriculture-Diesel	0	0.0	0	0.0	79	0.2	3,546	7.6
Home industry-Biomass	0	0.0	0	0.0	0	0.0	169	0.4
Total	47,233	100.0	41,833	100.0	36,620	100.0	46,662	100.0

Table 10 Average energy consumption (MJ/hh/yr) and relative share (%) by source for the households with different size of operating land in the three study communities.

Source of energy	Very small* (146 hh)		Small*(29 hh)		Medium* (55 hh)		Large* (42 hh)	
	MJ/hh/yr	%	MJ/hh/yr	%	MJ/hh/yr	%	MJ/hh/yr	%
Total living	26,736	63.7	25,405	63.2	24,973	54.1	29,919	56.1
-Living-Biomass	*12,390*	*29.5*	*18,079*	*45.0*	*18,281*	*39.6*	*24,292*	*45.5*
-Firewood	*6,646*	*15.8*	*11,133*	*27.7*	*9,967*	*21.6*	*13,735*	*25.7*
-Charcoal	*5,744*	*13.7*	*6,946*	*17.3*	*8,313*	*18.0*	*10,557*	*19.8*
-Living-LPG	*3,808*	*9.1*	*2,834*	*7.0*	*3,128*	*6.8*	*2,628*	*4.9*
-Living-Electricity	*10,539*	*25.1*	*4,492*	*11.2*	*3,565*	*7.7*	*2,999*	*5.6*
Transportation-Gasoline	15,019	35.8	13,086	32.5	17,798	38.5	15,489	29.0
-Motorcycle	*7,728*	*18.4*	*7,008*	*17.4*	*10,531*	*22.8*	*9,901*	*18.6*
-Car	*7,291*	*17.4*	*6,078*	*15.1*	*7,268*	*15.7*	*5,588*	*10.5*
Agriculture-Diesel	145	0.3	1,659	4.1	3,327	7.2	7,691	14.4
Home industry-Biomass	66	0.2	66	0.2	76	0.2	274	0.5
Total	41,966	100.0	40,216	100.0	46,174	100.0	53,373	100.0

*Very small = 0-1 ha, small = 1-2 ha, medium = 2-4 ha, large = >4 ha.

Table 11 Average energy consumption (MJ/hh/yr) and relative share (%) by source for households of different sizes in the three study communities.

Source of energy	< 3 persons (54 hh)		3-5 person (170 hh)		> 5 persons (48 hh)	
	MJ/hh/yr	%	MJ/hh/yr	%	MJ/hh/yr	%
Total living	21,886	65.3	26,251	58.0	33,870	63.3
-Living-Biomass	*9,607*	*28.7*	*16,149*	*35.7*	*22,808*	*42.6*
-Firewood	*4,683*	*14.0*	*8,837*	*19.5*	*13,813*	*25.8*
-Charcoal	*4,924*	*14.7*	*7,312*	*16.2*	*8,995*	*16.8*
-Living-LPG	*2,667*	*8.0*	*3,245*	*7.2*	*4,684*	*8.8*
-Living-Electricity	*9,611*	*28.7*	*6,857*	*15.1*	*6,378*	*11.9*
Transportation-Gasoline	10,295	30.7	16,872	37.3	16,200	30.3
-Motorcycle	*4,040*	*12.0*	*9,712*	*21.5*	*9,527*	*17.8*
-Car	*6,255*	*18.7*	*7,159*	*15.8*	*6,673*	*12.5*
Agriculture-Diesel	1,239	3.7	2,067	4.6	3,273	6.1
Home industry-Biomass	113	0.3	79	0.2	160	0.3
Total	33,532	100.0	45,269	100.0	53,503	100.0

Table 12 Average energy consumption (MJ/hh/yr) and relative share (%) by source for households with different levels of income in the three study communities.

Source of energy	Low* (24 hh)		Moderate* (164 hh)		Well -off * (84 hh)	
	MJ/hh/yr	%	MJ/hh/yr	%	MJ/hh/yr	%
Total living	25,879	80.7	27,670	64.3	25,135	49.7
-Living-Biomass	*16,990*	*53.0*	*17,993*	*41.8*	*11,907*	*23.5*
-Firewood	*7,610*	*23.7*	*10,517*	*24.4*	*6,081*	*12.0*
-Charcoal	*9,380*	*29.3*	*7,477*	*17.4*	*5,826*	*11.5*
-Living-LPG	*2,318*	*7.2*	*3,128*	*7.3*	*4,189*	*8.3*
-Living-Electricity	*6,571*	*20.5*	*6,548*	*15.2*	*9,039*	*17.9*
Transportation-Gasoline	4,920	15.3	13,218	30.7	22,807	45.1
-Motorcycle	*4,920*	*15.3*	*8,661*	*20.1*	*9,382*	*18.5*
-Car	*0*	*0.0*	*4,558*	*10.6*	*13,425*	*26.5*
Agriculture-Diesel	1,179	3.7	2,025	4.7	2,559	5.1
Home industry-Biomass	80	0.2	107	0.2	91	0.2
Total	32,058	100.0	43,021	100.0	50,593	100.0

*Low = below poverty line = <439 US$/yr, Medium = 439-3,864 US$/yr, Well-off = > 3,864 US$/yr.

4. Discussion

This study aimed to investigate whether biomass energy still plays an important role as a source of energy for household consumption across the urbanization spectrum of communities in Northeast Thailand. This was done by comparing the energy uses of households in three villages in Khon Kaen province that were selected to represent the rural, suburban and urban points on the rural-urban continuum, examining the functional roles of biomass energy in these communities, and determining the factors that caused the differences in household energy utilization among the three study communities. The results shows that, although the difference in average total household energy consumption among the three study communities was relatively small, urban households tended to use more energy than the suburban and the rural households, both in terms of consumption per household and per capita. Significant differences were observed among the three villages in the share of biomass energy consumed by their households, however, with the use of biomass energy decreasing with greater urbanization of the community. This finding is in line with the results of other studies (Pohekar et al., 2005; Cai and Jaing, 2008; Dhingra et al., 2008) and supports the general belief that the role of biomass energy will decline as rural communities become more urbanized. However, the decline in the share of biomass energy was rather small when going from the rural to the suburban community, but was quite substantial when going from suburban to urban community, with the share decreasing from 47.1 % of the total energy for the rural community to 35.4 % for the suburban community and to 9.9 % for the urban community. The amounts of biomass used per household also reflected the above trend, being high for the rural and suburban communities and considerably lower for the urban community. These results clearly indicated that although the use of biomass energy declines with urbanization, it still continues to be an important source of household energy, especially in the rural and suburban communities, and even in the urban community but to a lesser extent.

The results also show that different types of energy are used to fill different roles. Both firewood and charcoal were used primarily for living (i.e., cooking) and, to a small extent, for home industry, while LPG and electricity were used entirely for living and gasoline was mostly used for transportation with a smaller amount used for agriculture. Overall, biomass accounted for 34.0 % and gasoline for 43.3 % of total amount of energy consumed by households, while the share for electricity was 15 % and for LPG was only 7.8 %. The roles of different types of energy were the same in the rural, suburban and urban communities, however, their relative shares in the total energy mix used by households varied among the three communities. The share of biomass energy was highest for the rural community and declined with greater urbanization, while the opposite trend was observed for household uses of LPG and electricity. In fact, for urban households, non-biomass energy accounted for 81 % of energy used for living, of which 61 % was from electricity and 20 % was from LPG. These results agree well with previous reports that people tend to change the source of energy for living from biomass to cleaner sources (LPG and electricity) as their communities become more urbanized (Pohekar et al., 2005; Xiaohua and Zhenmin, 2005; Ouedraogo, 2006; Cai and Jaing, 2008; Dhingra et al., 2008). However, in the present study, the changes were relatively minor when moving from the rural to the suburban community, but were quite pronounced when moving from the suburban to the urban community.

The use of gasoline for transportation also increased in both amount and share with urbanization. In the rural community, gasoline was used for motorcycles more than for cars and trucks, but the reverse was true in the suburban and urban communities. This corresponded with the opposite trends in percentages of households that own cars and trucks and motorcycles in the three communities, i.e., there was a higher percentage of households with motorcycles in the rural community but a higher percentage of households with cars and trucks in the urban community. The amount of energy used for agriculture and for home industry declined as the community became more urbanized, corresponding to the decline in the number of households that do agriculture and home industry in the more urbanized communities.

All the four factors examined, i.e., occupation, size of household, area of cultivated land and income level, were found to influence household energy consumption to some extent with occupation having the greatest influence on both the amount and the types of energy used. Households that had regular income or owned businesses used much less biomass energy than the irregular income and the agricultural households. This could be explained by the differences in life style of households with different occupations as was reported in other studies (Senelwa and Sims, 1999; Nansaior et al., 2006; Bravo et al., 2008).

The results also indicated that households with larger areas of land tended to used more energy than those having smaller plots. However, the patterns of energy used for living for those with large, medium and small land areas were similar but were different from those with very small areas. For the former three groups, biomass, mostly firewood, constituted the major share of energy for living, while the latter group used more non-biomass energy, mostly electricity, than biomass energy for living. The results also showed that energy use for agriculture decreased with decreasing size of cultivated land. Increasing household size was found to increase total household energy consumption, as was previously reported (Mwampamba, 2007), and use of biomass energy increased with household size. Households with higher income were also found to use more energy than those with lower income. However, unlike what was found for household size, the share of energy for living as well as the share of biomass energy declined with increasing income level. Thus, rich people used relatively less biomass than poor people. Other studies also found that household income affected the form of energy consumed (Mahapatra and Mitchell, 1999; Senelwa and Sims; 1999; Dube, 2003; Ouedraogo, 2006;)

It was apparent that the four factors examined, i.e., occupation, household size, size of operating land and income level, were interrelated, which confounded their effects on household energy consumption. Among these factors, occupation appeared to be the dominant factor that could largely explain the differences in energy use by other factors as well. The employees of government offices and private enterprises who have regular income and the business owners tended to have higher incomes, smaller sized households and smaller areas of land than agricultural households. These households also tend to have a more urbanized life style and used relatively less biomass energy than the other two groups. On the contrary, the agricultural households have larger household size, larger area of land and lower income. They also have rural lifestyle and used more biomass energy for living than non-biomass energy. The irregular income households were the poorest, thus, could not afford to engage in a modern life style. They also depended a great deal on biomass energy for their living, even though they only have a small area of land from which to collect it.

The differences in household energy consumption among the rural, suburban and urban communities can largely be explained by the differences in percentages of households with different occupations in these communities. While most (94 %) of households in the rural community were agricultural households, the majority of households in the urban community were regular income households (49 %) and business owners (26 %). The patterns of energy use in the individual communities, thus, reflect the dominant lifestyle of their households as determined by their occupations and income levels. The occupational composition of the suburban community was in-between the rural and urban ones, but agricultural households (48 %) and irregular income households (37 %) were still dominant and retained an essentially rural life style. These two groups of households, which together accounted for 85 % of households in the suburban community, mostly used biomass as the source of energy for their living. This could explain why the energy use pattern of the suburban community was not much different from that of the rural community.

In conclusion, the results of this study indicated that even though the use of biomass energy by urban households has declined, it still played a very important role as a source of household energy in the rural and suburban communities, and a minor but significant role in the urban community. It should be pointed out that the rural community in this study is a "developed rural community," which is located at the upper end of the rural range in the rural-urban spectrum. In fact, at present, there are no real rural communities left in Thailand except perhaps in the very remote mountain areas. Yet, biomass energy still contributed a major proportion of the total supply of household energy in such a "developed rural community," as well as in a suburban community. In the future, although urban areas are expected to substantially expand, this expansion is unlikely to be very fast, particularly in the case of provincial towns and cities. Consequently, the majority of Thailand's populations are likely to continue to reside in rural and suburban areas for quite some time. Therefore, biomass is likely to remain an important source of household energy for an extended period. It is, therefore, recommended that, in developing alternative energy sources to cope with the diminishing supply and high price of fossil fuel, the government should pay more attention to biomass as a source of energy household consumption. This recommendation could be extended to other developing countries as well, as the role of biomass is expected to be even greater in counties at a lower level of economic development.

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