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Household Electricity Consumption: A study on the role of micro-renewable energy systems in Vietnam

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Household electricity consumption: A study on the role of micro-renewable energy systems in Vietnam

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Abstract: Although nearly all households in Vietnam have connected to the national grid, electricity shortage in the residential sector is still an issue. One measure of residential electricity shortage is the micro-renewable energy system (micro-RES), but little is known about the drivers for household adoption of such system and whether the presence of a micro-RES can help to reduce household energy consumption. This paper examines the characteristics of households that have adopted a micro-RES and investigates whether the presence of micro-RES would result in a decrease in energy demand by using fixed-effects models. Analysis was carried out on the 2016 and 2018 Vietnam Household Living Standard Survey data sets. The results show that the micro-RES adopters are likely to have lower educational level, lower income or living conditions, and live in the mountainous regions. Micro-RES adopters are found to spend less on electricity and fuel than the non-adopters and this finding is consistent across households of different income groups. The results also suggest that the support schemes may be beneficial to households adopting micro-RES because they really need it to meet the increasing demand in electricity.

Subjects: Development Studies; Economics and Development; Environment & the Developing World

Keywords: micro renewable energy systems; Vietnam; households; energy consumption

1. Introduction

Vietnam has witnessed a rapid increase in energy consumption in the past two decades. The electricity supply to all sectors in the country has increased over seven-fold, from 343.68 kWh per capita in year 2000 to 2412.42 kWh per capita by year 2020 (General Statistics Office, 2001, 2021). This increase was generated to meet the increased demand from domestic economy, which had become 14 times larger in terms of GDP over the same period (General Statistics Office, 2021). The domestic electricity supply is currently dominated by coal-fired and fossil fuel-based thermal power plants which account for 59% of the whole system (Vietnam Electricity, 2021) and this figure is projected to slightly reduce to 57.3% by 2030 (Ministry of Commerce and Trade, 2019). Meanwhile, the share of electricity supply from the renewable energy sources, i.e., solar energy, wind power, and biomass, is projected to increase to 21% in 2030 from 9.9% in 2020 (Ministry of Commerce and Trade, 2019).

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Up to 99.5% of all households have gained access to the national electricity grid and the residential sector currently accounts for over 33% of country's total electricity consumption (General Statistics Office, 2021). The share of residential electricity consumption in Vietnam is higher than both the ASEAN and the world average (IEA World Energy Balances, 2021). At the 26th UN Climate Change Conference of the Parties (COP26) Vietnam pledged to achieve the net-zero emissions target by 2050. This means household electricity saving is essential to reduce CO_2 emission in the country and to contribute to a more sustainable energy policy going forward (Apergis & Gangopadhyay, 2020; Hoang & Fogarassy, 2020). However, it is claimed that the current electricity pricing policies are not in favour of electricity savings since the retail price is being kept lower than the long-run marginal cost of production to avoid public dissatisfaction (Phu, 2020). Government policies have recently aimed at increasing the rate of households installing a rooftop PV system, a kind of renewable energy systems (RES), to 50% by 2050 (Government of Vietnam, 2015). However, such policies do not include financial supports for installing the RES.

To the best of our knowledge, only a handful of studies focus on residential electricity consumption using household level data in Vietnam (see Hien & Chi, 2020; Le & Pitts, 2019; Phu, 2020; Son & Yoon, 2020). These studies provide a basic profile of factors affecting electricity consumption behavior by Vietnam households, but no study has examined the role of a RES among determinants. This may result from the fact that the adoption of RES, such as a PV system, at household level in the country is relatively slow (Do et al., 2020). Thus, data on RES at household level might be overlooked. Our study contributes to this gap in a number of ways. Firstly, our study looks at the uptake of RES in Vietnam and the characteristics of households that have a RES system. The determinants of RES installations in Vietnam are also investigated. Our study also contributes to the understanding of household electricity saving behaviour in a developing country by investigating the determinants of electricity consumption and whether the adoption of RES may have an impact consumption of electricity among Vietnam households. Furthermore—our results should be of interest not only to other developing economies but also in the context of RES technological adoption and role in the wider context, as residential wind and solar in particular are being rolled out across many developed economies also (Virupaksha et al., 2019).

2. Literature Review

2.1. Adoption of renewable energy sources in the residential sector

The past two decades have seen growing attention given to factors influencing the adoption of micro-RES in the residential sector. The motivations behind households' decision to install micro-RES not only come from environmental and economic considerations but also from demographic characteristics and social network relations. Micro-RES is a measure to reduce carbon emission and early adopters of micro-RES were generally found to show their awareness of the environmental benefits of the systems (Faiers & Neame, 2006; Palm, 2020). However, the environmental motivation alone was not sufficient to explain the increased adoption of micro-RES. As micro-RESs have become more technically developed and geographically dispersed, economic concerns were found to be the main motivators. For instance, study by Schelly (2014) showed that adopters of micro-RES viewed the installed systems as a means to reduce monthly electricity bills. Study by Jacksohn et al. (2019) demonstrated that the cost-revenue considerations of micro-RES mostly determined households' decision to install the system or not.

The housing characteristics, households' social status and network relations are among other factors that intertwined with households' environmental and economic concerns in explaining the adoption of micro-RES. Micro-RES was reported to be more likely to be installed in a house as opposed to an apartment since houses may allow more open space to place pieces of the equipment (Jacksohn et al., 2019). Whereas some urban dwellers are afraid of annoying their neighbours with the rooftop micro-RES (Palm & Tengvard, 2011), the rural area offers wider open space to households, and this perhaps explain why micro-RES were found more likely to be installed in the rural area than in the urban setting (Jacksohn et al., 2019). Findings by Chesser et al. (2019) suggested that the dwelling size and the building materials also influenced household probability to install a micro-RES. Those who installed a micro-RES were

reported to be wealthy and well informed about the benefits of micro-RES (Welsch & Kühling, 2009). Perhaps, people should complete or reach some certain levels of education to be knowledgeable of the installed systems since evidence showed that adopters of micro-RES graduated from a university or technical school (Tsantopoulos et al., 2014). In some studies, the decision to adopt a micro-RES or not is found induced by people living nearby or socially related to the households. For instance, households might opt for a micro-RES to demonstrate their pro-environmental example to friends and neighbours (Palm & Tengvard, 2011; Welsch & Kühling, 2009) or the social networks were claimed to be an effective channel to promote the adoption of micro-RES by households (Schelly, 2014).

In many countries, the government provides financial incentive schemes to promote residential instalment of micro-RES but the motivations behind those policies may vary according to contexts. In developed countries, government policies to promote the dispersion of micro-RES primarily aim at reducing greenhouse-gas emissions (Crago & Chernyakhovskiy, 2017; Palm & Tengvard, 2011; Wasi & Carson, 2013), whereas developing countries' supportive policies for micro-RES act as a measure to deal with the problem of shortage of electricity supply (Malik & Ayop, 2020; Qureshi et al., 2017). However, Guta (2020) believes that studies on the demand-side of micro-RES in low-income countries are few and therefore this element should receive more attention from scholars.

2.2. Household's energy consumption behaviour

There have been many studies on household energy consumption behaviour in recent years given that households are an important target group for energy conservation. Emphasis has been placed on the households' demographic and economic characteristics, environmental concerns, dwelling context, and locational contexts as the determinants of residential energy consumption. Households' income and the number of occupants are the two popular demographic and economic factors found positively correlated with household's energy consumption (Brandon & Lewis, 1999; Fell et al., 2014; Ritchie et al., 1981). Study by Abrahamse and Steg (2009) indicated that people with environmental concerns might opt for more energy-saving measures provided that their budgets allowed them to afford the equipment. Dwelling type is also a relevant factor for the total energy consumption as families living detached houses were reported to spend more on energy than those living in apartments (Besagni & Borgarello, 2018). The heterogeneity in local contexts was also found to play a role in explaining variations in household energy consumption. For instance, households were reported to consume more energy in the locations where subsidised policies were in force (Albatayneh et al., 2022; Heiskanen et al., 2020).

Technological progress offers households with more energy-saving and environmental-friendly options (Yohanis, 2012). RESs gain momentum among available options because they are claimed to be useful in controlling carbon emissions by reducing household consumption of electricity produced by fossil power plants. However, the role of RES in residential electricity sector varies according to contexts. In developed countries, RESs are considered as a sustainable solution in reducing fossil fuel consumption (Chesser et al., 2018; Palm, 2020). In developing countries, in addition to environmental benefits, RESs may function as supplements to meet demand in locations where electricity supply from the national grid is either limited or unavailable (Kobayakawa & Kandpal, 2015, Li et al., 2015; Qureshi et al., 2017).

Findings on the association between the adoption of micro-RES and household energy consumption are also mixed. Kobayakawa and Kandpal (2015) find that the adoption of a micro-RES did not result in a decrease in household electricity consumption. Havas et al. (2015) claimed that the adoption of micro-RES alone could not change household electricity consumption behavior. Chesser et al. (2019) revealed that the presence of a RES even increased energy consumption in relation to wealthy households. However, the study by Park and Kim (2018) indicated a decrease in household electricity consumption in the locations where people expressed their interests in renewable energy, but their findings are mostly valid for the short run only.

3. Methodology

3.1. Data

This study uses household-level data collected from the Vietnam Household Living Standards Survey (VHLSS), the survey conducted by the General Statistics Office. Surveys have been conducted periodically in Vietnam since 1993 by the General Statistics Office to facilitate policy-making and socio-economic development planning (General Statistics Office, 2019). The VHLSS questionnaires are primarily designed to record household's social, demographic, and economic characteristics. The VHLSS 2016 and VHLSS 2018 contain 9,399 households in each survey. Normally, around half of the households in the sample are present in the two consecutive surveys. That means around half of the households in the VHLSS 2018 sample are also found in the VHLSS 2016 sample. This arrangement is controlled by the General Statistics Office. Our study uses the panel data created from the VHLSS 2016 and VHLSS 2018 by merging households that appeared in both surveys. The VHLSS 2016–2018 panel contains 3,786 households in each year. The panel data is useful in causal inference (Wooldridge, 2009), thus it facilitates the investigation of the impact of micro-RES on household electricity and total energy consumption.

The VHLSS 2016 and 2018 questionnaires ask only one question that records whether the household has installed a RES that produce electricity for home lighting. While the exact type of micro-RES that is in use is not specified in the questionnaire, it is possible to capture micro-RES more generally which is the key element for this study. Thus, a dummy variable was constructed to represent households with a micro-RES installed. Data were analysed using Stata.

3.2. Electricity consumption model

This section presents the model to investigate whether micro-RES has had an impact on the average monthly household electricity use. A log-linear model based on ordinary least squares (OLS) method is used. Two models are used, the first contains the electricity consumption as the dependent variable, while total fuel consumption is the dependent variable in the second model. The two models can be formulated using the following equation (1);

$$\mathrm{ENERGYUSE}_{it} = \beta_0 + \delta_0 \mathrm{POWERSOURCE}_{it} + \beta_i X_{it} + a_i + u_{it}, t = 2016, 2018 \quad (1)$$

where *ENERGYUSE* represents two dependent variables, which are the logarithm of average monthly household electricity use per capita and the logarithm of average monthly household expenditure for total energy. *POWERSOURCE* indicates whether the household is using electricity from RES or not. *X* is a list of covariates while *a* and *u* are, respectively, the unobserved time-constant factors and the time-varying factors that affect *ENERGYUSE* (see Tables 1 and 2). To control for possible endogeneity which arise from the variable *POWERSOURCE* in equation (1), *POWERSOURCE* is replaced by *POWERSOURCE** which stands for the probability that a household adopts a RES. *POWERSOURCE** is estimated by a logit model in which predictors were constructed following the study by Chesser et al. (2019). For space considerations, our paper does not completely describe the model further but refer the reader to that paper for further detail on the model.

The covariates *X* for equation (1) were selected based on previous literature (Chesser et al., 2019; Guta, 2020; Jacksohn et al., 2019; Wallis et al., 2016) comprise of households' socio-economic variables as well as dwelling and appliance variables. Households' socio-economic variables are as follows: logarithm of average monthly household income; ratio of working members in the household; dwelling location (urban or rural); age of householder; years of formal education of householder; number years living in the current dwelling; home ownership status (owner or tenant); and home internet access (those who answer "Yes" are denoted by 1). The dwelling characteristic variables are per-capita dwelling size, type of housing (villa type or detached house is denoted by 1) and building materials (concrete dwelling is denoted by 1). Appliance variables include television, fridge, air-conditioner, and water heater.

4. Results

Table 1 and 2 provide summary statistics and describe the data on households used in this study. Table 1 shows the small and decreasing proportion of households using electricity from micro-RES and this situation may be explained by the increase in the capacity of the national grid. About a third of households are living in urban areas where the living conditions are better than their counterparts. The proportion of families living in a villa type or detached houses tends to increase

Table 1. Descriptive statistics of categorical variables

Variable	Proportion (%)	
	2016	2018
Households adopting micro-RES		
Yes	1.45	0.92
No	98.55	99.08
Dwelling location		
Urban	27.68	27.73
Rural	72.32	72.27
Type of housing		
Villa type or detached house	20.47	23.40
Others	79.53	76.60
Construction materials of the frame		
Concrete	71.90	70.44
Others	28.10	29.56
Self-employment		
Yes	68.86	67.38
No	31.14	32.62
Terrain		
Hilly or mountainous region	49.63	49.63
Others	50.37	50.37
Internet access at home		
Yes	24.27	39.54
No	75.73	60.46
TV		
Household has a TV	90.86	91.47
Household has no TV	9.14	8.53
Fridge		
Household has a fridge	67.14	76.73
Household has no fridge	32.86	23.27
Conditioner		
Household has an air-conditioner	13.15	18.83
Household has no air-conditioner	86.85	81.17
Water heater		
Household has a water heater	24.75	30.16
Household has no water heater	75.25	69.84
Ownership		
Owner	97.97	98.10
Others	2.03	1.90
N	3,786	3,786

Table 2. Descriptive statistics of quantitative variables

Variable	Mean		Change
	2016	2018	
Electricity consumption per capita (kWh)	41.31	49.75	20.43%
Total fuel consumption per capita (1,000 VND)	196.37	237.20	20.79%
Monthly income per capita (1,000 VND)	2,869	3,698	28.88%
Number of persons living in household	3.87	3.79	
Ratio of income-generating members to total household size (%)	62.45	62.62	
Ratio of children in the household (%)	34.78	33.17	
Floor space per capita (m^2)	26.05	27.53	
Years of formal education of householder	7.82	7.86	
Age of householder	51.82	53.19	
N	3,786	3,786	

reflecting the rising number of wealthy households in the country. Most households own a TV, and many have a fridge, the two popular home appliances, whereas only one-fifth of households have an air-conditioner.

Table 2 provides figures on energy consumption and other social and economic variables for the sampled households. While most indicators are relatively stable for the period 2016–2018, electricity consumption per capita and total fuel consumption per capita all increase by over 20% after 2 years. This change may reflect a change in lifestyle as household income per capita rose by about 29%, the largest increase among variables over 2 years.

4.1. Adoption of a renewable energy source

This section presents results from the model predicting *POWERSOURCE** or the probability that a household uses electricity from a RES. Results from the logistic regression are presented in Table 3. The results show that household monthly income per capita, householders' education level and employment status, construction materials of the frame, and terrain characteristics are found to correlate with the use of electricity from micro-RES. These findings are statistically significant in both 2016 and 2018 models. Like other developing nations, small micro-RESs have been the solutions to supply electricity to the most difficult and remote areas in Vietnam (UN ESCAP, 2020). Those living in such unfavorable living conditions normally have lower income and years of formal education compared to their counterparts (General Statistics Office, 2019).

Also, the most difficult and remote areas in Vietnam are mostly located in the hilly or mountainous regions. This helps to explain why higher-income households and householders with higher years of education tend to be non-adopters of micro-RES in the VHLSS samples. This finding is different from findings in the studies conducted in developed countries which confirmed that higher-income households were more likely to use a micro-RES (Chesser et al., 2019; Jacksohn et al., 2019).

Other findings show that households in urban areas are less likely to use electricity from micro-RES than those living in the rural areas. This may be a result of the electrification in urban areas

Table 3. Logit regression results for the determinants of RES Installation

	Coef. 2016	Coef. 2018
Logarithm of income per capita	−1.083***	−0.926***
Number of persons living in household	0.394***	0.080
Dwelling location		
Urban	−2.406*	−1.306
Rural (reference category)		
Floor space per capita	0.018*	0.004
Years of formal education of householder	−0. 137***	−0.133**
Type of housing		
Villa type or detached house	−0. 976	−2.431**
Others (reference category)		
Construction materials of the frame		
Concrete Others (reference category)	−1.415***	−2.340***
Self-employment		
Yes	1.573*	1.945*
No (reference category)		
Terrain		
Hilly or mountainous region	2.497***	2.051***
Others (reference category)		
Constant	0. 000	1. 127
R^2	0.369	0.350

Notes: * significant at the 10 per cent level, ** significant at the 5 per cent level, *** significant at the 1 per cent level.

being better than in the rural areas. The number of people in the households and the floor space per capita positively increase the odds of using electricity from a micro-RES. This means those using electricity from micro-RES tend to have a larger family and their dwellings are normally found in rural settings. Wealthy households living in villa type or detached houses tend to use electricity from the national grid rather than from a micro-RES. However, all these findings are valid for either the 2016 or 2018 model only.

4.2. Household's energy consumption in relation to renewable energy sources

Table 4 displays the estimated regression coefficients from two panel data models with fixed effects and these results have already been accounted for heteroskedasticity via clustered standard errors. Energy consumption was modelled by electricity use (Model 1) and total fuel consumption (Model 2). The total fuel consumption comprises the consumption of electricity, fossil fuel, and biomass. As well as our main variable of interest, *POWERSOURCE*, our study investigated the influence of several household characteristics including socio-economic, dwelling and appliance factors. As noted in Section 3.2, *POWERSOURCE* was replaced by *POWERSOURCE** in regression to treat possible endogeneity in both models.

The presence of micro-RES in households was statistically significant for both electricity consumption and total fuel consumption and the coefficients representing effects of micro-RES on energy consumption were all negative in both models. This result is different from the studies in developed countries by Fikru et al. (2018) and Chesser et al. (2019) which conclude that RES adopters consume more energy than non-adopters. However, the study by Kobayakawa and

Table 4. Regression results for household's energy consumption (full sample)

	Model 1 Electricity consumption	Model 2 Total fuel consumption
Power source Renewable Other (reference category)	−1.159***	−0.973***
Ratio of income-generating members to total household size	0.201***	0.357***
Ratio of children in the household	−0.550***	−0.324***
Floor space per capita	0.005***	0.004***
Age of householder	0.006***	0.004**
Years of formal education of householder	0.012*	0.011**
Internet access at home Yes No (reference category)	0.094***	0.117***
TV Household has a TV Household has no TV (reference category)	0.120***	0.076**
Fridge Household has a fridge Household has no fridge (reference category)	0.357***	0.234***
Conditioner Household has an air-conditioner Household has no air-conditioner (reference category)	0.111***	0.135***
Water heater Household has a water heater Household has no water heater (reference category)	0.109***	0.084***
Type of housing Villa type or detached house Others (reference category)	0.109*	0.124**
Construction material of the frame Concrete Others (reference category)	0.069	0.085**
Ownership Owner Others (reference category)	−0.013	−0.095
Constant	1.341	3.377
R^2 (overall)	0.508	0.379

Notes: * significant at the 10 per cent level, ** significant at the 5 per cent level, *** significant at the 1 per cent level.

Kandpal (2015) in a non-developed context concludes that the presence micro-RES does not affect household monthly electricity consumption.

Results across social and economic variables were basically in line with findings from the previous studies. Households with higher ratio of income-generating members and larger floor space per capita results in an increase in both electricity and total fuel consumption. This finding is similar to studies by Lu et al. (2021) and Stephan et al. (2013). The fact that households having more income sources and larger dwelling space indicates they may have larger budget for daily energy consumption.

The larger the number of people living in a household, the higher the energy consumption, both for total overall fuel and for electricity use. Studies of Jones et al. (2015) and Kotsila and Polychronidou (2021) also reach the same conclusion. A household with a higher ratio of children to total members consumes less electricity and fuel overall when compared to a household with lower ratio of children. A similar relationship between the presence of children in the household and the energy consumption has been found by Bartiaux and Gram-Hanssen (2005) and Brounen et al. (2012). However, the householders' number of years of schooling does not have a role in explaining household energy consumption.

Results from appliance factors affecting energy use in a household were consistent across all the models. Household appliances for daily life comforts such as TV, fridge, air-conditioner, and water heater were found to be statistically significant in terms of increasing electricity and total overall fuel consumption. This is consistent with findings from the study by Wassie and Ahlgren (2022) conducted in a developing country. The presence of home internet was found to increase household energy consumption as well.

Results from the dwelling factors show that the type of housing and construction material of the frame were statistically significant in affecting household energy consumption. Energy consumption in villa type or detached houses are higher than other types of housing. Su (2019) also found that dwelling type was a determinant of households' electricity demand. Where the construction material of the frame is concrete, the amount of energy consumption is higher than other types of materials, e.g., wood, stone, bamboo, etc. These findings imply that wealthier households consume more energy than the poorer counterparts. Finally, contrary to the findings by Rodriguez-Oreggia and Yepez-Garcia (2014) and Su (2019), whether the dwelling is occupied by either owner or tenant did not influence both electricity and total fuel use.

5. Conclusion

In this paper, the determinants of household adoption of a micro-RES were firstly investigated using a logit regression approach. Secondly, whether the presence of RES would result in a decrease in energy demand was examined using fixed-effects models. Analysis was carried out on the 2016 and 2018 VHLSS data sets.

For the first research objective, we found that the adopters are likely to be lower-income households or those living in the mountainous regions. Given the issue of electricity shortage, micro-RESs have been a solution to provide off-grid electricity for households living in the remote and difficulties areas of Vietnam. The results suggest that the support schemes may be beneficial to households adopting micro-RES because they really need it.

The second research objective of this study was to find whether household micro-RES has had an impact on reducing energy consumption. Our findings were basically in line with those of previous studies. The adoption of micro-RES was found to reduce both electricity consumption and total fuel consumption.

The share of residential electricity consumption in Vietnam is higher than both the ASEAN and the world average and the country has pledged to achieve the net-zero emissions target by 2050. This means the residential sector has an important role in reducing CO_2 emission in the country. Given the fact that the Vietnam economy is claimed to be energy-intensive while facing the problem of electricity shortage, government policies should focus on enhancing the efficient use of energy and educating people's awareness of energy saving and the benefits of micro-RES.

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