# Household Fuel Use and Fuel Switching in Guatemala

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Joint UNDP/World Bank Energy Sector Management Assistance Programme
(ESMAP)

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# Acknowledgments

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# Abbreviations and Acronyms

| | |
|---|---|
| **CV** | Coefficient of variation |
| **ENCOVI** | Guatemalan National Survey of Living Conditions |
| **ESMAP** | Joint UNDP/World Bank Energy Sector Management Assistance Programme |
| **LPG** | Liquified Petroleum Gas |
| **LSMS** | Living Standards Measurement Survey |
| **OLS** | Ordinary least square |
| **PCE** | Per capita expenditure |
| **WHO** | World Health Organization |

# Units of Measure

| | |
|---|---|
| **Lb.** | Pound |
| **Q** | Quetzales |
| **MJ/kg** | Megajoules per kilogram |

# Executive Summary

1. Approximately 2.4 billion people in developing countries rely primarily on traditional biomass fuels, which tend to be used in inefficient ways with severe adverse implications for indoor and outdoor air pollution, health, productivity, and sometimes also forest cover. Hence, improving access to and use of clean and efficient energy forms part of the struggle against poverty and underdevelopment. This is often done through policies to promote interfuel substitution and improved stoves. This report focuses on household fuel use patterns and assesses the potential and the constraints for welfare-enhancement through policies to promote interfuel substitution. Household fuels are defined as energy sources used for domestic cooking, space heating, and lighting and exclude fuels used for transportation or commercial purposes.

2. Household fuel choice in the past has often been analyzed and understood through the lens of the energy ladder model. This model places relatively heavy emphasis on household fuel switching in response to rising incomes. This report views energy use through a household economics framework. The household economics framework clarifies that, in addition to income and market prices, the opportunity costs of firewood collection also need to be taken into account in shaping demand for all fuels. The opportunity costs of firewood collection are determined by household cash, labor, land, and wood resources. Fuel choices therefore need to be understood in terms of relative household resource scarcities. The household economics framework also makes it clear that it may be perfectly rational for households to use a portfolio of different energy sources at any point in time.

3. Household energy consumption patterns and the opportunities and constraints for interfuel substitution are analyzed using a Guatemalan Living Standards Measurement Survey (LSMS) known as ENCOVI 2000. Nearly one-quarter of Guatemala's population cook with firewood inside their house in a room that is not a partitioned kitchen—in other words with smoke affecting all those present while food is being cooked.

4. When the imputed value of self-collected fuels is factored in, household energy including electricity constitutes 10-12 percent of household expenditures among low-income groups. The budget share of household energy is lower in the high-income groups. When only cash outlays are considered, the budget share of household fuels and electricity is approximately 5-7 percent for most groups, but significantly higher than that for some urban low-income groups. Prices of household fuels can therefore have severe poverty implications. The study confirms that LPG is a fuel for the urban and the better off. Almost everyone in rural areas cooks in full or in part with firewood, and the same is true for almost half of the urban households. Urban consumers rely mostly on purchased wood. The evidence suggests that LPG tends to replace solid fuels among middle-class urban households, although there are also many instances where LPG and traditional

fuels are used jointly. In rural areas fuel complementation or "stacking" appears to be the more common response—modern fuels are widely used alongside traditional ones.

5. Multiple fuel usage is widespread—in urban areas 48 percent and in rural areas 27 percent cook with more than one fuel in a given month. Urban cooking fuel combinations typically involve LPG, wood, and charcoal (in that order). Even the top urban quintile has widespread wood usage, at 23 percent. Rural fuel combinations usually include firewood, sometimes LPG, and occasionally a small amount of kerosene. It therefore seems that LPG at best is partly effective as an instrument for combating indoor and outdoor air pollution through wood displacement, with the best chances of success in relatively developed urban settings.

6. The results of logit and multinomial logit regression analysis suggest that expenditure, education, household size, region, ethnicity, electrification status, and gender composition are important in influencing fuel choice. Prices and opportunity costs of firewood also matter.

7. Kerosene does not appear to have a clear price advantage vis-à-vis LPG in Guatemala. This is perhaps the reason it is used relatively little for cooking—most kerosene is used for lighting. Electricity plays a small role as a cooking fuel among the very best off. The dominant cooking fuels are wood and LPG. The wood–LPG interaction is therefore key to interfuel substitution in Guatemala.

8. It is intriguing that so many urban households continue to use wood, which is not a cheap fuel when it has to be purchased. The households that purchased wood appear to have outlays on fuelwood that are on average larger than the LPG outlays of households that use LPG for all their cooking. This suggests a potentially large scope for LPG taking over the market from firewood. When defined as the group that presently uses and pays for woodfuel and that could save on recurrent fuel costs by switching to LPG for all their cooking, the candidates for switching are approximately 40 percent of all households, among which nearly half already use LPG for part of their cooking.

9. Possible barriers for enhanced LPG usage might be high uptake costs and cultural factors. In 2002 it cost US$54–60 to begin using LPG. Broad lifestyle patterns and the desire to cook traditional wood-baked tortillas also seem important for wood usage. Households that abandon wood often live in the metropolitan area, are smaller and better educated, and purchase more ready-made food outside the house. It appears that wood usage shifts from these households to their retail suppliers.

10. Experience of household energy use in Guatemala suggests that household fuel policies elsewhere concerned with switching from biomass need to look beyond simple pricing instruments to a wider array of policy options. Household energy strategies must be based on the realization that large groups will continue to meet their cooking needs with fuelwood for the foreseeable future. Strategies therefore cannot rely exclusively on interfuel substitution. A balance needs to be struck between policies aiming at interfuel substitution and policies seeking to ameliorate the negative consequences of fuelwood such as improved stoves and better ventilation. Promotion of

LPG needs to be targeted primarily to areas where households rely on expensive purchased wood.

# 1

## Energy, Health, and Poverty

1.1 Approximately 2.4 billion people in developing countries rely primarily on traditional biomass fuels for their cooking and heating needs (IEA 2002). Biomass fuels used in inefficient and traditional ways have severe implications for health, productivity, gender equality, and the environment. In particular,

- *Indoor air pollution* from solid fuel use is a major cause of death and disease—the World Health Organization (WHO) ranks indoor air pollution from solid fuels the world's 8th largest health risk, causing 2.7 percent of global losses of healthy life (WHO 2002).[1] Indoor air pollution is caused by households burning solid fuels such as wood, charcoal, coal, cow dung, and crop residues in traditional stoves with inadequate ventilation. Solid fuels emit particulates and harmful gases when burned, causing elevated levels of indoor exposure that can reach 10-20 times above safe limits. Women, children, and the elderly are particularly exposed. The result is acute respiratory infections, chronic obstructive pulmonary disease (such as bronchitis), eye problems, and cancer of the lungs. Burns from open fires pose another significant health hazard.
- Solid fuels burned by households also contribute to *outdoor air pollution* when smoke is vented through chimneys and windows, contributing to high concentrations of particulates. This is

[1] See Smith (1999) for an overview of the issues and Bruce, Perez-Padilla, and Albalak (2000) for a comprehensive survey of the epidemiological evidence. Not all studies have controlled adequately for confounding factors (such as socio-economic factors that jointly affect fuel type and health status), but evidence from Guatemala suggests the link between fuel type and respiratory health does hold once confounding factors are controlled for (Bruce and others 1998, Torres 2002).

especially a problem in densely populated urban areas, and in cities relying heavily on coal.

?? Energy affects human *productivity* in many ways: long hours are spent collecting biomass fuels; ill health and sore eyes are induced by smoke; and animal dung is diverted to be used as a fuel instead of being used as a fertilizer to replenish soil nutrients. Electricity is also important for productivity: households that lack electricity frequently constrain activities after dark, causing a loss in productive time available and hindering school performance as alternative sources of light are of a low quality; voltage fluctuations damage equipment; and the need for expensive investment in backup power sources constrain business development.

?? *Gender inequalities* are perpetuated when women and children are those primarily responsible for fuel collection, adding to already strenuous working days without yielding monetary rewards to them or the family.

?? Fuelwood collection can sometimes cause *environmental problems* such as forest degradation and soil erosion. Firewood collection was previously thought to be unsustainable and an impending "other energy crisis" of massive wood shortages was predicted (Eckholm 1975); this is now known not to be true at the global level. Most deforestation is caused by clearing for agriculture and logging, not by wood collection. In the Sahel and other drylands, for example, limited tree cover was previously believed to be a sign of deforestation, but new research has ascertained that many such landscapes are at their climax vegetation, and that scarce rainfall rather than anthropoid causes result in prevailing vegetation patterns (ESMAP 2001). The impact of firewood collection is highly localized. Much wood is not collected from forested land. Firewood collection causes forest degradation only in certain places, particularly in areas of high population density, around cities, on fragile and sloping lands, and where common property resources are not managed well (Heltberg 2001).

?? On the positive side, collection and marketing of biomass fuels for sale is a source of *local employment* available also for the poorest of the poor who can rely on open access resources for its collection.

1.2 Improving access to and use of clean and efficient energy is therefore an important part of the struggle against poverty and underdevelopment. Clean, safe, and efficient energy is a merit good that greatly enhances consumer welfare. Development agencies pursue several different strategies in this field. Among these, the most important are interfuel substitution and improved stoves. Renewables arguably play a smaller role.

1.3 The first option, promotion of interfuel substitution, is to try to induce biomass-consuming households to switch to cleaner alternatives such as liquefied petroleum gas (LPG) or kerosene. This is often conceptualized as speeding up a fuel "switching" or "transition" process expected to take place anyway. Some countries subsidize LPG or kerosene. In some countries, such subsidy programs are ill targeted and may carry sizeable fiscal costs. Some people have suggested that subsidies on recurrent consumption of energy should be dismantled, and in some cases redirected to cover uptake costs, especially when targeted to the poor (ESMAP 2000). This is because LPG uptake costs can be quite substantial; besides paying for consumed fuels, households typically also need to invest in a stove and purchase or give a deposit for the cylinder itself. Some households invest in two cylinders. This is because two cylinders are often required to ensure continued LPG use during the cylinder refill, which can take some time depending on the local distribution systems. Such cash uptake costs are often thought to constrain LPG penetration among low-income and subsistence households.

1.4 The second option is to promote improved and more efficient biomass stoves that emit significantly less smoke, often by venting smoke through a chimney. China, India, Guatemala, and many other developing countries have had large-scale improved stove programs with varying success. Most of the programs have made improved stoves available at subsidized rates, hindering their commercialization. These programs have encountered problems often seen in other subsidy schemes: poor durability of the stoves, inappropriate stove design that does not take into account the users' needs, and the lack of technical support once installed in the field (see Barnes and others 1994 for a review).

1.5 Improved stove programs were originally conceived with the belief in an impending global fuelwood crises and therefore initially focused on reducing wood consumption through higher efficiency. The aim of lower indoor air pollution was added later, and may not always be achievable by common models of improved stoves. Although more evaluation of their impact on exposure reduction is required, it appears that improved stoves sometimes emit significant amounts of particulate matter resulting in hazardous exposure levels, low only by comparison to the open wood burning. Moreover, if lower indoor air pollution levels are achieved primarily by venting smoke outdoors, improved stoves are not a solution to outdoor air pollution.

1.6 Both options face challenges relating to adoption and use. It has proven difficult to get households to adopt them. And once adopted they are not necessarily used to their full extent. Improved stoves are sometimes used only for part of the cooking, and many households rely on multiple fuels, both modern and traditional. Entrenched cooking habits and taste preferences often make for partial fuelwood usage even where alternatives are available. And once adopted, stoves and fuels are sometimes later abandoned.

1.7 Affordability of modern fuels also constrains their uptake. This is particularly the case in rural areas with easy access to free biomass, where people see little need for switching into costlier alternatives or to invest in a wood-saving stove. The urban situation is different. Many residents in cities rely on purchased wood that is sufficiently costly as to provide a financial incentive for stove adoption or fuel switching. Difficulties of financing the stove investment and the startup costs of petroleum fuels may remain a significant barrier. Cooking habits and taste preferences accustomed to traditional woodstoves may also pose a barrier.

1.8 Program objectives sometimes differ from people's motive for changing fuel or stove. Official program motives have often emphasized the need to address deforestation, wood scarcity, and, increasingly, indoor air pollution. Intended beneficiaries may instead care more about easier cleaning of cooking utensils, avoiding sore eyes, convenient and rapid cooking, and possibly reducing collection time. This difference in the motives of people and policies is to some extent unavoidable given that clean household fuels are a merit good. However, since clean fuels and some models of improved stoves emit less smoke and also reduce soot deposition, the different objectives need not always cause problems. A good understanding of the mechanisms affecting household fuel use and fuel switching is necessary for successful adoption and continued use of new cooking technologies.

1.9 This report presents the results of a quantitative study of household fuel use in Guatemala. Guatemala was chosen because of the availability of a household survey (ENCOVI 2000) with substantial information on energy and fuel use. Moreover, Guatemala is an interesting case because five different energy sources—wood, LPG, charcoal, electricity, and kerosene—are used for cooking to a varying extent, giving hope that it will be possible to study interfuel substitution and competition.

1.10 After this introduction, chapter 2 describes theoretical approaches to household energy. Chapter 3 presents the data, and chapter 4 describes basic fuel use patterns. Chapter 5 analyzes the determinants of fuel usage using an econometric approach, while chapter 6 investigates interfuel competition and patterns of multiple fuel use. Conclusions are offered in chapter 7.

# 2

## Household Fuel Choice Theories

2.1 Household fuel choice has often been viewed in the past through the lens of the "energy ladder" model. This model places heavy emphasis on income in explaining fuel choice and tends to focus on fuel switching. Recent years have seen a change toward emphasizing a multiplicity of factors as important for fuel choices and to incorporate multiple fuel use—the idea that households prefer to have a portfolio of energy options at any one time.

### The Energy Ladder and Fuel Switching

2.2 The energy ladder model envisions a three-stage fuel switching process. The first stage is marked by universal reliance on biomass. In the second stage households move to "transition" fuels such as kerosene, coal, and charcoal in response to higher incomes and factors such as deforestation and urbanization. In the third phase households switch to LPG and electricity once their income is sufficient (Leach 1992). The simple energy ladder model is sometimes extended with more elaborate intermediate steps (Barnes and Floor 1999).

2.3 The major achievement of the energy ladder model in its simplest form is the ability to capture the strong income dependency of fuel choices. Yet the ladder image is perhaps unfortunate because it appears to imply that a move up to a new fuel is simultaneously a move away from fuels used previously. The closely related concept of fuel switching suffers from exactly the same drawback: it embodies an implicit, as yet unproven belief that introducing a new superior fuel will phase out traditional fuels. Evidence from a growing number of countries suggests that modern fuel adoption often results in multiple fuel use, where households consume a portfolio of energy sources at different points of the energy ladder (see for example Barnes and Qian 1992; Hosier and Kipondya, 1993; Davis 1998). This phenomenon has been termed fuel stacking (Masera, Saatkamp, and Kammen 2000).

2.4 Foley (1995) provided an interesting attempt at reformulating energy transition theory, suggesting a ladder of energy demand rather than of fuel preferences. As incomes grow people start to demand more diversified energy sources since they can afford to purchase a variety of appliances each of which requires a specific energy source. The poorest rural households, in contrast, are supposed to need only wood for basic cooking. Although undoubtedly true, the finding of widespread use of multiple fuels for cooking suggests genuine fuel stacking for a given purpose (see also Davis 1998).

2.5 With much of the earlier literature focused on the energy ladder and fuel switching, the relative importance of fuel stacking versus fuel switching is not generally known. To the extent multiple fuel usage is the norm, promotion of petroleum fuels may not induce the abandonment of traditional fuels and may therefore generate fewer benefits than sometimes hypothesized.

2.6 It is illuminating to consider the exceptions to the general energy model. In many countries, there are substantial numbers of middle-income households that in principle could afford modern, clean, and convenient fuels yet continue to rely fully or partly on traditional fuels. What could be the reason for this? Is it the taste or texture fuelwood imbibes to food? Traditional cooking techniques requiring open fires? Rationing because of supply constraints in fuel markets? Distance to the retailer? Temporary liquidity constraints? Prohibitive startup costs? Servants doing the cooking, possibly in a separate building? Considerations of supply security in light of volatile prices (particularly for petroleum fuels), income swings, and occasional supply constraints of petroleum fuels? The answer is not known although it would clearly be of policy interest and help address obstacles for greater penetration of new household fuels.

2.7 Another exception—poor people cooking with petroleum fuels from the top of the energy ladder—is also frequently observed in cities around the world. Here the explanation is more straightforward: in large cities wood is a commercial fuel that can be quite expensive. Fuelwood sold on markets competes in price with petroleum cooking fuels. It has therefore been suggested that the market price of the cheapest petroleum fuel imposes an upper limit on fuelwood prices. Price competition between fuelwood and petroleum fuels is likely to be particularly intense where wood is relatively scarce or distant from the city.

2.8 The energy ladder model has other shortcomings as well, at least in its simplest form. Many other factors beside income also matter in fuel choice. The model can lead to an excessive emphasis on the need to push LPG rapidly, which is regarded as the inevitable end-result in a unidirectional evolutionary process. But the energy ladder model provides little practical guidance as to how energy sector interventions can be designed to effectively promote welfare and health across the population. A more policy relevant and realistic theory of household energy demand is thus called for, and in the following an attempt is made to help provide the foundations for such a theory.

## Household Model for Fuel Choice

2.9 The inspiration for the framework presented in the following comes from the literature on household economic models, which provides a theoretical framework for studying household decisionmaking in circumstances where consumption and production decisions are interlinked. The household model has found widespread use within agricultural, health, and development economics; it is relevant for understanding energy demand because many households in poor countries both produce and consume biomass fuels, and because energy is not a final good but rather an input that complements household labor time. The framework may help understand how households react to resource constraints and scarcities and how that affects energy interventions (Dewees 1989).

2.10 Figure 2.1 provides a schematic overview of how energy maps to utility within the wider context of the household and its budget and time constraints. Energy is provided by a multiplicity of sources. Each energy source is a commodity with multiple attributes and multiple purposes. Purposes include cooking, heating, lighting, religion (in the case of candles), entertainment, and so on. Attributes include energy content, convenience, safety, speed of cooking, taste given to food, quality of light, and smoke emitted when burned. Energy sources are intermediate inputs into the utility function. Utility is derived from the final goods such as cooked food, heat, entertainment, and light, which energy sources help produce. Moreover, utility can also depend directly on certain attributes of energy sources, for example smoke.

2.11 Energy sources and household labor together enter the cooking production function, which is shaped by the stove. Liquid and gaseous fuels are complementary to labor in cooking because they enhance labor productivity—to get a pot of water boiling takes a long time with firewood in a traditional, open stove.

2.12 Households maximize utility, defined with respect to consumption, leisure, and fuel attributes, subject to cooking and agricultural production functions and time and income constraints. These constraints depend on the household's endowments of money, labor, and agricultural resources such as farm and common property land, trees, and animals. To a certain extent the time and budget constraints are interchangeable because time spent on the labor market reduces time for household activities. Likewise hired labor relieves the time constraint. The extent to which the budget and time constraints are interchangeable depends on how well labor markets function.[2]

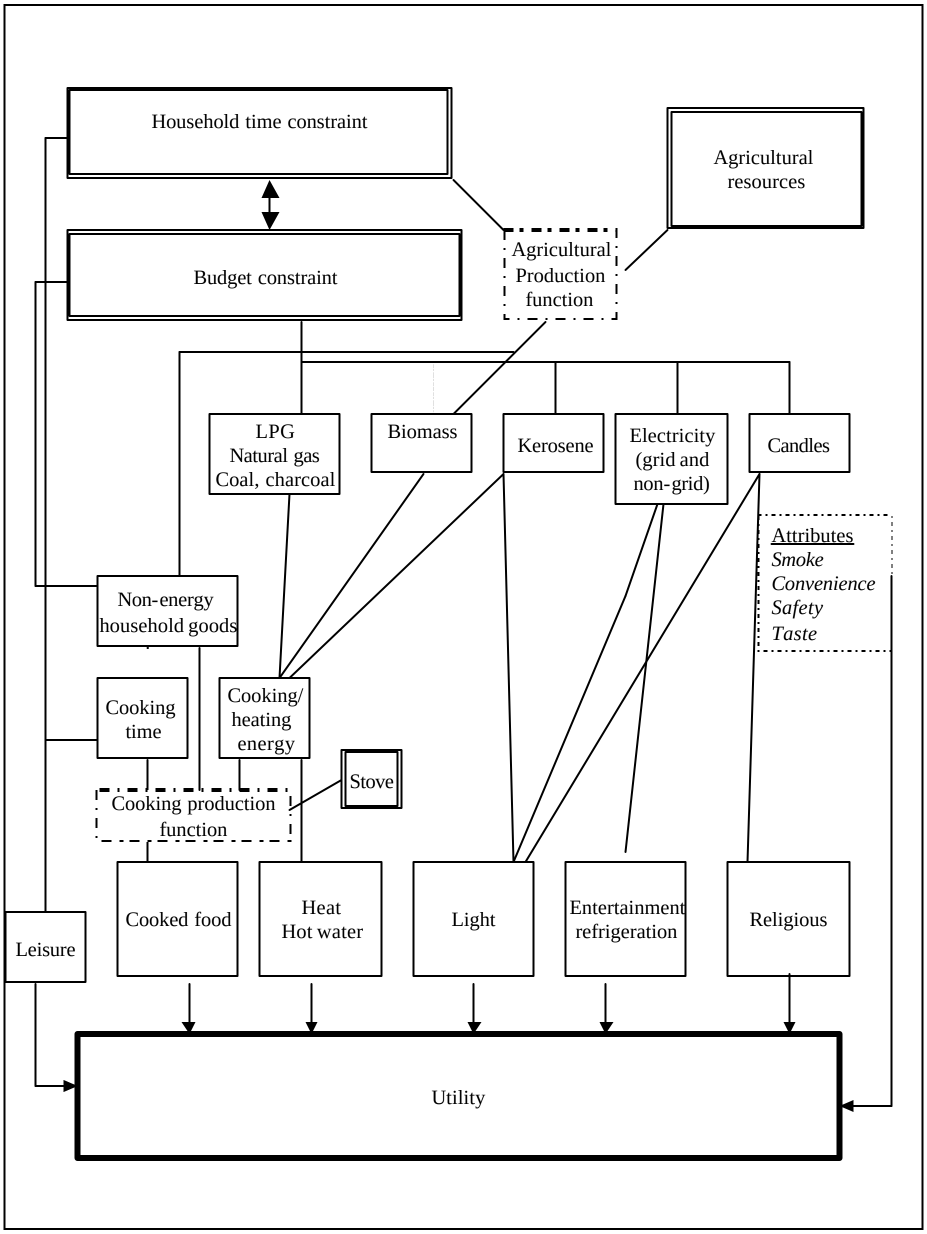
2.13 All energy sources carry a cost. Electricity and petroleum fuels have startup costs and consumption-dependent charges. Since consumption credit is usually very limited in developing countries, startup costs often need to be financed via the current-period budget constraint. Biomass fuels collected or produced by the household itself carry the opportunity cost of using labor, land, and sometimes dung to provide energy. The time and budget constraints implicitly capture the opportunity costs. From the household's overall maximization problem, one can derive a "reservation price" of biomass fuel. The reservation price is basically the opportunity cost to the household of

[2] This is the subject of *separability* discussed extensively in the literature on household models (Sadoulet and de Janvry, 1995; Singh, Squire, and Strauss, 1986).

biomass fuel when produced using the most efficient combination of labor and agricultural resources. When households operate in fuel markets, their decision price is determined by the market price.[3] Biofuels are therefore sometimes commercial fuels and sometimes not, typically because of high transport and transaction costs. For nonmarket participants, the decision price of biomass is the reservation price as determined by biomass availability and the opportunity cost of collection labor. The reservation price is specific to the household and unobservable (see Heltberg, Arndt, and Sekhar 2000 for a formal model).

[3] For households that sell fuels the decision price is the market price minus transaction costs and for households that purchase fuels the decision price is the market price plus transaction costs.

**Figure 2.1: Theoretical Framework**




2.14 Empirical evidence based on the household economic framework strongly suggests that the reason for widespread collection of firewood in rural areas—even in places of mounting or severe scarcity of wood—is the very low opportunity cost of collection labor time, including female and child labor. Studies from Nepal have found that better off-farm labor opportunities are crucial for stabilizing forest levels, basically because off-farm wages set a downward limit on the opportunity cost of time. This may be the only factor capable of regulating firewood supply from open access forests and commons (Bluffstone 1995). The combination of locally available biomass and low opportunity costs of collection labor time hinders uptake of commercial fuels in rural areas and small towns of low-income countries. Fuelwood becomes expensive where wood scarcity drives up its price or where rising opportunity costs of collection labor make self-collection unattractive. Once commercialized fuel markets exist, petroleum fuels can get their breakthrough if they can compete on price with fuelwood. City residents already paying for fuelwood are therefore the first to switch fuel. The nature of interfuel competition changes from price to quality competition once the purchasing power is comfortable (say in middle-income countries); natural gas, electricity, and LPG stand to win that competition as the most convenient fuels.

# 3

## Household Energy in Guatemala

3.1 The purpose of this chapter is to provide an overview of household energy issues and markets in Guatemala. It also describes the data set employed for the empirical analysis, highlighting the energy-related features, and surveys evidence on firewood-health links.

### Data Sources, Expenditures, and Energy Markets

3.2 This report employs Guatemala's National Survey of Living Conditions (ENCOVI 2000). The data set, which was collected during the year 2000, contains information on 3,424 urban and 3,852 rural households. Following standard practice in the literature on analysis of household surveys, welfare comparisons are based on a measure of total household expenditure per capita that includes both cash expenditures and the imputed value of the household's home use of its own production. This is the preferred indicator of household welfare and long-run or permanent income in much of the applied microeconomic literature; it is used in this report for welfare comparisons and to assess income effects on fuel demand in the regressions. Quintiles are defined in terms of expenditure per capita adjusted for spatial price variation, dividing the sample into five equal-sized groups of individuals.

3.3 Based on a national poverty line of 4,318 Quetzales (Q) per capita per year (or US$1.5 per person per day when evaluated at the market exchange rate), the total headcount is 56 percent, with 25 percent poverty in urban areas and 75 percent poverty in rural areas. An ultra-poverty line has also been defined at 44 percent of the poverty line (corresponding to US$0.66 per person per day), giving an ultra-poverty headcount of 11.3 percent. Thus, when interpreting the tables in the following, it is useful to remember that the poor correspond to roughly the bottom three quintiles and the ultra-poor to half the bottom quintile. All tables unless otherwise noted are based on nationally defined quintiles (that is, quintiles are not sector-specific). The bottom three quintiles therefore have a large rural majority and the top quintile has a large urban majority. Table 3.1 shows for each quintile its rural and urban population, poverty headcount, and median spending.

**Table 3.1: Population and Poverty in Guatemala by Quintile and Sector**

| *Quintile* | *Total number of people* | *Poverty headcount (%)* | *Ultra-poverty headcount (%)* | *Median expenditure (US$/pc/year)* |
|---|---|---|---|---|
| *Urban* | | | | |
| 1 | 188,259 | 100.0 | 65.6 | 228.3 |
| 2 | 386,320 | 100.0 | 0.0 | 348.6 |
| 3 | 745,276 | 82.9 | 0.0 | 498.7 |
| 4 | 1,237,370 | 0.0 | 0.0 | 796.7 |
| 5 | 1,840,629 | 0.0 | 0.0 | 1870.8 |
| Total | 4,397,854 | 0.27 | 2.8 | 1060.1 |
| *Rural* | | | | |
| 1 | 2,089,302 | 100.0 | 79.6 | 209.6 |
| 2 | 1,890,736 | 100.0 | 0.0 | 337.8 |
| 3 | 1,531,631 | 80.0 | 0.0 | 497.9 |
| 4 | 1,038,869 | 0.0 | 0.0 | 743.3 |
| 5 | 437,049 | 0.0 | 0.0 | 1349.4 |
| Total | 6,987,587 | 0.74 | 23.8 | 426.1 |
| *National* | | | | |
| Total | 11,385,441 | 56.2 | 11.3 | 601.6 |

*Source:* Author's calculations based on ENCOVI 2000

3.4 Foster, Tre, and Wodon (2000a) present estimates of the gross and net total energy consumption by households in Guatemala. Their findings suggest that the amount of energy used follows an inverse-U shape in which energy use first rises with expenditures and later falls. This pattern is especially pronounced for gross energy use, which peaks in the middle of the income distribution. The reason is the low energy efficiency of the fuels used by low-income households, in particular wood for cooking.

3.5 LPG is sometimes also referred to as propane or butane in Guatemala. Hydrocarbons can be imported and distributed freely in Guatemala subject to some technical and safety regulation as set out in the 1997 Marketing of Hydrocarbons law. Hydrocarbon price setting was liberalized in 1994 and 1995. Two Mexican firms dominate Guatemala's LPG sector. Since 2000 when the ENCOVI survey was undertaken these suppliers have engaged in a price war and as a result prices have fallen substantially. According to Matthews (2002), total consumption of LPG grew by 4.6 percent annually between 1996-2001. Most LPG is used in the residential sector (73 percent) with the rest used for commercial (15 percent), industrial (10 percent), and transport purposes (2 percent).

3.6 Foster and Araujo (2001) describe and analyze Guatemala's electricity sector. Several reforms occurred in the sector during the second half of the 1990s: competition was introduced, generation was partly privatized, and foreign investment was brought in. As a result, coverage improved with the connection rate increasing from 53 percent in 1996 to 70 percent in 1999. Prices have also risen substantially, however, and unmetered connections are problematic. Access to modern utilities including electricity is generally very unequal in Guatemala, but there are signs that things are improving as a result of the 1996 peace accords. Guatemala has an active policy goal to expand grid coverage to disadvantaged rural communities. Proceeds from the privatization of the power generation assets are used to this end. Since electricity is more than one hundred times more efficient than candles and kerosene lamps for lighting, access to the electricity grid has been shown to help significantly reduce the cost per unit of effective energy in Guatemala (Foster, Tre, and Wodon 2000b).

3.7 Guatemala has experienced substantial problems with forest degradation and soil erosion. Many national and international NGOs are active in Guatemala working on reforestation, forest management, and improved fuel-efficient woodburning stoves.

## Energy Data Issues

3.8 Some special energy-related features of the data merit attention. For each fuel, the survey asked households the total quantity consumed last month, the value of this consumption, and to provide a purpose breakdown. One can also distinguish purchased from self-collected wood and identify whether households are connected to the electricity grid. In addition, an accompanying community and price questionnaire provides price data at the community level for LPG, firewood, and kerosene. Compared to LSMSs undertaken in other countries, the present data set has much richer energy and fuel details, at least in principle.

3.9 At closer inspection, a number of data problems become apparent. For LPG (referred to as propane in the survey), households were asked to report how much they either purchased or consumed, and it is somewhat unclear when purchase and when consumption is reported. Most observations on LPG cluster at exactly 25 or 35 pounds per month, corresponding to the prevailing cylinder sizes. Only 12.4 percent of LPG users report less than 25 pounds. It is highly unlikely that so many households consume exactly one cylinder per month. Many households must have reported their purchase, finding it hard to estimate consumption of fractions of a cylinder. As the survey questionnaire unfortunately did not include a question on cylinder refill frequency, consumption cannot be estimated. Some respondents, however, report amounts that do not correspond to a prevailing cylinder size, suggesting they are instead reporting a consumption estimate. It is possible that the LPG quantity data have an upward biased.

3.10 Parallel problems appear on the expenditure side, resulting in clustered and possibly inflated LPG expenditure data. The median LPG expenditure is 65Q per month, equal to the median cost per 25-pound cylinder according to the accompanying price survey. Thus, many survey respondents reported their LPG expenditures as the cost of exactly one cylinder, even if they were supposed to report the value of actual consumption. Below it is found that cooking with LPG appears to be cheaper than cooking with purchased wood; this cost advantage of LPG is despite, not as a result of, the possible overstating of LPG expenses.

3.11 It is also not possible to identify whether the household has one or two LPG cylinders. Because of delays in delivery, two cylinders are normally required for uninterrupted use, and households with just one LPG cylinder may therefore be forced to use alternative fuels as backup during refill. For other energy sources, issues arise relating to recall error (electricity) and measures that are not uniform (firewood bundles vary in size).[4] The reliability of most data on energy consumption quantities is therefore in doubt. Usage—whether or not the household consumed a given energy source—should be correctly identified, however. Most of this report is therefore devoted to analyzing patterns of fuel usage.

3.12 The survey does not allow identification of market sales of wood. It does however allow one to make a distinction between households cooking with self-collected firewood and with those cooking with market-purchased firewood. The survey contains two similar questions on firewood purchases. The first is a question that asks directly how the household obtained its firewood last month; an option here is that all was purchased. The second question is whether the household bought any firewood last month. If the reply was "yes" to the second question, they would be prompted for quantity and value of consumption. Those who did not purchase wood were asked whether they used any firewood as well as the quantity and (subjectively imputed) value of self-collected wood. Although most responded in a mutually consistent manner to the two questions on the purchase of wood, 15 percent replied inconsistently (yes to one of the questions on wood purchase and no to the other question, whereas a consistent reply would have been "yes-yes" or "no-no'). For the purpose of this report, a household was defined as a firewood purchaser if it answered yes to both questions; in other words, where there is doubt the household is classified as a collector. This procedure is likely to misclassify as collectors some households who purchased a portion of their firewood, or the few who received firewood as a gift. It is hence a conservative estimate of firewood purchases. The value of self-collected wood is subject to substantial uncertainty: How did households impute its cost? Relative to local market prices, did they add or subtract transport costs? It is therefore used only little and the relevant figures for the market purchasers are provided alongside, referred to as "cash wood." The regression analysis

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[4] Kerosene—measured in liters and purchased in small quantities—seems to suffer less from these problems.

does not rely on unit costs; observed market prices from the price questionnaire are used instead.

## Firewood and Health Hazards

3.13 No data on emission concentration or exposure were collected. Since wood usage and type of kitchen are known, however, the survey data can give a rough sense of how many people are likely to be exposed to hazardous indoor air pollution. Elevated doses and durations of smoke exposure are found where solid fuels are used for cooking inside unvented houses. Highest at risk are those who burn solid fuels in an all-purpose room (not a designated kitchen) so that all household members at home are exposed and exposure is protracted beyond the duration of cooking. Exposure can be assumed as lower when households cook outside the house. Cooking in a kitchen (a room with a partition) presumably results in intermediate amounts of exposure, depending on ventilation, cooking duration, number of people present, and other factors. Table 3.2 analyzes the interrelationship between cooking with wood and the place of cooking: whether the household normally cooks inside the house in a kitchen, inside the house but not in a kitchen, in a separate building outside the house, or in the open.

**Table 3.2: Firewood Usage and Cooking Arrangement**

*In % and number of persons*

| | *Place of cooking:* | | | | | |
|---|---|---|---|---|---|---|
| | *Inside* | | *Outside* | | *Total* | *Number of people* |
| | *with partition* | *no partition* | *separate building* | *open air* | | |
| *Urban* | | | | | | |
| Do not use firewood | 27.9 | 17.5 | 1.0 | 0.1 | 46.5 | 2,037,870 |
| Use firewood | 23.1 | 17.1 | 10.2 | 3.1 | 53.5 | 2,342,795 |
| Total | 51.0 | 34.5 | 11.2 | 3.2 | 100.0 | 4,380,665 |
| Number of people | 2,235,144 | 1,513,255 | 490,498 | 141,768 | 4,380,665 | |
| *Rural* | | | | | | |
| Do not use firewood | 1.5 | 1.0 | 0.3 | 0.0 | 2.8 | 198,308 |
| Use firewood | 35.9 | 29.0 | 30.0 | 2.3 | 97.2 | 6,781,502 |
| Total | 37.4 | 30.0 | 30.3 | 2.3 | 100.0 | 6,979,810 |
| Number of people | 2,611,157 | 2,095,075 | 2,115,710 | 157,868 | 6,979,810 | |
| *National* | | | | | | |
| Do not use firewood | 11.7 | 7.3 | 0.6 | 0.0 | 19.7 | 2,236,178 |
| Use firewood | 30.9 | 24.4 | 22.4 | 2.6 | 80.3 | 9,124,297 |
| Total | 42.7 | 31.8 | 22.9 | 2.6 | 100.0 | 11,360,475 |
| Number of people | 4,846,301 | 3,608,330 | 2,606,208 | 299,636 | 11,360,475 | |

*Note:* The table is population-weighted. Percentages and numbers represent individuals, not households.

*Source*: World Bank calculations and ENCOVI 2000

3.14 Among firewood-using households, one-third in rural areas and one-fourth in urban areas cook outside the main home, mostly in a separate building. This share is much larger as compared to households not using firewood. Cooking outside the main home limits the overall household smoke exposure, although the cook and any infants with her remain exposed.[5] A substantial proportion (24.4 percent) of the country's population, however, resides in households that cook with firewood inside their house in a room that is not a partitioned kitchen. Exposure levels are likely to exceed safe levels for this group, of which only 18 percent live in a house with a chimney. People cooking

[5] Most cooking in Guatemala is done by women. Households using only wood spend 2–3 hours daily on cooking. Infants are usually with their mother while she is cooking (Torres, 2002).

with firewood in a partitioned kitchen or in a separate building—53.3 percent of the population—are also exposed to high levels of smoke, but their exposure is likely to be more confined to the cook(s) and during the time that cooking takes place.

3.15 Exposure to indoor air pollution is much larger in rural areas as compared to urban areas. Firewood usage is almost double in rural areas, and this is only partly compensated by more rural outdoor cooking. Therefore, the proportion of people in rural areas using fuelwood indoors without a partition, at 29 percent, remains well above the corresponding figure for urban areas, which is 17 percent. Also, breaking down cooking patterns by quintile (not shown in the table) reveals that the poor are over-represented among firewood users cooking inside without a partition. Indoor air pollution, however, is encountered in most income groups in both rural and urban areas.

3.16 Table 3.3 tabulates the incidence of respiratory symptoms among infants below six years of age. All surveyed mothers were asked whether their infants had any cough, cold, bronchitis, breathing trouble, or respiratory infection during the last month. This is a broad group of symptoms, comprising both severe and mild cases, and it does not allow identification of acute respiratory infections. Among wood users 48 percent of the infants experienced some of these respiratory symptoms as compared to 43 percent in households that did not use fuelwood. With the exception of the tiny group of people cooking in the open, wood use is associated with increased prevalence of respiratory symptoms for all cooking arrangements. And the highest prevalence of infant respiratory symptoms occurs among households cooking with wood indoors in an unpartitioned room, as hypothesized above. Cuellar (2002), using the same data and a regression setup where several confounding factors are controlled for, confirms a significant effect on respiratory symptoms of cooking with wood. The probability of developing respiratory infections is largest if the household is poor and if the infant has malnutrition problems. Restricting the analysis to acute respiratory infections, Torres (2002) finds similar effects of fuels and cooking arrangements on health outcomes. These findings help motivate the importance of examining the potential for interfuel substitution in reducing indoor air pollution and increasing welfare.

**Table 3.3: Infant Respiratory Symptoms by Wood Usage and Cooking Arrangement**

*In %*

| | *Place of cooking:* | | | | *Total* |
|---|---|---|---|---|---|
| | *Inside* | | *Outside* | | |
| | *With partition* | *No partition* | *Separate building* | *Open air* | |
| *National* | | | | | |
| Do not use firewood | 44 | 43 | 34 | 87* | 43. |
| Use firewood | 48 | 53 | 42 | 53 | 48 |

*Note:* Proportion of infants with respiratory symptoms (cough, cold, etc) last month

* The sample size in this case is very small and the figure may not be representative

*Source*: Author's calculations based on ENCOVI 2000

# 4

## Energy Expenditure and Fuel Usage

4.1 As already mentioned, the survey makes it possible to map each fuel to usage: [6]

- ?? Most electricity is used for lighting (94 percent) with the rest for cooking and business
- ?? LPG is almost only for cooking (98 percent) with a little bit for business
- ?? Kerosene goes mostly for lighting (85 percent) with the rest for cooking
- ?? Firewood and charcoal are used almost all for household cooking, with a little bit for business purposes
- ?? Candles are used for lighting, with approximately 10 percent for religious purposes

4.2 Table 4.1 shows median energy budget shares defined as the value of energy spending in proportion to total expenditures broken down by sector and quintile. Two sets of data are shown: total value of all energy consumption[7] divided by total expenditures and cash energy expenditures (the difference between the two is made up of self-collected firewood).[8]

4.3 The median total energy expenditure share is 8.6 percent. It is higher for the poor, who spend 10–13 percent of their budget on energy, double of what the top

[6] Note that the survey coding did not include an option for heating. In the highlands of Guatemala, some of the firewood and kerosene may therefore be used for heating rather than cooking as reported here. This aspect would in any case be hard to quantify, however, since heat and cooking are produced jointly.

[7] For self-collected biomass, gifts, and consumption out of stocks, households were asked to report what the fuel would have cost had it been purchased. Almost 7 percent of wood users, however, did not report any value of their firewood consumption. The figures on total budget share (but not those for cash outlays) are therefore biased downward for firewood consumers. For LPG spending figures may well be upward biased as already discussed.

[8] Although the most extreme observations on budget share were omitted, the medians are reported here to avoid undue influence by outliers. Averages are higher.

quintile spends. Energy is thus a basic good that constitutes a major expenditure item for the poor, although not all of it is in the form of cash outlays. The total energy budget share does not differ all that much between rural and urban areas, but this changes once the imputed value of self-collected firewood is excluded. The urban cash energy budget share consistently exceeds the rural in each quintile. Also, whereas the cash energy budget share is quite constant across quintiles in rural areas, some of the urban low-income groups spend relatively more of their income on commercial fuels than the upper quintiles. This is because the rural poor largely substitute self-collection for cash fuels, something that the urban poor are not always able to do (with the exception of urban households in the bottom quintile). Barnes, Krutilla, and Hyde (2002) report a similar finding of energy budget shares declining steeply with income in a sample of 45 cities worldwide. Providing affordable fuels for the urban poor is therefore important for poverty alleviation.

**Table 4.1: Median Household Expenditure Share on Energy**

*In percent*

| | *Quintile* | | | | | *Total* |
|---|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | *5* | |
| *Urban* | | | | | | |
| All energy expenditures | 9.8 | 10.5 | 9.2 | 6.9 | 4.3 | 5.7 |
| Cash expenditures only | 5.2 | 8.1 | 7.8 | 6.4 | 4.2 | 5.1 |
| Rural | | | | | | |
| All energy expenditures | 10.2 | 8.9 | 7.9 | 7.4 | 5.4 | 8.2 |
| Cash expenditures only | 3.6 | 3.5 | 4.4 | 5.1 | 4.5 | 4.0 |
| *National* | | | | | | |
| All energy expenditures | 10.1 | 9.1 | 8.5 | 7.0 | 4.5 | 7.1 |
| Cash expenditures only | 3.7 | 3.7 | 5.4 | 5.8 | 4.2 | 4.6 |

*Note:* Table shows household energy expenditures (including electricity and cooking fuels) in proportion to total expenditures. "All energy" includes the imputed value of self-collected wood; "Cash expenditures" excludes self-collected wood.

*Source:* Author's calculations based on ENCOVI 2000

## Expenditure by Fuel

4.4 This subsection discusses usage and spending patterns for each energy source, making no attempt to distinguish between different purposes for which the fuels are used (this is done from paragraph 4.11 onward). Table 4.1 shows the proportion of households in each group that uses a particular fuel. In addition to electricity and fossil household fuels, the table also shows firewood from all sources as well as just purchased firewood.[9]

4.5 In urban areas, the most commonly used energy source is electricity, consumed by 95 percent of the households, followed by LPG which 78 percent use, firewood used by 46 percent (two-thirds of which is bought), charcoal (25 percent) while few use kerosene. In addition, batteries and candles are also used widely (not shown). Usage patterns depend on quintile: one-third of the poorest urban quintile is not covered by electricity, LPG and charcoal usage is much lower, and firewood is universal (a larger share of the firewood used by the poor is self-collected). In rural areas, almost everybody uses firewood (one-third of which is bought), while 56 percent use electricity, 41 percent use kerosene, and only 20 percent use LPG. When we look specifically at the rural poor, firewood is universal, much fewer have electricity, and instead kerosene is more important.

[9] Recall that automotive fuels are excluded throughout this paper.

**Table 4.2: Usage Rates of Energy Sources, by Quintile and Sector**

*In percent*

| | *Quintile* | | | | | *Total* |
|---|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | *5* | |
| *Urban* | | | | | | |
| Electricity | 66.6 | 83.1 | 90.8 | 97.0 | 99.1 | 95.5 |
| LPG | 6.7 | 24.6 | 58.9 | 81.4 | 91.8 | 77.9 |
| Kerosene | 28.3 | 12.3 | 7.4 | 4.3 | 1.5 | 4.4 |
| Charcoal | 2.0 | 6.8 | 11.1 | 18.9 | 34.7 | 24.7 |
| Firewood (all sources) | 97.5 | 90.7 | 76.0 | 60.3 | 23.0 | 46.4 |
| Firewood (cash only) | 38.4 | 49.9 | 49.6 | 42.3 | 16.8 | 30.7 |
| *Rural* | | | | | | |
| Electricity | 31.3 | 49.7 | 64.7 | 72.7 | 78.0 | 56.2 |
| LPG | 1.3 | 5.8 | 17.7 | 40.9 | 64.8 | 20.2 |
| Kerosene | 60.1 | 47.0 | 34.2 | 24.8 | 23.3 | 40.5 |
| Charcoal | 0.7 | 1.3 | 2.7 | 6.6 | 13.1 | 3.7 |
| Firewood (all sources) | 99.6 | 99.4 | 97.5 | 93.0 | 77.2 | 95.5 |
| Firewood (cash only) | 22.7 | 26.9 | 40.3 | 40.1 | 37.3 | 32.5 |
| *National* | | | | | | |
| Electricity | 34.2 | 55.1 | 73.0 | 85.0 | 94.6 | 73.1 |
| LPG | 1.7 | 8.9 | 30.7 | 61.4 | 86.2 | 45.1 |
| Kerosene | 57.5 | 41.3 | 25.7 | 14.4 | 6.1 | 24.9 |
| Charcoal | 0.8 | 2.2 | 5.4 | 12.8 | 30.2 | 12.7 |
| Firewood (all sources) | 99.5 | 98.0 | 90.7 | 76.4 | 34.3 | 74.4 |
| Firewood (cash only) | 23.9 | 30.7 | 43.3 | 41.2 | 21.1 | 31.7 |

*Note:* Table shows the proportion of households using each fuel, irrespective of purpose

*Source:* Author's calculations based on ENCOVI 2000

4.6 Table 4.3 reports the average total value spent by households on each fuel (cash outlays for purchased energy sources, imputed values for collected firewood). Mean spending refers to users only—averages are taken over nonmissing and nonzero values. Table 4.4 reports per capita average spending. The general conclusions do not depend on which measure is used.

4.7 The largest energy expenditure items are firewood, electricity, and LPG. Outlays on kerosene and charcoal are substantially lower as those fuels are mostly used as supplements for others. In all but the best-off quintile, firewood represents the single largest energy expenditure item. Since most households consume it, the value of firewood constitutes a large share of the average household energy budget. It is also the largest cash outlay for those who purchase it. LPG spending is also substantial among its users, while electricity spending is large for the best off and relatively modest for others.

**Table 4.3: Household Energy Expenditures by Energy Sources**

*In Quetzales/month/household*

| | *Quintile* | | | | | *Total* |
|---|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | *5* | |
| *Urban* | | | | | | |
| Electricity | 35.6 | 41.6 | 59.3 | 74.9 | 150.8 | 110.4 |
| LPG | 55.7 | 63.8 | 63.4 | 64.8 | 80.7 | 74.2 |
| Kerosene | 19.3 | 14.5 | 17.7 | 14.6 | 9.0 | 15.1 |
| Coal | 2.0 | 4.6 | 10.5 | 10.3 | 11.4 | 10.9 |
| Firewood (all sources) | 72.4 | 89.2 | 101 | 82.3 | 77.9 | 85.7 |
| Firewood (cash only) | 87.1 | 104.2 | 96 | 94.5 | 89.1 | 94.1 |
| *Rural* | | | | | | |
| Electricity | 34.2 | 28.9 | 39.2 | 51.5 | 89.1 | 46.3 |
| LPG | 60.2 | 64 | 66 | 64.9 | 72.1 | 67.3 |
| Kerosene | 10.4 | 10.6 | 13 | 13.5 | 11.7 | 11.4 |
| Coal | 20.8 | 5.7 | 5.5 | 15 | 13.5 | 12.3 |
| Firewood (all sources) | 74.5 | 86.1 | 90.7 | 85.6 | 88.7 | 84.5 |
| Firewood (cash only) | 85.1 | 111 | 108.3 | 98.2 | 120.5 | 104.2 |
| *National* | | | | | | |
| Electricity | 34.4 | 32 | 47.1 | 65.1 | 140.1 | 82.3 |
| LPG | 58.7 | 63.9 | 64.4 | 64.8 | 79.4 | 72.4 |
| Kerosene | 10.8 | 10.7 | 13.4 | 13.6 | 11.2 | 11.7 |
| Coal | 17.1 | 5.1 | 8.8 | 11.5 | 11.6 | 11.2 |
| Firewood (all sources) | 74.3 | 86.6 | 93.5 | 84.3 | 83.1 | 84.8 |
| Firewood (cash only) | 85.4 | 109.2 | 103.8 | 96.3 | 100.8 | 100 |

*Note*: Table shows expenditures in Quetzales/month/household averaged over users

*Source:* Author's calculations based on ENCOVI 2000

**Table 4.4: Per Capita Energy Expenditures by Energy Sources**

*In Quetzales/month/household member*

| | *Quintile* | | | | | *Total* |
|---|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | *5* | |
| *Urban* | | | | | | |
| Electricity | 4.8 | 7.2 | 10.3 | 15.5 | 42.6 | 28.5 |
| LPG | 10.6 | 10.7 | 11.6 | 14.3 | 26.0 | 21.0 |
| Kerosene | 3.0 | 3.0 | 3.8 | 3.8 | 3.7 | 3.5 |
| Coal | 1.4 | 2.0 | 2.4 | 3.1 | 5.5 | 4.1 |
| Firewood (all sources) | 10 | 15.1 | 18.7 | 16.4 | 24.5 | 18.4 |
| Firewood (cash only) | 12.4 | 17.1 | 16.1 | 18 | 28 | 20.1 |
| *Rural* | | | | | | |
| Electricity | 4.4 | 4.7 | 7 | 12 | 25.7 | 10 |
| LPG | 7.9 | 11.2 | 11.4 | 14.9 | 24 | 16.8 |
| Kerosene | 1.5 | 2 | 2.9 | 4.4 | 5.3 | 2.5 |
| Coal | 2.4 | 3.4 | 3.2 | 4.4 | 9.1 | 3.9 |
| Firewood (all sources) | 10.4 | 15.4 | 18.4 | 22.3 | 30.1 | 17.4 |
| Firewood (cash only) | 11.9 | 19.8 | 20 | 24.2 | 36.7 | 21.6 |
| *National* | | | | | | |
| Electricity | 4.5 | 5.3 | 8.3 | 14 | 39.7 | 20.4 |
| LPG | 8.8 | 11 | 11.5 | 14.5 | 25.7 | 20 |
| Kerosene | 1.6 | 2.1 | 3 | 4.3 | 5 | 2.6 |
| Coal | 2.3 | 3.2 | 2.9 | 3.8 | 6.3 | 4 |
| Firewood (all sources) | 10.3 | 15.4 | 18.5 | 20 | 27.1 | 17.7 |
| Firewood (cash only) | 11.9 | 19.1 | 18.6 | 21 | 31.2 | 21 |

*Note:* Table shows expenditures in Quetzales/month/capita averaged over users

*Source:* Author's calculations based on ENCOVI 2000

## A Closer Look at Firewood

4.8 It is particularly striking from the previous tables how much the poor appear to spend on firewood, especially those who purchase their wood. Although the proportion of wood users who purchase it rises with total expenditure and urbanization, substantial numbers of poor and rural also purchase fuelwood. It is surprising that 24 percent nationally of households in the bottom and 31 percent in the second quintile purchase wood. The implication is that firewood markets are important for the poor, who need them both as buyers and sellers.[10] Many nonpoor also consume firewood: in the top quintile 23 percent of urban and 77 percent of rural households use wood. It is also surprising to note that wood purchasers are spending more in absolute terms on purchasing wood every month than LPG users spend buying LPG. This is true in each quintile in both urban and rural areas. This is intriguing and raises the possibility that a lot of households presently purchasing firewood could save money by switching to LPG. Given that LPG is widely recognized as a superior cooking fuel (cleaner, faster, more convenient) it begs the question: why so many households then continue to cook with apparently more expensive purchased fuelwood? The straightforward comparison of average LPG spending with average woodfuel spending, however, is perhaps misleading since so many households use more than one cooking fuel. Chapter 6 below returns to this issue and compares spending between households cooking only with LPG and only with firewood.

4.9 It is also of interest to consider how much time is spent collecting firewood. Table 4.5 reports how much time household members in total spent collecting firewood the day before being surveyed.[11]

**Table 4.5: Firewood Collection Time**

| *Minutes per day per household* | | | | | |
|---|---|---|---|---|---|
| *Quintile* | *Women* | *Men* | *Girls* | *Boys* | *All members* |
| *Urban* | | | | | |
| 1 | 28 | 44 | 5 | 39 | 116 |
| 2 | 7 | 18 | 1 | 13 | 39 |
| 3 | 2 | 11 | 1 | 20 | 34 |
| 4 | 2 | 4 | 0 | 1 | 7 |
| 5 | 1 | 1 | 0 | 0 | 2 |
| Total | 2 | 6 | 1 | 5 | 13 |
| *Rural* | | | | | |
| 1 | 15 | 47 | 13 | 33 | 108 |
| 2 | 13 | 36 | 3 | 25 | 77 |
| 3 | 11 | 29 | 2 | 11 | 53 |
| 4 | 8 | 16 | 3 | 6 | 33 |
| 5 | 4 | 9 | 3 | 1 | 16 |
| Total | 11 | 30 | 5 | 18 | 64 |

*Source:* World Bank calculations and ENCOVI 2000

[10] The survey does not allow analysis of firewood sales.

[11] The figures are for average total number of minutes per household (not per person) and broken down by quintile, sector and adult men, adult women, boys and girls (age 14 and below).

4.10 Average firewood collection time is 40 minutes per household per day—note for comparison that fetching water on average takes 23 minutes.[12] Generally speaking, collection time is more in rural areas and in poorer households. The poorest 20 percent of households on average spend an astonishing two hours per day collecting wood. Much of this wood has to be for sale.[13] Better-off households spend very little time collecting wood, and since they do consume wood this probably implies reliance on market purchases (large farms with plentiful biomass is probably also a factor). This striking difference in wood collection time at the national level is replicated within each of Guatemala's eight major regions (not shown in the table), implying that it is not caused merely by regional differences in where the poor and the nonpoor live. In Guatemala, most wood collection is carried out by adult men and by boys; this may, however, reflect collection as a commercial activity as opposed to collection for domestic use.

## Threshold Effects in Uptake of Cooking Fuels

4.11 It is clear that expenditure matters a great deal to choice of energy source, as enshrined in the energy ladder model. When trying to assess the market potential for new fuels it can be useful to operate with some kind of threshold expenditure, if only as a rule of thumb, above which household adoption can reasonably be expected. The idea is that if a new fuel is clearly superior, then most households that can afford it will adopt it. If, in contrast, adoption is better characterized as a smooth and continuous process, the calculation of potential demand becomes more complicated. This issue is explored in figure 4.1 for the five cooking fuels used in Guatemala. The figure divides the rural and the urban samples into 4-percent quantiles, yielding 25 groups of equal size in each sector. For each 4-percent quantile, the average adoption rate of LPG, firewood, kerosene, charcoal, and electricity for cooking purposes is plotted against quantile average per capita expenditure. Note that the use of an energy source for purposes other than cooking are ignored in this figure and through the remainder of this report, something that mostly affects kerosene and electricity which are used much more for lighting and appliances than for cooking.

4.12 The top panels show LPG and wood usage in urban and rural areas, respectively. There are interesting differences. At any level of expenditure, urban households are more likely to use LPG and rural households are more likely to use wood. LPG usage increases with expenditure in both urban and rural areas. What happens to firewood in response? Urban firewood usage decreases rapidly with expenditure suggesting LPG is displacing wood, whereas rural firewood usage remains universal

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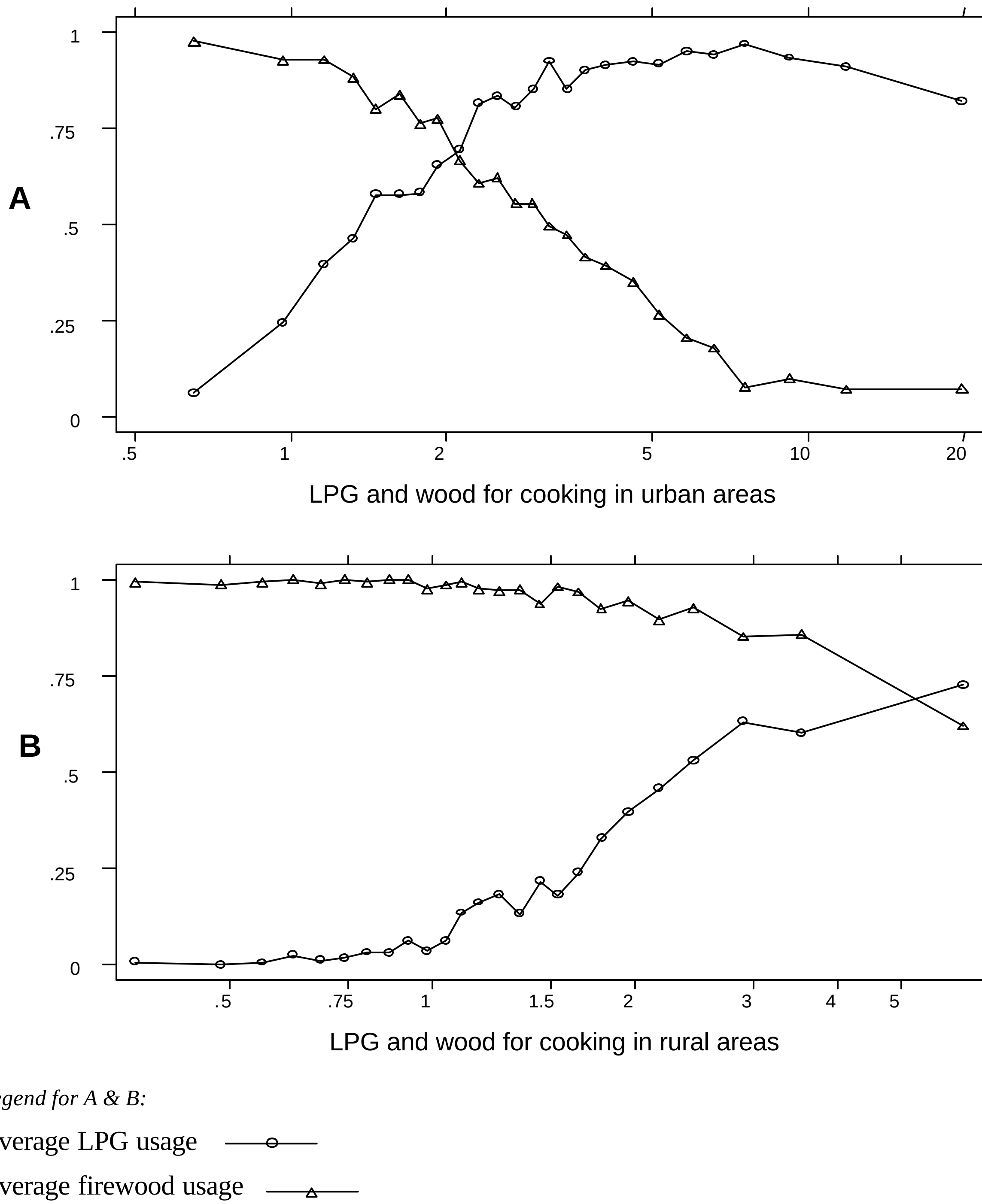
[12] Almost all of this time is exclusively for collecting wood as only a few also accomplish other chores meanwhile. Figures on average collection time mask a large diversity – most households report zero collection time the day before being surveyed, with a minority reporting what is sometimes a very large number of hours.

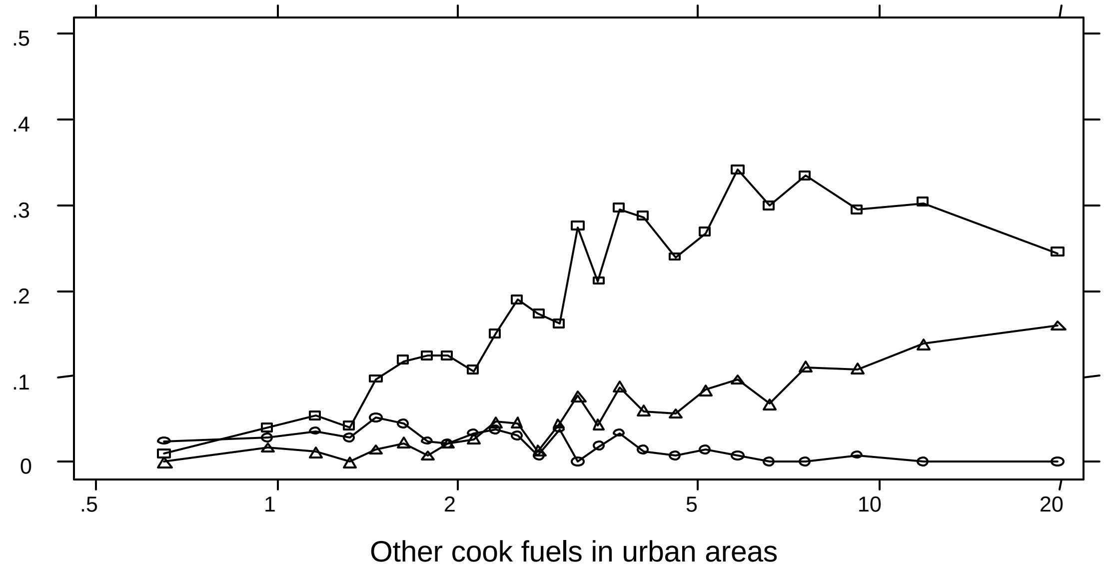
[13] Exactly how much of the enormous wood collection time of the poor that relates to wood destined for sale unfortunately cannot be discerned from the survey.

among the poor majority and only declines to a limited extent in the top end of the rural income distribution. This suggests that fuel stacking is more prominent in rural areas.

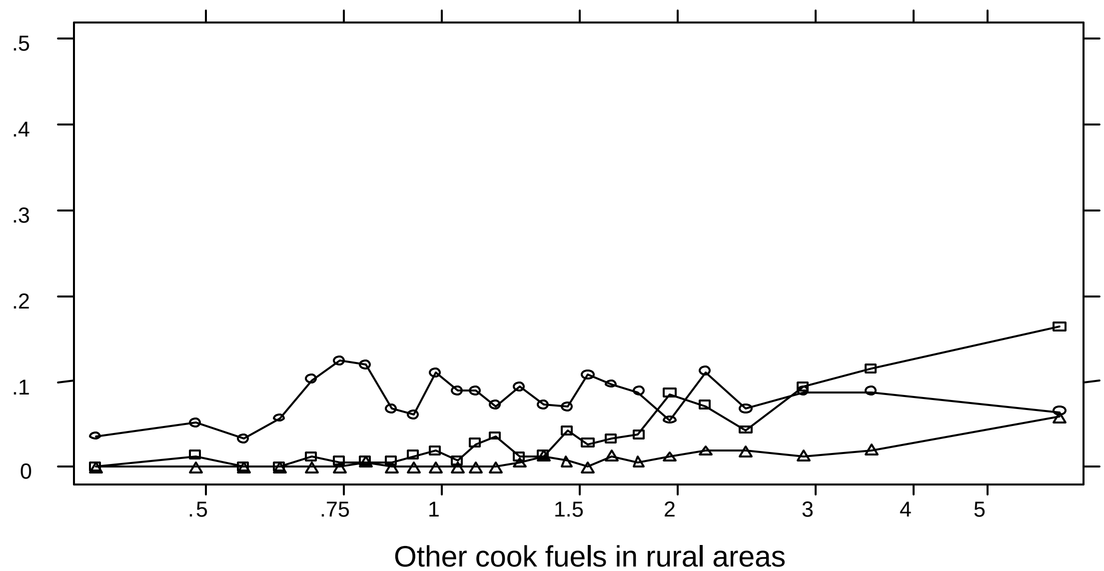
**Figure 4.1: Usage for Cooking of Various Fuels by Quantile and Sector**



C




D




*Legend for C & D:*

Average kerosene usage for cooking

Average charcoal usage

Average electricity usage for cooking

*Note:* PCE ($/pc/day – log scale) PCE=Per capita expenditure

4.13 Thus it seems that fuel switching is the predominant response to increasing welfare in urban areas while fuel stacking or multiple fuel use dominates in rural areas. The reason for this divergence is a substitution and an income effect operating in opposite directions. The income effect implies that when expenditures increase, households can afford to consume a larger variety of energy sources in greater amounts, resulting in nondecreasing firewood use. The interfuel substitution effect means that high-expenditure households can afford switching to costlier liquid and gaseous fuels. Apparently, the income effect dominates in rural areas whereas the interfuel substitution effect is stronger in urban areas, where incomes also are much higher.[14] The reason for this difference is the low relative price and opportunity cost of firewood in rural areas. An additional factor might be the lower share of cash in the total household expenditure in rural areas—corresponding to a higher share of imputed self-production—and cash is required to buy LPG.

4.14 Regarding thresholds, urban LPG usage rises rapidly in a smooth and continuous manner from 6 percent in the bottom 4 percent to 25 percent in the next-lowest quantile to almost everyone once per capita expenditures of US$3–4 per day are reached. At this level, LPG usage stabilizes above 80 percent and cooking with electricity kicks in. In rural areas a clearer threshold exists at approximately US$1.5–2 per day, implying that only the rural nonpoor are realistic targets for LPG. Only the rural top 16 percent, however, have LPG penetration above 50 percent.

4.15 The other fuels play a smaller role as can be seen on the bottom panels of the figure. Charcoal for cooking picks up to some extent for the middle classes. Electricity as mentioned plays a limited role as a cooking fuel for some of the high-income urban groups. Kerosene use for cooking is very marginal in Guatemala, in contrast to some other developing countries.

## Conclusion

4.16 The conclusions so far are that LPG is a fuel for the urban and the better off. The evidence suggests that LPG tends to replace solid fuels among middle-class urban households. In many other instances LPG seems to complement traditional fuels, especially in rural areas. The tentative conclusion is that LPG is at best a partial instrument for combating indoor (as well as outdoor) air pollution except among high income urban households. Its prospects are best in relatively developed urban settings. The fuel switching theory does not seem to adequately capture the demand patterns observed among rural and low-income urban households. Similar patterns have been observed in many other places. For example, Barnes and Qian (1992) and Barnes, Krutilla, and Hyde (2002) report that urban households around the world continue to use fuelwood at a surprisingly large, albeit declining, rate. It also depends on city size—large cities have less fuelwood usage.

[14] Kebede, Bekele, and Kedir (2002) find that in urban areas of Ethiopia the income effect dominates so that households consume more of *all* energy sources as budgets grow.

4.17 The preceding analysis gives rise to a number of questions. What are the drivers of fuel usage, apart from expenditure and income? Is there scope for enhanced LPG penetration? And if yes, what are its barriers? Why does LPG sometimes replace wood and at other times complement it? If cooking with market-purchased wood is more expensive than LPG, why not switch completely to LPG? And more generally, what characterizes the competition among individual cooking fuels? How widespread is and what causes multiple fuel usage? These topics are pursued in the following chapters.

# 5

## Regressions of Energy Usage

5.1 The previous chapter confirmed that expenditures play a strong role in shaping demand for cooking fuels. But other factors likely also matter, something that is taken up in this chapter where regression analysis is used to explore the determinants of cooking fuel adoption. A few examples can illustrate how better understanding of fuel demand can be helpful when designing energy development interventions. Many energy development projects aim to expand consumption of electricity or LPG through enhanced coverage or supply. Key planning parameters such as income and price elasticities of demand, of vital importance for financial viability, are sometimes merely guessed when preparing such projects. There is also a clear need to understand better how energy interventions promoting one type of energy affects usage of other energy sources, something which requires knowledge of energy demand cross-price elasticities (Pitt 1985). For example, the effect of kerosene and LPG subsidies on woodfuel demand—and thereby indoor air pollution—can be judged from the cross-price elasticities of woodfuel demand with respect to kerosene and LPG prices.

### Econometric Approach

5.2 Given the problems in the quantity data described above, the endogenous variables are dummies for usage of each cooking fuel. For each cooking fuel j, the desired amount of consumption for cooking purposes q* can be written as a function of the exogenous variables:

$$(1) \qquad q_j^* ? ?_j ? ?_j \ln x ? ?_{jj} \ln p_j ? \underset{i?j}{?} ?_{ji} \ln p_i ? ?'_j z ? ?_j$$

x is household per capita expenditure, $p_j$ is the price of the energy source j, $p_i$ is a price vector of alternative energy sources, and z is a vector of household and area characteristics that also influence demand patterns. The desired amount of consumption is unobserved. Instead we observe a dummy variable:

$$(2) \qquad \begin{array}{l} q_j ? 1 \quad if \quad q_j^* ? 0 \\ q_j ? 0 \quad if \quad q_j^* ? 0 \end{array}$$

which can be estimated using logit in a straightforward manner. An equation for cooking with each fuel—LPG, kerosene, wood, charcoal, and electricity (urban areas only)—is estimated. Estimation is performed separately for the urban and rural subsamples since conditions and behavior differ so much between sectors.

5.3 In developing countries it is not unusual to see substantial spatial variation in prices, a fact which has been widely explored by economists to estimate the price responsiveness of demand based on cross-sectional data (see for example Deaton 1997). Two alternative sources of price information are available: (i) Unit costs can be calculated by dividing values with quantities. (ii) A community and price survey was carried out, and the prices of kerosene, LPG, firewood, and candles were obtained from shops in the survey respondents' communities.[15] There are problems with the unit costs: they show an implausibly high degree of variation across households,[16] and the mean unit cost of LPG appears too high.[17] The price survey shows a mean LPG price of 65Q per 25-pound cylinder with a minimum of 50, a maximum of 86, and a standard deviation of 6.2.[18] The price survey therefore appears a more attractive data source. Cases of missing data[19] are handled by replacing the missing values with the mean price from the nearest larger spatial unit of which this particular community is a part.

5.4 Special issues arise when estimating the wood equation. Recall that some households purchase wood while others rely on self-collection. The market price is an important decision parameter for the buyers but is not necessarily relevant for all the nonbuyers, who are guided by unobservable reservation prices. Even in simple household models it is highly complex to account rigorously for market and reservation prices across multiple regimes (van Soest, Kapteyn, and Kooreman 1993). Following the approach of Heltberg, Arndt, and Sekhar (2000) it was decided to pool the entire sample of buyers and nonbuyers in a single regression for estimating the wood equation.[20] The reason is that among the nonbuying households some are selling wood—but the data does not allow us to identify who that is. Moreover, some households reporting to be nonbuyers in the month preceding the survey might be buying or selling at the margin, occasionally. In the pooled approach it was also decided to maintain the market price of

[15] Electricity prices are not available, but unlike fuel prices they do not vary spatially. Charcoal prices were also unavailable.

[16] Probably induced by recall error.

[17] Relative to the price questionnaire and price data given by Matthews (2002). The median unit cost of LPG however is plausible and matches the price survey almost exactly.

[18] This gives a coefficient of variation (CV) of 0.1 for LPG price. Kerosene price has a CV of 0.2 and for firewood price it is 0.5 (based on price survey data). Considering the tradability of these products, this seems a fair ranking of their CVs.

[19] Some communities declined to participate in the community and price survey, and prices of some goods were not obtained in some communities that did participate.

[20] Simply splitting the sample into buyers and nonbuyers and running logit regressions on the separate subsamples would be inconsistent – it would cause sample selection bias since households are distributed among regimes in a nonrandom fashion. A Heckman approach has been commonly used to correct for sample selection bias in similar circumstances. Although consistent, the Heckman procedure is known to suffer from low precision and identification problems and is not desirable for the present purpose.

wood for all households, irrespective of whether they buy or not. For the nonbuyers, the market price of wood is likely to proxy their unobservable reservation prices.[21]

[21] Heltberg, Arndt, and Sekhar (2000) argue that fuelwood prices are likely to be partly endogenous in their sample of four relatively remote villages in Northwest India. The present case is somewhat different: An OLS regression of the log of wood prices on the other right-hand side variables has an $R^2$ of only 0.16. This—together with the high share of households in Guatemala that participate in firewood markets—make it attractive to include wood prices among the regressors for all the households.

**Table 5.1: Mean and Standard Deviation of Regressors by Sector**

| | *Urban* | | *Rural* | |
|---|---|---|---|---|
| | *Mean* | *Std. Dev.* | *Mean* | *Std. Dev.* |
| Per capita expenditures log | 8.97 | 0.80 | 8.15 | 0.65 |
| LPG log price | 4.18 | 0.10 | 4.19 | 0.09 |
| Kerosene log price | 1.17 | 0.17 | 1.17 | 0.21 |
| Firewood log price | -0.60 | 0.46 | -0.74 | 0.42 |
| Log household size | 1.45 | 0.52 | 1.63 | 0.53 |
| Primary education | 0.32 | 0.47 | 0.67 | 0.47 |
| Secondary education | 0.42 | 0.49 | 0.15 | 0.36 |
| Post-secondary education | 0.20 | 0.40 | 0.03 | 0.18 |
| Number of rooms in house | 2.83 | 1.78 | 1.78 | 1.08 |
| Farm household | 0.22 | 0.41 | 0.71 | 0.45 |
| Share of females in household | 0.53 | 0.22 | 0.50 | 0.19 |
| Indigenous ethnic group | 0.29 | 0.45 | 0.48 | 0.50 |
| Median distance to firewood source (log meters) | 4.28 | 2.91 | 6.07 | 2.18 |
| North | 0.11 | 0.32 | 0.11 | 0.31 |
| Northeast | 0.11 | 0.31 | 0.06 | 0.23 |
| Southeast | 0.10 | 0.29 | 0.13 | 0.33 |
| Central | 0.13 | 0.33 | 0.21 | 0.41 |
| Southwest | 0.12 | 0.33 | 0.18 | 0.38 |
| Northwest | 0.12 | 0.32 | 0.20 | 0.40 |
| Peten | 0.08 | 0.27 | 0.08 | 0.28 |
| Electricity access dummy | 0.93 | 0.26 | 0.55 | 0.50 |

*Note:* Values are the unweighted means and standard deviations of variables used in the regression analyses.

*Source*: Author's calculations based on ENCOVI 2000

5.5 The explanatory variables were selected in order to stay as close as possible to the theoretical framework and its implications as outlined in chapter 2.[22] The first group of regressors includes variables such as log per capita expenditures, LPG, kerosene, and firewood log prices and log household size to account for economies of scale. These are core explanatory variables that belong in any demand equation on a priori theoretical grounds. The variables in the second group include the share of females in the household to control for gender-specific labor sharing and female bargaining power; distance to the usual source of firewood (in meters) averaged over all members in the community and in log form. Together with a dummy for farm households, this is intended to capture the opportunity cost of firewood collection; dummies for whether the maximum education of any household member is primary, secondary, or postsecondary (with no household member having completed primary education the omitted category); access to electricity (grid connection) to capture derived effects from electricity to other fuels; dummy for households belonging to an indigenous ethnic group (mostly Maya); number of rooms in the house since space heating and cooking are often joint; and a regional dummy for each of Guatemala's seven major geographic areas. The mean and standard deviation of all these right-hand side variables are shown in table 5.1.

## Regression Results for Fuel Usage

5.6 The baseline regression results, provided in tables 5.2 and 5.3 for urban and rural areas respectively, use the full list of regressors. An additional set of results, reproduced in tables 1.1 and 1.2 in the appendix, rely on a shorter list of explanatory variables selected from among the full list according to the following criteria: all variables in the core group of a priori theoretically important regressors were retained; from among the noncore regressors, only variables found to be statistically significant (at or nearly at the 5 percent level) were retained in each equation, using a "general to specific" iterative approach to exclude statistically insignificant variables. With a few exceptions, the results of the full set and the reduced set of regressors do not differ much from one another. In addition, paragraphs 5.21-23 below presents estimates for a subsample of urban households with expenditures above the threshold for LPG uptake. Robust "Huber-White" estimates of standard errors are given in parentheses throughout.

5.7 As expected income is highly significant for fuel choice. LPG and electricity for cooking are both normal goods—their usage increases with total expenditure. Charcoal is also a normal good. Firewood is inferior—it has negative expenditure elasticities. The inferiority of wood is especially strong in urban areas as the descriptive statistics also showed. Kerosene is, on average, inferior in urban areas and normal in rural areas. This, no doubt, is because urban income levels are higher. In urban areas, the probability of using firewood drops as fast as the probability of using LPG increases, suggesting that interfuel substitution is taking place. In contrast, in response to

[22] It is common that household economic models provide only broad guidance as to the choice of regressors and functional form, see for example Sadoulet and de Janvry (1995).

increasing income, rural LPG demand rises much faster than the relatively slow pace at which firewood is abandoned.

5.8 LPG and firewood usage are both ordinary goods—they respond negatively to the own price. The own-price usage elasticities of LPG and firewood are statistically significant in the shortened versions and sometimes in the full version. LPG uptake is elastic—a one percent increase in its price leads to more than a one percent drop in its usage. The elasticity of firewood usage is a lot less elastic, suggesting that nonprice factors could be more important drivers of firewood usage. Kerosene demand for cooking does not seem to be price responsive; this can seem odd but may be an artifact of the small sample of people cooking with kerosene.

5.9 Several interesting findings emerge even as some cross-price usage elasticities are insignificant or do not have the expected signs. Strong evidence shows that kerosene usage depends on the price of LPG in both rural and urban areas; this suggests the role of kerosene as a cooking fuel is to some extent determined by local LPG prices and that kerosene substitutes for LPG. The reverse does not hold, however; since LPG is a much more widely used fuel than kerosene, it is harder to demonstrate any meaningful cross-price relationship for LPG than it is for kerosene.

5.10 Surprisingly, there is no evidence of price competition between LPG and firewood, the two largest cooking fuels. The widespread prevalence of wood purchasing would have led one to expect competition based on prices. Perhaps LPG is just so much more convenient that regional price variation is unimportant for the switching decision. Income and other factors apparently matter more than price for LPG-wood switching decisions. This has potential policy implications: it implies that LPG subsidies would not be able to induce households to abandon fuelwood (Guatemala does not have such subsidies).

5.11 The evidence on firewood versus kerosene is rather conflicting. Firewood usage reacts significantly to kerosene prices (in rural areas only), but kerosene usage does not depend on wood prices. Cooking with electricity in urban areas depends significantly on LPG prices, suggesting the two are near substitutes. Finally, charcoal and wood are substitutes (significantly so) in rural areas; charcoal and LPG are substitutes (significantly) in urban areas; and charcoal and kerosene are significant complements everywhere.

**Table 5.2: Logit Regression Results—Urban Sample Complete Set of Regressors**

| | *LPG* | *Kerosene* | *Wood* | *Electricity* | *Charcoal* |
|---|---|---|---|---|---|
| Log of per capita expenditures | 1.506 | -0.782 | -1.396 | 1.341 | 0.836 |
| | (11.74)** | (2.91)** | (12.10)** | (7.41)** | (8.00)** |
| Log price of LPG | -0.991 | 6.008 | -0.184 | -2.420 | -1.339 |
| | (1.58) | (3.16)** | (0.30) | (2.37)* | (2.23)* |
| Log price of kerosene | 0.111 | 0.067 | 0.302 | -0.525 | 0.598 |
| | (0.40) | (0.09) | (1.04) | (0.85) | (1.92) |
| Log price of firewood | 0.181 | -0.231 | -0.355 | 0.621 | 0.032 |
| | (1.47) | (0.81) | (2.91)** | (2.89)** | (0.26) |
| Log household size | 0.424 | -0.275 | 0.511 | 0.704 | 0.692 |
| | (3.08)** | (0.98) | (3.91)** | (2.92)** | (5.49)** |
| Primary education | 0.745 | 0.244 | -0.468 | 1.155 | -0.206 |
| | (3.55)** | (0.42) | (1.58) | (1.14) | (0.70) |
| Secondary education | 1.401 | 0.604 | -1.169 | 1.554 | 0.074 |
| | (6.23)** | (0.95) | (3.88)** | (1.55) | (0.25) |
| Post-secondary education | 1.243 | -0.116 | -1.343 | 1.626 | -0.303 |
| | (4.62)** | (0.14) | (4.13)** | (1.62) | (0.95) |
| Number of rooms in dwelling | 0.102 | 0.152 | -0.083 | -0.023 | 0.022 |
| | (2.57)* | (1.60) | (2.43)* | (0.41) | (0.74) |
| Farm household | -1.128 | 0.492 | 1.893 | -0.245 | -0.346 |
| | (9.97)** | (1.75) | (11.44)** | (0.83) | (2.34)* |
| Share of females in household | 0.430 | -0.316 | 0.678 | 0.064 | 0.129 |
| | (1.66) | (0.55) | (3.09)** | (0.16) | (0.60) |
| Indigenous | -0.563 | -0.225 | 0.685 | -0.324 | -0.325 |
| | (4.95)** | (0.68) | (5.14)** | (1.09) | (2.25)* |
| Community median firewood distance | -0.035 | 0.080 | -0.031 | 0.011 | -0.018 |
| | (2.01)* | (1.59) | (1.81) | (0.36) | (1.02) |
| North | -0.277 | 0.120 | 1.300 | 1.509 | -0.728 |
| | (1.19) | (0.16) | (6.18)** | (4.23)** | (3.17)** |
| Northeast | -0.407 | 1.718 | 0.751 | 2.530 | -0.040 |
| | (1.81) | (2.96)** | (4.23)** | (9.80)** | (0.24) |

**Table 5.2: Logit Regression Results—Urban Sample Complete Set of Regressors**

| | *LPG* | *Kerosene* | *Wood* | *Electricity* | *Charcoal* |
|---|---|---|---|---|---|
| Southeast | -0.148 | 0.218 | 1.107 | 0.698 | -0.683 |
| | (0.65) | (0.31) | (5.53)** | (1.58) | (3.11)** |
| Central | 0.291 | 0.387 | 0.986 | 1.208 | 0.050 |
| | (1.35) | (0.58) | (5.35)** | (3.65)** | (0.29) |
| Southwest | 0.237 | 0.289 | 0.855 | 0.468 | -0.502 |
| | (1.09) | (0.41) | (4.67)** | (1.29) | (2.80)** |
| Northwest | -0.033 | | 1.576 | 0.381 | -0.217 |
| | (0.15) | | (7.40)** | (0.79) | (1.10) |
| Peten | -0.800 | 1.032 | 2.118 | -0.241 | -1.375 |
| | (2.90)** | (1.30) | (8.02)** | (0.31) | (3.92)** |
| Household has electricity | 1.386 | -0.247 | -0.867 | | 1.778 |
| | (6.54)** | (0.55) | (2.66)** | | (2.99)** |
| Constant | -10.830 | -23.394 | 12.695 | -7.717 | -6.536 |
| | (3.65)** | (2.74)** | (4.42)** | (1.62) | (2.36)* |
| Observations | 3330 | 2926 | 3330 | 3330 | 3330 |

Robust z statistics in parentheses
*Significant at 5%; ** significant at 1%

**Table 5.3: Logit Regression Results—Rural Sample Complete Set of Regressors**

| | *LPG* | *Kerosene* | *Fuelwood* | *Charcoal* |
|---|---|---|---|---|
| Per capita expenditures log | 2.361 | 0.406 | -0.493 | 1.124 |
| | (14.91)** | (2.69)** | (2.33)* | (4.44)** |
| LPG log price of | -1.273 | 1.386 | 0.658 | -0.538 |
| | (2.12)* | (1.99)* | (0.65) | (0.56) |
| Kerosene log price | -0.706 | 0.610 | 1.410 | -0.824 |
| | (2.71)** | (2.26)* | (3.96)** | (1.77) |
| Firewood log price | 0.152 | 0.015 | -0.307 | 0.585 |
| | (1.04) | (0.10) | (1.40) | (2.63)** |
| Log household size | 0.819 | 0.361 | 1.338 | 0.761 |
| | (5.36)** | (2.10)* | (5.36)** | (2.85)** |
| Primary education | 0.853 | -0.039 | -0.535 | -0.423 |
| | (3.43)** | (0.21) | (1.41) | (1.16) |
| Secondary education | 1.606 | 0.145 | -1.564 | 0.198 |
| | (5.83)** | (0.58) | (3.77)** | (0.50) |
| Post-secondary education | 1.361 | -0.301 | -2.125 | 0.274 |
| | (3.52)** | (0.72) | (4.23)** | (0.52) |
| Number of rooms in dwelling | 0.341 | -0.141 | -0.285 | 0.114 |
| | (6.64)** | (1.99)* | (3.77)** | (1.35) |
| Farm household | -0.790 | 0.298 | 1.353 | -0.662 |
| | (6.56)** | (1.90) | (6.36)** | (3.39)** |
| Share of females in household | 0.577 | -0.650 | 1.096 | 0.457 |
| | (2.16)* | (1.92) | (2.79)** | (0.98) |
| Indigenous | -0.249 | -0.305 | 0.211 | 0.375 |
| | (1.91) | (2.04)* | (0.89) | (1.54) |
| Community median firewood distance | -0.126 | -0.042 | 0.036 | -0.048 |
| | (5.57)** | (1.41) | (1.08) | (1.24) |
| North | -0.261 | 0.467 | 1.358 | -2.359 |
| | (0.75) | (0.82) | (2.62)** | (2.85)** |
| Northeast | 0.489 | 0.522 | 0.427 | -0.056 |
| | (1.48) | (0.92) | (1.19) | (0.13) |
| Southeast | 0.103 | 0.328 | 1.382 | -0.448 |
| | (0.36) | (0.59) | (3.66)** | (1.11) |

**Table 5.3: Logit Regression Results—Rural Sample Complete Set of Regressors**

| | *LPG* | *Kerosene* | *Fuelwood* | *Charcoal* |
|---|---|---|---|---|
| Central | 0.483 | 0.738 | 0.373 | -0.298 |
| | (1.80) | (1.39) | (1.37) | (0.87) |
| Southwest | 0.205 | 0.739 | 1.100 | -1.100 |
| | (0.74) | (1.37) | (3.22)** | (2.70)** |
| Northwest | -0.844 | -0.334 | 1.638 | -1.401 |
| | (2.74)** | (0.59) | (3.33)** | (2.75)** |
| Peten | -0.202 | 1.119 | 1.099 | -1.922 |
| | (0.56) | (2.03)* | (1.99)* | (2.30)* |
| Household has electricity | 0.977 | -1.122 | -0.864 | 0.178 |
| | (6.76)** | (6.92)** | (3.46)** | (0.67) |
| Constant | -17.560 | -12.148 | 0.489 | -9.596 |
| | (5.93)** | (3.81)** | (0.11) | (1.94) |
| Observations | 3883 | 3883 | 3883 | 3883 |

Robust z statistics in parentheses

*Significant at 5%; ** significant at 1%

5.12 Household size also matters, and is significant in almost all cases. The larger the household, the more likely it is to use almost any cooking fuel (the exception is kerosene in urban areas). This means that the number of fuels used must increase with household size. Large households may prefer to maintain several options for their fuel security, or large families may have more than one kitchen and stove at their disposal. Also, in the case of firewood the impact of household size could reflect the enhanced availability of collection labor time. For LPG and electricity, this result could reflect the better ability of larger households to shoulder the relatively high startup costs involved (costs which reduce on a per capita basis).

5.13 Education affects energy choices in a fairly robust manner. Households with more education are less likely to cook with wood and more likely to cook with LPG. Education, in itself, therefore helps trigger fuel switching in both rural and urban areas. This effect is likely to be caused by opportunity costs of collection labor rising with education; pure changes in fuel preferences induced by education may also play a role. Incidentally, the association between education and fuel choice conforms well with numerous previous studies that have found positive links from parental—and especially maternal—education to child health.

5.14 The number of rooms in the house has a similar effect of triggering fuel switching to LPG away from wood. This is probably a wealth effect; considerations based on the need for space heating would certainly not have predicted firewood to decline with the number of rooms. Farm households more often use firewood and are less likely to cook with LPG and charcoal. Simple considerations based on the notion that opportunity costs of firewood are very low for farmers can explain this (for some reason farmers also use more kerosene).

5.15 The share of females in the household significantly increases the likelihood of cooking with LPG (in rural areas) while also raising the likelihood of using firewood (both rural and urban). Given that females bear the major burden of indoor air pollution and assuming that a high female ratio entails enhanced female bargaining power, it could be hypothesized that the effect of gender composition on LPG usage is attributable to air quality considerations by the women. This, however, is unlikely and the increase in firewood usage does not fit well with this interpretation. Another interpretation fits better with the evidence: females who tend to do the cooking appreciate the convenience of LPG and are therefore more likely to adopt it; but because of the availability of female collection and cooking labor time they also continue using firewood. Alternative regressions were also run with a dummy for female head of household included instead of female share. The results are not shown for space reasons. Urban female-headed households are significantly more likely to use wood and less likely to use charcoal. No other effects are anywhere near to being significant.

5.16 Households belonging to indigenous communities are traditionalists when it comes to fuel choice. They rely on wood. They tend not to use LPG (both rural and urban); less charcoal and more wood (urban); and less kerosene (rural). Distance to firewood source appears to be negatively associated with LPG usage (significant in the rural equations, and almost so in the urban ones). This, of course, is contrary to expectations, and it is also surprising that firewood usage is not significantly related to the distance to the collection site.

5.17 Being connected to the electricity grid appears to affect fuel choice. Having electricity is associated with a higher probability of using LPG and a lesser likelihood of firewood usage. These effects are significant in both rural and urban areas. Electricity also reduces kerosene usage significantly in rural areas. Barnes, Krutilla, and Hyde (2002) report the same finding for a sample of urban respondents around the world: that electrification appears to increase LPG usage and decrease the use of traditional fuels. The present analysis confirms this finding and extends it to rural areas.

5.18 Barnes, Krutilla, and Hyde (2002) suggest two possible explanations for the electricity-LPG link: (i) "where electricity is available, fewer barriers constrain other modern fuels as well" and (ii) "availability of lighting and other appliances spurs people to a greater acceptance of modernity and modern fuels." One could add to this two additional possibilities: (iii) that areas that are in some sense more "modern" (for example large as opposed to small towns and places with better infrastructure) get connected first to the electricity grid. These areas are also more motivated to adopt modern fuels. If this is the case, the regression results of electrification merely reflect a joint correlation rather than a causality; expanding electricity to unconnected areas will not, in itself, cause people to adopt LPG as well. Finally, (iv) assume that energy needs are organized in a hierarchy where electricity is the most desired innovation and modern fuels follow further down the list of priorities. Then households without a grid connection may be unmotivated to adopt LPG—they would skip a ladder in the hierarchy of needs. In this case grid expansion does in fact have an independent, causal effect on LPG uptake. Testing between these conjectures would therefore be of policy interest. This is left for future research.

5.19 Finally, dummies are included to control for the eight major geographic regions of the country. As usual all dummy variable effects need to be judged relative to the omitted category, which is the metropolitan area. Several of the regional dummies are significant, implying that even though the regressions control for a range of factors (and are separate urban and rural), regional differences remain important. Differences in market development and ease of access to individual fuels are likely causes of the observed effects.

## Cooking Fuel Choice among the Urban Top Two-Third

5.20 As explained above, it is intriguing that many urban nonpoor households defy the stylized facts of the "energy ladder" model by continuing to use firewood, possibly alongside more modern fuels and often despite having to purchase fuelwood in the market at a seemingly higher cost than what it would require to cook exclusively with LPG.

5.21 The best-off urban two-thirds have an annual per capita expenditure above 6000Q, or more than US$2.1 per capita per day. Eighty-nine percent of households in this group cook with LPG and 32 percent cook with firewood (obviously some of them use both, and some also use other cooking fuels). In the following, it is investigated whether the determinants of the LPG-woodfuel choice among the better-off urban households differs from the overall sample. This is relevant because the urban top two-third were earlier found to be above the threshold for LPG uptake. Hence affordability ought not to be a key factor for this group. Regressions are carried out for cooking with LPG and with firewood. Full and short specifications are presented following the same procedure as above.

5.22 Results appear in table 5.4. Generally speaking, most factors that accounted for fuel use in the overall urban sample seem to be important for this restricted sample, including expenditure, education, household size, and electrification status. Expenditure, albeit still significant, is quantitatively less important than for the overall urban sample because the urban top two-third are all above the threshold for LPG uptake and LPG usage rates remain above 80 percent for this group. The price of firewood, however, does significantly affect LPG and firewood usage in the predicted manner. Wood use increases with household size. As before, absence of fuel switching is induced by lack of education, being a farm household, being indigenous, and not having electricity. Certain regions outside the metropolitan area are also associated with continued woodfuel usage. The conclusion is that there are significant differences in household characteristics (and to some extent prices) between the urban nonpoor that in a systematic fashion can help account for partial fuel switching.

**Table 5.4: Logit Regression of Urban Top Two-Third**

| | *Full specification* | | *Short specification* | |
|---|---|---|---|---|
| | *LPG* | *Wood* | *LPG* | *Wood* |
| Per capita expenditures log | 0.852 | -1.565 | 0.890 | -1.643 |
| | (4.36)** | (10.57)** | (4.75)** | (11.52)** |
| LPG log price | -0.829 | -0.764 | -1.393 | -0.773 |
| | (1.02) | (1.10) | (2.02)* | (1.11) |
| Kerosene log price | 0.336 | 0.405 | 0.584 | 0.369 |
| | (0.94) | (1.25) | (1.70) | (1.13) |
| Firewood log price | 0.282 | -0.487 | 0.340 | -0.502 |
| | (1.73) | (3.44)** | (2.49)* | (3.56)** |
| Log household size | 0.577 | 0.376 | 0.672 | 0.295 |
| | (3.28)** | (2.62)** | (4.12)** | (2.14)* |
| Primary education | 0.569 | -0.727 | | -0.794 |
| | (2.02)* | (2.31)* | | (2.49)* |
| Secondary education | 1.224 | -1.494 | 0.786 | -1.575 |
| | (4.05)** | (4.66)** | (5.13)** | (4.84)** |
| Post-secondary education | 1.064 | -1.641 | 0.592 | -1.759 |
| | (3.13)** | (4.75)** | (3.01)** | (5.04)** |
| Number of rooms in dwelling | 0.091 | -0.062 | | |
| | (1.83) | (1.67) | | |
| Farm household | -0.915 | 1.916 | -0.898 | 1.864 |
| | (5.73)** | (10.41)** | (5.93)** | (10.12)** |
| Share of females in household | 0.596 | 0.746 | | |
| | (2.02)* | (3.11)** | | |
| Indigenous | -0.477 | 0.744 | -0.376 | 0.742 |
| | (2.97)** | (4.85)** | (2.49)* | (4.86)** |
| Community median firewood distance | -0.025 | -0.036 | | -0.037 |
| | (1.04) | (1.91) | | (1.92) |
| North | 0.097 | 1.370 | | 1.341 |
| | (0.35) | (5.88)** | | (5.79)** |

**Table 5.4: Logit Regression of Urban Top Two-Third**

| | *Full specification* | | *Short specification* | |
|---|---|---|---|---|
| | *LPG* | *Wood* | *LPG* | *Wood* |
| Northeast | -0.275 | 0.658 | -0.353 | 0.653 |
| | (1.13) | (3.25)** | (1.89) | (3.24)** |
| Southeast | 0.098 | 1.070 | | 1.069 |
| | (0.36) | (4.79)** | | (4.79)** |
| Central | 0.281 | 0.910 | | 0.908 |
| | (1.11) | (4.30)** | | (4.31)** |
| Southwest | 0.614 | 0.792 | 0.518 | 0.780 |
| | (2.13)* | (3.77)** | (2.16)* | (3.74)** |
| Northwest | 0.170 | 1.599 | | 1.585 |
| | (0.64) | (6.85)** | | (6.79)** |
| Peten | -0.335 | 2.135 | | 2.151 |
| | (1.03) | (7.46)** | | (7.51)** |
| Household has electricity | 1.495 | -1.024 | 1.560 | -0.986 |
| | (4.57)** | (2.43)* | (4.99)** | (2.38)* |
| Constant | -6.165 | 17.047 | -3.618 | 18.222 |
| | (1.57) | (5.19)** | (1.03) | (5.62)** |
| Observations | 2304 | 2304 | 2411 | 2304 |

Robust z statistics in parentheses

*Significant at 5%; ** significant at 1%

# 6

## Competition and Complementarity among Cooking Fuels

6.1 This chapter studies the interrelationship among fuels. The previous chapter confirmed a number of significant interrelationships among individual fuels related to prices, opportunity costs, and other factors. Fuel interrelationships take two forms. On the one hand individual cooking fuels compete in price, convenience, and other parameters. On the other hand, fuels are often consumed in conjunction. This chapter starts out by quantifying multiple fuel use by households, focusing on cooking fuels. The chapter subsequently goes on to assess the competition between LPG and alternatives with the aim of clarifying the constraints and potential opportunities for increased LPG penetration. A multinomial logit analysis is used to assess the determinants of choice of cooking fuel combination.

### Combinations of Cooking Fuels

6.2 Table 6.1 takes a close look at the combinations in which people use cooking fuels. With five fuels used for cooking, there are a confusingly large number of possible combinations. Fortunately, only a handful of combinations are commonly used. The top of the table shows that the most common combinations are, in order of national importance: wood only; wood and LPG; LPG only; charcoal and LPG; kerosene and wood; and charcoal, wood, and LPG.

6.3 A number of uncommon combinations are listed further below in the table. The table also shows that consuming only LPG is fairly common in urban areas (34 percent) but rare in rural areas (3 percent); instead rural households tend to use wood which they sometimes supplement with either LPG (14 percent) or kerosene (7 percent). Charcoal is quite important in urban areas (24 percent use it), but only in conjunction with LPG. Kerosene plays a small role as a cooking fuel in rural areas as a supplement to wood; among its users the median kerosene consumption for cooking is 1.5 liters/month per household and only 5 percent of users consume more than 5 liters/month. Kerosene plays a greater role in providing lighting. The widespread urban combination of LPG together with wood or charcoal is surprising: these fuels are at the bottom and the top, respectively, of the energy ladder. Why would so many urban households with access to LPG want to continue to use biomass?

**Table 6.1: Combinations of Cooking Fuels**

| *% of households and mean expenditure (in Quatzales) per capita in group* | | | |
|---|---|---|---|
| | *Urban* | *Rural* | *Total* |
| *Common combinations* | | | |
| LPG only | 33.7% | 2.6% | 16.0% |
| | 15340 | 10182 | 14859 |
| LPG and wood | 19.4% | 13.8% | 16.2% |
| | 7317 | 6866 | 7099 |
| Wood only | 17.3% | 70.7% | 47.7% |
| | 4464 | 3360 | 3532 |
| Charcoal and LPG | 16.0% | 0.9% | 7.4% |
| | 17664 | 11797 | 17239 |
| Charcoal, wood and LPG | 5.6% | 1.2% | 3.1% |
| | 9506 | 7869 | 9138 |
| Kerosene and wood | 0.6% | 6.9% | 4.2% |
| | 3796 | 3639 | 3649 |
| *Uncommon combinations* | | | |
| LPG, wood and kerosene | 0.4% | 1.2% | 0.9% |
| | 6579 | 7857 | 7598 |
| Charcoal and wood | 1.5% | 1.1% | 1.3% |
| | 7729 | 5153 | 6439 |
| Electricity only | 1.0% | 0.0% | 0.4% |
| | 39764 | 47070 | 40112 |
| Electricity and wood | 0.1% | 0.1% | 0.1% |
| | 4878 | 3722 | 4251 |
| Electricity and LPG | 1.2% | 0.1% | 0.6% |
| | 20906 | 24417 | 21145 |
| Electricity other combination | 0.4% | 0.3% | 0.3% |
| | 6963 | 8006 | 7467 |
| Charcoal only | 0.2% | 0.0% | 0.1% |
| | 9619 | - | 9619 |
| Charcoal, other combination | 1.0% | 0.1% | 0.5% |
| | 20644 | 27717 | 21500 |

**Table 6.1: Combinations of Cooking Fuels**

| *% of households and mean expenditure (in Quatzales) per capita in group* | | | |
|---|---|---|---|
| | *Urban* | *Rural* | *Total* |
| Other and missing | 1.6% | 0.9% | 1.2% |
| | 20248 | 6981 | 14535 |
| Total | 100.0% | 100.0% | 100.0% |
| | 12113 | 4351 | 7696 |

*Source:* World Bank calculations and ENCOVI 2000

6.4 Table 6.2 shows a breakdown of single fuel and multiple fuel users. A little less than half of the urban households use multiple fuels; their combinations evolve around LPG, wood, and to a lesser extent charcoal. In contrast, only one-fourth of rural households use multiple fuels, and almost all of these combinations involve cooking with firewood.

**Table 6.2: Summary of Fuel Groups**

| *Share of households in groups (in %)* | | | |
|---|---|---|---|
| | *Urban* | *Rural* | *Total* |
| Single fuel users | 52.2 | 73.4 | 64.2 |
| Multiple fuel users | 47.8 | 26.6 | 35.8 |

*Source:* Author's calculations based on ENCOVI 2000

6.5 There is a systematic regional variation in the prevailing combinations of cooking fuels. Table 6.3 shows the prevalence of combinations in the major geographical regions of Guatemala. For simplicity, the combinations are merged into just six groups:

1. Only wood: lowest rung of the energy ladder.
2. Both wood and either kerosene or charcoal: lowest and intermediate step on the energy ladder.
3. Both wood and LPG or electricity (and possibly some intermediate fuels): spanning the entire ladder.
4. Both charcoal or kerosene and LPG or electricity: the intermediate and top of the ladder.
5. Only LPG or LPG and electricity: the top of the ladder.
6. Other combinations and missing.

**Table 6.3: Summary Cooking Fuel Group by Region and Sector**

| | *Summary cooking fuel group* | | | | | | *Total* |
|---|---|---|---|---|---|---|---|
| | *Wood only* | *Wood and charcoal or kerosene* | *Wood and LPG or electricity* | *Charcoal or kerosene and LPG or electricity* | *Only LPG or LPG and electricity* | *Other* | |
| *Urban* | | | | | | | |
| Metropolitana | 4.7 | 1.5 | 17.4 | 25.4 | 48.2 | 2.7 | 100 |
| North | 40.9 | 1.5 | 31.3 | 3.5 | 20.8 | 2.0 | 100 |
| Northeast | 20.9 | 2.2 | 23.7 | 9.8 | 31.9 | 11.6 | 100 |
| Southeast | 28.4 | 1.9 | 34.5 | 6.6 | 26.2 | 2.3 | 100 |
| Central | 28.1 | 4.0 | 36.2 | 9.7 | 20.2 | 1.8 | 100 |
| Southwest | 28.2 | 2.6 | 34.7 | 5.0 | 25.9 | 3.5 | 100 |
| Northwest | 40.9 | 0.8 | 34.5 | 5.0 | 16.2 | 2.6 | 100 |
| Total | 17.3 | 2.1 | 25.5 | 16.0 | 35.9 | 3.2 | 100 |
| *Rural* | | | | | | | |
| Metropolitana | 55.2 | 5.0 | 27.6 | 4.3 | 6.5 | 1.5 | 100 |
| North | 85.3 | 8.0 | 5.2 | 0.0 | 0.8 | 0.7 | 100 |
| Northeast | 54.8 | 9.2 | 24.7 | 3.6 | 6.4 | 1.4 | 100 |
| Southeast | 72.5 | 7.2 | 17.8 | 0.2 | 1.9 | 0.5 | 100 |
| Central | 57.3 | 7.4 | 24.4 | 1.7 | 6.2 | 2.9 | 100 |
| Southwest | 68.0 | 8.8 | 19.4 | 0.3 | 2.0 | 1.5 | 100 |
| Northwest | 91.4 | 4.2 | 3.4 | 0.1 | 0.2 | 0.7 | 100 |
| Peten | 68.4 | 23.4 | 6.2 | 0.0 | 1.1 | 0.9 | 100 |
| Total | 71.7 | 8.2 | 15.6 | 0.7 | 2.5 | 1.3 | 100 |
| *National* | 47.7 | 5.5 | 20.3 | 7.4 | 17.0 | 2.1 | 100 |

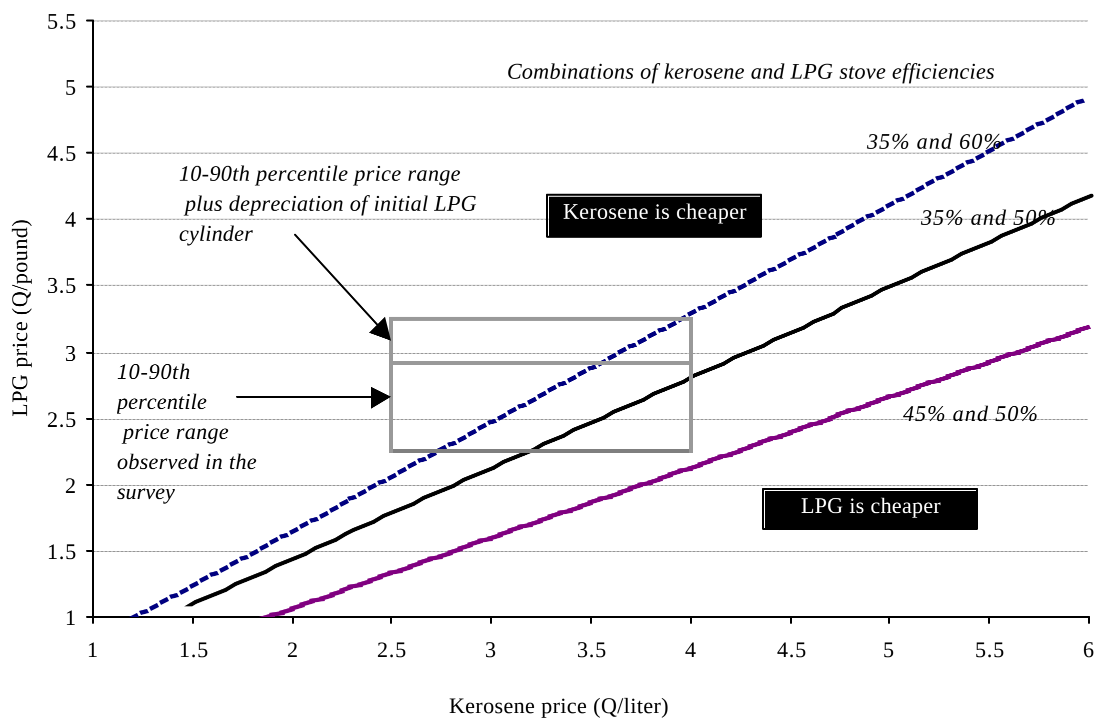
*Source:* Author's calculations based on ENCOVI 2000

6.6 The metropolitan region has a lot more LPG and less wood than elsewhere in the country. The share of wood in consumption profiles varies to a very large extent across regions. A plausible conjecture is that local variations in the price and availability of wood determine much of this. Also, it may be noted that kerosene and charcoal usage is much more widespread in Peten than elsewhere. Joint use of wood and LPG is widespread, however, in urban areas throughout the country albeit less so in the capital.

## LPG-Kerosene Price Competition

6.7 The competition between LPG and kerosene can be illustrated using calculations of "breakeven" prices. These are the prices that make LPG and kerosene equally costly per unit of useful energy output delivered, based on stove efficiencies typically encountered in developing countries. The results are depicted in figure 6.1 for three different sets of assumptions about the efficiency of kerosene and LPG stoves. The three straight lines correspond to three relative prices that will make kerosene and LPG cost the same per megajoule of useful energy output based on energy content and each set of assumed stove efficiencies. Price combinations below the lines correspond to situations where LPG is cheaper than kerosene on a useful energy basis. Conversely, prices above the breakeven lines correspond to kerosene being cheaper than LPG. The inserted square shows the range of actual prices found in Guatemala according to the survey. The lower part of the square marks the 10th to the 90th percentile of survey prices. In other words, 80 percent of observed LPG prices and 80 percent of kerosene prices lie within the interval depicted by the square. The upper portion of the square adds an allowance for depreciation of the initial cylinder, the only element of startup costs that is unique to LPG.

**Figure 6.1: LPG/Kerosene Breakeven Prices for Different Stove Efficiency**




*Note:* The lines show the breakeven combinations of kerosene and LPG prices that make the two fuels cost the same per unit of useful energy based on three different assumptions about the relative energy efficiency of the stoves.

6.8 The calculations imply that in Guatemala one cannot say in general which fuel is cheaper. The effective relative prices of the two fuels are sufficiently close that local variations in prices and stove efficiency can determine the outcome of the calculation. Prices of both fuels fluctuate widely on international markets so the same calculation done at another point in time might show different results. Once LPG startup costs are considered, kerosene appears to be cheaper than LPG for a greater part of the sample. The same is true where the stove efficiency is low for LPG and high for kerosene. This conclusion is reversed, however, where the LPG/kerosene price is in the lower end of the observed range, the LPG stove efficiency is good, or the LPG startup costs do not feature heavily (for example, because the household already has a gas burner); in those cases LPG seems more affordable. Therefore, given the inevitable uncertainties involved in these calculations and the variation in prices and stove efficiencies encountered on the ground, it cannot be concluded with any certainty which fuel is cheaper. As documented above, many more households in Guatemala use LPG than kerosene as their cooking fuel. This is not surprising. In light of the apparent modest price differences, consumers choose LPG because it is cleaner, faster, and more convenient than kerosene. It is also safer, although the general public does not always perceive this fact.

### LPG–Firewood Competition

6.9 What is the relative affordability of LPG versus firewood? It was not feasible to calculate the cost per unit of effective energy for wood because of uncertainties about quantities and wood energy content in the ENCOVI survey. Using different data, however, Foster and Tre (forthcoming) estimate that firewood and LPG cost the same in Guatemala per unit of net effective energy, but reckon that the upfront capital costs of LPG still make the poor prefer firewood.

6.10 A different approach to cost comparison can also be useful. Actual fuel spending by different user groups—households using only LPG, only cash wood, both LPG and cash wood, and both LPG and charcoal —can be compared. Average actual fuel spending by each of these groups will indicate what it costs to satisfy normal household cooking needs using LPG, wood, charcoal or a combination. Given differences in economic position and household size between fuel groups, comparison is made quintile for quintile in urban areas only, looking at cash fuel spending per household, fuel spending per capita, and fuel budget share.

6.11 The results are intriguing. The group that uses both LPG and wood tends to have the highest fuel spending in most quintiles, regardless of whether comparison is made for fuel spending in total, per capita, or as a share of total expenditures. Households using only wood tend to spend almost as much as the LPG-wood group (and in fact spend slightly more in the third urban quintile and the same in the fourth). Households using only LPG or LPG together with charcoal spend substantially less on fuel. It is interesting to note that when LPG is supplemented with wood, substantial spending is incurred on both LPG and wood whereas LPG is supplemented with only small quantities of charcoal. The magnitude of fuel spending in the both-LPG-and-wood group suggests a far greater role for wood than merely as an occasional backup during LPG cylinder refill. All the urban users of wood appear to be able to access LPG. It can certainly be concluded that wood is not a cheap fuel when it is procured from the market. Users of purchased wood—alone or in conjunction with LPG—tend to spend more on fuel than those who cook only with LPG. These findings confirm the suggestion made above that many households currently that purchase wood could save money by using LPG instead for all their cooking needs. In other words, purchased wood cannot compete with LPG on costs. This helps explain why no significant cross-price effects were found between LPG and wood in the logit regressions in paragraphs 5.7-20. Wood is not consumed because of low costs—at least for nearly half its users who rely on purchases.

**Table 6.4: Characteristics of LPG and Cash Wood Users**

*Urban Guatemala: Per household and per capita LPG and biomass cash expenditure (Q/month.)*

| | *LPG only* | *Wood only* | *LPG & Wood* | *LPG & Charcoal* |
|---|---|---|---|---|
| *1st urban quintile* | | | | |
| LPG spending | 60 | 0 | 64 | 59 |
| Wood spending | 0 | 109 | 94 | 0 |
| Charcoal spending | 0 | 0 | 0 | 5 |
| Total fuel spending | 60 | 109 | 159 | 64 |
| Per capita fuel spending | 11 | 18 | 24 | 17 |
| Fuel budget share | 3.8 | 7.8 | 8.4 | 6.2 |
| *2nd urban quintile* | | | | |
| LPG spending | 65 | 0 | 68 | 61 |
| Wood spending | 0 | 115 | 78 | 0 |
| Charcoal spending | 0 | 0 | 0 | 9 |
| Total fuel spending | 65 | 115 | 145 | 70 |
| Per capita fuel spending | 15 | 27 | 27 | 14 |
| Fuel budget share | 3.3 | 5.9 | 6.1 | 3.4 |
| *3rd urban quintile* | | | | |
| LPG spending | 66 | 0 | 71 | 63 |
| Wood spending | 0 | 152 | 79 | 0 |
| Charcoal spending | 0 | 0 | 0 | 8 |
| Total fuel spending | 66 | 152 | 150 | 71 |
| Per capita fuel spending | 18 | 45 | 34 | 16 |
| Fuel budget share | 2.6 | 6.6 | 5.0 | 2.3 |
| *4th urban quintile* | | | | |
| LPG spending | 74 | 0 | 76 | 71 |
| Wood spending | 0 | 150 | 72 | 0 |
| Charcoal spending | 0 | 0 | 0 | 9 |
| Total fuel spending | 74 | 150 | 148 | 80 |
| Per capita fuel spending | 24 | 46 | 45 | 22 |
| Fuel budget share | 2.2 | 4.4 | 4.3 | 2.0 |
| 5th urban quintile | | | | |

| | | | | |
|---|---|---|---|---|
| LPG spending | 88 | 0 | 76 | 94 |
| Wood spending | 0 | 106 | 65 | 0 |
| Charcoal spending | 0 | 0 | 0 | 13 |
| Total fuel spending | 88 | 106 | 141 | 107 |
| Per capita fuel spending | 38 | 59 | 97 | 31 |
| Fuel budget share | 1.6 | 2.4 | 4.8 | 1.3 |

6.12 Thus, we need to look beyond cost factors to understand why so many continue to use wood, and especially the large number of households who purchase it. If those factors can be identified and targeted in energy interventions, there would be a large potential market for LPG. In fact, all of those who presently pay for their wood can be considered potential candidates for switching entirely to LPG. This is the case for 31 percent of all households nationally—and similar in urban and rural areas. In the group of wood purchasers only 45 percent already consume LPG. In the following, it is investigated further what might be the likely reason LPG has not (yet) overtaken the market, at least for wood purchasers.

## LPG Barriers: Startup Costs and Access

6.13 In the following, two commonly mentioned explanations for why LPG is not more widely adopted are considered: startup costs and lack of access to a distribution point—rural households in particular are sometimes just too far from the nearest LPG distributor.

6.14 The startup costs of LPG are often mentioned as an important factor, so it makes sense to look at their size relative to total expenditure in the context of Guatemala. Table 6.5 is an attempt at quantifying the initial costs of LPG uptake. Including the cost of the cylinder (which comes with a small amount of LPG) and the stove, in 2002 households would need to pay US$54-60 to adopt LPG. Retailers sometimes offer schemes where the payment is spread over, for example, three monthly installments; this increases the total costs consumers have to pay (Matthews 2002).

**Table 6.5: LPG Uptake Costs**

| *Typical LPG costs (values pertain to 2002). In US$* | |
|---|---|
| 25 lb. cylinder uptake* | 31.6 |
| 2-burner stove | 22.2 |
| 3-burner stove | 27.9 |
| Uptake, total | 54-60 |
| 25 lb. cylinder refill | 8.3 |
| Cylinder, stove and first refill combined | 62-68 |
| *Uptake exceeds 50% at monthly per capita expenditure of*** | |
| In urban areas | 61.6 |

| | |
|---|---|
| In rural areas | 66.1 |

*Notes:*

*Including valve, tubing and a small amount of LPG

**Based on the LPG usage regressions in chapter 6.

*Source:* Matthew 2002 and World Bank calculations.

6.15 The uptake costs can be compared to the expenditure levels at which LPG usage reaches 50 percent. Figure 4.1 and the LPG logit regressions in paragraphs 5.7–20 above both indicate LPG usage rates reach 50 percent at per capita expenditures of roughly US$2/day or US$60/month. This makes it look as if households are good candidates to start using LPG when their monthly expenditures per capita exceed uptake costs plus the first refill. Of course, it may be a pure coincidence and it is impossible from this data to confirm the exact role played by startup costs in constraining LPG uptake.

6.16 Access to LPG can be defined and measured in different ways. Table 6.6 shows first the proportion of households that live in communities where nobody among the survey respondents is using LPG, where somebody is using LPG, and then where everybody is using it. It can be seen that the vast majority of people have neighbors in their community who consume LPG. Next, the table also shows LPG access according to the price and community questionnaire—the vast majority of households appear to have access to LPG. It is therefore unlikely that complete geographic isolation from LPG distribution centers is blocking many households from adopting LPG—people have chosen not to consume it. One cannot rule out the distance to a distributor as a factor; the impact of distance obviously depends on vehicle ownership and transport opportunities in general. But it seems that in most communities in Guatemala there are ways of accessing LPG.

**Table 6.6: Community Spread of LPG**

| *In percent* | *Urban* | *Rural* | *Total* |
|---|---|---|---|
| Nobody in community is using LPG | 1 | 33 | 19 |
| Somebody in community is using LPG | 70 | 64 | 67 |
| All respondents use LPG | 29 | 3 | 14 |
| | | | |
| LPG available according to price questionaire | 80 | 71 | 75 |

*Source:* Author's calculations based on ENCOVI 2000

## Joint LPG and Wood Use: Descriptive Analysis

6.17 The most remarkable case of all the cooking fuel combinations considered is perhaps that of the joint use of LPG and wood. Joint LPG-wood use is especially intriguing in urban areas where wood tends to be commercialized and using wood adds considerably to the household fuel bill. Table 6.7 describes the fuel combinations of new LPG users in order to assess whether multiple fuel usage is simply a transitional phenomenon caused by a lag time from when LPG is adopted until other fuels are abandoned. The definition of a new LPG user is a household that adopted LPG less than two years ago. Average fuel patterns for “old” LPG users (more than two years), new LPG users, and all LPG users are shown. New LPG users consume more wood than others, but less charcoal. Yet many old LPG-using households also continue to use wood. The new users certainly do not drive the overall average for fuel mix. Joint use of wood and LPG is therefore more than just a matter of time lags for switching.

**Table 6.7: Fuel Combinations Used by “New” and “Old” LPG Consumers**

| | *% of LPG users also cooking with..* | | | |
|---|---|---|---|---|
| | *Kerosene* | *Wood* | *Electricity* | *Charcoal* |
| *Urban areas* | | | | |
| Have used LPG for more than 2 years | 0.8 | 32.1 | 3.5 | 29.6 |
| Have used LPG for less than 2 years | 0.6 | 49.7 | 2.0 | 21.0 |
| Total | 0.8 | 33.3 | 3.4 | 29.0 |
| *Rural areas* | | | | |
| Have used LPG for more than 2 years | 5.7 | 79.6 | 1.9 | 12.9 |
| Have used LPG for less than 2 years | 8.1 | 90.7 | 2.9 | 2.2 |
| Total | 6.1 | 81.6 | 2.1 | 11.1 |

*Source*: World Bank calculations and ENCOVI 2000

**Table 6.8: Characteristics of Urban Single-Fuel and Mixed-Fuel Households**

| | *LPG Only* | *LPG-Wood Mix* |
|---|---|---|
| Number of households | 317,866 | 239,866 |
| Expenditure per capita | 15,340Q | 7,788Q |
| Household size | 3.9 | 5.3 |
| Share residing in metropolitan city | 67.5% | 34.1% |
| Share residing in other urban areas | 32.5% | 65.9% |
| Spending on food outside the house | 53.2Q | 18.2Q |
| *Frequency of cooking maize* | | |
| Not often | 88.2% | 34.1% |
| Daily | 3.0% | 34.5% |
| Twice a week | 3.6% | 15.3% |
| Weekly | 0.4% | 4.2% |
| Other frequency | 4.7% | 11.9% |
| Total | 100.0% | 100.0% |

*Source:* World Bank calculations based on ENCOVI 2000

6.18 Another explanation sometimes put forward relates to the role of cultural factors, lifestyle, and cooking habits. To address such questions, table 6.8 compares some salient characteristics of that part of the sample that is (i) urban and (ii) belongs in either the LPG-only or the LPG and wood category of fuel use combinations. There are clear differences between these two groups. The table shows that most LPG-only households live in the metropolitan city whereas more than half of the other group lives in other and smaller towns. LPG-only households are smaller and better off. The lifestyle in a big city differs from that of other urban areas. For example, households that use only LPG spend much more on food outside the house. This could suggest they often purchase tortillas and hence do not need to burn wood in order to eat woodbaked tortillas, the staple diet of Guatemala. This conjecture is supported by data on the frequency of cooking maize. Those who complement LPG with wood, cook maize much more often than LPG-only households. Hence it may be that the LPG-only households avoid wood by instead purchasing woodbaked products (tortillas). In some sense, then, there may be lifestyle involved in the shifting from home cooking to reliance on the purchase of prepared food. Firewood use migrates from households to tortilla bakeries. This may be good for overall exposure to woodfuel smoke if bakeries are better ventilated than the average private home. The cultural norm of preparing certain dishes using wood, and the reluctance by less affluent households from smaller urban areas to substitute purchased tortillas for homebaked tortillas, appear significant for maintaining wood in the household fuel mix (similar observations have been made in India concerning traditional ovenbaked breads).

## Joint LPG And Wood Use: Multinomial Logit Analysis

6.19 A more formal analysis of what determines the most important combinations of cooking fuels was also carried out. The analysis relies on multinomial logit, a regression technique used to assess factors associated with households' choices among mutually exclusive groups. Focus here is on the three or four most important groups: LPG-only, wood-only, and joint wood-LPG. In urban areas, the LPG-charcoal combination is also considered. Eighty-seven percent of the households belong in one of these groups. The joint wood-LPG group is taken as an omitted category. The choice of an omitted category does not affect results. It merely influences how parameters are to be interpreted. Estimated parameters are presented as relative risk ratios. Parameters greater than one indicate the regressor is associated with a probability of the outcome that is greater than the probability of the base case, everything else equal. Parameters below one indicate that the variable is causing the outcome to have a smaller probability than the base case. For example, a significant parameter below one for wood-only therefore suggests the variable is causing adoption of LPG since it causes households to move out of the wood-only group. Likewise, a significant parameter above one in the LPG-only equation means a move away from wood.

6.20 The results, shown in table 6.9, are interesting. In urban areas higher expenditure is associated with a significant move away from wood and into LPG. The top group complements LPG with charcoal. Expenditure is not significant for fuel switching in rural areas. Prices matter to some extent: high LPG prices increase the chance of consuming just wood in rural areas, and high firewood prices increase the probability of using LPG only in urban areas. There is a symmetry in these results because wood dominates rural cooking with LPG as an occasional complement whereas LPG dominates urban cooking with wood on the side. The complement's high prices lessens its use as predicted by basic theory.

**Table 6.9: Multinomial Logit Analysis of Wood, LPG and Charcoal Combinations**

| *Omitted category: Both LPG and woodfuel* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Urban* | | | | | | *Rural* | | | |
| | *Only LPG* | | *Only wood* | | *LPG&Charcoal* | | *Only LPG* | | *Only wood* | |
| *Variable name* | *ß* | *z-stat* | *ß* | *z-stat* | *ß* | *z-stat* | *ß* | *z-stat* | *ß* | *z-stat* |
| Expenditures per capita (log) | 2.70 | 7.27 | 0.18 | -10.80 | 5.35 | 0.93 | 1.11 | 0.37 | 0.09 | 0.02 |
| LPG log price of | 1.44 | 0.48 | 1.97 | 0.83 | 0.57 | 0.56 | 0.37 | -0.76 | 3.01 | 2.05 |
| Kerosene log price | 0.60 | -1.44 | 0.62 | -1.43 | 1.13 | 0.55 | 0.18 | -3.51 | 1.75 | 0.51 |
| Firewood log price | 1.47 | 2.58 | 1.03 | 0.19 | 1.53 | 0.29 | 1.37 | 1.07 | 1.01 | 0.17 |
| Log household size | 0.47 | -4.79 | 0.77 | -1.52 | 1.18 | 0.25 | 0.25 | -4.49 | 0.43 | 0.08 |
| Primary education | 2.21 | 2.12 | 0.47 | -2.88 | 0.92 | 0.49 | 1.94 | 0.84 | 0.33 | 0.10 |
| Secondary education | 3.92 | 3.61 | 0.27 | -4.65 | 1.74 | 0.92 | 4.96 | 1.95 | 0.17 | 0.05 |
| Post-secondary education | 4.94 | 4.01 | 0.21 | -4.33 | 1.49 | 0.83 | 12.88 | 2.91 | 0.20 | 0.09 |
| Number of rooms | 1.08 | 1.91 | 0.85 | -3.20 | 1.11 | 0.05 | 1.12 | 1.22 | 0.71 | 0.04 |
| Farm household | 0.15 | -9.20 | 2.54 | 6.64 | 0.16 | 0.05 | 0.22 | -5.32 | 1.91 | 0.26 |
| Share of females in household | 0.46 | -2.83 | 0.89 | -0.35 | 0.41 | 0.14 | 0.19 | -3.07 | 0.45 | 0.13 |
| Indigenous | 0.52 | -4.14 | 1.75 | 3.92 | 0.42 | 0.10 | 0.96 | -0.12 | 1.34 | 0.20 |
| Community median firewood distance | 1.03 | 1.54 | 1.04 | 1.73 | 1.03 | 0.03 | 0.93 | -1.69 | 1.14 | 0.03 |
| Electrified | 1.80 | 1.19 | 0.36 | -4.25 | - | - | 2.31 | 1.99 | 0.44 | 0.07 |
| North | 0.27 | -5.06 | 2.17 | 2.17 | 0.15 | 0.05 | 0.14 | -2.77 | 1.13 | 0.44 |
| Northeast | 0.43 | -3.55 | 3.62 | 3.46 | 0.47 | 0.13 | 0.65 | -0.89 | 0.56 | 0.20 |
| Southeast | 0.31 | -4.86 | 2.01 | 1.95 | 0.19 | 0.06 | 0.33 | -2.33 | 0.87 | 0.28 |
| Central | 0.31 | -5.14 | 1.34 | 0.87 | 0.36 | 0.10 | 0.73 | -0.78 | 0.57 | 0.17 |
| Southwest | 0.42 | -4.05 | 1.23 | 0.62 | 0.18 | 0.05 | 0.25 | -2.90 | 0.66 | 0.20 |
| Northwest | 0.21 | -6.07 | 1.71 | 1.58 | 0.18 | 0.06 | 0.22 | -1.69 | 1.97 | 0.68 |
| Peten | 0.13 | -6.37 | 3.98 | 3.44 | 0.04 | 0.02 | 1.10 | 0.13 | 1.11 | 0.46 |
| Observations/Pseudo R-squared | | | 2845 / 0.34 | | | | | | 3385 / 0.41 | |

Note: ß refers to the estimated parameter for the relative risk ratios. Values below one indicate smaller chance of belonging to group, values above one higher chance, relative to the omitted category which is joint wood and LPG.

Source: Author's calculations based on ENCOVI 2000.

6.21 Increasing household size is associated with higher probability of using multiple fuels and therefore smaller use of only LPG. The gender composition of the household has identical effects in that a high female share significantly reduces the likelihood for using only LPG but does not affect the likelihood of belonging to the other groups. Thus, having a high share of females is likely to be similar to having a large family, there is ample collection and cooking labor time available and hence no compelling reason to entirely abandon time-consuming fuelwood.

6.22 Education is a strong determinant of fuel switching. The more education, the greater is the probability of using only LPG (significant in both urban and rural areas) and the less is the chance of using only wood (significant in urban areas only). Education does not affect the likelihood of belonging in the LPG-charcoal group. The reason may be that education increases the opportunity cost of collection time. In urban areas the number of rooms is significantly associated with switching away from only wood and into only-LPG. This is presumably a wealth effect. Being a farm household has the opposite effect: farmers are less likely to use only LPG (significant everywhere) and more likely to use only wood (significant in urban areas only). This is probably caused by low opportunity costs of woodfuel.

6.23 Indigenous ethnic groups have a fuel portfolio that is significantly different only in urban areas, resulting in a much higher likelihood of using only fuelwood. Lifestyle and cultural factors may lead to a preference for fuelwood. Distance to a fuelwood source does not appear important in this specification. Having electricity is again found to be associated with fuel switching. In urban areas it results in a significantly lower probability of using only wood and more LPG usage (all the households using both LPG and charcoal in the sample were electrified). In rural areas it causes a significantly greater probability of consuming only LPG. Hence the electrification results here are a little weaker than in the single equation logit, but basically confirm a correlation between electricity and fuel switching.

6.24 The regional dummies mostly indicate less exclusive reliance on LPG relative to the omitted region, the metropolitan area. They also suggest a greater probability of using wood-only (significant in urban areas of some of these regions).

## Conclusion

6.25 The descriptive analysis suggested broad lifestyle factors are involved in deciding whether fuelwood can be entirely abandoned, notably living in a large city and purchasing prepared foods. LPG uptake costs are also likely to play a role. The multinomial regression analysis added to this by confirming that a number of other variables such as opportunity cost and total expenditures are also important for the fuel combination. Hence many factors help trigger fuel switching and abandonment of fuelwood: higher expenditure; education; electrification; urban and even more so big city life; a small household; the scarcity of women in a household; not being a farmer; and to some extent relative prices. Among these variables only prices are normally considered policies for fuel switching. Although prices have a role to play for fuel choice, a host of other factors consistently appear equally if not more important for demand. There are important lessons from this for any country that has or is considering introducing price subsidies to liquid and gaseous fuels (Guatemala does not have such subsidies): beside being regressive, price subsidies may not achieve substantial switching out of fuelwood. Variables such as electrification and education are of course also amenable to policy but are normally discussed and pursued with other aims in mind.

# 7

## Conclusions

7.1 This report has analyzed fuel consumption patterns using a Guatemalan household survey data set. As in most other countries in comparable income categories, LPG in Guatemala was not found to be used much by poor or rural households. LPG is used mostly by the top half of the population, and predominantly in urban areas. Instead the poor continue to rely largely on firewood for cooking with electricity (where available) and otherwise candles or kerosene for lighting.

7.2 Energy is a basic good, and it therefore has a disproportionately large budget share among the poorer groups. Many of the rural poor rely on self-collected fuelwood, and are therefore able to keep their cash energy expenditures down to approximately 5 percent of total expenditures, approximately the same as the nonpoor. But many urban low-income groups do not have this option, and often spend up to 12 percent of total expenditures on energy alone. Fuel prices can therefore have severe budgetary implications especially for urban low-income groups. Although household fuel policies need to keep this high energy budget share in mind, the implication is not that household cooking fuels should be subsidized. Countries considering price subsidies to LPG fuels can learn from the analysis here that LPG subsidies are likely to be captured to a large extent by the non-poor, may often be distributed in a regressive fashion, and may not achieve substantial switching out of biomass fuels. Many of the results suggest that LPG subsidies might have a modest impact in terms of leading to abandoning of fuelwood. This is because LPG uptake often goes hand-in-hand with continued wood usage, and because many factors beside price appear to matter more for fuel choice. Traditional cooking techniques relying on fuelwood sometimes make people continue to use wood even where wood is more expensive than available alternatives. Upfront costs of commencing LPG use also appear to play a role in limiting uptake.

7.3 A number of household characteristics and policy variables were found to be important for fuel choice. Given that multiple fuel usage is widespread, it is necessary to distinguish more sharply between variables inducing fuel switching—interfuel substitution—and variables leading to fuel "stacking"—a growing energy portfolio.

7.4 Income exerts a robust influence. In urban areas rising household expenditures often—but far from universally—induce fuel switching, while multiple fuel usage or fuel stacking is a more common response in rural areas. In fact only the very best off in rural areas abandon wood. Education and electrification appear to be associated with fuel switching. Large household size and high female ratio often lead to fuel stacking due to low firewood opportunity costs. Ethnicity, prices, and region of residence also matter for fuel choice.

7.5 Opportunity costs of firewood are important for fuel choice. This can be seen, for example, in the fact that educated households are less likely to use fuelwood ostensibly because they value the time-savings provided by hydrocarbon fuels, or in the greater fuelwood use by farmers. The role of cultural factors and cooking habits is difficult to capture theoretically and predict in practice. This is because culture and habits change over time with a speed and magnitude that is hard to predict. Education and big city life undoubtedly play a role in speeding up cultural change, including adoption of new cooking techniques and fuels and abandonment of traditional ones.

7.6 Household fuel strategies need to be based on the realistic proposition that firewood will remain responsible for fully or partly meeting household cooking needs for a substantial share of the population. Strategies for safe and efficient household energy therefore cannot rely exclusively on fuel switching. An appropriate balance needs to be developed between policies aiming at interfuel substitution and policies seeking to ameliorate the negative consequences of woodfuel consumption. Ways must be found to make solid fuels less risky for health, for example by considering improved stoves and awareness campaigns seeking to spur better ventilation or outdoor cooking.

7.7 Careful targeting of each strategy to relevant segments is required. Areas with plentiful free biomass are unrealistic targets for LPG—other interventions are required to combat indoor air pollution in such areas. Improved stoves should not be promoted in areas where households use expensive purchased wood and LPG uptake would be the better option.

# Appendix 1 : Logit Regression Results

**Table A1: Urban Sample Reduced List of Regressors**

| | *LPG* | *Kerosene* | *Wood* | *Electricity* | *Charcoal* |
|---|---|---|---|---|---|
| log of per capita expenditures | 1.485 | -0.599 | -1.518 | 1.462 | 0.838 |
| | (11.49)** | (3.82)** | (13.22)** | (10.62)** | (9.32)** |
| Log price of LPG | -1.165 | 5.413 | -0.176 | -2.635 | -1.654 |
| | (1.97)* | (3.69)** | (0.29) | (2.79)** | (2.90)** |
| Log price of kerosene | 0.126 | 0.057 | 0.346 | -0.343 | 0.658 |
| | (0.46) | (0.11) | (1.16) | (0.57) | (2.21)* |
| Log price of firewood | 0.188 | -0.249 | -0.600 | 0.525 | 0.010 |
| | (1.70) | (1.09) | (5.07)** | (2.73)** | (0.09) |
| Log household size | 0.395 | -0.031 | 0.407 | 0.880 | 0.721 |
| | (2.87)** | (0.12) | (3.26)** | (4.43)** | (6.20)** |
| Primary education | 0.711 | | | | -0.269 |
| | (3.37)** | | | | (2.16)* |
| Secondary education | 1.372 | | -0.692 | | |
| | (6.07)** | | (5.78)** | | |
| Post-secondary education | 1.214 | | -0.830 | | -0.367 |
| | (4.52)** | | (5.06)** | | (2.87)** |
| Number of rooms in dwelling | 0.107 | | -0.073 | | |
| | (2.72)** | | (2.14)* | | |
| Farm household | -1.134 | | 1.949 | | -0.360 |
| | (10.18)** | | (11.85)** | | (2.51)* |
| Indigenous | -0.479 | | 0.797 | | -0.369 |
| | (4.44)** | | (5.98)** | | (2.64)** |
| Community median firewood distance | -0.035 | | | | |
| | (2.02)* | | | | |
| Household has electricity | 1.378 | | -0.796 | | 1.870 |
| | (6.51)** | | (2.73)** | | (3.17)** |
| North | -0.366 | | 0.992 | 1.305 | -0.609 |
| | (2.31)* | | (5.36)** | (4.33)** | (3.05)** |
| Northeast | -0.469 | 1.643 | 0.436 | 2.462 | |
| | (2.80)** | (5.28)** | (2.75)** | (11.74)** | |

**Table A1: Urban Sample Reduced List of Regressors**

| | *LPG* | *Kerosene* | *Wood* | *Electricity* | *Charcoal* |
|---|---|---|---|---|---|
| Peten | -0.819 | 1.269 | 1.742 | | -1.287 |
| | (4.19)** | (3.49)** | (7.13)** | | (3.95)** |
| Share of females in household | | | 0.700 | | |
| | | | (3.22)** | | |
| Southeast | | | 0.711 | | -0.647 |
| | | | (3.98)** | | (3.41)** |
| Southwest | | | | | -0.423 |
| | | | | | (2.74)** |
| Constant | -9.595 | -22.108 | 13.305 | -6.939 | -5.383 |
| | (3.39)** | (3.22)** | (4.70)** | (1.68) | (2.05)* |
| Central | | | 0.615 | 0.953 | |
| | | | (3.71)** | (3.15)** | |
| Northwest | | | 1.223 | | |
| | | | (6.44)** | | |
| Observations | 3330 | 3438 | 3438 | 3438 | 3438 |

Robust z statistics in parentheses* significant at 5%; ** significant at 1%

**Table A2: Rural Sample Reduced List of Regressors**

| | *LPG* | *Kerosene* | *Wood* | *Charcoal* |
|---|---|---|---|---|
| Per capita expenditure log | 2.360 | 0.329 | -0.622 | 1.360 |
| | (15.14)** | (2.62)** | (3.03)** | (7.50)** |
| LPG log price | -1.798 | 1.308 | 1.187 | -0.661 |
| | (3.27)** | (1.90) | (1.33) | (0.70) |
| Kerosene log price | -0.642 | 0.549 | 1.363 | -1.012 |
| | (2.44)* | (2.00)* | (3.83)** | (2.30)* |
| Firewood log price | 0.116 | -0.007 | -0.382 | 0.563 |
| | (0.83) | (0.04) | (1.85) | (2.59)** |
| Log household size | 0.803 | 0.280 | 1.152 | 1.011 |
| | (5.34)** | (1.87) | (5.43)** | (4.73)** |
| Primary education | 0.851 | | | -0.637 |
| | (3.43)** | | | (3.18)** |
| Secondary education | 1.607 | | -1.046 | |
| | (5.85)** | | (5.13)** | |
| Post-secondary education | 1.323 | | -1.649 | |
| | (3.42)** | | (5.19)** | |
| Number of rooms in dwelling | 0.337 | | -0.284 | |
| | (6.58)** | | (3.80)** | |
| Farm household | -0.784 | 0.237 | 1.468 | -0.655 |
| | (6.55)** | (1.56) | (7.35)** | (3.28)** |
| Share of females in household | 0.595 | -0.673 | 1.090 | |
| | (2.23)* | (1.98)* | (2.82)** | |
| Indigenous | -0.286 | -0.271 | | |
| | (2.32)* | (2.05)* | | |
| Community median firewood distance | -0.127 | | | |
| | (5.70)** | | | |
| Household has electricity | 1.015 | -1.102 | -1.065 | |
| | (7.51)** | (7.12)** | (4.32)** | |
| Central | 0.356 | 0.211 | | |
| | (2.69)** | (1.33) | | |
| Northwest | -0.941 | -0.875 | 1.270 | -1.060 |

**Table A2: Rural Sample Reduced List of Regressors**

| | *LPG* | *Kerosene* | *Wood* | *Charcoal* |
|---|---|---|---|---|
| | (4.62)** | (4.04)** | (2.87)** | (2.77)** |
| Peten | | 0.614 | | -1.866 |
| | | (3.38)** | | (2.56)* |
| North | | | 0.844 | -1.935 |
| | | | (1.91) | (2.57)* |
| Southwest | | | 0.654 | -0.696 |
| | | | (2.49)* | (2.55)* |
| Constant | -15.321 | -10.961 | -0.025 | -10.917 |
| | (5.60)** | (3.58)** | (0.01) | (2.47)* |
| Southeast | | | 0.855 | |
| | | | (2.92)** | |
| Observations | 3883 | 3883 | 3883 | 3883 |

Robust z statistics in parentheses * significant at 5%; ** significant at 1%

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