Residential energy demand in rural Cambodia:

An empirical study for Kampong Speu and Svay Rieng

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UNDP Cambodia

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UNDP CAMBODIA ENERGY AND ENVIRONMENT PROGRAMME

Rural energy preparatory assistance project

Background:

Cambodia is an agricultural country. More than 85 percent of Cambodians live in rural areas with agriculture as their primary livelihood, including farming, fishing, raising livestock, and harvesting forest and non-forest products. Most poor rural families rely on firewood for cooking. Increasing time is needed to collect scarce firewood and indoor smoke pollution is a burden for rural women. The pressure on forest resource depletion continues. Less than 20 percent of rural households have access to grid-quality electricity services. Almost all people in rural areas use firewood for cooking, kerosene for lighting, and lead-acid rechargeable batteries for household appliances. Energy use is inefficient, inconvenient, costly and environmentally unsustainable. Inefficient use of batteries and kerosene are the other main energy sources for rural families.

Purpose:

The preparatory activities aim to establish a systematic data monitoring system for rural energy and to formulate a full size project to develop rural livelihoods through improved access to sustainable energy services. Access to sustainable energy will be critical for Cambodia to reach the Millennium Development Goals as well as the targets set in the National Strategic Development Plan for the reduction of fuel wood dependency and poverty. To plan an effective intervention for rural energy development, systematic baseline data for monitoring needs to be in place. A rural energy balance sheet will capture the demand and supply of rural energy services and can be used as an effective tool to formulate a rural energy development strategy at both national and provincial levels.

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ACRONYMS AND ABBREVIATIONS

ADB	*Asian Development Bank*
BAU	*Business as Usual*
CPAP	*UNDP Country Programme Action Plan*
DIME	*Department of Industry, Mines and Energy*
EC	*European Commission*
EdC	*Electricité du Cambodge* (Electricity of Cambodia)
EDFM	*Energy Demand Forecasting Model*
GDP	*Gross Domestic Product*
GERES	*Groupe Energies Renouvelables, Environnement et Solidarités* (Group for Renewable Energy, Environment and Solidarity)
GJ	*Giga Joule = 1000 Mega Joules*
JBIC	*Japanese Bank for International Cooperation*
JICA	*Japan International Cooperation Agency*
kWh	*Kilowatt Hours*
LEAP	*Long Range Energy Alternative Planning*
LPG	*Liquified Propane Gas*
MDG	*Millennium Development Goals*
MIME	*Ministry of Industry, Mines and Energy*
NGO	*Non-Governmental Organization*
NIS	*National Institute for Statistics*
NSDP	*National Strategic Development Plan, 2006 - 2010*
REE	*Rural Electricity Enterprise*
REP PoR	*Regional Energy Programme for Poverty Reduction*
RGC	*Royal Government of Cambodia*
SME	*Small and Medium Scale Enterprises*
TJ	*Tera Joule = 1000 Giga Joules*
UNDAF	*United Nations Development Assistance Framework*
UNDP	*United Nations Development Programme*
WB	*World Bank*

FOREWORD

For the past decade, there has been mounting pressure on Cambodia's rural households, which struggle to cope with the depletion of traditional biomass energy sources and increasing costs for fuels such as kerosene and diesel. Although considerable progress has been made to expand electrification into rural areas, a large segment of our rural households remain without electricity and rely on energy forms that are inefficient and pollute the domestic environment. Lack of modern energy is closely linked to rural poverty and lack of opportunities for our population in rural and remote areas.

With financial support from the United Nations Development Programme (UNDP), the Ministry of Industry, Mines and Energy (MIME), with technical assistance from the international non-governmental organisation (NGO) *Groupe Energies Renouvelables, Environnement et Solidarités* (Group for Renewable Energy, Environment and Solidarity – GERES), Cambodia launched a project in 2006 entitled "Preparatory Activities for a Rural Energy Development Program". The project included a study on rural household energy demands. This report confirms with detailed data that meeting their basic energy needs is a daily struggle for many families in rural areas. Most families have neither electricity nor gas for lighting and cooking. Rural inhabitants often spend hours each day gathering wood and other biomass. These hours might otherwise be spent on productive rural business, agriculture or learning. Indoor pollution through open fires is a serious health hazard. At the same time, forest resources are under ever increasing pressure from firewood extraction and charcoal production.

Based on the results of this study, we now have to take up the challenge and use the insights gained. Together with UNDP and other development partners, we have to move ahead and simultaneously improve the policy framework for rural energy while developing and implementing projects.

I would like to thank UNDP for its valuable support to the study and ensure that the Ministry will fully support the development of the programme that UNDP is developing in cooperation with other donors to improve rural households' access to more modern, sustainable and efficient rural energy services at an affordable price to all, including the poor.

H.E. Tun Lean
Director General
Ministry of Industry, Mines and Energy

1. INTRODUCTION

Cambodia has a low electrification rate and high electricity costs.

1.1 Background

More than 85 percent of Cambodians live in rural areas with agriculture as their primary means of livelihood. Rural families in Cambodia make a living from farming, fishing, livestock, and harvesting forest and non-forest products. Since the end of internal conflicts in 1991, Cambodia has made important progress in ensuring peace and security, rebuilding institutions and infrastructure, establishing a stable macroeconomic environment, and putting in place a liberal investment regime. In spite of these achievements, rural development remains a major challenge. With a per capita Gross Domestic Product (GDP) of approximately US$571 in 2007, Cambodia remains one of the poorest countries in the world. Poverty is still widespread, particularly in rural areas. In 2004 it was estimated that 34.7 percent of the population lived below the poverty line, although that number is down from 47 percent ten years ago as a result of the RGC's poverty reduction strategy. Inequality appears to be increasing and recent economic expansion has been narrowly based. Economic growth has not led to a significant reduction in rural poverty. Against this background, it has been widely acknowledged by the Royal Government of Cambodia (RGC) and development partners that development progress in Cambodia will depend on achievements in rural areas.

Rural development requires opportunities for income generation and the provision of infrastructure such as roads, safe water supplies and affordable energy. While progress has been made in recent years in the area of rural infrastructure, Cambodia has one of the lowest electrification rates in Asia (less than 20 percent of households have access to grid electricity) and has among the highest electricity costs in the region (US$0.35-0.90/kWh).

1.2 Energy policy framework of the RGC

Access to sustainable energy services is a critical element for Cambodia to reach the Millennium Development Goals (MDGs) as well as the targets set in the National Strategic Development Plan, 2006-2010 (NSDP) for the reduction of fuel wood dependency and poverty. Rural energy development supports all four pillars of growth in the RGC's Rectangular Strategy: agricultural productivity, promotion of small and medium scale enterprises (SMEs), energy infrastructure development and greater gender equity. In its Rectangular Strategy the RGC has acknowledged the link between poverty alleviation and energy supply.

In 1999, the RGC approved the Cambodia Power Sector Strategy 1999-2016. The objectives of this policy are:

1. to provide an adequate supply of energy throughout Cambodia at reasonable and affordable price;
2. to ensure a reliable, secure electricity supply at prices, which facilitate investment in Cambodia and development of the national economy;
3. to encourage exploration and environmentally and socially acceptable development of energy resources needed for supply to all sectors of the Cambodian economy;
4. and to encourage efficient use of energy and to minimize detrimental environmental effects resulting from energy supply and use.

Based on this Power Sector Strategy, the RGC approved in 2006 the Rural Electrification by Renewable Energy Policy as an integral part of the Government's overall agenda for the Energy

Sector. The main objective of this policy is to create a comprehensive enabling framework for renewable energy technologies to increase access to electricity in rural areas. The policy acknowledges the Master Plan Study on Rural Electrification by Renewable Energy in the Kingdom of Cambodia as the guiding document for the implementation of projects and programs. The Master Plan envisions: 1) To achieve the 100 percent level of village electrification including battery lighting by 2020; 2) To achieve the 70 percent level of household electrification with grid quality electricity by 2030. While the policy framework for rural electrification is quite comprehensive, there is a policy gap with respect to other types of energy that are essential for the rural population. In other words, cooking energy that is supplied by biomass, or fuels such as Liquified Petroleum Gas (LPG) is not yet covered by a specific policy.

Donors such as the World Bank (WB), Asia Development Bank (ADB), Japanese Bank for International Cooperation (JBIC), Japan International Cooperation Agency (JICA) and, more recently, UNDP have pledged to support the strategic energy sector goals of the RGC.

1.3 UNDP's country strategy and rationale for involvement in energy

In recognition of the daunting problems of rural energy, UNDP Cambodia has included the energy sector in the current Country Programme Action Plan (CPAP) that outlines the cooperation between the two partners from 2006 until 2010. UNDP sees rural energy as a logical expansion of the organization's traditional support for a variety of rural development initiatives over the last 15 years. Rural energy also has multiple linkages to the approved United Nations Development Assistance Framework 2006-2010 (UNDAF) which, in turn, is consistent with the Government's Rectangular Strategy and with its NSDP covering the same period. The UNDAF identifies four major priorities where the UN can make a significant contribution:

1. good governance and human rights,
2. agriculture and rural poverty,
3. capacity building and human resource development, and
4. support for the design and implementation of the NSDP.

In recent years UNDP Cambodia has established itself as one of the key partners supporting the RGC in its efforts to establish conditions for sustainable rural development, economic growth and poverty alleviation. Given the close link between rural development and sustainable energy supply UNDP, in consultation with the RGC, decided to launch a rural energy initiative. This new initiative will contribute to achieving the NSDP macro indicators, especially Indicator 25: reduction of fuel wood dependency of households.

UNDP, in partnership with other donors, is recognized and accepted in Cambodia as a key catalyst for rural development and poverty alleviation. The key value-added stems from UNDP's ability to promote a policy framework that can facilitate integrated rural development solutions with energy as a theme that cuts across sectors such as agriculture, infrastructure, health, education and rural business development. Given the importance of securing rural energy services, UNDP Cambodia took a first step in developing a rural energy program with participation in the Regional Energy Program for Poverty Reduction (REP-PoR), which seeks broad-based interventions to improve access to energy services, promote efficient use of energy and increase access to financing for sustainable energy. The regional process was followed by country-level stakeholder consultations with both government and civil society to determine specific energy-poverty linkages and related gaps, and to suggest mechanisms and modalities to close them. The REP-PoR analysis revealed that the lack of a pro-poor vision framework hampers the effectiveness of the ongoing energy programs in meeting overall socioeconomic development goals. This is exemplified by inadequate program focus on energy sources other than grid electricity, while it is clear that a large portion of Cambodia's rural population will not enjoy grid access in the foreseeable future.

Charcoal production, and the ensuing deforestation in Kampong Speu, threatens the Aural Wildlife Sanctuary.

Following participation in the regional REP-PoR, UNDP Cambodia launched the national initiative 'Preparatory Activities for a Rural Energy Development Program'. While at the national level considerable work has been done in the area of energy policy development, strategic planning and capacity development, comprehensive planning efforts have not been made to reach out to the communes and villages where pro-poor rural energy projects need to be planned and implemented. As part of the preliminary rural energy activities, this study aims at providing empirical data and baseline information that allow effective planning of rural energy projects and efficient monitoring of their results.

1.4 Objectives

The objective of the study presented here is to provide a framework exploring options with the government, donors and other development partners for Cambodia's future directions in rural energy development. Collection and analysis of energy supply and demand data for two pilot provinces provide a profile of existing conditions in the rural energy sector, and highlight areas for priority attention to achieve sustainable energy supply. These priorities include enabling the energy sector to expand its contribution to rural incomes and employment. The baseline data compiled will also allow better design, planning, and implementation and monitoring of rural energy projects. The study is not a stand-alone exercise in social research. It provides the basis for the development of a major rural energy project that UNDP intends to implement together with the RGC and other development partners.

1.5 Approach and methodologies

The study presented here was undertaken by the Ministry of Industry, Mines and Energy (MIME) with funding support from UNDP and technical assistance provided by the international NGO GERES (*Groupe Energies Renouvelables, Environnement et Solidarités* – Group for Renewable Energy, Environment and Solidarity). A multidisciplinary team performed a variety of tasks over

a period of approximately 12 months. The study explores empirically and conceptually the connections between energy supply and demand and poverty in Cambodia. It aims to show that securing a sustainable energy supply should be considered a core component of any rural poverty alleviation strategy. It emphasizes how and why rural energy interventions must be carefully designed to consider poverty concerns. Thus, the methodology aims to capture the relationship between access to modern energy, affordability and the potential of income generation through energy-related rural activities. The study's ultimate goal is to lay the groundwork for the design of a poverty-oriented rural energy project that would be supported by the RGC, UNDP and a variety of other partners. Under the activity 'Preparatory Activities for a Rural Energy Development Programme', all necessary primary and secondary data have been collected to assess residential rural energy demand with the view to formulate a 'Rural Energy Development Project'. Survey work for this study was accompanied by training of local staff in data management. Capacity development included practical training of MIME staff in the General Department of Energy and staff in the provincial Departments of Industry, Mines and Energy (DIME) in Kampong Speu and Svay Rieng.

This publication is the result of a combination of field research, desk studies, policy analysis, capacity development efforts and stakeholder consultations. Empirical work was based on surveying a sample of households using questionnaires. The study also reflects the contributions of government staff, policymakers, academics and community representatives. The National Institute of Statistics (NIS) analyzed existing secondary data. Various national surveys that have been executed by NIS since 1993 were used to identify trends and cross-check empirical data. Based on these data, energy trends have been derived showing changes in energy use patterns for Phnom Penh, and provincial urban and rural areas.

Survey teams visited households in Kampong Speu and Svay Reign to collect data on rural energy use.

Field research has been conducted in two provinces: Kampong Speu and Svay Rieng. A total of 2,159 households were randomly selected and interviewed about energy use for cooking, lighting and other appliances (e.g., rice cooker, radio/TV). Prior to field research, surveyors were trained. The survey teams spent three weeks in each province. The level of confidence of

the sample size is more than 95 percent, and 1,050 households in Kampong Speu and 1,109 in Svay Rieng were surveyed with respect to their energy use. Table 1 displays the sample sizes used for the household survey. It should be noted, however, that accurate measurement of the units in which energy is used can be critical to data quality. The difficulty of accurately capturing this information varies substantially across energy forms. Some are measured in formal scientific units such as kg LPG or kWh of electricity. However, respondents often think more in terms of wood bundles or in terms of cylinders and bottles in which a fuel is sold. Kerosene, for example, is regularly sold in a variety of bottles having different contents. The wood consumption figures in particular involve a considerable uncertainty. This problem was overcome by providing the enumerator with scales so that they could measure fuel wood samples and ensure that the correct weight was entered.

Securing a sustainable energy supply should be considered a core component of any rural poverty alleviation strategy.

A distinction between urban and rural households was also made. The percentages of urban and rural households in the sample were defined according to the statistics on urban and rural households in the NIS database. The data were analyzed with the statistical software SPSS and further energy specific calculations and simulations were performed using spreadsheet software and the software tool Long Range Energy Alternative Planning (LEAP). The LEAP system is a Windows-based software system for energy and environmental policy analysis. It is widely used for integrated energy planning and climate change mitigation analysis and has been applied in hundreds of different organizations in over 140 countries. LEAP is developed and supported by the U.S. Center of the Stockholm Environment Institute, a non-profit research institute based at Tufts University in Somerville, Massachusetts.

Table 1 Household and sample size in selected provinces

	Urban households	% Urban	Rural Households	% Rural	Total
Total Cambodia	382,114	15%	2,217,054	85%	2,599,168
Kampong Speu	8,875	6%	128,253	94%	137,128
Sample Size	62	6%	988	94%	1,050
Svay Rieng	3,517	3%	9,522	97%	113,039
Sample Size	138	12%	971	88%	1,109

The rationale for selecting the two provinces was based on a variety of considerations:

- First, the two provinces cover all three topographical zones found in Cambodia and their associated agro-ecological characteristics: alluvial plains, undulating terrain and mountainous areas.
- Second, the provinces represent different endowment levels with respect to natural resources. While Svay Rieng represents a typical lowland paddy rice-producing area with a high population density and very little in natural forest resources, Kampong Speu shows significantly more diversification in economic activities including forest products, palm sugar and wine. Serving the urban charcoal markets, Kampong Speu is an energy exporter, while resources in Svay Rieng are insufficient to satisfy the province's wood fuel needs. Both provinces require support to ensure a sustainable energy supply.

While the study's main goal is to establish baseline data for project preparation and monitoring, the study also extrapolates findings to the national scale. Based on the data in Kampong Speu and Svay Rieng the total energy demand in Cambodia is projected and forecast. The forecast is based on historic trends established by the NIS and empirical data from the survey. Forecasting rests on the assumption that rural areas will gradually follow the energy development path of provincial urban centres, and provincial urban areas that of the Phnom Penh area. In addition to the statistical analysis, a detailed study on wood and charcoal flow to Phnom Penh and wood and charcoal production was conducted in Kampong Speu. Data was gathered by monitoring trucks and interviewing 130 wood and charcoal producers.

Data collected in interviews established a baseline for project preparation and monitoring, as well as allowing the findings to be extrapolated to a national scale.

2. SURVEY RESULTS

Given the role that energy services play in poverty reduction, the RGC desires to implement policies and allocate resources that will accelerate the transition from the use of traditional biomass fuels to clean modern fuels and electricity. As a consequence, policymakers increasingly seek empirical evidence of the relationship between investments made in energy supply infrastructure, the energy policies they implement, and tangible improvements at the household level. The survey results discussed below provide such evidence.

2.1 The provinces of Kampong Speu and Svay Rieng

Administratively, Cambodia is divided into 24 Provinces (including four municipalities). At the next level there are 183 districts, then approximately 1,600 communes, and 13,400 villages. In rural areas, there are typically eight villages in each commune, with approximately 150 households in each village. In the rural area, the average household size is 5.2 occupants. Both Kampong Speu and Svay Rieng are classified as rural provinces. With respect to their resource endowment, their agricultural production and their energy economy, the two provinces show significant differences. Table 2 summarizes key data on the two provinces.

Table 2 Key features of the surveyed provinces

Feature	Kampong Speu	Svay Rieng
Total Population	714,000	532,000
Number of Households	138,000	110,000
Surface Area km2	7,017	2,966
Population Density persons/km2	102	180
Average Household Size	5.2	4.8
Number of Districts	8	7

Kampong Speu

Kampong Speu is located to the west of Phnom Penh. It borders Kampong Chhnang and Pursat to the north, Phnom Penh to the east, Kampot and Takeo to the south and Koh Kong to the west. The area of the province is 7,017 square kilometres. Kampong Speu's topography is variable, from a large area of lowland paddy fields in the east to lowland and upland forested areas in the west. These forest areas provide the feedstock for the province's important charcoal production. Cambodia's highest mountain, Phnom Aural, is located here. In 2004 the estimated population was 714,000. The population of children aged under-five-years was 95,000, which was 13 percent of the total provincial population (NIS 2004). The total number of households in 2004 was 138,000, giving an average household size of 5.2 persons.

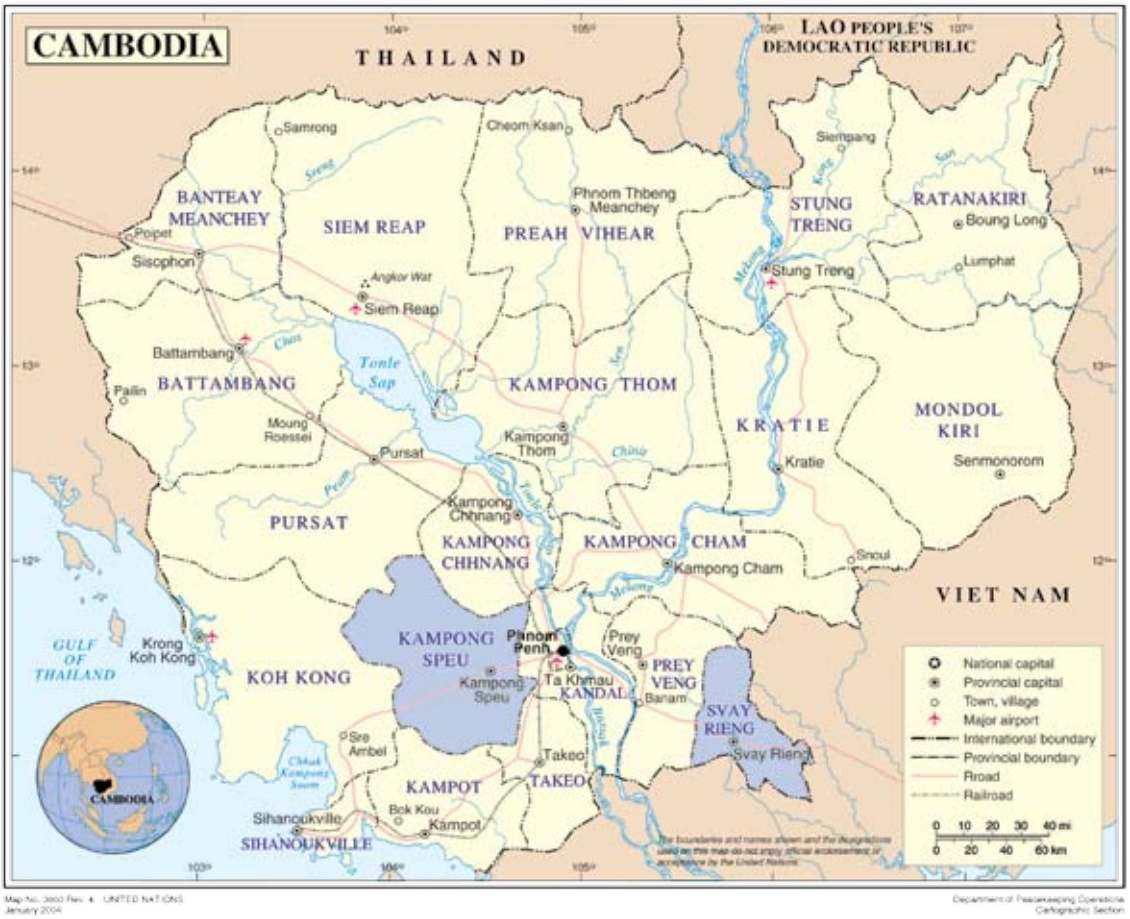
The people of Kampong Speu live in eight districts composed of 87 communes and 1,358 villages. The population density of the province is 102 persons per square kilometre compared to an average population density for Cambodia of 75 per square kilometre. In Kampong Speu the rice balance falls far below the minimum rice food needs of the population. Among the communes of the province, only 9 percent of communes produce enough rice to meet minimum food needs, while 91 percent produce less than minimum food needs.

Svay Rieng

Svay Rieng is located in southeastern Cambodia. The entire province is in the low-lying alluvial plain, which comprises about 25 percent of Cambodia's total area. It borders Kampong Cham to the north, has a long border with Vietnam from east to south, and borders Prey Veng to the west. The area of the province is 2,966 square kilometres. The topography is mostly lowland paddy fields. Upland and lowland forests are only found in the northern district of Romeas Hek. In 2004 the estimated population was 532,000. The population of children aged under-five-years was 57,000 thousand, which was 11 percent of the total provincial population. The total number of households in 2004 was 110,000, giving an average household size of 4.8 persons.

The people of Svay Rieng live in seven districts composed of 79 communes and 690 villages. With 180 persons per square kilometre, the province is comparatively densely populated. The high population density and the lack of forest resources in Svay Rieng are responsible for a critical supply situation with respect to biomass supply for energy purposes. With a rice production of 177 percent of its needs, Svay Rieng province produces a significant rice surplus.

Figure 1 Map of Cambodia showing the two pilot provinces



2.2 Social classes

Rural families in Cambodia face numerous challenges and risks that limit rural earnings and social progression. The predominance of subsistence agriculture and dependence on common property natural resources limit incomes, especially for the poorest households. Poor rural

households operate in a risky environment in which the incidence of shocks and crises such as floods, crop and animal losses through disease, health crises, and land grabbing by powerful groups or individuals is high. Low and seasonal agricultural revenues force rural households to continually search for work or other income-generating activities, the majority of which would be temporary and poorly rewarded. Many activities are directly or indirectly related to the rural energy sector, in particular the wood fuel sub-sector. Significant improvements in how natural wood and forest resources are managed are essential to ensure sustainable availability of natural resources.

In order to better understand the rural poverty-energy link and to allow an analysis of rural energy problems from a poverty perspective, the study categorized the surveyed population according to social classes. In line with common practice in rural social surveys, the quality of housing has been used to define four social classes. Figure 2 displays the variety of house types found in rural Cambodia.

Figure 2 House types

In order to rationalize social classes to a manageable number, only four housing categories were used as a proxy for social class. Table 3 displays the social classes together with the number of households that fall into the respective housing categories in each province.

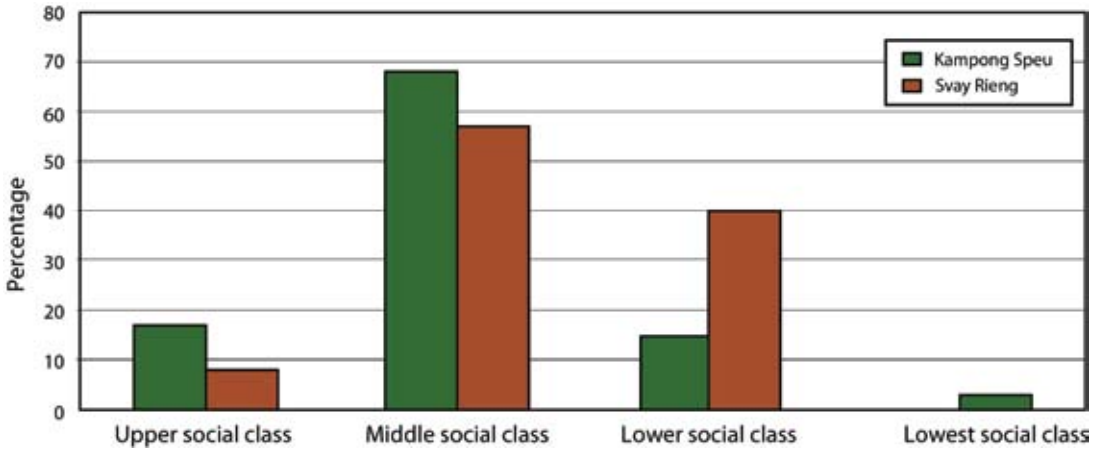
The social class categorization does not provide accurate information on household income. It is, however, safe to assume that there is a strong correlation between housing standard and family income. Interestingly, households had difficulties stating their monthly incomes. The reason may be a combination of a number of factors including unwillingness to disclose income, significant fluctuations in income (as a function of season, harvests, and casual jobs), and a changing variety of income sources.

However, the households were in a position to provide aggregated monthly expenditure figures. With monthly expenditures averaging US$47, Svay Rieng appears to be a poorer province than Kampong Speu where monthly expenditures average US$76. The relative poverty of Svay Rieng is also supported by the lower housing standard found in this province. In Kampong Speu, on the other hand, brick and wood houses were more common and no houses in the lowest housing category were found there (see Table 3 and Figure 3).

Table 3 Sample size social classes

No.	Class	House type	Households Kampong Speu	Households Svay Rieng
1	Upper social class	Brick, brick/wood	161	78
2	Middle social class	Wood + tile/iron/asbestos	652	555
3	Lower social class	Thatch + iron	148	306
4	Lowest social class	Clay + iron/thatch	0	31

Figure 3 Social classes in Kampong Speu and Svay Rieng



2.3 Energy used for cooking

Energy for cooking is the most basic energy need in Cambodia where both urban and rural households still rely on biomass fuels. Exposure to smoke from the burning of traditional fuel wood for cooking increases the risk of disease, most notably acute lower respiratory infection, in both children and adults. Women and children are disproportionately affected because of women's primary role in food preparation and child care, which exposes them to indoor air pollution.

Cooking in urban areas

Urban households typically use several energy sources for cooking. The most common are firewood, LPG, charcoal and electricity, the latter mainly used for rice cooking. The survey results reveal significant differences between the two provinces: in Svay Rieng even the urban households collect most of their firewood themselves; in Kampong Speu most of the firewood demand of urban households is met by purchasing. The user percentages for purchased fuel wood, LPG and electricity for rice cookers are significantly higher in Kampong Speu than in Svay Rieng. The widespread use of electric rice cookers – 60 percent of the urban households in Kampong Speu use these appliances – is another distinguishing feature that underlines the more sophisticated energy economy of Kampong Speu. In Svay Rieng only 13 percent of urban households use electric rice cookers.

Table 4 depicts the urban energy mix used for cooking. The figures illustrate significant differences in the two provinces. In Kampong Speu, 42 percent of the households use commercial firewood. Consumption averages 90 kg per month. LPG use is widespread, with 66 percent of the households using an average quantity of 10 kg per month. Households that use LPG may also use purchased wood and many families also have electric rice cookers. Although 13 percent of urban Svay Rieng households own rice cookers, this appliance is used less frequently there where electricity is relatively cheap. With an average consumption of only four kWh per month, rice cookers would only be used two or three times a week, whereby a consumption of ten kWh in Kampong Speu suggests a much more frequent use of the cookers there.

The results of the survey show clearly that households are using more than one source of energy for cooking. Although Svay Rieng has very little forest resources, even urban cooking is

still dominated by firewood. Thirty percent of the households use commercial firewood and 67 percent of the families collect firewood themselves. Even in the absence of closed forest cover, it seems that the biomass resources of Svay Rieng and its neighbouring provinces are still sufficient to support an energy economy dominated by fuel wood. There are, however, strong indications that the current biomass usage rate is not sustainable in Svay Rieng. While the fuel wood cycle has not been studied in detail, it appears that urban fuel wood demand in Svay Rieng is satisfied by a combination of harvesting of woody biomass (mostly bushes and dead wood from isolated trees) and of wood imports from forested areas in the north of Svay Rieng and from neighbouring provinces. A baseline study for the National Biodigester Program showed that 67 percent of the people collecting firewood had to go further and further every year.

Figure 4 Share of households using particular energy sources

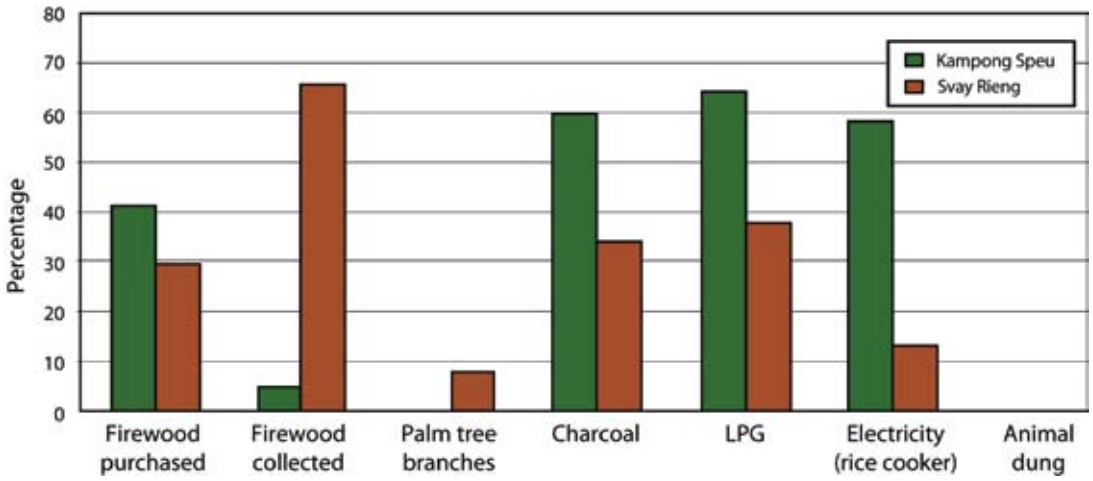


Table 4 Energy sources used for cooking in urban Kampong Speu and Svay Rieng

Urban cooking	Kampong Speu		Svay Rieng	
Energy source	**HH User %**	**Units per HH per month**	**HH User %**	**Units per HH per month**
Firewood purchased	42%	90 kg	30%	147 kg
Firewood collected	5%	40 kg	67%	143 kg
Palm fronds	0%	0	8%	70 kg
Charcoal	61%	28 kg	35%	16 kg
LPG	66%	10 kg	38%	8 kg
Electricity (rice cooker)	60%	10 kWh	13%	4 kWh

Cooking in rural areas

Household energy consumption in rural areas follows a pattern that is similar to cooking practices in urban areas. Table 5 indicates that low cost energy sources are more prominent in both provinces, both in absolute and in percentage terms. Eighty-seven percent of Svay Rieng's rural households use collected firewood. However, with 145 kg, the quantities used per household per month are lower than in Kampong Speu where families that collect firewood consume an average of 175 kg per month. While this finding supports the hypothesis that Svay Rieng faces resource constraints with respect to firewood, the consumption figures for both collected and commercial firewood are still high.

Energy for cooking is the most basic energy need in Cambodia where both urban and rural households still rely on biomass fuel.

User percentages for modern fuels are significantly higher in rural Kampong Speu where 12 percent of the households use LPG and 2 percent use electricity. Charcoal consumption is also significantly more prominent. This higher penetration of modern fuels in Kampong Speu is most probably explained by higher cash incomes of rural households. It could also indicate local shortages of freely accessible firewood. The consumption pattern in Svay Rieng suggests that rural families resort to the collection of any type of biomass to satisfy their cooking needs. The increased use of low-grade fuels, such as palm fronds and animal dung, indicates constraints in the availability of proper fuel wood. Although a small proportion of the families use only animal dung, households that resort to this low-grade fuel use significant quantities (169 kg per household per year). The LPG plus electricity combination, undoubtedly the top combination on the so-called energy ladder, moved from being a prevalent energy mix in urban Kampong Speu to a much lower position in rural areas.

Table 5 Energy sources used for cooking in rural Kampong Speu and Svay Rieng

	Kampong Speu		Svay Rieng	
Energy source	**HH User %**	**Units per HH per month**	**HH User %**	**Units per HH per month**
Firewood purchased	38%	149 kg	13%	148 kg
Firewood collected	53%	175 kg	87%	145 kg
Palm fronds	22%	79 kg	15%	80 kg
Charcoal	24%	37 kg	6%	10 kg
LPG	12%	9 kg	8%	4 kg
Electricity (rice cooker)	2%	9 kWh	0.5%	7 kWh
Animal dung	1%	83 kg	1%	169 kg

2.4 Energy for lighting and appliances

Urban lighting

Urban areas in the two provinces show energy consumption patterns similar to those found in other Asian countries. Besides lighting, a considerable variety of appliances can be found in households ranging from rice cookers to refrigerators, fans, TVs and other electronic equipment including the occasional computer. In both provinces urban electrification rates are high with 98 and 97 percent in Kampong Speu and Svay Rieng respectively. Surprisingly, there is

still widespread use of candles and kerosene, particularly in Svay Rieng where electricity is provided by cross-border connections from Vietnam. Cross-border supply from Vietnam is sold at standard *Electricité du Cambodge* (EDC – Electricity of Cambodia) rates and thus significantly cheaper than Rural Electricity Enterprise (REE) supplied diesel electricity or self-generation.

Although kerosene consumption is rather low in absolute terms, the finding that 40 percent of households in Svay Rieng still use kerosene for lighting is not easy to explain. Lack of reliability and frequent power outages may be one reason for the households to maintain a diversified energy mix. The same reason may be behind the common use of candles in the province. Households in Kampong Speu that are served by REE may have to use candles, batteries and kerosene because electricity is only supplied for a couple of hours each day at a scheduled time. Through the use of kerosene they may also want to save on costs, as REE electricity rates are quite high.

Batteries are still very popular as an electricity source

Table 6 Energy sources used for lighting and other appliances in urban areas

	Kampong Speu		Svay Rieng	
Energy source	**HH User %**	**Unit per HH per month**	**HH User %**	**Unit per HH per month**
EDC (grid electricity)	32%	48 kWh	97%	31 kWh
REE	66%	67.5 kWh	–	–
Own Generator	–	–	–	–
Battery	2%	2.4 kWh	9%	1.8 kWh
Kerosene	8%	1 kg	40%	1.2 kg
Candles	24%	0.6 kg	38%	0.47 kg

Rural lighting in Kampong Speu and Svay Rieng

In the absence of grid supply, rural households in both provinces satisfy their lighting needs using lead acid batteries and kerosene. With only 23 percent and 7 percent of the rural households served by either EDC or REEs, the most prevalent energy mix for rural lighting and appliances is clearly a combination of batteries, kerosene and candles.

Table 7 illustrates that higher electrification rates in Kampong Speu – 27 percent of households have EDC, REE or their own generators – reduces the prevalence of batteries and kerosene. While 62 percent of the Kampong Speu households use batteries, the figure climbs to 84 percent in Svay Rieng where only 7 percent are supplied by grid electricity.

The results also demonstrate the importance of electricity to rural households: in both provinces rural households make sure that they have some access to electricity even if it is only based on 12-volt batteries. Electricity consumption from lead acid batteries averages at 3.8 kWh per months in Svay Rieng. This is a surprisingly high value.

In the absence of grid supply, rural households in both provinces satisfy their lighting needs using lead acid batteries and kerosene.

Assuming that the standard battery holds a usable charge of not more 0.5 kWh, this figure implies that a family in this province buys two battery charges a week. Despite the widespread use of batteries, kerosene is still a very important source for lighting showing user percentages of 62 percent and 75 percent respectively for Kampong Speu and Svay Rieng. This again demonstrates that rural households maintain a portfolio of energy options, probably in an attempt to satisfy energy service needs at a minimum cost.

Table 7 Energy sources used for lighting and other appliances in rural areas

	Kampong Speu		Svay Rieng	
	HH User %	Quantity per HH per month	HH User %	Quantity per HH per month
EDC	2%	27.71 kWh	6%	27.62 kWh
REE	21%	20.57 kWh	1%	11.09 kWh
Own Generator	4%	5.61 kWh	2%	3.07 kWh
Battery	62%	1.38 kWh	84%	3.80 kWh
Kerosene	62%	1.88 kg	75%	1.34 kg
Candles	21%	0.74 kg	9%	0.63 kg

2.5 Energy use by social class

This section explores the relation between energy consumption and the households' social class. Although the survey performed did not include questions with respect to household income, the division of the households into three classes in Kampong Speu and four classes in Svay Rieng can be considered as a proxy for household income. This is underlined by the results of the energy expenditure survey that shows significant differences between the four classes identified. Figure 5 displays the results of this survey.

Figure 5 Monthly energy expenditure by social class

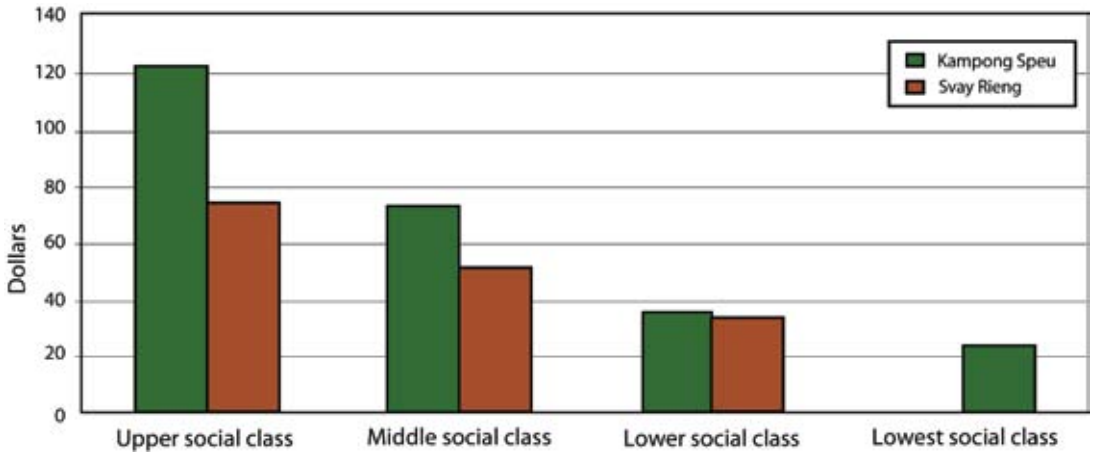


Table 8 confirms the close correlation between house type and energy expenditure: the better the housing standard, the higher the energy expenditure. Even within the social classes defined in the survey, this correlation holds.

The expenditures depicted in Table 8 correspond with current average prices for energy services in the two provinces as shown in Table 9. The actual cost for the energy services listed in Table 9 varies quite considerably. Lead acid batteries show the highest cost fluctuations per unit of energy. Not only do charging costs vary significantly, the batteries are often in poor

shape and hold significantly less usable electricity than their nominal rating would suggest. The cost of privately generated electricity can also vary quite considerably per unit (kWh) as generator efficiency and fuel supply costs fluctuate from application to application.

Table 8 Monthly expenditure per house type

	Kampong Speu		Svay Rieng	
Social Class	**Type of house**	**Monthly expenditure $**	**Type of house**	**Monthly expenditure $**
1	Brick	146	Brick	74
	Brick/Wood	113	Brick/Wood	73
2	Wood/Tile	79	Wood/Tile	63
	Wood/Corrugated Asbestos	67	Wood/Corrugated iron	47
	Wood/Corrugated Iron	66	Wood and thatch	44
3	Thatch	35	Thatch/Corrugated iron	33
4			Clay/Corrugated iron or thatch	23
	Total average	**76**	**Total average**	**47**

Table 9 Average cost per unit of energy

Energy source	Average cost per unit
EDC grid power	720 Riel per kWh (650 Riel per kWh for Svay Rieng)
Privately generated electricity	2000- 3800 Riel per kWh
Battery	1000 Riel per 50 Ah battery (4000 Riel per kWh)
Gas (LPG)	3500- 3750 Riel per kg
Kerosene	3000-3300 Riel per litre
Charcoal	300-500 Riel per kg
Firewood	200 per kg (or bundle)

Cooking energy and social class

A similar correlation can be seen in Table 10, this time in an inverted manner: in both provinces, the poorer the household, the more likely it is that firewood is being collected. What is a real surprise is that survey results suggest that households that do collect firewood in Kampong Speu spend more than double the time of their counterparts in Svay Rieng. This phenomenon is not easy to explain, especially in the light of the figures presented in Table 5, which suggest that the amount of fuel wood used per household is practically identical for both provinces. Anecdotal evidence suggests that many villages in Svay Rieng have a considerable number of trees scattered in the vicinity of the dwellings, allowing families to collect tree branches as fuel wood without travelling very far. The uncertainty with respect to biomass resources clearly indicates that the data on biomass requires verification and further analysis.

Even households in the upper social classes (25 percent of the households in Kampong Speu and 60 percent in Svay Rieng) collect their firewood themselves. Only the highest social class shows a relatively low user percentage (around 30 percent in both provinces). The other social classes, especially in Svay Rieng, show extremely high user percentages. In that province, 88 percent of the middle social class, 89 percent of the lower social class and 90 percent of the lowest social class collect fuel wood. In Kampong Speu these percentages are lower, but still considerable: 55 percent for the middle social class and 80 percent for the lower social class.

Table 10 Average hours spent collecting firewood per social class

	Kampong Speu			Svay Rieng		
Social class	**Type of house**	**% per type of house**	**Hours per day**	**Type of house**	**% per type of house**	**Hours per day**
1	Brick	7%	2.33	Brick	66%	0.83
	Brick/Wood	31%	2.37	Brick/Wood	57%	1.17
2	Wood/Tile	59%	2.88	Wood/Tile	85%	1.11
	Wood/Corrugated Asbestos	61%	2.49	Wood/Corrugated iron	84%	0.97
	Wood/Corrugated Iron	59%	2.44	Wood and thatch	91%	0.98
3	Thatch	80%	3.33	Thatch/Corrugated iron	86%	0.83
4				Clay/Corrugated iron or thatch	100%	0.87
	Total (average)	**57%**	**2.81**	**Total (average)**	**84%**	**0.95**

Further analysis of the data obtained provides some interesting insights into the modalities of firewood collection. Contrary to conventional wisdom, men seem to be the main providers of fuel wood. Figure 6 illustrates that this holds for both provinces and all social classes. In Svay Rieng this percentage (averaging 50 percent) is a little higher than in Kampong Speu (averaging 40 percent). Women seem to take on a third of the workload, with percentages increasing in the lower social classes. This is more prominent in Svay Rieng.

The demand on children to collect firewood differs between the two provinces. In Kampong Speu 27 percent of the children in the upper social class are responsible, while this is 21 percent for the lower social class. In Svay Rieng the same decrease in participation is noticeable, but the difference between the upper social class and lowest social class is more significant. In 29 percent of the households a child is the main responsible for collecting firewood in the upper social class, while this is only 10 percent for the lowest social class.

Charcoal, a refined and cleaner form of fuel wood, is mostly used by higher income households. Charcoal production involves the removal of volatile matter from woody biomass, providing a fuel that is high in pure carbon. Charcoal burns almost smokeless and is less polluting than wood. Forty-four percent of high-income households in Kampong Speu and 24 percent in Svay Rieng use charcoal. The percentage decreases

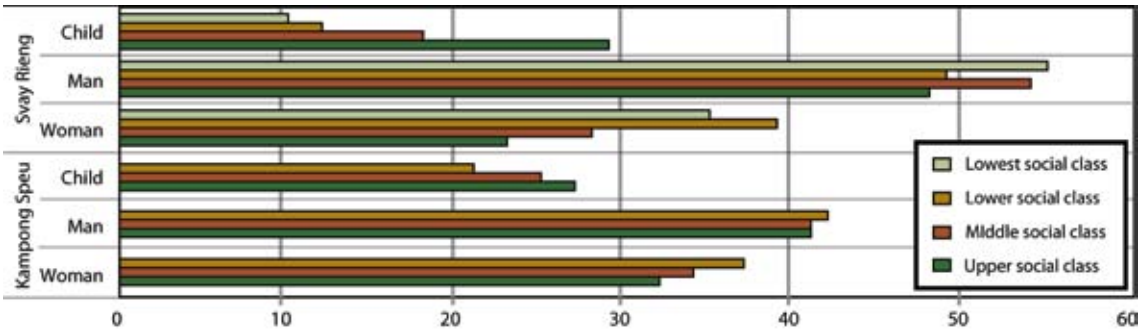
Cooking practices observed

In order to verify the figures obtained in the survey on energy consumption for cooking purposes, ten households in Vor Sor village (Samrong Tong district, Kampong Speu province) were selected for complementary small scale research. Household energy consumption was monitored for five days. The families consisted of five to seven household members. The observations coincided with the times when the families had their meals (breakfast, lunch and dinner). The households were using different energy sources (wood, charcoal and LPG) and tools (stone stoves, LPG with one or two burners, traditional Lao stoves) for cooking.

The results show more similarities than differences in cooking practices between the types of houses (brick/wood/thatch). In all the households, women make decisions about cooking and also carry out the actual cooking. Firewood is the main energy source used for cooking, and the supply is stored in or close to the kitchen area. Only two families used LPG and only one used charcoal, both LPG and charcoal were used in limited numbers. All families had a preference for firewood since it is cheaper than LPG and charcoal. They all indicated they would rather use LPG or charcoal but that it is too expensive for them. One kg of firewood costs 200 Riel, one kg of charcoal 700 Riel and 200 gram of LPG costs 800 Riel.

rapidly with class. In Svay Rieng the middle, lower and lowest social classes use hardly any charcoal at all. LPG is mainly used by higher social classes. On average the user percentage is 13 percent for Kampong Speu and 8 percent for Svay Rieng. When LPG is used, the higher social classes use the highest quantity per month.

Figure 6 Percentage of responsible household members collecting firewood per social class



Rural middle class housing

Lighting and appliance energy and social class

Poor families in rural areas in Cambodia are highly dependent on kerosene as an energy source for lighting. The relatively high cost of kerosene is a burden for most families, but better alternatives are not always available or are too costly. Especially for households without access to electricity and batteries, kerosene is the best available energy source at the moment. This is reflected by the higher user percentage and quantities used per month by the lower social classes.

Rising kersosene prices are a burden for poor rural households

Table 11 Kerosene use per social class per month

	Kampong Speu			Svay Rieng		
Social class	Type of house	% per type of house	Litres per month	Type of house	% per type of house	Litres per month
1	Brick	24%	1.75	Brick	53%	1.13
	Brick/Wood	57%	1.83	Brick/Wood	72%	1.49
2	Wood/Tile	63%	1.79	Wood/Tile	75%	1.22
	Wood/Corrugated asbestos	63%	1.83	Wood/Corrugated iron	72%	1.50
	Wood/Corrugated iron	64%	1.82	Wood and thatch	82%	1.29
3	Thatch	80%	2.16	Thatch/Corrugated iron	82%	1.29
4				Clay/Corrugated iron or thatch	84%	1.63
	Total (average)	**64%**	**1.88**	**Total (average)**	**76%**	**1.35**

Table 11 illustrates that the kerosene user percentages are higher in Svay Rieng than in Kampong Speu, indicating a less sophisticated energy economy in the former province. Again a very strong correlation between user percentages and social class becomes obvious: the lower the social class and income, the higher the user percentage for kerosene.

Electricity is used in two forms: grid power from either EDC or REE and battery power from lead acid batteries. User percentages in the upper social class in Kampong Speu show a significant percentage of high-income households using both forms, which indicates a high diversification of energy options. Scheduled electricity supply in Kampong Speu, where electricity is mostly provided by REE for a couple of hours a day, could be a reason for high-income households to maintain redundancy.

Table 12 Cumulative average consumption figures and user percentages from Kampong Speu

	Electricity		Batteries		Kerosene		Firewood purchased		Firewood collected		Charcoal		LPG	
Social class	User %	KWh/ month	User %	Capacity Ah	User %	Litres/ month	User %	Kg/ day	User %	Kg/ day	User %	Kg/ day	User %	Kg/ month
1	54%	26.7	70%	95	48%	1.82	52%	4.54	29%	5.81	44%	1.34	30%	10.87
2	22%	18	80%	75	64%	1.80	41%	5.00	55%	5.88	23%	1.15	11%	8.45
3	2%	10	60%	61	80%	2.16	15%	4.87	80%	5.41	11%	1.19	2%	6.20

In Svay Rieng the figures indicate that grid power and batteries are the only sources of electricity. High-income households also use significantly more kWh per month than lower classes. The same holds for the average size of battery. Battery size should not, however, be confused with electricity consumption per time unit. It is the frequency of charging that determines the amount of electricity consumed. A maximum value extractable from a 100 Ah 12 volt battery would be approx 3 kWh per week when well managed and charged properly.

The absolute consumption figures for electricity in Svay Rieng are higher for all social classes that use power. This can be explained by the fact that power would be EDC supplied from cross-border connections with Vietnam, making unit cost significantly cheaper than in Kampong Speu. There seems to be a certain degree of price elasticity here. This is supported by consumption figures of LPG, another modern urban fuel. Though retail prices for LPG are identical in both provinces, Svay Rieng LPG users use less LPG than their Kampong Speu counterparts. This seem to indicates that electricity may – for some applications, such as rice cooking – be a more convenient and perhaps cheaper choice in Svay Rieng where power is supplied at comparatively low rates by EDC.

Table 13 Cumulative average consumption figures and user percentages Svay Rieng

Social class	Electricity		Batteries		Kerosene		Firewood purchased		Firewood collected		Charcoal		LPG	
	User %	KWh/ month	User %	Capacity Ah	User %	Litres/ month	User %	Kg/ day	User %	Kg/ day	User %	Kg/ day	User %	Kg/ month
1	35%	33.4	67%	77	60%	1.29	29%	4.54	63%	4.81	24%	0.36	17%	6.46
2	8%	21	90%	63	75%	1.38	13%	4.97	88%	4.93	6%	0.33	10%	3.24
3	4%	12	84%	44	82%	1.29	8%	4.81	89%	4.42	2%	0.39	3%	3.81
4	0%	0	74%	42	84%	1.63	0%	0	90%	3.84	3%	0.03	0%	0

Table 14 shows energy expenditure for actual users. This provides some very interesting insights: although all forms of energy are purchased and used, fuel wood is still the predominant form of energy throughout all social classes. For the upper and middle social classes, LPG also plays an important role – more prominent in Kampong Speu than in Svay Rieng. In both provinces, both of the middle social classes spend most on firewood, LPG and charcoal and the lowest social class spends most on kerosene and batteries. The lowest variation is found with kerosene: it is used across the classes and provinces and it appears that quantities consumed by individual households are in the same order of magnitude. Another interesting result is the importance of charcoal as a fuel in Kampong Speu. Charcoal users in all three classes spend nearly US$4 a month, an amount similar to that spent by electricity users for grid power.

Table 14 Average expenditure per month per energy type per social class (US$)

Social class	Electricity		Batteries		Kerosene		Firewood (purchased)		Charcoal		LPG	
	Kampong Speu	Svay Rieng	Kampong Speu	Svay Rieng	Kampong Speu	Svay Rieng	Kampong Speu	Svay Rieng	Kampong Speu	Svay Rieng	Kampong Speu	Svay Rieng
1	4.81	5.43	2.55	1.70	1.46	1.07	6.81	6.81	4.02	1.08	10.05	5.98
2	3.24	3.41	1.70	1.70	1.44	1.22	7.50	7.46	3.45	0.99	7.82	3
3	1.80	1.95	1.70	1.19	1.73	1.07	7.31	7.22	3.57	1.17	5.74	3.52
4	-	-	-	1.19	-	1.71	-	-	-	0.09	-	-

2.6 Supply cost and affordability

In order to gauge the significance of energy expenditure and its relevance for poverty alleviation, the average expenditure on energy sources as a percentage of total household expenditure has been analyzed. Table 15 depicts results that are somewhat surprising as all surveyed households consistently reported a figure of 11 to 12 percent in Kampong Speu and 8 to 10 percent in Svay Rieng. One could speculate that the 10 percent figure might be a household target. The option to collect free firewood in case of a cash shortage allows a household to keep energy expenditure in this range. In other words, cash management is helped by the availability of the wood collection option.

Woodlots generate income and fuel at the same time

Table 15 Share of energy costs of total monthly expenditure per social class

	Monthly total expenditure $ per household		Monthly energy expenditure $ per household		Energy expenditures as % of total expenditure	
Social class	Kampong Speu	Svay Rieng	Kampong Speu	Svay Rieng	Kampong Speu	Svay Rieng
1	122	74	13.41	6.93	11%	9%
2	73	52	7.72	4.05	11%	8%
3	35	33	4.04	2.66	12%	8%
4	-	23	-	2.32	-	10%

In absolute terms, the picture looks dismal for the poorest households in Svay Rieng which, after energy expenditure, have just US$20 to cover all other expenses such as food, clothing, education, transport, etc. This picture may deteriorate rapidly in the future if depletion of natural resources is not accompanied by rural growth based on both extending areas under agricultural production and ensuring sustainable availability of natural resources. While the current natural resources management framework has provided very limited benefits in terms of rural growth and poverty reduction, there are several indications of rapidly decreasing availability of biomass resources. Both intensification and expansion of agricultural activities will put additional pressures on the resource base. This indicates the need to establish viable land-use planning mechanisms, and develop socially acceptable mechanisms for allocating biomass use rights to agricultural households. Secure access to natural resource assets will be an essential fix to broad-based rural growth and reduction of vulnerability.

Charcoal production is a thermal process that involves the removal of volatile matter from woody biomass, providing a fuel that is high in pure carbon.

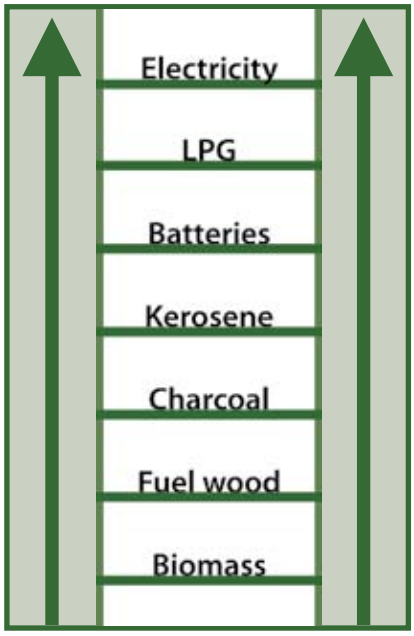
2.7 Energy Transition

A significant body of literature on household energy transitions that has focused on how households ascend what has been called an energy ladder supports the findings of this study. At the bottom of the ladder, many people use low-grade biomass fuels (e.g., straw, dung, and wood) in inefficient and unhealthy ways. At transitional points along the ladder, consumers purchase commercial fuels such as charcoal and kerosene. Finally, consumers change to cleaner, efficient and more convenient forms of energy such as LPG and electricity. The ladder model assumes that households move in incremental steps on the ladder, a theory that is supported by the findings of the household surveys performed in Kampong Speu and Svay Rieng. However, at the same time there are many indications that moving up is, in reality, a complex process. Various factors determine the energy transition of households in Cambodia. Access, income, price, and degree of urbanization are clearly critical parameters that determine speed and degree of improvements in living conditions.

High up-front cost of modern energy systems obstacle for rural poor

While increases in household incomes are an obvious driver, very often access or availability forces households to move on the ladder. As rural settlements urbanize, fuel wood becomes scarcer or unavailable while commercial fuels become more readily accessible as a result of improved economies of scale in transport and fuel distribution. However, the surveys have also discovered that the pathways to a better energy supply are often multifaceted and do not necessarily always involve a smooth transition from one rung to the next. Households in Cambodia seem to maintain a range of fuel options leading to the variety of possible transitional conduits shown in Figure 7.

Figure 7 Energy transition



This is an important insight and should be seriously considered when designing rural energy projects. When deciding on their energy options, households aim to minimize risk by considering reliability of supply together with the cost for the various options. Other variables include substitutability of energy sources, degree of convenience, level of safety, and pollution emitted into the home associated with the various energy sources. These insights should be taken into consideration when designing policies or programs. For poor households, initial investment or start-up cost is certainly one of the most critical obstacles when moving up the energy ladder. Policy and project designs must focus on addressing these barriers if pro-poor energy interventions are to be successful. While a multi-pathway energy ladder model is certainly a valid concept for long-range planning, the model also indicates that energy utility or service might be more important to consumers than previously thought.

Rural fuel traders

As income levels are very difficult to examine, the parameter expenditure was used to compare the different social classes and evidently shows that Kampong Speu is a richer province (in monetary terms) than Svay Rieng where households on average spend only US$47 per month per family of five to six members. This is significantly lower than the poverty level, which is assumed to be US$1 per day per person. A strategic response to this situation is promoting the establishment of woodlots. This has the potential to generate income and alleviate serious

Traditional cooking methods are inefficient and unhealthy

biomass shortages at the same time. Fast growing species could substantially increase income levels of poor rural families.

The second priority should be the improvement of the hygienic situation in kitchens. The popular 'three stone stoves' are very inefficient and generate irritating and hazardous smoke that mainly affects woman and children. Improved cook stoves can save up to 50 percent of fuel wood compared to cooking with the 'three stone stove'.

Water filters also improve the hygienic situation in kitchens and save fuel wood at the same time. Water filters costs US$7.50, which is the equivalent of about three months fuel wood supply used for boiling drinking water. Other energy efficiency technologies are best promoted through increases in household incomes. The study results suggest that once families are able to spend more money they will instantly start an energy transition towards LGP gas for cooking and batteries for lighting.

3. FUTURE DEMAND IN SURVEYED PROVINCES

With a total of 41,000 Giga Joules (GJ) in Kampong Speu, these rural electricity enterprises supply about 70 times more energy to their customers than REEs in Svay Rieng

3.1 Forecasting methodology

In this section, the energy demand is forecasted for the provinces of Kampong Speu and Svay Rieng. This forecast forms the basis of a nationwide energy demand/supply model described in Section 3.5. In the demand forecast the distinction between cooking and lighting has been maintained. The forecast is based on probable trends derived from historical data from NIS. The forecast rests on the assumption that provincial urban areas will follow the trend of Phnom Penh and rural areas the trend of the provincial urban areas. The final energy demand is calculated with LEAP software that included GDP figures, population and income growth.

The forecast presented here can be considered as the baseline or business as usual (BAU) scenario. It does not consider increasing scarcity of resources or price increases for energy services. The BAU also does not consider the reasons why a particular household lacks access to a modern fuel or electricity. It takes into account neither supply-side failures nor demand-side failures, the latter being the case when a household chooses not to use the available service because it is too expensive, culturally unfamiliar, or otherwise inappropriate. Because the policy implications of these supply- and demand-side failures vary significantly, more data to differentiate between the two situations would be necessary.

Table 16 depicts the basis from which energy forecasting has been performed in the framework of this study. In terms of energy units, it is very clear that cooking energy is much more important than lighting and appliance use. The base table also shows the relative importance of REEs in Kampong Speu. With a total of 41,000 Giga Joules (GJ) in Kampong Speu, these rural electricity enterprises supply more than eight times the energy to their customers than REEs in Svay Rieng.

Table 16 Total energy use in Kampong Speu and Svay Rieng (GJ/year)

Cooking			Lighting/Appliances		
Source	**Kampong Speu**	**Svay Rieng**	**Source**	**Kampong Speu**	**Svay Rieng**
Firewood purchased	1,412,631	406,395	EDC	9,671	13,059
Firewood collected	2,231,390	2,617,870	REE	41,025	595
Palm tree branch	415,945	254,909	Own Generator	1,291	255
Charcoal	449,509	30,167	Battery lighting	4,610	15,286
LPG	115,813	24,680	Battery other	16,157	
Electric rice cooker	1,321	140	Kerosene	80,486	60,951
Animal Dung	17,137	19,262	Candles	9,945	3,347
Total	**4,643,745**	**3,353,423**		**163,184**	**93,495**

3.2 Demand and supply modelling using historical data

In the framework of the research undertaken, MIME has developed an 'Energy Demand Forecasting Model' (EDFM). Such a customized model seemed necessary in order to overcome limitations of existing tools such as LEAP. LEAP uses variables such as GDP, population growth and income growth for demand forecasting, but does not allow the inclusion of parameters such as behavioural change in order to balance supply and demand. Thus, EDFM was developed to simulate a dynamic change in the energy mix by including fuel switches as a response to

income growth. EDFM merges existing historical demand data with the correlation between income and the preference for a type of energy source.

The EDFM uses forecasting results of LEAP where GDP, income and population growth parameters can be included. EDFM then simulates the shift in energy supply sources in the future. The results are highly relevant for policy responses and the design of interventions aimed to ensure sustainability of energy supplies. It should be noted, however, that the model is still under trial and has its own limitations. It is, as is any other forecasting tool, based on certain assumptions and forecasting and does not include all drivers relevant for the balance of supply and demand. It does not, for instance, include increasing scarcity and price elasticity changes over time. The model is, however, flexible enough to consider some of these parameters in a scenario analysis. The distinguishing characteristic of EDFM as a specialized modelling tool is a greater depth of energy planning from the perspective of energy policy analysts. Analysts can use such information to quantify the benefits of electric lighting for rural households, using methods involving available cash and willingness to pay.

EDFM simulation rests on the following assumptions:

- The income level of people living in rural areas will gradually increase over the years;
- Income level directly influences a household's choices regarding the use of an energy source;
- The future shift between energy sources in the provincial urban areas will follow the historical shift between energy sources in Phnom Penh;
- The shift between energy supply in the rural areas will follow the historical shift between energy sources of provincial urban areas;
- The energy transition from now to 2030 will follow the same progression that can be observed in the NIS income quintiles from poor to rich.

NIS regularly conducts a Socio-Economic Survey including questions about energy use. Data is available from the years 1993, 1996, 1998, 2000 and 2003/4. NIS analyzed existing data for the purpose of this study in order to establish historical trends for Phnom Penh and all provinces. Cooking energy and energy sources for lighting and other appliances were distinguished in the trend analysis. The NIS data also contains information on the use of different energy sources per income category for Phnom Penh, provincial urban areas and rural areas. The population is divided into five income categories or income quintiles as shown in Table 17.

Table 17 NIS income quintiles

Quintile	Average income per household per month (riel)	Average income per month (dollar)
1	264,677	64.56
2	570,484	139.14
3	978,959	238.77
4	1,810,044	441.47
5	8,128,360	1,982.53

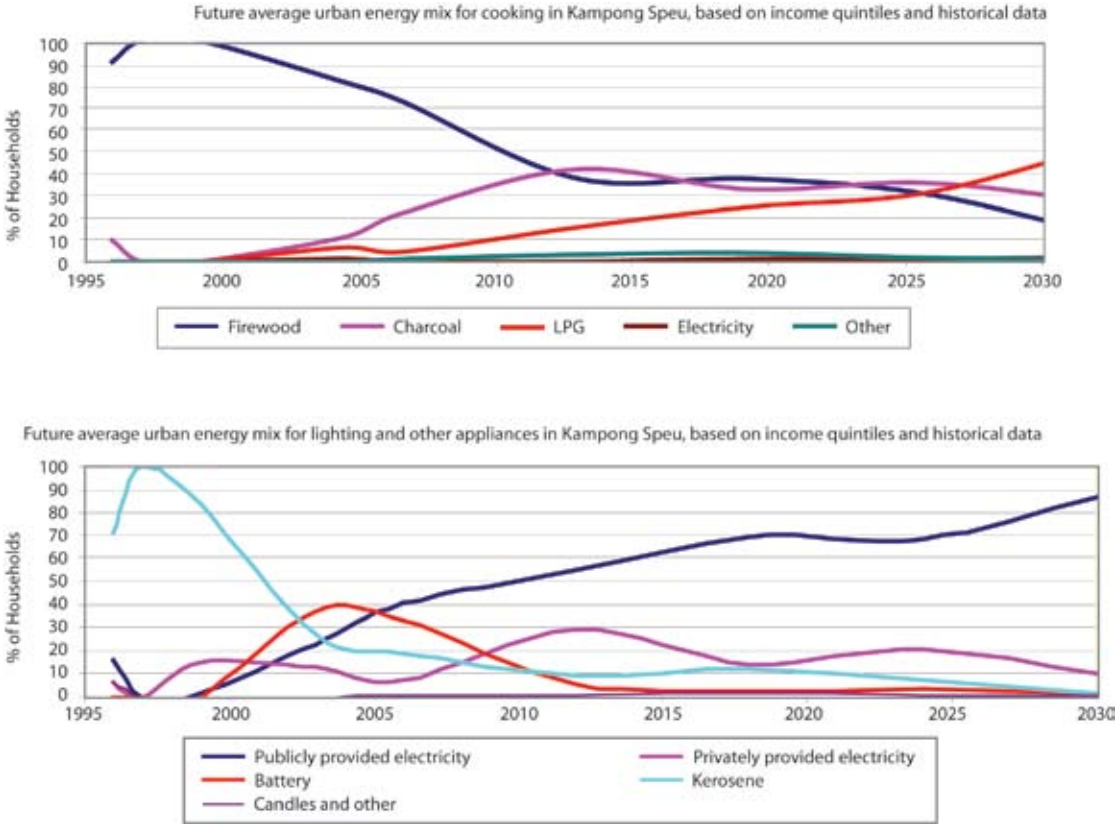
EDFM probably provides the most accurate energy model for rural Cambodia at the moment. However, the trends derived from historical data are based on data that is not sophisticated enough and may cause distortions. These distortions are assumed to cause deviations on the order of 15 percent in 2015 and of 25 percent in the year 2030. Further refinement of data will allow increasing accuracy of the model.

Kampong Speu province

Information derived from the historical trend in the urban cooking energy mix in Kampong Speu shows that fuel wood still is the main energy source. Its importance started to decrease after 1999 together with an increase in the use of charcoal and LPG. Historical shifts have occurred in the energy mix for lighting and other appliances. The role of kerosene has declined dramatically since 1997 and privately provided electricity has increased along with EDC power and the use of batteries.

The modelling results for the urban energy mix in Kampong Speu are shown in Figure 8. Significant changes are expected for both cooking and lighting. The decrease of wood and later charcoal as cooking fuels is mirrored by an increase in LPG use. At the same time, kerosene is rapidly decreasing and batteries are pushed out and substituted by either EDC or privately generated electricity. It is interesting that urban Kampong Speu shows an energy mix that deviates significantly from Phnom Penh with fuel wood retaining an important role for poor families, but also for families in higher income groups. The use of charcoal will rapidly increase in the near future (40 percent in 2010), but will steadily decline after 2013, reaching 30 percent in 2030. LPG is hardly used at the moment, but will show a constant increase until 2030, making up 50 percent of the energy mix in 2030.

Figure 8 Urban energy mix projection Kampong Speu

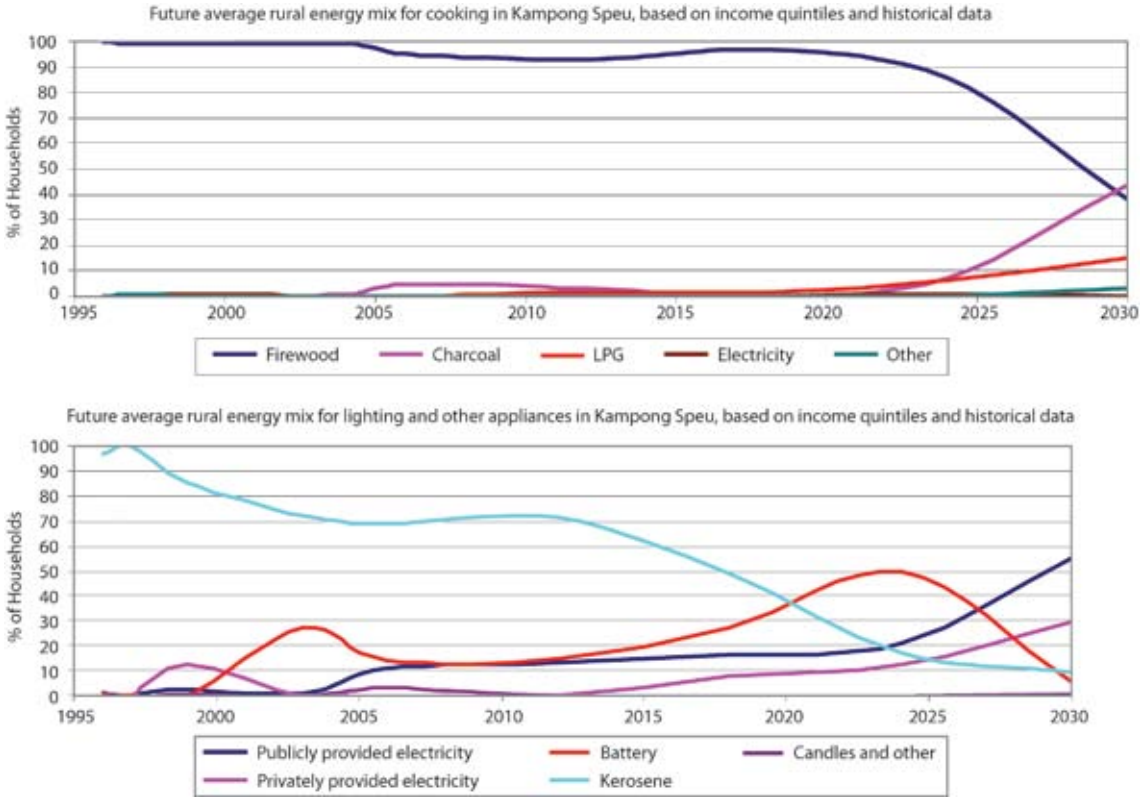


Changes in the lighting and appliances mix follow a more complex pattern. The use of kerosene seems to be fading. In 1997 the share was 100 percent, but in 1993 it was only 30 percent. The total use of kerosene will drop in the near future stabilizing at 5 percent for ten years and then drop to nil by 2030. For all income groups, batteries remain an important energy source. For the two lowest income categories, the share is between 30 to 40 percent, for income categories three and four the share is between 40 and 70 percent. Only for the highest income category is the use of batteries decreasing. The model predicts a significant fluctuation in the

share of privately provided electricity that can be explained by the transitional nature of self-generation. It becomes obsolete the moment grid power is provided. In 2030 it is predicted that all income groups will use publicly provided electricity, although its share in the energy mix is smaller in lower income categories than it is in higher income categories.

The predicted development of the rural energy mix in Kampong Speu is depicted in Figure 9. The dependence on fuel wood is more prominent than in urban areas showing that 100 percent of the households use this fuel in 2007 irrespective of income categories. However, wood shows a rapid decline in the distant future, to be used by only 35 percent of the households in 2030. Similar to urban areas, LPG becomes more important and 15 percent of the households are expected to use it by 2030. Lighting energy, which is currently still dominated by kerosene, will gradually be replaced by battery power and later by an increasing share of grid electricity. A moderate 10 percent is expected by 2020 and beyond. Electricity use will increase from just 2 percent now to about 20 percent in 2025. Thereafter, penetration will increase more rapidly, reaching 50 percent in 2030. This penetration of electricity is responsible for the phasing out of battery use, dropping from 50 percent in 2025 to less than 10 percent in 2030.

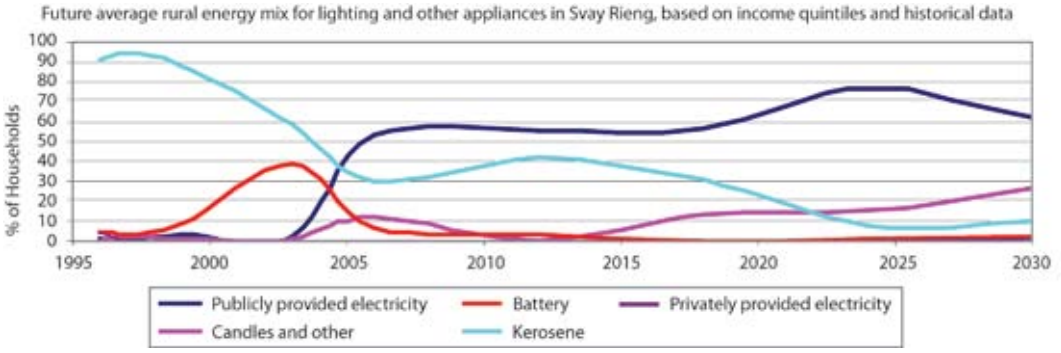
Figure 9 Rural energy mix projection Kampong Speu



Svay Rieng province

For Svay Rieng a picture emerges when supply and demand is forecast using historical trends. As an example, Figure 10 shows the development of the rural energy mix for lighting and appliances. Again, a rapid transition from a kerosene-dominated household sector to publicly and privately provided electricity characterizes the results based on historical trend.

Figure 10 Rural energy mix projection Svay Rieng



3.3 Refined modelling

In order to eliminate possible distortions that are inevitable when using historical trends, this section presents filtered data that not only consider the historical trends derived from NIS data, but also the results of the questionnaire-based household survey conducted in 2007. The forecast models are divided into 'rural' and 'urban', and within those categories a further distinction has been made between energy sources used for 'cooking' and 'lighting and other appliances'.

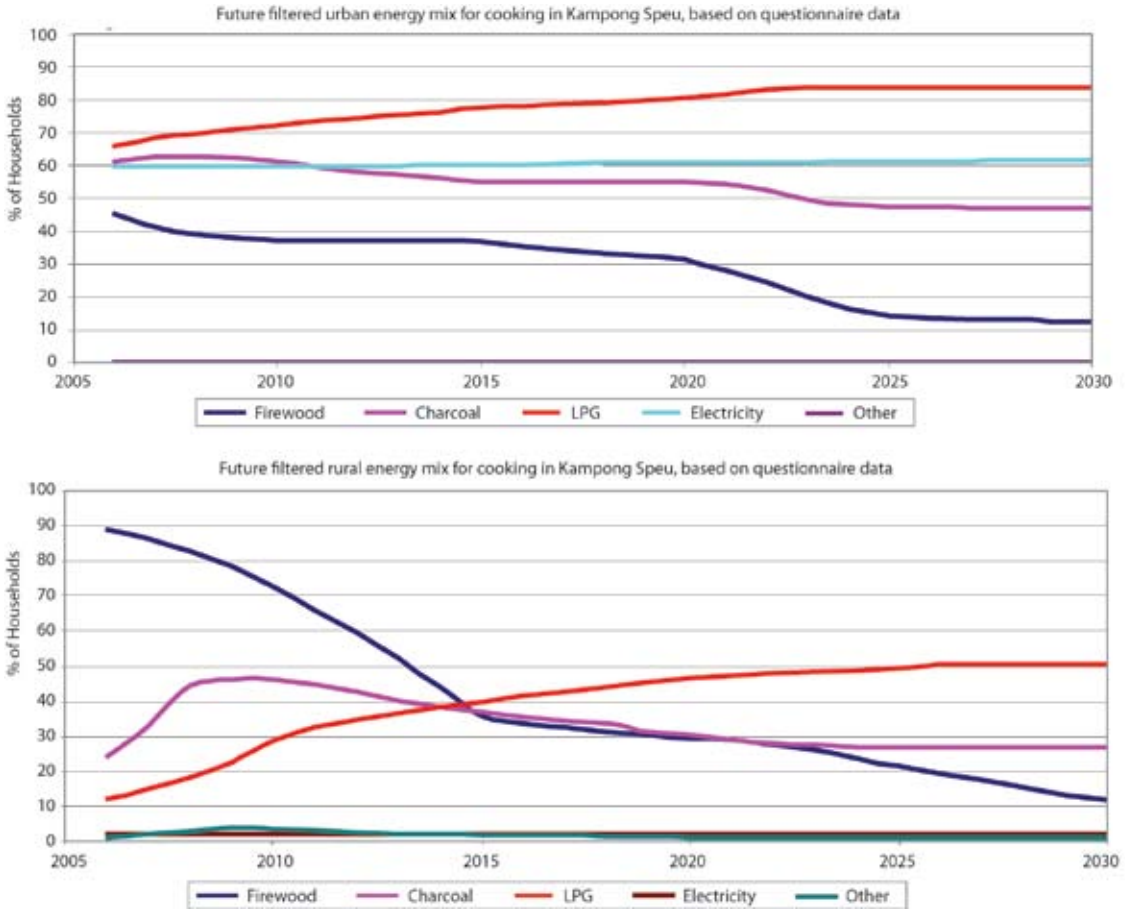
Charcoal in Kampong Speu ready to be transported to Phnom Penh markets.

Kampong Speu

Figure 11 shows the modelling of cooking energy for urban and rural Kampong Speu. In the urban sector LPG clearly is the predominant fuel with 68 percent of the households using it now, increasing to about 85 percent in 2030. LPG gradually replaces wood and charcoal, which will be used by only 15 percent and 35 percent of the households respectively. Elec-

tricity is used by 60 percent of the households and will remain at this level until 2030. Rural cooking in Kampong Speu will follow a similar path with a sharper drop in the use of firewood during the next eight years. LPG becomes a cooking fuel for 50 percent of the households in 2030. Surprisingly, the modelling of charcoal consumption shows that rural households in Kampong Speu do not exactly follow the trend of urban areas (i.e., charcoal will never become a predominant fuel as households transition directly to LPG).

Figure 11 Energy use in Kampong Speu

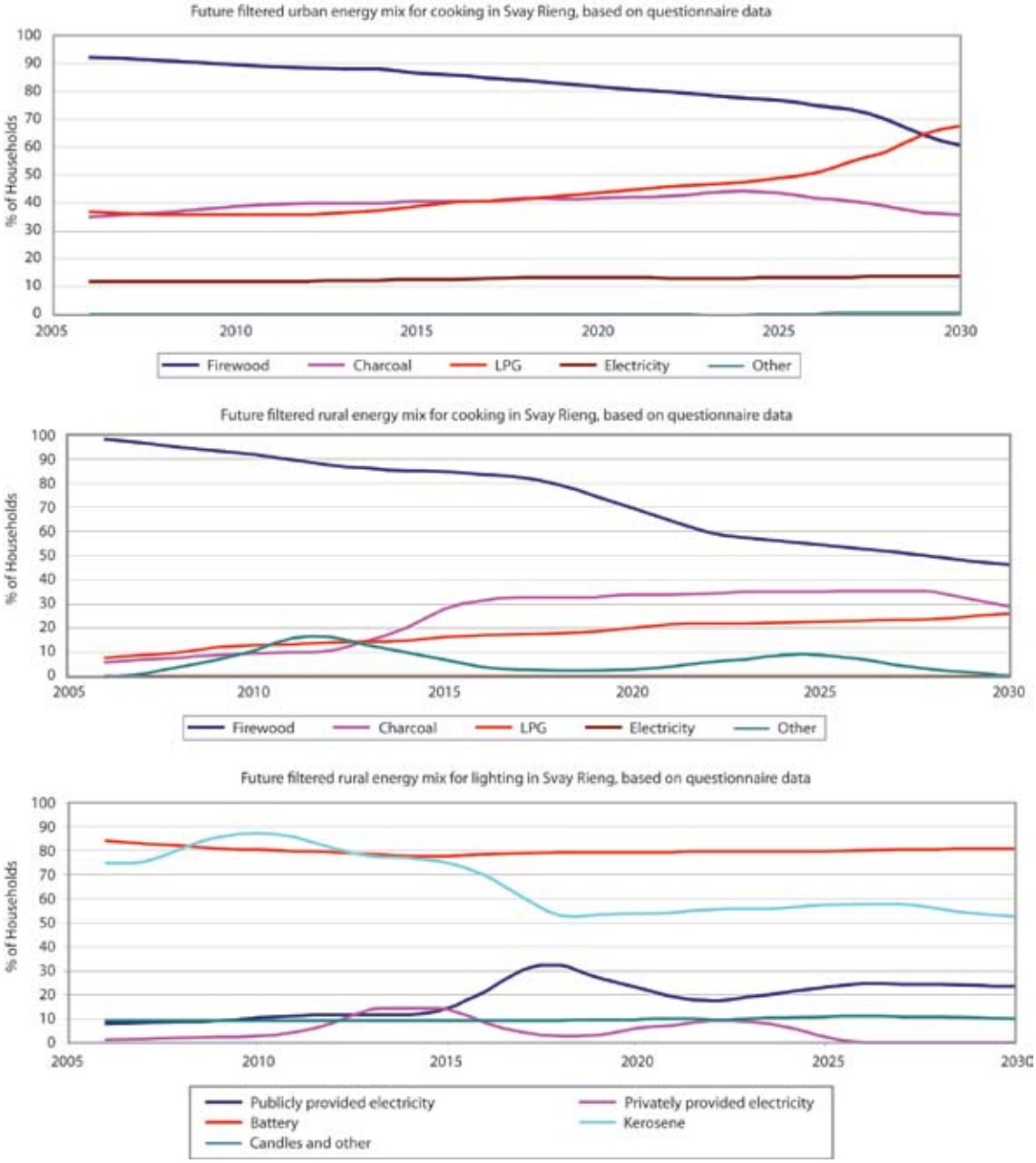


Svay Rieng

Compared to the results for Kampong Speu, the energy transition in Svay Rieng follows a similar, while more biomass-dominated, path. Fuel wood remains the main energy source for cooking for both urban and rural households. LPG substitutes wood and charcoal at a much slower rate than in Kampong Speu, reaching 65 percent penetration in urban and 25 percent in rural Svay Rieng. According to the modelling, 60 percent of urban households will still use wood in 2030, as opposed to 45 percent in rural areas.

The model also produces interesting results with respect to the energy use for lighting and appliances in rural Svay Rieng. Accordingly, batteries retain an unchanged penetration rate of 80 percent over the entire projection timeframe, while kerosene will only used by 50 percent of the households in 2030. What is more striking is the electricity use model. While one would normally expect a steady rise in the use of publicly-provided electricity as a result of government driven electrification programs, electricity use fluctuates and shows a significant drop after 2017.

Figure 12 Energy use Svay Rieng



3.4 Demand forecasts

Cooking

Figure 13 shows the forecasted urban energy use for cooking in both provinces. Accordingly the mix of energy sources used will change over time. Charcoal and LPG will become the main energy sources, while firewood first initially increases, but declines towards the end of the forecasting period. This decline starts earlier in Kampong Speu than in Svay Rieng. Even though the use of firewood as a direct cooking energy source is decreasing, a decrease in the total wood demand for charcoal and firewood is not expected. Without interventions, wood demand will actually increase dramatically as 6 kg of wood are needed to produce 1 kg of charcoal. Even when considering the higher heating value of charcoal, traditional charcoal-making

technologies involve very low energy efficiencies. Up to 80 percent of the energy content of the wood used for charcoal burning in earth mound kilns is lost in the process. This trend is a serious concern as forest resources are already under serious pressure and modern fuels such as LPG will not penetrate the urban markets fast enough to avoid deterioration of biomass resources.

Figure 13 Total urban energy use cooking (GJ)

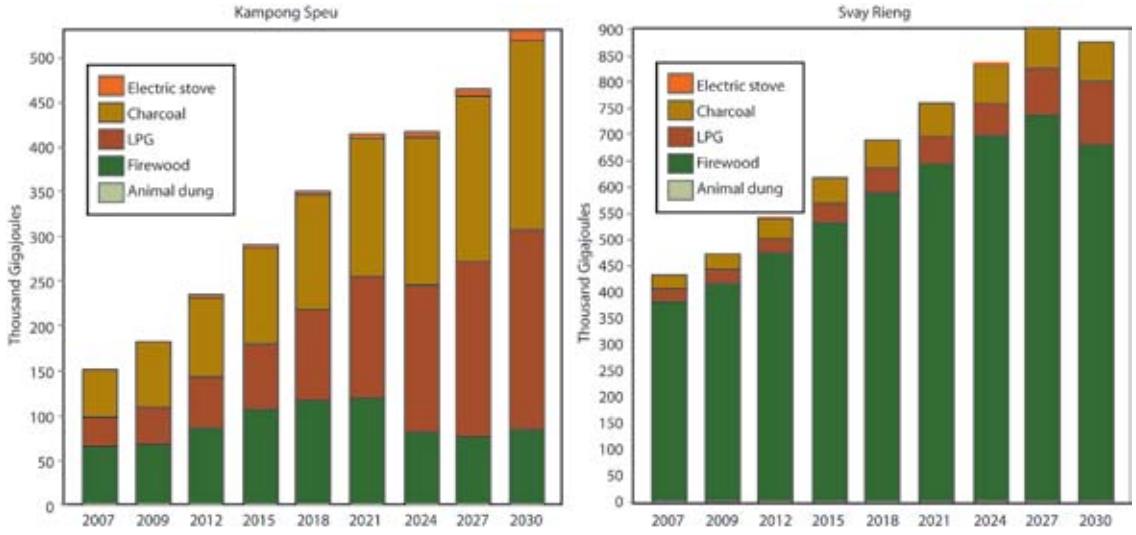


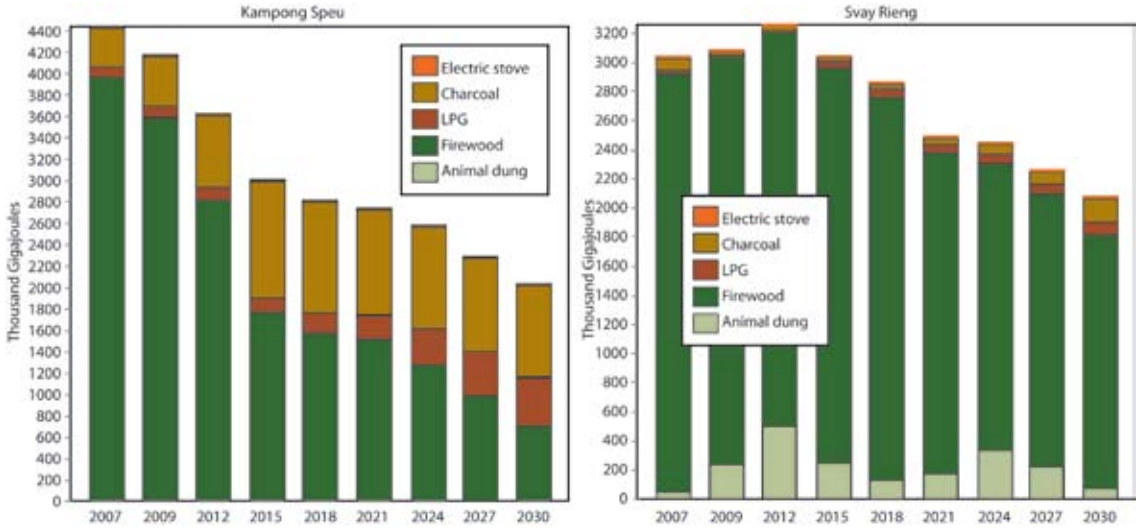
Figure 14 shows that total energy use, expressed in energy content or Giga Joules (GJ), in rural Kampong Speu for cooking will decline by about half from 2007 to 2030. The use of fuel wood is expected to decline dramatically. Similar to the forecasted development in urban areas, charcoal use will increase, particularly in Kampong Speu (i.e., even in rural areas the pressure on woody biomass will increase). LPG demand also shows a five-fold increase from 2007 to 2030. In Svay Rieng a decline in total energy use is noticeable, but it is less dramatic than in Kampong Speu. Firewood remains the main energy source.

Phnom Penh baseline

The EDFM simulation assumes that provincial urban areas will follow the energy demand/supply trend of Phnom Penh where some dramatic changes in energy use have occurred over the last ten years. The use of fuel wood for cooking has decreased rapidly in ten years time with households shifting to LPG. Forty percent of lower income households use LPG, rising steadily with income to approximately 70 percent in the highest income category. However, fuel wood is still a substantial energy source for cooking, especially for low-income households. Charcoal is also still an important cooking fuel in Phnom Penh with LPG apparently also substituting for charcoal. Contrary to the use of firewood, the share of charcoal seems to be comparable for all families regardless of their income. Only for the highest income households does charcoal not seem to play a role as a fuel.

Grid electricity and privately generated electricity (85 percent and 10 percent respectively) are almost the sole energy sources for lighting appliances. Households in lower income categories are more likely to use privately generated electricity, indicating that the EDC grid does not yet serve some low cost urban areas in Phnom Penh. Kerosene, an energy source that was important in 1993 (20 percent share), dropped to nil ten years later, indicating a high consumer preference for safe and clean electricity.

Figure 14 Total rural energy use for cooking (GJ)



Lighting and appliances

With increasing standards of living, total urban energy use for lighting and other appliances will increase sharply in both provinces (Figure 15). Kampong Speu is expected to experience a significant expansion of EDC services. Despite this expansion, REE will remain the predominant supplier of electricity. In urban Svay Rieng EDC will remain the most important supplier of energy. This is due to the fact that households have access to relatively cheap electricity imported from Vietnam. It is impossible for diesel-based REEs to compete with cross border supplies. However, a change in policy could give REE a more prominent role in Svay Rieng. Instead of generating power using expensive diesel and low efficiency equipment, REEs could become bulk buyers of cross-border electricity supply and retail the power in local areas.

Figure 15 Urban energy use for lighting and other appliances (GJ)

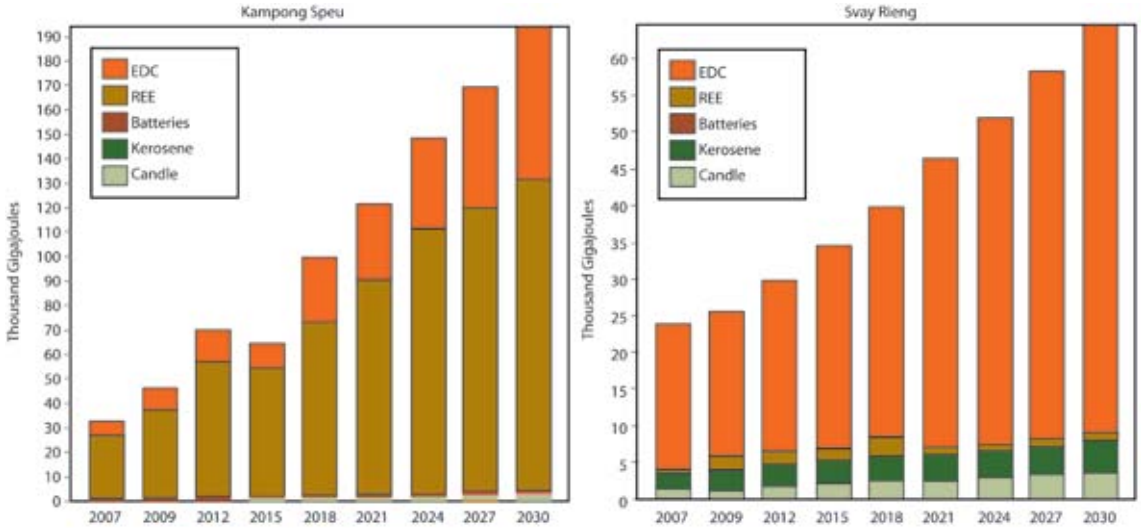


Figure 16 Rural energy use for lighting and other appliances

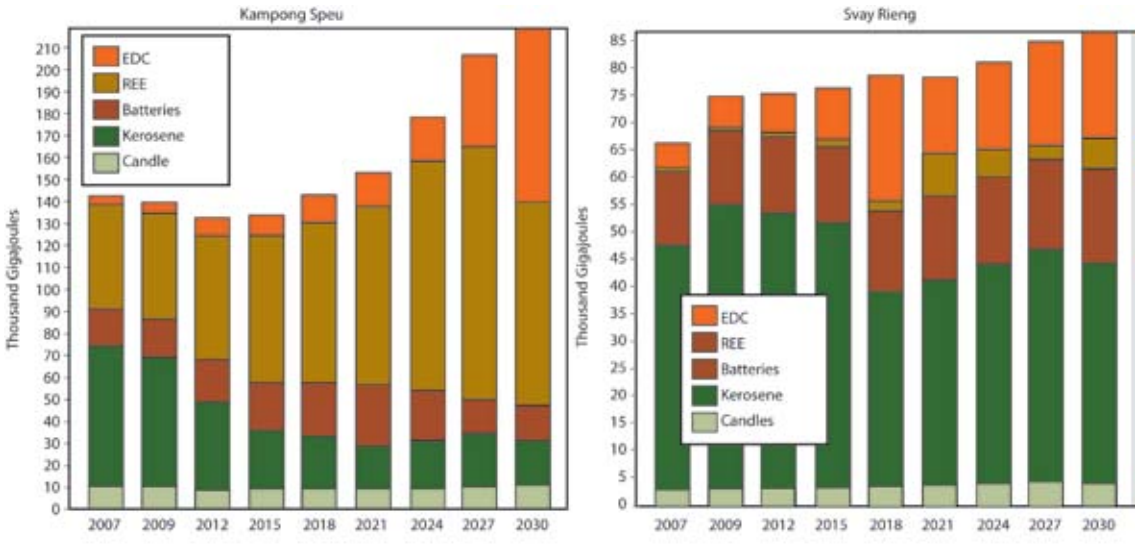


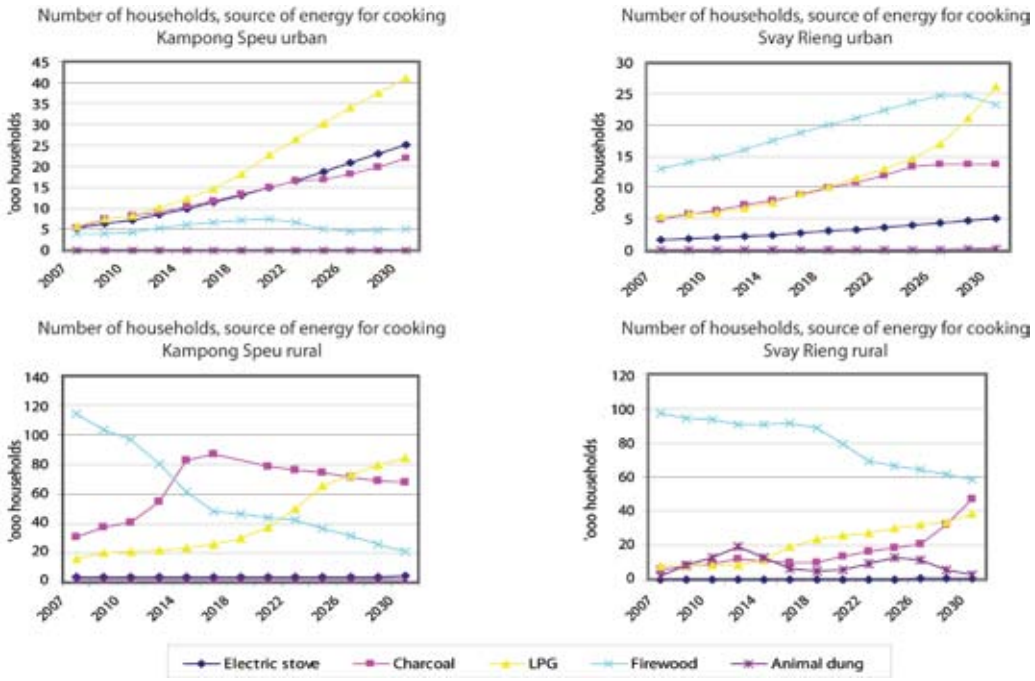
Figure 16 displays the trends in rural areas. In Kampong Speu, a sharp increase in demand for EDC and REE electricity is expected. With declining battery and kerosene use, electricity will become the main energy source by 2030. Villages along the main roads are expected to become urbanized centres with dynamic transitions to a more urban energy use pattern. While other energy sources (batteries, kerosene and candles) will still be used, their contribution to the average energy mix will constantly fall over the forecasting period. Nevertheless, the number of households connected to grid electricity will remain low. In quantitative terms, batteries and kerosene are low intensity energy supplies (i.e., the total energy use figures might be a weak indicator for actual improvements in the energy mix of the majority of the population). Thus, total household energy use data is insufficient for extensive energy policy analysis.

Household access to modern energy

A better measure for the actual impact of energy transitions on the population is an analysis of accessibility (i.e., a forecasting of household numbers that use certain types of energy). The results of this analysis are depicted in Figure 17. Accordingly, cooking habits will change rapidly during the projection timeframe. In Kampong Speu, for instance, urban use of LPG will increase rapidly from 5,000 households in 2007 to 41,000 households in 2030. The use of charcoal and of electric rice cookers will also increase, albeit at a slower rate. Wood use will increase slowly until 2020 and decline slowly thereafter. Svay Rieng, the more rural province, will experience a similar transition, but with a time lag as the number of urban households using LPG will initially increase gradually, then rapidly after 2026. In contrast to Kampong Speu, wood will remain the most important energy source in Svay Rieng until 2030.

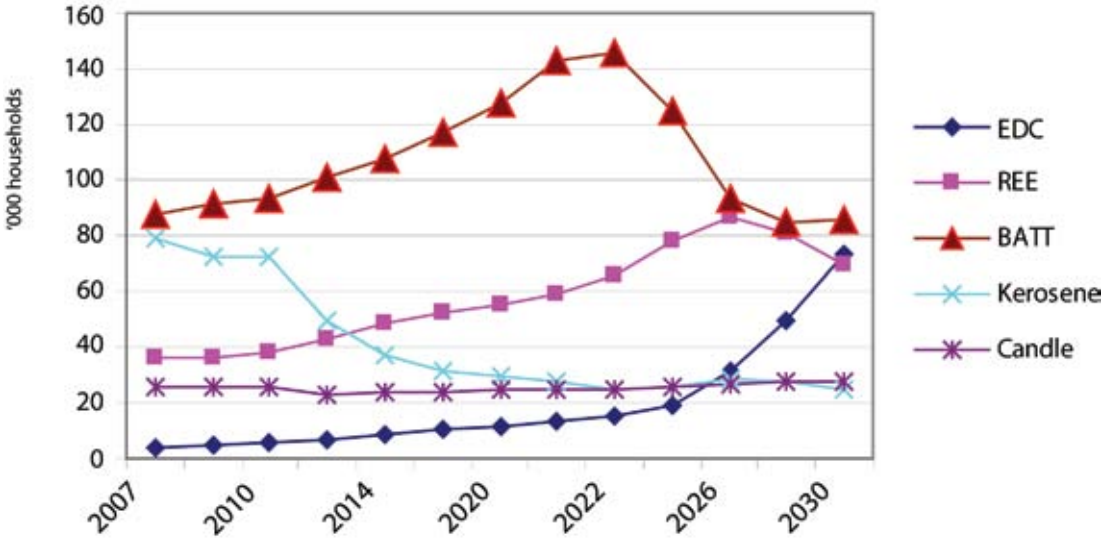
The rural cooking energy mix shows a different transition path. In both provinces the number of rural households using firewood will decrease gradually over the entire projection timeframe. While LPG will penetrate rural areas rapidly, the use of electricity for cooking will remain insignificant, indicating limited access to grid electricity in rural areas. In 2030 most rural households in Kampong Speu will exhibit an almost urban energy mix, while Svay Rieng will still have a fuel wood dominated cooking energy mix. Approximately 54,400 households will still be using wood in 2030, with charcoal and LPG following with 47,500 and 38,700 respectively.

Figure 17 Household sources of energy for cooking



The forecasted energy mix for lighting and appliances show similar trends towards modernization. Access to EDC or REE grid power in urban Kampong Speu will gradually increase from 2,900 EDC supplied households in 2007 to 32,100 households in 2030, and for REE supply from 5,800 households in 2007 to 32,100 in 2030. In urban Svay Rieng a rapid increase of the number of households using EDC is expected due to the expansion of cross-border supply from Vietnam.

Figure 18 Rural transition in Kampong Speu



For rural Kampong Speu the forecasting yields some interesting results, as depicted in Figure 18: from a high number of households using batteries in 2007, battery use will increase to a peak of 146,100 households in 2022. Thereafter battery use will drop due to a substitution for battery power by EDC and REE. However, towards the end of the projection timeframe the importance of REE starts to decline due to the availability of cheaper and EDC power. The

Cross border supplies from Vietnam to improve electricity supply in Svay Rieng

Despite the shift to modern energy, demand for wood fuels, kerosene and batteries remains strong

number of households using candles remains more or less constant. Kerosene use shows a steep drop until 2016 and then gradually decreases.

3.5 Extrapolation to national level

Based on the energy forecasting for Kampong Spey and Svay Rieng, an indicative extrapolation can be simulated for Cambodia's total energy demand. In order to show a band in which demand will develop, simulations were calculated based on Kampong Speu and on the Svay Rieng data. Table 18 shows the results for the simulation based on Kampong Speu, a province with a more urban characteristic and a high use of electricity, charcoal and LPG. The Svay Rieng based simulation is displayed in Table 19. It shows a more rural energy use pattern with a slower penetration of LPG and electricity and a significantly higher demand for fuel wood and kerosene.

Table 18 Total residential energy use in Cambodia based on Kampong Speu

Year	2007	2010	2012	2015	2017	2020	2022	2025	2027	2030
Total electricity demand (GWh)	750	932	1,098	1,217	1,296	1,472	1,613	1,887	2,026	2,222
Total charcoal demand (thousand tonne)	321	424	535	801	807	770	756	729	719	724
Total firewood demand (thousand tonne)	4,696	4,013	3,400	2,236	2,099	1,993	1,880	1,508	1,286	973
Total LPG demand (thousand tonne)	61	77	83	96	110	147	180	232	255	283
Total kerosene demand (thousand tonne)	26	24	16	11	10	9	8	10	10	9
Total candle demand (tonne)	5	5	4	5	5	5	5	5	6	6
Total animal dung (thousand tonne)	25	28	28	27	28	29	29	30	31	32

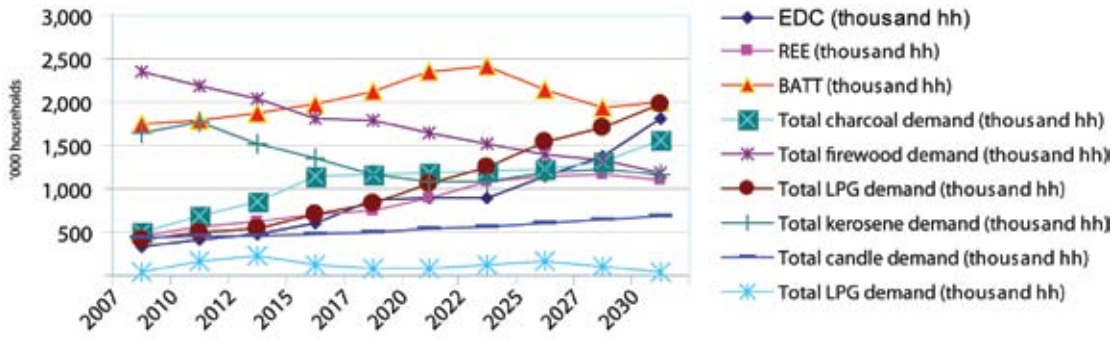
Table 19 Total residential energy use in Cambodia based on Svay Rieng

Year	2007	2010	2012	2015	2017	2020	2022	2025	2027	2030
Total electricity demand (GWh)	279	303	327	374	478	503	532	569	602	663
Total charcoal demand (thousand tonne)	42	58	70	71	73	90	103	119	138	198
Total firewood demand (thousand tonne)	4,889	4,825	4,767	4,872	4,916	4,476	4,092	4,004	3,940	3,639
Total LPG demand (thousand tonne)	22	24	26	40	45	55	60	70	80	103
Total kerosene demand (thousand tonne)	24	29	27	26	22	21	22	23	24	23
Total candle demand (tonne)	2	3	3	3	3	3	4	4	4	4
Total animal dung (thousand tonne)	87	643	940	468	261	270	449	631	414	145

The reality of Cambodia's energy balance will probably be between the two scenarios developed with data from Kampong Speu and Svay Rieng. Although there is a massive shift towards modern energy sources in both scenarios, the demand for firewood, charcoal, kerosene and batteries will remain high over the next decades.

Simulated energy transitions are shown in Figure 19, which displays the number of households using particular types of energy.

Figure 19 Projection of households using different sources of energy



Again, a more urban style transition is represented by the Kampong Speu based model, while the model using Svay Rieng data as a basis exhibits the characteristics of a more rural transition. In any of the scenarios, households use a variety of energy sources for cooking, lighting and other purposes. The Kampong Speu based forecast shows a significant decrease in fuel wood use together with an increased use of charcoal. Although EDC and REEs are expected to connect about four million households by 2030, the use of batteries will remain high. Charcoal demand will also increase. This will put additional pressure on biomass resources as current conversion technologies require six kg of wood to produce one kg of charcoal. Under this scenario, interventions to ensure a sustainable supply of fuel wood become critically important. It should be noted that not only the residential fuel wood market needs to be supplied, but that small industrial consumers such as palm sugar manufacturers and distilleries rely on biomass fuel as well. Additional pressure on forests is expected from demand for export timber. Without massive efforts to boost wood production, the search for energy will remain a daily grind for rural Cambodians. In many remote locations these people have neither electricity nor LPG to cook their food. Women and children from these families will continue to spend hours each day gathering low grade fuels – time they might otherwise be able to spend on productive work or education.

Table 20 displays the projected rural energy demand for Cambodia in TJ. The replacement of inefficient energy sources results in a continuous drop in the aggregated demand from 84,345 TJ in 2007 to 64,679 in 2030. However, this transition will not occur automatically, at least not in a smooth manner. A smooth shift from environmentally unsustainable and unhealthy energy sources to modern fuels will have to be managed and guided by an appropriate policy framework. Such a policy framework needs to acknowledge the needs of the poor and carefully balance social objectives with the economic need to price fuels at their supply cost.

Table 20 Estimated rural energy demand in Cambodia (TJ)

	2007	2010	2012	2015	2017	2020	2022	2025	2027	2030
Total electricity	1,787	2,155	2,493	2,790	3,118	3,476	3,777	4,328	4,636	5,095
Total charcoal	5,107	6,796	8,532	12,323	12,441	12,156	12,153	11,998	12,137	13,112
Total firewood	73,637	67,920	62,785	54,742	54,038	49,749	45,866	42,355	40,178	35,522
Total LPG	1,885	2,313	2,512	3,135	3,591	4,671	5,570	7,020	7,763	8,964
Total kerosene	1,108	1,166	978	843	735	673	674	731	767	717
Total candle	139	144	140	148	154	164	171	186	194	203
Total animal dung	683	4,117	5,945	3,030	1,763	1,821	2,915	4,026	2,703	1,068
Total	**84345.5**	**84610.5**	**83383**	**77009**	**75838.5**	**72707**	**71125**	**70642**	**68376.5**	**64679.5**

Energy sector development has favored urban areas

4. LESSONS LEARNED

4.1 Rural energy supply in Cambodia

The empirical data gathered in the framework of the project and its subsequent use for energy modelling provides the groundwork for both further research and project planning. The results show that households are using a mix of different sources for cooking like firewood, charcoal and LPG, and for lighting are using kerosene and car batteries and sometimes also grid electricity, depending on availability and income. The analysis has also shown that the development of the energy sector has strongly favoured urban areas, leaving rural areas behind. Phnom Penh in particular has a modern energy sector with most people connected to affordable grid electricity and a high percentage of LPG use for cooking. The provincial urban areas are following the trend of Phnom Penh, with provincial urban areas growing fast. Rural areas along major roads also seem to urbanize, particularly in Kampong Speu. Svay Rieng is a remoter, poorer and more rural province, and traditional fuels dominate its energy sector characteristics.

Rural electricity enterprises, like this one in Kampong Speu, are bringing electricity to areas where grid electricity is unavailable.

In both provinces lower income households use mainly firewood and sometimes charcoal for cooking, while higher income families use mainly LPG. However, even high-income households still use charcoal to prepare certain dishes. A similar, special purpose use for charcoal exists in rich Western countries where charcoal is used for barbeques. Poor households use mostly kerosene for lighting, while higher income households use grid electricity if available. In the absence of grid power high-income households use small generators, car batteries or a combination of both. In Kampong Speu, 60 percent use kerosene and batteries for lighting, 20 percent have grid electricity. In Svay Rieng, 75 percent use kerosene, 84 percent use batteries and only 6 percent of the households have access to grid electricity.

As local REE grids often only provide electricity during peak hours in the evening, households often use batteries to ensure availability of electricity beyond grid service hours. The data analysis revealed that households in the two surveyed provinces use more or less a constant share of their available cash to procure energy services. This share is approximately 10 percent of total monthly expenditures for all social classes (for details, refer to Table 15). Clearly, this shows that increasing household income would be a way to promote a transition to a more modern rural energy sector in Cambodia.

For many households, however, access is as much of a problem as affordability. Cambodia has one of the lowest electrification rates in Asia and among the highest electricity costs in the world. The problem is not necessarily that people are unwilling to pay for clean modern energy. Results of this survey suggest that households will spend a significant share of their incomes on clean energy, which in turn improves the quality of their life or enables them to become more productive. Privately operated REE have been supplying electricity to rural cus-

Cooking needs are quantitatively more important than lighting and appliances

tomers for years, but many enterprises are challenged by low customer demand and rising operating costs. REE-type expansion of electricity supply is thus limited to areas where at least a minimum of demand density can be found. Remote areas that show low population densities are unlikely to be covered by an expansion of private supply. Without access to electricity, poor households are denied a host of modern services such as high quality electric lighting and refrigeration. The use of lead acid batteries has been widely adopted in Cambodia to provide a minimum of power, however, at unit costs that are several times the cost of grid electricity provided by the national utility.

The supply of sustainable cooking energy may, however, be more critical for rural households than the availability of electricity services for the foreseeable future. In most rural areas fuel wood extracted from common resources is still the dominant energy source for cooking, although in Kampong Speu, 38 percent of the households already purchase firewood and 24 percent are using charcoal. In Svay Rieng, nearly every household uses wood, while 13 percent purchase wood and only 6 percent use charcoal. Wood and charcoal will remain the main energy sources for cooking till 2030. It is expected that without massive interventions, forests will disappear at alarming rates, especially in Kampong Speu where fuel wood extraction for direct use and charcoal production has already degraded vast forest areas. While difficult to quantify, the economic costs of fuel wood extraction and use are considerable. At the same time, traditional fuels have become an important rural industry providing a livelihood for many families. It is estimated that in Kampong Speu alone, approximately 8,000 families are producing more than 100,000 tons of charcoal per year and 2,700 families are cutting and selling more than 200,000 tons of fuel wood. It will be necessary to find innovative ways to engage those already working in the rural energy industry to implement strategies to boost the production of fuel wood and increase the efficiency of both conversion and end use technologies. To promote energy saving technologies will also result in a cleaner and healthier cooking environment. The high exposure risk to indoor air pollution particularly affects women and children. The proximity of the pollution source and recipients exacerbates the risks. The concentration of harmful substances in the air of a traditional kitchen is typically orders of magnitudes greater for cooking-fire generated pollution than for pollutants produced from outside sources such as power plants. Energy efficient stoves will also reduce the burden of wood collection or the expenditure households have to make for energy purchases.

Improved cook stoves help to reduce the burden of wood collection or the expenditure households have to make for energy purposes.

4.2 Next steps

The problems of rural energy in Cambodia should certainly not be dealt with in isolation. Poverty and dependence on low-grade fuels are closely related, and increases in household incomes normally trigger a switch to modern fuels if these are accessible. A purely energy sector scheme for improving rural energy may, therefore, not succeed if economic growth is

prevented. In an appropriate framework of policies that promote economic development in rural areas, one of the most powerful ways to ensure sustainable energy supplies is to guarantee that the energy market is determined by consumers' choices. Energy prices should reflect total supply cost including externalities such as environmental degradation and productivity loss. Obviously, a transition to prices that reflect supply cost cannot be achieved immediately without hurting the poor. Policy must recognize the need for price adjustments to go hand in hand with increases in rural households' incomes. Government policies should also encourage competition and consumer choice on a level playing field for different stakeholders in the energy sector including utilities, private companies, and enterprises set up by the local communities.

Unlike in other developing countries, the rural energy sector in Cambodia has enjoyed quite a liberal environment in the past with little or no rules and regulations that would have stifled the emergence of REE, fuel traders or battery charging businesses. Consequently, most rural energy is either provided by private enterprise or by household members collecting low-grade fuels. On the other hand, surprisingly little activity has developed in the area of wood production. Given the fact that wood is still an extremely popular fuel, which is increasingly commercialized, this can only be explained by the fact that in many parts of the country, forests are considered a free common resource. Even when traded, the price for wood normally only reflects the cost of harvesting and transportation and does not include resource costs (i.e. the cost of replanting).

Therefore, a high priority should be given to three-pronged interventions that address the lack of sustainable management and protection of existing forest resources, the promotion of wood production schemes, and the dissemination of more efficient technology simultaneously. Integrated, large-scale wood production programs would not only reduce the pressure on natural forest resources, but they would also create employment and income. Sustainable wood production would allow charcoal production to continue and the introduction of gasification technology to generate electricity. A sustainable wood energy supply that also addresses land management and ownership issues would produce significant benefits for rural communities. Community forestry laws are already in place and communities need assistance to develop management plans for community forestry projects. Such a program has the potential to be cost efficient and could be replicated throughout the country.

Leucaena Cephalous ***trees, a fast growing species, are being used in rural electricity generation.***

The problems of rural energy in Cambodia have long been recognized and the results of the research performed for this study reconfirm the need for quick and coordinated action. While UNDP can play an important catalytic role, real progress in tackling the threat of a rural energy crisis is critically linked to the implementation of policy and institutional changes, mobilization of local private sector, donor and NGO resources, and the development of innovative responses to the energy needs of Cambodia's rural population.

TABLES

FIGURES

Cambodia

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March 2008