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## The impacts of energy insecurity on household welfare in Cambodia: Empirical evidence and policy implications

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## **ADB Working Paper Series**

### **THE IMPACTS OF ENERGY INSECURITY ON HOUSEHOLD WELFARE IN CAMBODIA: EMPIRICAL EVIDENCE AND POLICY IMPLICATIONS**

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**Abstract**

This study investigates the impacts of energy insecurity on household welfare in Cambodia. The notion of energy insecurity is not well understood in the literature or in local contexts. This study defines household energy insecurity as the status quo derived from the interplay of inadequate and insufficient energy consumption that prevents households from meeting their basic energy needs. The notion of energy insecurity can only be understood well through an investigation in the local context, as it varies from place to place. Households facing insufficient energy consumption may forgo many other opportunities. Having defined energy security in the Cambodian context, the study employs the Cambodia Socio-Economic Survey Data (2015) to investigate the impacts of household energy insecurity. The study confirms that energy insecurity has an enormous negative impact on households' welfare, with a further negative impact on children's human capital formation. The findings lead to policy implications for improving household energy security and thus influencing economic, social, and environmental development.

**Keywords:** energy insecurity, schooling, welfare

**JEL Classification:** Q48, C39, I39

## Contents

1.	INTRODUCTION.....	1
2.	REVIEW OF CAMBODIA'S ENERGY SECURITY POLICIES .....	2
3.	THE NEED TO DEFINE HOUSEHOLD ENERGY INSECURITY.....	4
4.	STYLIZED FACTS ABOUT PEOPLE'S ENERGY INSECURITY.....	4
5.	THE EMPIRICAL FRAMEWORK .....	5
6.	DATASET AND VARIABLES.....	6
7.	RESULTS AND DISCUSSION .....	7
8.	CONCLUSION AND POLICY IMPLICATIONS .....	11
	REFERENCES .....	13

# 1. INTRODUCTION

Studies have investigated energy security extensively at the national and regional levels, and its meaning changes depending on its scope. From a supply perspective, researchers use several indicators as a proxy for energy security, such as the self-sufficiency ratio, import dependency, diversification of import source countries, and strategic oil reserves. Most research studies on energy security have referred to the “securing of the amount of energy required for people’s lives, economic, social, and defense activities, among other purposes, at an affordable prices” (Kutani 2013). In the context of the East Asia Summit (EAS),<sup>1</sup> the leaders adopted the Cebu Declaration in 2007, reaffirming their commitment to energy security by working closely together to reduce the dependence on conventional fuels through intensified energy efficiency and conservation programs and the expansion of renewable energy systems and biofuel production/utilization (ASEAN 2007). In recent years, the ASEAN has been working toward diversifying its energy mix and has agreed on an aspirational target to increase the share of renewable energy to 23% by 2025 in the primary energy mix (ACE 2019). In recent developments in the past few years, many countries of the ASEAN have been accelerating the installation of solar farms as well as the introduction of solar rooftop generators, thanks to the speed of cost reduction of solar modules and the gradual shift of know-how capacity to handle the solar and wind technologies in the ASEAN (ASEAN Post 2018). However, despite huge attempts and efforts by the leaders of the ASEAN to ensure electricity access to all members of the population, challenges remain in some countries of the ASEAN, where the electricity access is still low and the electricity cost is high, thus making both accessibility and affordability a core economic disadvantage as well as threatening the energy security of households, as these accessibility and affordability issues threaten people’s daily life (Han and Kimura 2019).

Taking a broad view, the predicted primary and final energy demand from 2015 to 2040, which is likely almost to double in the EAS region during the forecasting periods, is posing an increasing threat to energy security (Han 2015). Further, 80% of Middle Eastern oil exports are bound for ASEAN and East Asian countries, making the region largely vulnerable to unforeseen oil disruptions as the transportation route passes through the Strait of Hormoz, which is highly vulnerable due to the political tensions in the Middle East, and another bottleneck occurs in the Malacca Strait in Singapore due to the high volume of vessels passing through this small strait (Otaka and Han 2016).

At the country level, Cambodia has a very high level of import dependency on imports of coal, oil (petroleum products), and electricity. Statistics have shown that Cambodia’s import dependency increased from 50% to almost 60% during the period 2013–2016 (MME 2016). Realizing the energy supply risk, Cambodia’s government is making efforts to develop energy infrastructures, such as oil refineries, and tap domestic oil production by 2020.

However, unlike the above concept, which views energy security from the supply side, this study considers it as the interplay of inadequate and insufficient consumption of households to meet their basic energy needs. This concept strongly links energy security with fundamental human rights, as the 65th UN General Assembly’s resolution reflected, declaring 2012 as the international year for “sustainable energy for all” (UN 2011). This resolution highlighted the importance of energy services, which have a profound effect on productivity, health, education, climate change, food and water

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<sup>1</sup> The EAS is composed of the ASEAN plus Australia, the People’s Republic of China, India, Japan, the Republic of Korea, and New Zealand. The EAS invites the United States and the Russian Federation to join its summits or other important meetings.

security, and communication services. It further stated that the lack of access to clean, affordable, and reliable energy hinders human, social, and economic development and is a major impediment to achieving the Millennium Development Goals.

Politicians' and decision makers' lack of understanding of energy insecurity in terms of inadequate and insufficient household and individual energy consumption could delay energy access for all. Thus, this study defines household energy security as the amount needed to meet the basic needs for daily life of individuals and households in terms of cooking, lighting, washing/cleaning, and warming/cooling the house.

This study assumes that improving households' energy security could also improve their income, health, and education. The World Bank (2016) reported that households in developing countries had seen their income increase and their children perform better at school just through having adequate lighting and a reliable supply of electricity in the evening, as this necessary electricity can allow children to study at night and facilitate households' factors of income generation. However, access to electricity alone does not imply adequate energy consumption. People with less wealth and a lower income tend to use electricity only for important activities, such as making dinner and lighting for a few hours at night, leading to insufficient consumption.

This study investigates the impacts of energy insecurity on household welfare in Cambodia using the 2015 Cambodia Socio-Economic Survey (CSES), defining household energy insecurity and determining how it affects welfare. The results will help in the formulation of policy implications to strengthen the energy security of households.

The paper is organized as follows. First, the study reviews the current government's policy toward energy security and then defines the concept of energy insecurity of households in Cambodia, presents stylized facts on energy insecurity, and then conceptualizes the impact of energy insecurity on households' welfare. Second, the study describes the dataset and variables followed by the results. Finally, it presents the conclusion and policy implications for strengthening households' energy security.

## **2. REVIEW OF CAMBODIA'S ENERGY SECURITY POLICIES**

Securing an adequate supply via affordable prices and environmentally sustainable uses is the main objective of Cambodia's overall energy policy. However, Cambodia has experienced rapid growth of the energy demand, higher oil import dependence, a growing high share of coal use, and, thus, greater challenges to energy security and the management of CO<sub>2</sub> emissions (Shigeru and Han 2019). These could threaten the stable supply of national and local affordable energy.

Cambodia's energy policy focuses on supply rather than access. However, the Power Sector Strategy 1999–2016 seems to have a greater focus on household energy security given its objectives to provide an adequate supply of energy throughout Cambodia at reasonable and affordable prices and to ensure a reliable and secure electricity supply at appropriate prices for the expansion of Cambodia's economy. In 2019, the Prime Minister, Hun Sen, addressed the public about a huge shortage of 400 megawatts (MW) of electricity during the dry season from March to June. This kind of unpredictable shortage of electricity was due to the weather conditions, which produced a low water level in a hydropower reservoir (Phnom Penh Post 2019). This obvious large electricity shortage undermines the level of energy security and implies the weak capacity of Electricity of Cambodia (EDC) to manage such a vulnerable power supply mix.

Nonetheless, the Power Sector Strategy guided the development and policy framework of all the energy sectors in Cambodia, including the Rural Electrification by Renewable Energy Policy, the Renewable Electricity Action Plan 2002–2012, and the Energy Efficiency and Conservation Goals.

In addition, the government passed the Electricity Law in 2011, with the aim, amongst others, of ensuring the protection of the rights of consumers to receive a reliable and adequate supply of electric power services at reasonable costs. However, the Cambodian electricity cost/tariff (18.5 US cents/kWh for the residential sector, in which the electricity consumption is over 201 kWh/month) is the highest in the ASEAN (EAC 2019). In fact, Cambodia should provide a fair electricity price, as most of the investment costs in power generation, such as coal-fired power plants and hydropower, are based on conventional technology. Meanwhile, Singapore, with the second-highest electricity tariff in the ASEAN, has internalized the externality cost, such as carbon dioxide (CO<sub>2</sub>), into the tariff structure. Other countries, such as Thailand, Malaysia, and Indonesia, have a fairly low electricity price, and many new fleets of power generation are based on high technologies, such as ultra-super critical technology for coal-fired power plants or the gas-combined cycle for gas turbines, yet these countries can still afford to provide a relatively low electricity tariff. Cambodia may need to improve the governance system of the electricity sector to ensure that the costs can be reduced through the transparent process of the cost/tariff structure. Currently, it seems that there is public discomfort about the way in which Electricity of Cambodia (EDC) manages the supply of electricity (with very frequent blackouts) together with the high cost of electricity.

In 2006, the Royal Government of Cambodia approved the Rural Electrification by Renewable Energy Policy, which acknowledged the Master Plan Study on Rural Electrification by Renewable Energy in the Kingdom of Cambodia as the guiding document for the implementation of its projects and programs. The Master Plan envisioned the achievement of a 100% level of village electrification, including battery lighting, by 2020 and a 70% level of household electrification with grid-quality electricity by 2030. By 2015, Cambodia had already achieved a 15% level of rural electricity from solar, small hydropower, and distributed energy systems. The Master Plan also laid out clear targets, investments, and responsibilities, aiming to connect 1,828,485 households to the national grid by 2020. An additional 260,000 households in very remote areas—too far from the planned grid extension—will receive an off-grid supply via fossil fuel and renewable energy (220,000 households) and solar home systems (40,000 households). Estimates indicate that the total cost for expanding the rural grid will be US\$1.37 billion. In the plan, Electricity of Cambodia will be responsible for the overall planning, development, investment, and operation of the rural medium-voltage sub-transmission lines, and it will partner with private rural energy enterprises to expand, operate, and maintain low-voltage distribution and service lines.

The energy efficiency and conservation goals that the country submitted to the 5th EAS Energy Ministers Meeting, held on 20 September 2011 in Brunei Darussalam, stated that the country uses the final energy demand as the efficiency indicator and aims to achieve a 10% reduction from the business-as-usual scenario by 2030. The Ministry of Mines and Energy (MME) of Cambodia has faced challenges, as the country's primary energy consumption has doubled over the past 10 years (MME 2019). This strong growth of energy consumption requires the Ministry to take appropriate actions in terms of energy efficiency and conservation. In the recent development in May 2019, the MME, with technical support from the Economic Research Institute for ASEAN and East Asia (ERIA), launched a study on the Cambodia Energy Efficiency Master Plan (CEEMP). The plan aims to review the existing and needed policies to support the energy efficiency programs and projects in Cambodia. The plan will use the best practices and adopt the



appropriate energy efficiency road map in the commercial, residential, industrial, and transportation sectors. The expectation is that the CEEMP will guide all programs and projects toward investments in energy efficiency, as it will set the targets for energy savings by sectors, which will require the serious implementation of energy efficiency in all sectors. The country anticipates that the Cambodia Energy Efficiency Master Plan will be completed by early 2020.

### **3. THE NEED TO DEFINE HOUSEHOLD ENERGY INSECURITY**

As mentioned in the introduction, a household faces energy insecurity if its consumption is insufficient to meet the basic needs of daily life in terms of the requirements for cooking, lighting, washing/cleaning, and warming/cooling the house. In Cambodia, the average annual electricity consumption is about 300 kWh/person (Shigeru and Han 2019); however, its subsidy policy is applicable to any household of which the electricity consumption is less than 50 kWh/month or 600 kWh/year. With the average household size of 4.6 in Cambodia, this means that a person can receive an electricity subsidy if she/he has annual electricity consumption of less than 130 kWh, which is significantly below the average electricity consumption in Cambodia. The United Nations Development Programme (UNDP) (2010) used a standard of electricity consumption within the range of 50 to 100 kWh per person per year to sustain life. Similarly, in the case of Sri Lanka, Tennakoon (n.d.) used the quantitative threshold of per capita annual consumption of 120 kWh electricity for lighting and 35 kg of liquefied propane gas equivalent for cooking. However, some studies have used an energy requirement per household cut-off at 2,125 kWh using Guatemalan data for 1998–99 (Foster, Tre, and Wodon 2000).

The quantitative measures defining minimum energy needs are sometimes arbitrary, because differences in cooking practices and heating/cooling by region, climate, and culture complicate the level of energy required (Shahidur, Barnes, and Samad 2012).

Some empirical works have defined insufficient energy consumption as a condition in which a household's energy expense is more than 10% of its total income, such that it will begin to affect the general household welfare. The idea is that, when households have to spend as much as 10% of their income on energy, they are deprived of other basic goods and services (Barnes 2010). Based on the UK Department of Energy and Climate Change (DECC 2015), a household will need to spend more than 10% of its income to acquire sufficient energy to have an adequate standard of warmth.

This study adopts both approaches—using the 10% threshold of household energy expenditure as an energy insecurity cut-off point and using the minimum 600 kWh/year household electricity consumption threshold. However, using the electricity approach as a cut-off point has a drawback, as it is limited to those houses that are connected to electrical grids.

### **4. STYLIZED FACTS ABOUT PEOPLE'S ENERGY INSECURITY**

Energy insecurity exists not only in developing countries but also in developed countries; for instance, a study conducted by the US Energy Information Administration (EIA 2018)

found that about one-third of US households struggled to pay their energy bills just to maintain adequate heating and cooling in their homes in 2015. According to the same report, about one in five households reported reducing or forgoing necessities such as food and medicine to pay an energy bill, and 14% reported receiving a disconnection notice for an energy service. Households may also use less energy than they would prefer; 11% of the households surveyed reported keeping their home at an unhealthy or unsafe temperature.

In Europe, 50–125 million people in 2009 struggled to meet their energy needs, including people in some countries that have undergone economic austerity reforms. For example, since the outbreak of the economic crisis in Greece in 2009, 64% of the country's northern population faced difficulties affording space heating, and about 80% of the population mentioned that they used less heat than needed to make ends meet (Papada and Kaliampakos 2016).

Despite significant progress in providing electricity access to all, as stated in the United Nations Sustainable Development Goals (MDGs), the world is likely to fall short of the target set in 2030 to ensure electricity access for all citizens. Currently, in 2019, about 840 million people do not have access to electricity. Estimates indicate that about 640 million people will remain without access to electricity by 2030, most of whom live in the developing countries of Asia and sub-Saharan Africa (WB 2019a). In ASEAN countries, access to modern energy remains a policy priority, as countries like Cambodia, Myanmar, and the Lao PDR still have low access to electricity in rural areas. With a total population of nearly 640 million, an estimated 65 million people remain without electricity and 250 million are reliant on solid biomass as a cooking fuel (IEA 2017). While some countries in Southeast Asia, such as Malaysia, Singapore, Thailand, and Viet Nam, have achieved almost 100% energy access, Cambodia and Myanmar are still struggling to accomplish this (Han 2015). Data from the World Bank (2019b) show that about 50% of Cambodia's population and 57% of Myanmar's population had electricity access in 2016. However, the rate of electricity access achieved in Cambodia from 2016 to 2019 has remarkable, as the number of households connected to grid electricity reached almost 80% (MME 2019). However, the challenge remains for rural areas, where several parts of remote areas of Cambodia and Myanmar have almost no electricity at all.

## 5. THE EMPIRICAL FRAMEWORK

In this study, we suspected that the energy insecurity of households is likely to exert a direct impact on food consumption and the education expenditure/consumption for children. Based on the above-conceptualized energy insecurity, we can write the following:

$$P(Y_i = 1) = I(Y_i = E > 10\%) \text{ if energy insecurity;}$$

$$P(Y_i = 0) \text{ otherwise.}$$

where  $E$  is the share of energy expenditure in the total expenditure,  $I(.)$  is an indicator function that takes the value of  $\{1\}$  if the bracketed expression is true and the value of  $\{0\}$  otherwise. Then  $I(.)$  equals the value of  $\{1\}$  and we can consider the household to be energy insecure.

Thus, the incidence of energy insecurity is:

$$Energy\ Insecurity_i = \frac{1}{N} \sum_{i=1}^n [I(Y_i = E > 10\%)]$$

We can apply a similar approach to household energy insecurity using electricity consumption with the threshold of 50 kWh/month or 600 kWh/year. Having determined the energy insecurity indicator, it is very important to investigate whether it has any impact on households' welfare.

The hypothesis showed that energy insecurity is likely to have a substantial impact on households' welfare, including the food consumption, education, and health of the individuals in the household. To investigate energy insecurity in relation to households' welfare, we construct two structural equations. The right-hand side of the first structural equation uses the independent variable "energy insecurity" explicitly, as it will affect households' welfare. In the second structural equation, the right-hand side variable, "share of energy expenditure in total expenditure," is used to investigate the magnitude of the impact. Thus, the model specification can be written as:

$$Welfare_i = \alpha_0 + \beta_1 Energy\ Insecurity_i + \beta_2 X_i + U_{i1} \quad \text{Eq. (1)}$$

$$Welfare_i = \alpha_0 + \beta_1 Share\ of\ Energy\ Expenditure_i + \beta_2 X_i + U_{i1} \quad \text{Eq. (2)}$$

where "welfare" is the dependent variable representing a household's food consumption, education consumption/expenditure, children's schooling outcome, and health outcomes. The proxy variable "schooling outcome" is an index of the Schooling Attainment Relative to Age (SAGE) variable (Han & Kimura, 2019). The SAGE index is simply derived from the equation below:

$$SAGE = \left( \frac{Years\ of\ schooling}{Age - Age\ of\ School\ Entry} \right) \times 100$$

The higher the index, the better children's schooling outcome.

## 6. DATASET AND VARIABLES

The study uses the 2015 CSES dataset for analysis. CSES is a survey of households and their members regarding housing conditions, education, economic activities, production and income, level and structure of consumption, health, victimization, vulnerability, energy source and consumption, and so on. The National Institute of Statistics opens the CSES database to external researchers for research and analysis; in 2015, it comprised 3,840 households. The key variables of interest for the investigation include "energy insecurity" and "welfare," which are the "health outcome," "school outcome," "earning outcome," and "hours worked of children" variables. The variable "energy insecurity" is derived from the probability function based on several criteria, as the methodology described. Table 1 presents the other household and community characteristics.

**Table 1: Description of the Variables**

Name of Variable	Description of Variable	Mean Statistics
Log household food consumption	Logarithm of household food consumption in the past 12 months (KR)	15.99678

Log household education consumption/expenditure	Logarithm of household education/expenditure in the past 12 months (KR)	13.39273
Share of energy expenditure in total expenditure	Share of energy expenditure in total expenditure (percentage)	6.129855
Household size	Household size	4.506642
Log household's income	Logarithm of household's income in the past 12 months	16.4995
Electricity access	=1 if household has electricity access; =0 otherwise	.7272017
Without piped water access	=1 if without piped water access; =0 otherwise	.0080771
Without tubed well access	=1 if without tubed well access; =0 otherwise	.2342366
Household head with no education	=1 if household head has no education; =0 otherwise	.1802553
Household head with incomplete primary education	=1 if household head has incomplete primary education; =0 otherwise	.4464704
Household head with complete primary education	=1 if household head has completed primary education; =0 otherwise	.1875488
Household head with upper-secondary education	=1 if household head has upper-secondary education; =0 otherwise	.0255275
Household head with university education	=1 if household head has a university degree; =0 otherwise	.041417
Electricity consumption per capita	Electricity consumption per capita (kWh/capita/year)	252.5145
Female household head	=1 if female household head; =0 otherwise	.756968
Rural	=1 if rural; =0 otherwise	.5965095

KR = Cambodian riel.

Source: 2015 Cambodia Socio-Economic Survey.

## 7. RESULTS AND DISCUSSION

Based on the definition provided, the study estimates that 27% of the total households remain energy insecure. However, when broken down into on-grid and off-grid groups, 13% of the households connected to the grid still face energy insecurity, while 32% of the households living off-grid face energy insecurity (Table 2).

To investigate the main hypothesis, the study regresses the households' food consumption and education expenditure/consumption on the share of energy expenditure in the total expenditure and on sets of household and community characteristics (Tables 3 and 4). It is possible to interpret the results of the coefficient estimates as follows.

**Table 2: Prevalence of Household Energy Insecurity by Off-Grid and On-Grid Electricity**

	Households with Energy Security (Frequency and Percentage)	Households with Energy Insecurity (Frequency and Percentage)	Total
On-grid	914 87.30%	133 12.70%	1,047 100%
Off-grid	1,898 68.00%	893 32.00%	2,791 100%
Total	2,812 73.27%	1,026 26.73%	3,838 100%

Source: Author's calculation.

***The impact of energy insecurity on welfare, such as food consumption and education expenditure for children:*** The coefficient estimates of the share of energy expenditure in the total expenditure in Table 3 show that a household is likely to reduce its food consumption by about 4.1% for every 1% increase in the share of energy expenditure in the total expenditure. This means that every percentage point of energy expenditure will influence a household's food consumption substantially. As the data indicate, this will further affect the general household health, especially that of the children and elderly persons living in the household. Likewise, the coefficient estimates for the "share of energy expenditure in total expenditure" in Table 4 show that households are likely to reduce their education consumption/expenditure by about 5.8% for every 1% increase in the share of energy expenditure in the total expenditure/consumption. This means that every percentage point of energy expenditure will affect the household's education consumption/expenditure substantially.

Again, energy insecurity is likely to reduce a household's food consumption by about 38% compared with households that are energy secure. Likewise, energy insecure households are likely to reduce their education expenditure by 26% as compared with energy secure households. Thus, the impacts of energy insecurity are enormous, as they affect direct food consumption and education expenditure, which are fundamental to support the growth and human capital formation of children.

There is a belief that less spending on education and less food consumption in households will further influence children's performance at school, especially their human capital formation. Therefore, the regression results in Table 5 show that every percentage increase in the "share of energy expenditure in the total expenditure" is likely to reduce the children's SAGE index by 47%.

***The impact of a household's income on welfare, such as food consumption and education expenditure for children:*** The coefficient estimates of a household's income show that food expenditure is likely to increase by about 7% for every doubling of a household's income; similarly, education consumption and expenditure are likely to increase by about 17%. Thus, the impact of a household's income has a direct benefit for the welfare of the household.

***The impact of a household head's education on welfare, such as food consumption and education expenditure for children:*** The coefficient estimates of a household head's completion of university has a positive impact on both food consumption (a 6% increase) and education expenditure/consumption (a 20% increase).

**Table 3: Regression Coefficient Estimates of Food Consumption**

Dependent Variable “Log Household Food Consumption”	Multiple Regression Model (a)	Multiple Regression Model (b)
	Coefficient	Coefficient
Energy insecurity of household	None	-.3871497*** (.0321373)
Share of energy expenditure in total expenditure	-.0413496*** (.0081013)	None
Household size	.126217*** (.0050765)	.1115705*** (.0047435)
Log household's income	.0720751*** (.0093409)	.1010312*** (.0095474)
Electricity access	.0819193*** (.0145262)	.0762213*** (.0150818)
Without piped water access	-.1786928*** (.0529703)	-.2073098** (.0637238)
Without tubed well access	-.0935054*** (.0133904)	-.1066915*** (.0140031)
Household head with no education	-.1081735*** (.0220311)	-.1493641*** (.023567)
Household head with incomplete primary education	-.0766681*** (.0196922)	-.1048406*** (.0207686)
Household head with complete primary education	-.0120718 (.0202931)	-.0290963 (.0223665)
Household head with upper-secondary education	-.0264382 (.0387978)	-.0040873 (.0420527)
Household head with university education	.0626308** (.036567)	.1151599** (.0353296)
Electricity consumption per capita	.0009257*** (.000142)	.0003998*** (.0000859)
Female household head	.0864377*** (.0139653)	.0854652*** (.0144705)
Rural	-.137467*** (.0144018)	-.1628727*** (.0160552)
Constant	14.29294*** (.1479394)	13.84663*** (.1443285)

(a) The regression model includes the independent variable “share of energy expenditure in total expenditure.”

(b) The regression model includes the independent variable “energy insecurity of the household.”

Goodness of fit:

Number of obs. = 1,155; F(14, 1,140) = 26.57; Prob>F = 0.0000; R-squared = 0.2471; Root MSE = 1.105.

Source: Author's calculation.

The impact of other household and community characteristics on welfare, such as food consumption and education expenditure for children: Among other household characteristics, size has a direct impact on the food consumption and education of children. The characteristics of the community, such as households living in a rural area, seem to have a negative impact on food consumption as well as education expenditure. This result indicates that households spend less on food and children's education if they live in a rural or remote area. The result also points to the fact that households living in rural areas engage in a subsistence economy in which their labor is not counted and they make their own living by farming.

The results also show that a household head who has a university degree has substantial positive impacts on a household's food consumption and education expenditure. Likewise, a household head with just primary education or less has negative impacts on food consumption and education expenditure. This is self-evident, because education is crucial to a household's ability to earn an income, and it further affects its purchasing power.

Finally, other community characteristics, such as electricity access and access to water sources, such as piped or tubed wells, are keys to a positive impact on households' welfare. Access to electricity and water sources represents the impact of infrastructure on welfare.

**Table 4: Regression Coefficient Estimates of Education Consumption/Expenditure**

Dependent Variable "Log Household Education Consumption/Expenditure"	Multiple Regression Model (a)	Multiple Regression Model (b)
	Coefficient	Coefficient
Energy insecurity of household	None	-.2621564** (.124238)
Share of energy expenditure in total expenditure	-.0585014*** (.0130137)	None
Household size	.0965153*** (.0278622)	.079152** (.0266817)
Log household's income	.1666177*** (.0484125)	.2035521*** (.0455854)
Electricity access	.2905582*** (.1107727)	.2782467** (.1121011)
Without piped water access	.2213673 (.3583839)	.1756231 (.3712069)
Without tubed well access	.0945942 (.0918691)	.0902604 (.0931144)
Household head with no education	-.6045892*** (.1477813)	-.6577931*** (.1492502)
Household head with incomplete primary education	-.3900032*** (.0949524)	-.4435312*** (.0968051)
Household head with complete primary education	-.0935535 (.0977389)	-.1159162 (.100138)
Household head with upper-secondary education	-.0713393 (.1437776)	-.0661887 (.1488217)
Household head with university education	.2170157 (.1482588)*	.3188259** (.1445511)
Electricity consumption per capita	.0015156*** (.0004294)	.0007297** (.0002679)
Female household head	.1336658 (.0829068)	-.1501823* (.0850642)
Rural	-.5287331*** (.078998)	-.5313*** (.0800466)
Constant	10.29859*** (.7414394)	9.711694*** (.712983)

(a) The regression model includes the independent variable "share of energy expenditure in total expenditure."

(b) The regression model includes the independent variable "energy insecurity of the household."

Goodness of fit:

Number of obs. = 1,155; F(14, 1,140) = 27.92; Prob>F = 0.0000; R-squared = 0.2739; Root MSE = 1.0851.

Source: Author's calculation.

**Table 5: Regression Coefficient Estimates of Schooling Attainment Relative to Age (SAGE)**

Dependent Variable “SAGE”—An Index of Schooling Attainment Relative to Age	Multiple Regression Model (a)	Multiple Regression Model (b)
	Coefficients	Coefficients
Energy insecurity	None	–2.06767** (1.049695)
Share of energy expenditure in total expenditure	–.4792831*** (.1270687)	None
Without piped water access	1.160382 (5.151614)	–1.407132 (5.177143)
Without tubed well access	2.150683 (1.365153)	1.960529 (1.36468)
Household head with no education	–13.5516*** (1.971471)	–14.24124*** (1.973232)
Household head with incomplete primary education	–9.285921*** (1.562142)	–9.720728*** (1.563496)
Household head with complete primary education	–1.226556 (1.690172)	–1.444921 (1.70026)
Household head with upper-secondary education	2.440661 (2.553496)	2.665434 (2.58741)
Household head with university education	11.25608*** (2.553982)	12.80953*** (2.523761)
Electricity consumption per capita	.014578*** (.0030274)	.0067002** (.0029038)
Female household head	.3292066 (1.288788)	.3081961 (1.288737)
Rural	–4.979571*** (1.212425)	–5.220719*** (1.227291)
Constant	82.81464*** (1.957626)	82.4632*** (1.983757)

(a) The regression model includes the independent variable “share of energy expenditure in total expenditure.”

(b) The regression model includes the independent variable “energy insecurity of the household.”

Goodness of fit:

Number of obs. = 3,837; F(14, 3,822) = 208.74; Prob>F = 0.0000; R-squared = 0.4795; Root MSE = .3566.

Source: Author’s calculation.

## 8. CONCLUSION AND POLICY IMPLICATIONS

Research has widely investigated energy security from the supply side perspective, whereby leaders try to secure energy supplies and reduce the dependency on fossil fuel imports. Generally, leaders try to build an energy policy framework that shields countries from supply disruption risks. However, energy insecurity occurs when households are deprived of the energy needed to meet their basic minimum requirements for cooking, lighting, and heating/cooling. Since the concept of energy insecurity fluctuates, the study adopted a 10% share of energy consumption in the total expenditure as the threshold for household energy insecurity. With this definition, it estimated the national incidence of energy insecurity to be about 27% of the total households in Cambodia. The study further separated the incidence of energy insecurity into off-grid and on-grid households. The result shows that about 13% of the households connected to the grid still face energy insecurity and about 32% of the households living off-grid face energy insecurity.



The major findings about household food consumption show that it is likely to decrease by about 4.1% for every 1% increase in the share of energy expenditure in the total expenditure, with education consumption/expenditure similarly declining by about 5.8%. Energy insecure households consume about 38% less than energy secure ones and are likely to spend 26% less on education. Thus, the impacts of energy insecurity are enormous. The study further found that every percentage point increase in the share of energy expenditure in the total expenditure is likely to reduce children's school performance by 47%.

For every doubling of a household's income, the study found that it increases food expenditure by about 7%, and the expectation is that education consumption and expenditure will similarly increase by about 17%. Thus, a household's income has a direct link to its welfare. The household head's completion of university has a positive impact on both food consumption (a 6% increase) and education expenditure/consumption for children (a 20% increase). Among other household characteristics, size has a direct impact on food consumption and education expenditure, while residency in a rural area seems to have a negative impact. The other community characteristics, such as access to electricity and water sources, represent the positive impact of the infrastructure on household welfare.

Thus, this study confirmed that energy insecurity has an enormous negative impact on households and the human capital formation of children. The above findings imply the following:

- **Welfare impacts:** policy makers will need to identify households with energy consumption that is insufficient to meet their basic needs. Having identified them, the appropriate energy policy should target those vulnerable households to support them in having sufficient energy. Electricity access is the first priority, followed by a subsidy. In addition, the policy needs to address off-grid and on-grid families differently.
- **Infrastructure:** Access to electricity, piped water systems, and other infrastructure are fundamental to increase households' opportunities and income. Nonetheless, access to electricity is the first step for households to consume clean electricity in comparison with biomass or kerosene for heating and lighting. Thus, policy makers will need to find appropriate policies to ensure that households are connected to the electrical grid as quickly as possible. While the development of the power grid and distribution will remain slow due to investment patterns, other measures, such as rooftop solar photovoltaics, solar farms, and stand-alone small generators, will provide fast access for remote areas. The government will need to design policies to support these distributed energy systems to support the investment in this area.
- The government may need to review the current policy of subsidies for households with electricity consumption that is below 50 kWh/month, as this threshold is too low to meet their basic needs. The threshold could increase up to double in the first step and then the government can check how it affects the households' welfare. Thus, further study will be necessary to determine how much subsidy the government can afford and the extent to which the subsidy could have a positive long-term impact on household welfare.

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