Electricity Demand and the Changes from Urban to Rural Households in Vietnam

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Abstract: Based on the results of a survey conducted in 2007 for 452 households (HHs) in Ho Chi Minh City and the Mekong Delta in Vietnam, the electricity demands of 5 main electrical appliances: television, refrigerator, air conditioner (AC), washing machine, and fan have been estimated up to 2030. Employing 3 scenarios for gross domestic product growth rates, for the first time, the trends of electricity demand associated with economic development within the specific boundaries of urban (UB), peri-urban (PU), and rural (RR) areas were demonstrated. In 2007, UB HHs were found to be the main consumers, using 2.2 and 2.9 times more electricity than PU and RR HHs. An increasing trend has been recognized in all study areas: the annual electricity demand growth rates in UB, PU, and RR areas are 1.1–1.5%, 2.6–2.7%, and 1.3–2.1% for the 2007–2030 period. Among the 5 main appliances, cooling devices (fans and AC) consume the most electricity presently, and will continue to do so in future.

Key words: electricity demand, Ho Chi Minh city, Mekong Delta, urban, peri-urban, rural

INTRODUCTION

During the past decade, the electricity demand in Vietnam has grown at a rate of more than 15.0% per year, which is significantly higher than the gross domestic product (GDP) growth rate for the same period, 7.1% (IE, 2005). However, Vietnam is still considered to be a country with low energy demand. In 2007, the per capita electricity consumption of Vietnam was 602.3 kWh. The residential sector, especially in urban (UB) areas, is considered to be the largest consumer (APERC, 2006), while rural (RR) households (HHs) consume only 15 kWh energy per month (Mai, 2007).

Due to the rapid income growth, moderate rate of urbanization and the government’s recent policies on promoting rural electrification, Vietnamese HHs are expected to increase their electricity consumption at a rate of 8.1% in 2002–2030 (APERC, 2006). Many appliances have become standard items for the vast majority of HHs, especially in UB areas. As a result of these developments, important questions have been raised: (1) what is the trend of electricity demand in relation to urbanization and economic development and (2) what are the differences in demand among UB, peri-urban (PU), and RR areas? Thus, this study aims to: (i) estimate the current electricity demand in the HH sector, (ii) project the future electricity demand in areas of different socio-economic development conditions, and (iii) analyze factors influencing the electricity demand.

1. DATA AND METHODS

1.1. Study areas and data sources

This study focuses on the HHs in the Mekong Delta (MD) and Ho Chi Minh city (HCMc) (Fig. 1). Data on HH appliances were collected in 2007 from electrified HHs via door-to-door interviews using a questionnaire (Saito et al., 2007; Dang et al., 2007). The numbers of UB, PU, and RR HHs interviewed were 50, 50, and 352, respectively. The

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1.3. Method for projecting electricity demand

There are direct and indirect drivers for projecting the future electricity demand in the residential sector (Eq. 1). We assumed that the growth in the number of HHs ($EH_a$) and the increase in an appliance’s diffusion rate ($S_{j}$) (McNeil, 2005) are the two major drivers. In low-income countries, demand is also driven by expansion of the electricity grid ($CR_a$) and changes in a given appliance’s capacity ($C_{j}$) and efficiency ($F_{j}$). The projections of $EH_a$ and $S_{j}$, in accordance with the economic development as well as the changes in $C_{j}$ and $F_{j}$, are explained in the following sub-sections. The projection framework, which integrates the above major parameters and influence factors, is shown in Fig. 2.

This study assumes that $U_{j}$ and $D_{j}$ will not change during the projection period. While $CR_a$ in UB and PU is 100.0% in all projection years, it is assumed to increase from 94.0 in 2007 to 97.0 in 2010, and then reach 100.0% from 2020 in RR areas.

1) Projecting HH number

The population of a country may be partitioned into young people aged 0–19 years ($Y_0$), who usually reside with their parents; woman aged 20–49 years who are likely to form a couple, have children, and raise a HH ($W_0$), and people aged more than 50 years old ($E_0$) who may live independently without their children. The ratios $Y_0/W_0$ and $E_0/W_0$ are therefore closely associated with the total fertility rate for the fertility and median age for the aging in population (Jennings et al., 1999). Evidence from 77 of 88 countries studied, including Vietnam, showed that the number of HH per persons ($\mu$) is inversely related to a measure of fertility and directly related to a measure of ageing (Jennings et al., 1999). The modified ratios $Y_0/W_0$ and $E_0/W_0$ can thus be used to estimate the HH size ($\mu$) (Eq. 2).

\[
TED = \sum_{i} EH_i \times CR_i \times \sum_{j} \left( S_{j} \times U_{j} \times D_{j} \times C_{j} \times E_{j} \right) \times 10^9
\] (1)

where $EH_i$ is the number of HHs in $i$ during $t$ (HH); $CR_i$ is the electricity coverage rate in $i$ during $t$ (%); $S_{j}$ is the diffusion rate per electrified HH of appliance $j$ in $i$ during $t$, (unit/electrified HH); $U_{j}$ and $D_{j}$ are the usage time per day (h/day) and usage days per year (day), respectively, of $j$ in $i$; $C_{j}$ and $E_{j}$ are the capacity (W/unit) and energy coefficient of $j$ during $t$; $i$ is a UB, PU, or RR area, while $j$ is a TV, RE, AC, WM, or fan.

Three data sources were used to estimate the current electricity demand ($TED_{2005}$):

- $EH_i$ and $CR_i$ were obtained from the national statistics data (GSO, 2006);
- $S_{j}$, $U_{j}$, and $D_{j}$ were obtained from the results of our survey.
- No official data was available regarding the average $C_{j}$ and $F_{j}$ in Vietnam. Thus, this study used the mean values of $C_{j}$ and $F_{j}$, which were obtained from the catalogues of the available products of appliances available in Vietnam's market as well as from data of previous studies in China (Murata et al., 2008) and Cambodia (Sovannara, 2002).
relate the population to age groups in MD and HCMc, \( \mu_t \) can be predicted by multiplying \( \mu_t \) by the conversion ratio \( \eta_t \) which is the ratio of the HH size in the study area to that in the country (Eq. 2).

\[
\mu_t = \eta_t \times \mu_t = \eta_t \times \frac{1}{(1 + \beta \times \text{HHs}) + \gamma \times (E_t \times \text{HHs})}
\]

where \( \alpha, \beta, \) and \( \gamma \) are constants equal to 0.15, 0.07, and 0.07, estimated using the least-square approximation method for the census data in 1999, 2004, 2005, and 2006\(^9\). \( \eta_t \) is equal to 0.96, 0.97, and 1.04 for the UB, PU, and RR areas\(^9\), respectively. \( P_t, W_t, Y_t \) and \( E_t \) were obtained from an international database\(^6\). However, only permanent and officially registered migrants, who accounted for 1.9% and 17.4% of migrants in HCMc and MD, respectively, were included in the census\(^6\). The number of non-registered migrant HHs (\( Hm_d \)) was estimated separately.

Among the non-registered migrants, 80.0% were single residents living in rented or owned houses\(^4\), which can be considered individual HHs. \( Hm_d \) can thus be estimated by Eq. (3).

\[
Hm_d = M_d \times (1 + e)^{100} \times (1 - R_c) \times 80\% \quad (3)
\]

where \( M_d \) is the number of migrants in 2007 (persons); \( R_c \) is the registered migrant rate (\( R_{HCMM} = 1.9\%, R_{MD} = 17.4\% \)), and \( e \) is the net migration ratio.

A previous study (Phuong, 2008) suggested that migration pressure would remain strong in near future as long as the population is young and increasingly educated, and there are insufficient non-farm economic opportunities. \( ECMC \) and \( EMID \) were therefore set as the mean values of the last 5 years at 20.6% and 1.0%, respectively.

\( EH_d \) can be estimated from the sum of \( H_d \) and \( Hm_d \) values. The projected numbers of households in UB, PU, and RR are shown in Table 1.

2) Appliance’s diffusion rate projection

The diffusion rate of appliances is expressed as a function of HH income (Murata et al., 2008) by:

\[
S_t = A \exp(-\chi (I_t + \mu_t)^n) \quad (4)
\]

\[ IC_t = a_t + b_t \times GDP_t \times (1 + c_t)^{100} \quad (5)\]

where \( A, \chi, \) and \( m \) are positive constant parameters.

<table>
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<th>Table 1. Projected number of households (10^6 HH)</th>
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<td>Year</td>
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<td>PU</td>
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estimated by the nonlinear regression method using survey results of HH income and diffusion rate: \( IC_t \) is the per capita income (VND/year); \( a_t \) and \( b_t \) are constants of the linear regression. \( ECMC \) and \( EMID \) are 3,082.2 and 0.5, respectively, and the corresponding values for MD are 436.5 and 0.8, respectively. In both areas, \( P < 0.01, R^2 > 99.2\% \), and \( R_{ECMM} > 98.6\% \); \( c \) is the GDP growth rate (%/year) and \( GDP_t \) is the per capita GDP of the area in 2007 (VND/capita).

In order to examine the impact of economic development on the projected electricity demand, this study considers three cases: a low case (SC1), a medium case (SC2), and a high case (SC3). The GDP growth rates for SC1, SC2, and SC3 are equal to the minimum, average, and maximum rates during the period 2000–2007. In HCMc, the GDP for SC1, SC2, and SC3 will grow at an annual rate of 9.5%, 11.2%, and 12.2%. It is considered 7.8%, 10.8%, and 12.4% per year in SC1, SC2, and SC3 in MD.

3) Change in an appliance’s capacity and efficiency

The assumptions of the change in appliance types and capacities were based on the information collected in HH surveys. To obtain information on the efficiency improvement, the data on trends in Japan was used as a reference\(^5\). The study only considers the change in efficiencies of TVs, REs, and ACs, which have already been included in Japan’s Top Runner Program. We assumed that the capacity and efficiencies of WMs and fans would not change by 2030.

TV: The use of LCD and plasma TVs is assumed to predominate the study areas by 2030. Also, we assumed that the number of medium: (21–32 inch) and large-sized (>32 inch) TVs will increase, while that of small-sized ones (<21 inch) will decrease (Table 2).

RE: At present, the distribution of small- (<200 L) and medium-sized (200–399 L) REs is the same in the areas surveyed, with a share of 80.0% and 20.0%, respectively. URENCO (2007) reported

<table>
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<th>Table 2. Distribution of TV type and size (%)</th>
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<td>UB</td>
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<td>&gt;32 in</td>
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<td>CRT</td>
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that when HHs replace their REs, most used REs are collected, repaired, and resold to the lower income customers. We assumed that the existing REs in UB areas will be replaced by new and larger-sized REs. The replaced REs from UB will be collected and resold to HHs in RR areas, which results in our assumption that the average size of REs in RR will be smaller than in UB and PU areas (Table 3).

We assumed that the average electricity consumed by TVs and REs will not change until 2010. It will rise up to the consumption level of products currently used in Japan by 2020 and to the level of Japan’s top-runners products of 2008 by 2030.

AC: The average cooling performance of AC in the HHs surveyed was 3.0 kW with a coefficient of performance (COP) of approximately 2.6–3.0. In Japan, the COP is currently more than 6.0. Our study assumed that the average COP will be 4.5 and 6.0 by 2020 and 2030, respectively.

2. CURRENT ELECTRICITY CONSUMPTION

For all the appliances considered, the estimated diffusion rate decreases from UB to PU to RR (Table 4). Fans and TVs have the highest diffusion rates. The diffusion rates of WMs and ACs in PU and RR areas are very small at present (Table 4). We found that HHs in more urbanized areas, which own more and larger appliances, tend to use more electricity (Fig. 3). In 2007, electricity consumption in UB areas was 2,714.5 kWh/year/HH, about 2.2 and 2.9 times higher than in PU and RR areas, respectively.

Among the 5 appliances considered, cooling devices (fans and AC) are the major consumers of electricity, using 61.7% to 68.7% of the total electricity supplied. In the PU and RR areas, fans were the dominant cooling devices, and consumed 93.5% and 97.4% of the electricity used for cooling purposes. In contrast, this share was reduced to 47.6% due to the popularization of ACs in UB areas. TVs accounted for 24.4%–27.0% of electricity. REs consumed 7.9%, 13.2%, and 4.4% of HH electricity in UB, PU, and RR areas, respectively. WMs consumed the least electricity in all 3 areas.

3. ELECTRICITY DEMAND PROJECTIONS

3.1. Electricity demand per HH

By 2030, UB HHs will be the highest consumers of electricity, with total demand for SC1, SC2, and SC3 reaching 3,521.3, 3,694.8, and 3,794.8 kWh/year (Fig. 4). The demand from UB HHs is 1.6 times higher than that from PU HHs, and 2.5–2.8 times higher than that from RR HHs. In terms of demand growth rate per HH, PU has the highest rate, growing at 2.6%–2.7% per year during the period 2007–2030. Next are HHs in RR (1.3–2.1%) and UB (1.1–1.5%) areas.

Our projected results also demonstrate a positive correlation between a HH’s electricity demand and economic development. However, the dependence on these two factors is different between areas. In UB and PU areas, while income grows at the same rate, the electricity demand growth rate in PU areas is twice as high as that of UB HHs.

3.2. Total electricity demand and its distribution

In terms of demand distribution, cooling devices are predicted to be the main source of electricity a consumption in all 3 study areas, accounting for

![Fig. 3. Electricity consumption per HH in 2007](image)

![Fig. 4. Projected electricity demand](image)
58.2%–66.8% of the total demand (Fig. 5). TVs and REs rank second (28.9%–35.5%) and third (3.4%–6.6%), and WMs will be a minor source of consumption in 2030.

The total electricity demand in all 3 areas studied (WS) is projected to increase with average growth rates of 2.6, 4.4, and 3.6% in UB, PU, and RR areas, respectively (Table 5). UB HHs accounting for 24.6–25.8% of the number of HHs in WS will be the largest consumers, and consume approximately 50% of the total demand.

4. DISCUSSION

4.1. HH electricity demand

Electricity demand in the HH sector of Vietnam was estimated using door-to-door survey results. Since GDP is useful in forecasting residential electricity use (McNeil and Letscher, 2005), per capita GDP was used as a verification tool for the estimated results.

Due to the similarity in per capita GDP between Shanghai (2003) and HCMC (2007), the per capita electricity demand in UB areas was estimated to reach 662.7 kWh/year, almost the same as UB HHs in Shanghai.

In terms of future demand, Khanh (2005) projected the HH electricity demand in UB and RR residential sectors of Vietnam using GDP elasticity. However, due to the lower assumption of GDP growth rate (6.1–7.2%), the projected values in his report are approximately 3.9–12.5% and 1.5–22.6% lower than our results for UB and RR areas, respectively. Further, as our projection shows, the impact of economic development on HH electricity demand in RR areas is stronger than that on UB and PU. Since only one scenario was analyzed in Khanh’s study, the complete effect of economic development on electricity demand was not demonstrated.

4.2. Factors determining the electricity demand

In accordance with McNeil’s report (McNeil and Letscher, 2005), our study demonstrated that the increase in an appliance’s diffusion rate with increasing incomes is a major driver of growth in HH electricity consumption. In addition, there is a significant positive correlation between HH income and their electricity demand ($P < 0.01$); however, the value of the coefficient correlation is gradually reduced over projection periods. This means that in future, there will be an impact of additional factors on the final electricity demand in the residential sector.

Among the parameters used in the HH electricity demand projection, appliance efficiency is the most uncertain factor, and can significantly influence the final results. The improvement of appliance efficiency might lead to the conservation of electricity with a reduction of 300–700 kWh/HH per year (Murata et al., 2008). The highest saving potential was found in areas with high space cooling demand. The same situation might be observed in our study areas, along with a significant increase in the AC diffusion rate. Over the projection period, the diffusion rate of AC is expected to increase by 2.6, 13.9, and 9.5 times in UB, PU, and RR areas, respectively. However, by 2030, due to efficiency improvement, the increase in electricity demand for AC will be reduced by 56.7% in comparison with the case of no efficiency improvement.

![Fig. 5. Electricity demand per HH and their income according to area and development](image_url)
5. CONCLUSION

Until date, due to the lack of provincial data regarding HH appliances and their usage, the trend of residential electricity demand in UB, PU, and RR areas in Vietnam was not known. In this study, HH electricity demand over the period 2007–2030 was estimated using door-to-door survey results. The estimation takes into account both the change in demography and the change directly related to appliances such as diffusion rate, size, and efficiency.

First, UB HHs, which have higher living standards, tend to use more electricity than PU and RR HHs. In 2007, electricity demand per HH in UB, PU, and RR was 2,714.5, 1,248.9, and 932.4 kWh, respectively. Per capita electricity demand in Vietnam’s UB HHs was found to be at the same level as Shanghai’s UB HHs in 2003.

Second, the projected results clearly indicate the trend of electricity demand in study areas. PU areas have the highest electricity demand growth rate, at 2.6–2.7% per annum over the period 2007–2030, followed by RR and UB areas.

Third, there is a positive correlation between HH electricity demand growth rate, and economic development over the projection period, but the correlation intensity differs among areas.

Finally, among the studied appliances, cooling devices (ACs and fans) are the main consumers of electricity, accounting for more than 60% of the final electricity demand. ACs, which is considered as luxury appliances at present, will potentially become the main electricity consumer in UB and PU areas. Issuing a standard for appliance efficiency, particularly for ACs, might help to control the increase in HH electricity consumption.

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NOTES


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