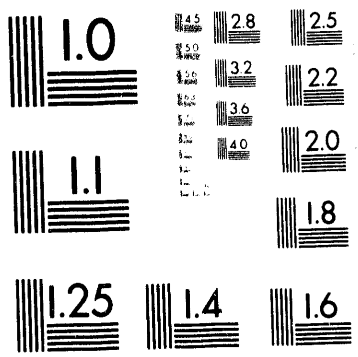
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SUSTAINABLE FUELWOOD USE IN RURAL MEXICO

VOLUME I: CURRENT PATTERNS OF RESOURCE USE

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THIS WORK IS THE RESULT OF A COOPERATION PROJECT BETWEEN THE MEXICAN COMMISSION FOR ENERGY CONSERVATION (CONAE) AND THE U.S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF POLICY ANALYSIS, DIVISION OF GLOBAL CLIMATE CHANGE THROUGH THE U.S. DEPARTMENT OF ENERGY CONTRACT NO. DE-AC03-76SF00098.

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EXECUTIVE SUMMARY

The present report summarizes the results of the first phase of a project of cooperation between the Mexican National Commission for Energy Conservation (CONAE) and the United States Environmental Protection Agency (U.S. EPA) on sustainable biofuel use in rural Mexico.

This first phase has been devoted to (i) conducting an in-depth review of the status of fuelwood use in rural and peri-urban areas of Mexico, (ii) providing improved estimates of biomass energy use, (iii) assessing the socio-economic and environmental impacts of fuelwood use, and (iv) identifying preliminary potential lines of action to improve the patterns of biomass energy use in Mexico; in particular, identifying those interventions that, by improving living conditions for rural inhabitants, can result in global benefits (such as the reduction in greenhouse gas emissions). A comprehensive review of the existing documentation of biofuel use in rural and peri-urban Mexico was conducted. Reports from official, academic, and non-governmental organizations were gathered and analyzed. A computerized rural energy database was created by re-processing a national rural energy survey. Because of the paucity of information about biofuel use in small rural industries, most of the analysis is devoted to the household sector.

Current Pattern of Fuelwood Demand

Fuelwood still represents the primary residential fuel in Mexico. Approximately 25.6 million people in the country (31.4% of the total population) use fuelwood for cooking. Ninety percent of rural households depend on fuelwood. A large number of small industries, most belonging to the informal sector, also consume substantial amounts of fuelwood and other biofuels (charcoal and sawdust).

Total fuelwood demand is estimated at 355 PJ/yr (equivalent to 22.2 million ton/yr or 37.0 million m^3/yr) in 1990. This amount represents 46% of total residential energy use and is 4.6 times the commercial (legally authorized) timber harvested in the country. Approximately 93% of total demand comes from the household sector. The high fuelwood demand is, to a larger extent, the result of low efficiencies at the end use. More than 80% of rural households cook with three-stone fires, of estimated efficiencies of 17%. Average household fuelwood unit consumption reaches 60 GJ/yr. Most fuelwood consumption goes to cooking. Within cooking, tortilla making may account for more than 50% of total consumption. Energy intensities (i.e., the energy input per physical unit of output) in many small industries are also considerable.

The patterns of fuelwood use, i.e., the amount and type of fuelwood demand, preferred tree species, and fuelwood saturation, show important regional variations. These patterns also differ markedly by socio-economic group.

Environmental and Health Impacts

Local-regional impacts. Current fuelwood demand presents several environmental concerns. While fuelwood use is not leading to extensive deforestation at the national level, it has become a source of forest degradation in specific regions. In general, fuelwood scarcity is more a byproduct than a cause of deforestation. Most fuelwood for household use comes from dead wood, branches, and twigs from non-commercial tree species. Demand from peri-urban households is in general more environmentally damaging than rural demand. The environmental impact of small industries is significant at the regional level, where they have contributed to deforestation and forest degradation. Fuelwood scarcity is critical in several portions of the highlands of central and southern Mexico. These regions combine high population densities, growth of fuelwood users, a rapidly disappearing forest resource base, and a sizeable biofuel demand from small industries.

Greenhouse gas emissions. We estimate that roughly 30% of household fuelwood demand and 50% of biofuel demand in small industries are met by non-sustainable fuelwood harvesting. This pattern of fuelwood use results in net greenhouse gas emissions of 4.3 MtonC equivalent per year. Gross greenhouse gas emissions total 13.3 MtonC equivalent per year.

Health risks. Indirect evidence in the country suggests that combustion in open fires is associated with chronic respiratory illnesses in women. The international literature suggest that indoor air pollution may represent a major health risk for fuelwood-using rural residents.

Future prospects for fuelwood use

(i) A *sustained fuelwood demand.* Total fuelwood demand is expected to remain high in the mid-term due to the following factors:

a. The increase in per capita unit consumption, driven by the on-going reduction of average family size both in urban and in rural households.

b. Limited fuel substitution in households. Low household incomes, the dispersion and small size of most villages, together with the relatively high front-end costs of LPG stoves and their inability to accommodate traditional cooking practices – specifically tortilla making – limit the extent of fuel switching.

c. Problems for fuel switching in small industries. Very low investment possibilities and the characteristics of the markets for their output also limit the possibilities for fuel switching in most small industries. Charcoal production for export is increasing at a rapid pace.

(ii) *An increasing share of mixed LPG-fuelwood users.* LPG is expected to continue its market penetration, particularly in peri-urban areas and in the more accessible rural villages. Fuel switching will likely be only partial in most cases. Fuelwood savings from using LPG will depend on the specific pattern of cooking practices, evolution of the relative prices of both fuels and of rural incomes, and on the reliability of the LPG supply network.

(iii) *An increase in fuelwood scarcity, and consequently, an intensification of the negative impacts associated with fuelwood use.* As deforestation continues in the country, fuelwood resources are expected to become scarcer. Half of rural households already indicated experiencing increases in fuelwood-collection distances. Competition for wood wastes from the industrial sector will likely increase fuelwood scarcity in some regions. Scarcity will negatively impact both rural and peri-urban residents and the environment.

(iv) *The intensification of contrasts in the regional patterns of household fuelwood demand.* The differences in fuelwood-use patterns between northern and southern Mexico will probably increase. Fuelwood users are expected to continue diminishing in the North, driven by the better economic situation and infrastructure in this region. The bulk of fuelwood users will thus continue to concentrate in southern Mexico, where fuelwood scarcity will likely increase more rapidly.

Towards sustainable fuelwood use

If adequately managed, fuelwood and other biofuel resources can represent an important, renewable and environmentally-sound component of Mexico's future energy supply. Given the complex and inter-related problems associated with fuelwood demand, only an integrated approach that encompasses a whole range of actions, from institutional issues to technical measures, will prove effective in assuring a sustainable pattern of fuelwood use in Mexico. Urgent actions to facilitate this goal include the following:

(i) *Integrate fuelwood concerns into rural development strategies.* Rural energy, forest management, and public health programs need to have a fuelwood component. The numerous links between fuelwood use, public health, the environment, and socio-economic development provide good opportunities for the sharing of resources and for a productive inter-institutional collaboration.

(ii) *Provide the appropriate institutional framework to facilitate the long-term management of forest and fuelwood resources.* Currently, insecure land tenure, excessive bureaucracy in forest regulations, disparities between those who own and those who economically benefit from forest resources, and extreme poverty of rural inhabitants, encourage the "mining" of forest resources. Strong institutional support, and changes in rural development policies are needed to reverse the stated situation.

(iii) *Improve the existing database on fuelwood use, particularly for small industries.* The information on fuelwood-use patterns is still fragmented. We need to understand better the regional and historical evolution of fuelwood-use patterns and prices and the end-use structure of fuelwood demand.

(iv) *Launch a national program to disseminate improved cookstoves in rural and peri-urban households.* Improved cookstoves offer the best possibilities for reducing fuelwood demand in the short run. Fuelwood savings might amount to more than 30% (50% in tortilla making) with relatively modest investments.

(v) *Encourage fuel substitution in peri-urban centers.* Fuel switching can be fostered by assuring a more reliable LPG supply, designing stoves appropriate to rural cooking, and reducing the capital investment needed to cook with this fuel.

(vi) *Assure an adequate and renewable fuelwood supply.* Different schemes, from energy plantations and agroforestry to living fences, might be investigated. In general, those schemes that provide a multiplicity of benefits for local users are likely to be the most successful.

(vii) *Increase support for R&D activities in bioenergy.* The current financial and institutional support for bioenergy is clearly insufficient given the problems and challenges associated with the use of these sources. Research priorities include the health and environmental implications of fuelwood demand, design of improved fuelwood-using end-use devices, biogasification schemes (producer gas and biogas), and integrated energy farms, among other options.

ACKNOWLEDGMENTS

The present report has been the result of a collective effort. Margarito Sanchez and Gustavo Rodríguez assisted in the re-processing of the rural energy survey carried out by the Energy Ministry. José Garza Caligaris developed the computer program for the re-processing of the rural energy survey conducted by the Energy Ministry (SEMIP) in 1987. I wish to thank Guillermo Fernández de la Garza, director of the *Comisión Nacional para el Ahorro de Energía* of the Energy Ministry in Mexico, and Dennis Tirpak from the Climate Change Division of the U.S. Environmental Protection Agency for the financial and logistic support for the research. The *Dirección General de Investigación y Desarrollo* of the Energy Ministry (SEMIP) provided the information necessary to process the energy survey. I am indebted to Yolanda Mendoza and to Juan Manuel Fraustro for their valuable comments and support throughout the project. I am also grateful to Hernando Guerrero and to Ana María Martínez for providing valuable information. I wish to thank Gautam Dutt, Gerald Leach, and Jaime Navia for reviewing the document and for their many useful comments and suggestions. I also wish to thank Leonor Gutierrez for her help with the project logistics. The opinions expressed in this work are those of the author and do not necessarily reflect those of the affiliated institutions or of the respective government agencies.

I. INTRODUCTION

Biomass, estimated to account for 10% of final energy demand in Mexico (SEMIP, 1991), constitutes the second largest energy source in Mexico. Approximately 80% of total bioenergy demand is met by fuelwood, which is the primary cooking fuel in rural households. Fuelwood still dominates national residential energy demand (Masera et al., 1992a). Biofuels are also the main energy source for many small industries that provide employment for an important number of rural residents.

The large fuelwood demand has strong environmental, socio-economic, and public health implications. Because Mexico's forests are disappearing at a rapid pace, the current patterns of fuelwood use impose increasing, potentially negative consequences for regional and global environmental problems (e.g., greenhouse gas emissions) and for local residents.

Because of the importance of fuelwood, sustainability plans need to be incorporated into rural development strategies, but fuelwood consumption has not been studied in depth. Important efforts have been conducted in the past to understand particular aspects of biomass energy-consumption patterns; however, no study integrates this information for the country as a whole. Most studies have provided a "static" picture, rather than give insights on the historic patterns of biofuel demand (SEMIP, 1988; IIE, 1986). The dynamics, opportunities, and constraints for increasing fuelwood efficiency or encouraging fuel substitution have not been studied in detail.

From an international perspective — particularly from Latin America — understanding patterns of fuelwood use and fuel substitution in Mexican households offers useful insights. Mexico has a sizable rural population, the second largest in Latin America after Brazil, with enormous variations in the socio-economic, environmental, and cultural characteristics. The range of conditions, from poor villages with acutely scarce resources to relatively wealthy settlements with important uses of modern fuels, is represented in the country. The ecological settings vary from arid to tropical landscapes and from coastal to alpine conditions. Because access to modern fuels is more widespread in rural and peri-urban Mexico than in many other developing countries, the study of fuel-switching patterns might offer insight on the potential evolution of the patterns of fuelwood use in other countries.

The present report summarizes the first phase of a collaborative project between the Mexican National Commission for Energy Conservation (CONAE) and the United States Environmental Protection Agency (EPA) on sustainable biofuel use in rural Mexico. The project's aim is to identify key interventions to improve the sustainability of fuelwood use in rural Mexico; in particular, to identify those interventions that, by improving living conditions for rural inhabitants, can result in global benefits (such as the reduction in greenhouse emissions).

The first phase of the project has been devoted to (i) conducting an in-depth review of the status of fuelwood use in rural and peri-urban areas of Mexico; (ii) providing improved estimates of biomass energy use; (iii) assessing the socio-economic and environmental impacts of fuelwood use; and (iv) conducting a preliminary identification of potential lines of action to improve the patterns of biomass energy use in Mexico. Due to the lack of information on biofuel use in small rural industries, most of the analysis is devoted to the household sector.

The report begins with a methodological section. The patterns of biofuel use in the household and small industry subsectors are separately analyzed. Preliminary analyses of the health and environmental implications of the current patterns of biofuel use in the country are also provided. Finally, the challenges and opportunities for sustainable fuelwood management in Mexico are discussed. The report ends with a series of policy recommendations for improving the conditions of fuelwood use in rural Mexico.

II. METHODOLOGY

Data Gathering and Processing

This report is based on a comprehensive review of the existing literature of biofuel use in Mexico. Reports from official (SEMIP, 1988; IMP, 1987; INEGI 1960/70/80/90; Frausto, 1992), academic (IIE, 1986; Guzmán et al., 1985, Cervantes et al., 1984), and, to the extent possible, non-governmental organizations (GIRA, 1991) were gathered and analyzed. These reports provided information about the energy, socio-economic, and environmental aspects of biofuel use. Limited information was also available about biofuel use in small industries, which allows for a preliminary assessment of their consumption patterns.

For the household sector, a major task involved the re-processing of a national energy survey conducted by the Mexican Energy Ministry (SEMIP) in 1987. In this survey 3825 households were interviewed in 170 villages sampled throughout the country. Data gathered included information on patterns of fuelwood energy use and a general assessment of the economic and environmental implications as well as the regional variations in these patterns. A computerized database was created that allow processing the survey information according to different geographical scales (regions, states, macro-regions, and country-wide), and climatic conditions (Masera, 1993).

We analyzed the 1980 and 1990 census data (INEGI, 1980 and 1990) to obtain the historic evolution of total population, population and dwellings by main cooking fuel, and population by village size at the local (*municipios*), state, and macro-regional levels (Masera, 1993).

The analysis covers fuelwood-consumption patterns in the household sector, and fuelwood and other biofuel use (charcoal and sawdust) in small industries. It was not possible to determine consumption of agricultural residues, shrubs, or charcoal in rural households; however, the use of these fuels is thought to be relatively small in most of the countryside.

Data Analysis

Fuelwood-use patterns are analyzed within the larger structural and demographic changes in Mexico's rural sector. Emphasis is given, where information allows, to the understanding of the historic trends and the regional patterns of fuelwood use. Fuelwood consumption is analyzed separately with regard to fuel saturation (percentage of households using a particular fuel or device) and unit consumption (energy use per household using a particular fuel or device). A preliminary disaggregation by end uses is also conducted. Socio-economic differences in fuelwood use are briefly discussed. Both local and global environmental implications of the current fuelwood-use patterns are preliminary estimated.

III. GENERAL CHARACTERISTICS OF MEXICO'S RURAL SECTOR

Currently (1990), the Mexican Rural Sector, living in a diverse set of economic, cultural, and ecological conditions, comprises 29% of total population.[1] Economic development strategies have traditionally favored the urban-industrial sector in Mexico, resulting in rural settlements becoming poverty-stricken places from which population emigrate. Most villages still lack basic services and infrastructure. A severe ecological degradation is present in large tracts of the countryside. Below we provide a brief discussion of the structural characteristics of this sector.

Mexican rural population is 23.3 million people (1990 figures), with a total of 3.9 million households. Total population in 1990 was 81.1 million. Rural population growth has been very low for the past 20 years (0.5%/yr vs. 2.4%/yr for total population) (Table III.1). Because urban population has increased more rapidly than rural population, the urban-to-rural split has shifted from 58%/42% in 1970 to 71%/29% in 1990. The relative stagnation in rural population growth is largely the result of an extensive migration from villages to urban centers. There are also important seasonal and permanent migratory movements to the United States and to selected cities and towns of northern Mexico.

A demographic transition is occurring in rural areas as family size shrinks from an average of 7 in 1970 to 6 in 1990. This trend has resulted in a faster increase in the number of households relative to that of population.

Rural population is scattered in more than 150,000 villages, 91% of which have less than 500 inhabitants (Figure III.1). Fifty-seven percent of the population lives in about 11,000 villages with 500 to 2500 people. Table III.2 presents the geographical distribution of rural population in 10 characteristic regions, together with their average growth rates during the 1980s. Approximately 77% of the population is concentrated in southcentral and southern Mexico. This share is even increasing as these macro-regions are growing faster than the northern ones. In some states of northern Mexico, rural population has declined in the last decade.[2]

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[1] Any partition of the population into rural and urban sectors has problems. In this report, we consider "rural" the population living in settlements smaller or equal to 2500 people, which is the convention used in most official publications.

[2] Part of this negative growth could be the result of inconsistencies between the Census of 1980 and that of 1990 (INEGI, 1980 and 1990). However, independently of the precise figure, the general trend holds: rural population is growing much faster in southern Mexico than in northern Mexico. In contrast, urban settlements have experienced

The Mexican territory covers a vast range of climates and orographic conditions. All 102 life-zones identified by Holdridge are present in the country. Eighty percent of Mexico lies in areas with substantial slopes. The large number of villages and the rugged territory pose tremendous challenges for the provision of basic infrastructure and services to villages. By 1990 an estimated 60% of rural population was electrified. Most villages lack drinking water, drainage, and other basic services (INEGI, 1990).

Most rural inhabitants live under limited economic conditions, with differences across regions. Estimates put 43% of the rural population living below the poverty line, and 19% are indigent (Table III.1). Socio-economic conditions are worst for the more than 54 ethnic and indigenous groups of the country (Toledo, 1991). As a result of the economic crisis of the past decade, seasonal and permanent migration to the U.S. and to northern Mexico have accelerated. The country's economic recovery of the last two years has yet to reach most households, particularly the small farmers (which comprises 80% of total rural population).

IV. HOUSEHOLD FUELWOOD USE

The structural characteristics discussed above have shaped the patterns of energy use in the countryside. One of the salient features of these patterns is the relative resilience of traditional fuels. While in urban areas commercial fuels (specifically LPG and electricity) now account for the bulk of energy use, rural settlements still rely on an intensive use of fuelwood. Kerosene is also important for lighting (see Figure IV.1). Human and animal power are also used extensively.

Available estimates of household fuelwood use in the country range from 246-293 PJ/yr to 406 PJ/yr (see Table IV.1). Volumetric estimates range from 17 million m^3 (Castillo et al. 1989) to 32 million m^3 (Cervantes et al., 1984). Discrepancies among the sources include differences in the assumed energy content of fuelwood, wood density, size of rural population, and per capita fuelwood unit consumption.

Estimates of fuelwood use for the entire country are difficult to obtain because most consumption occurs through informal channels. The structure and evolution of household fuelwood use are also the result of complex interrelationships among several variables: *demographic* (family size and age composition and population growth); *socio-economic* (family income, rules of access to wood resources, ownership of means of transportation, and education); *environmental* (type and abundance of the natural resource endowments, climate); *technical* (the type of fuel burnt and efficiency of the device); and *cultural* (cooking habits and practices). The availability and investment requirements of fuel substitutes, such as LPG, also influence fuelwood use. Accordingly, household-fuelwood patterns usually present an important regional and socio-economic variability (Agarwal, 1986; Dewees, 1989; Leach and Mearns, 1988; Masera, 1990; Morse et al. 1984; Soussan et al., 1990)

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a boost in the northern states, particularly along the U.S. border.

Below we examine the patterns of fuelwood use, disaggregating consumption into fuelwood saturation and unit consumption. We also preliminarily examine the end-use structure of wood consumption and discuss the socio-economic differences in fuelwood use.

Fuelwood Saturation

Fuelwood is the main energy source for most rural households. Its uses include cooking, water heating, space heating, and even lighting. Cooking is, by far, the energy need for which the use of biofuels is most widespread (see below). The analysis of population by main cooking fuel thus provides a proxy for estimating household fuelwood saturation.

Historic evolution

Figure IV.2 presents the historic evolution of total population by main cooking fuel since 1960, as estimated by the National Bureau of Statistics (INEGI). According to INEGI (1960-90), fuelwood users reached 18.7 million in 1990, down from 22.6 million in 1960; the number of fuelwood users has diminished only slightly from 1980 to 1990. Encouraged by very favorable pricing policies and by improvements in the distribution networks, the use of LPG has increased rapidly, particularly in urban areas.[3]

The statistics presented by INEGI underestimate fuelwood users because they do not account for mixed LPG-fuelwood cooking. Several case studies (IIE, 1986; Masera et al., 1989; Evans, 1984) reveal that most LPG users continue to use fuelwood for making *tortillas*. Including mixed fuelwood-LPG cooking, the SEMIP survey shows that more than 90% of rural households still used fuelwood in 1987 (Table IV.2).

Taking SEMIP's figure as the overall saturation of rural fuelwood users (i.e., including households that use only fuelwood for cooking and those that cook with fuelwood and LPG), and assuming that the difference between SEMIP's and INEGI's estimates are mixed fuelwood-LPG users, we estimate a total of 25.6 million fuelwood users for cooking, out of which 21.1 million are located in rural areas (Figure IV.3 and IV.4). Urban saturation of fuelwood users reaches 11%, seven percent of which are fuelwood-only users (Table IV.3).

Biofuel water heaters are common in some urban areas, but the overall saturation is low (5%, see Table IV.3) and diminishing due to the increased use of LPG water heaters. Woodburning stoves for space heating are common in middle- to high-income dwellings (and in hotels) in some regions, but no information is available concerning the saturation for this particular end use.

Fuelwood use and village size

A strong, inverse correlation exists between fuelwood use and village size. About 39% of

[3] The price of LPG has dropped by almost 60% in real terms since the early 1970s.

fuelwood-only users are concentrated in villages with fewer than 500 inhabitants (Figure IV.4). The share of fuelwood-only users drops rapidly as settlement size increases, passing from 75% for villages of fewer than 500 inhabitants to approximately 3% for cities with more than 15,000 people (Figure IV.5).

Regional differences

Important regional differences affect fuelwood saturation. In northern Mexico, fuelwood-only users number between 20 to 60% of the total rural population and have diminished in the last decade; in southcentral and southern Mexico, fuelwood users make up between 80 to 140% of the rural population, i.e., the number of fuelwood users is larger than the rural population and are located in peri-urban areas. In these last regions, the number of fuelwood users has increased between 1980-90, in some cases, like Quintana Roo and Chiapas, at above 3%/yr (See Appendix II). In the villages sampled by SEMIP, fuelwood saturation ranged from an average of 66% to 93% in northern Mexico to more than 97% in the south of the country (Table IV.2).

Fuelwood Unit Consumption

Reliable estimates of fuelwood unit consumption are difficult to obtain. Most studies of rural energy show average household energy use (IMP, 1987; SEMIP, 1988; IIE, 1986; Willars and Heredia, 1990), i.e., consumption that includes fuelwood and non-fuelwood users, and therefore underestimate fuelwood consumption. Also, there has been no consistent methodology on how to measure consumption. Large-scale surveys, for example, rely on oral interviews with respondents, which has been shown to be inaccurate (Masera et al., 1989). Fuelwood consumption estimates in case studies are more accurate, but because of their limited scale, are difficult to extrapolate to the whole country. Average, rather than unit fuelwood consumption, is usually reported, leading to incorrect estimates, particularly in villages where LPG saturation is high. Variation in fuelwood consumption estimates also results from the use of simple or weighted averages (this last is used to adjust family size according to the family members' age and sex).

Table IV.4 shows the available estimates from surveys and case studies. Household fuelwood unit consumption ranges between 1.5 kg/cap/day for villages with scarce wood resources to 3.5 kg/cap/day where forest resources are plentiful. The only in-depth fuelwood use measurement conducted in the country – daily measurements for one week a month during one year in one village – gives a unit consumption of 1.9 kg/cap/day (Masera et al., 1989). Unit consumption where fuelwood use was measured for at least a week ranges from 1.8-2.0 kg/cap/day to 3.1 kg/cap/day (Table IV.5). The national rural survey conducted by SEMIP (1988) gives per capita unit consumption of 2.4-2.5 kg/day with regional differences ranging from 1.7 to 5.7 kg/cap/day (Table IV.5).

Considering only the fuelwood consumption estimates from the more reliable case studies, we propose a conservative working mean of 2.0 kg/cap/day for overall fuelwood unit consumption in rural Mexico. In the absence of more detailed information, we also use this unit consumption for the small percentage of urban households that use fuelwood for cooking (Table IV.3).

The high fuelwood unit consumption results from the widespread use of traditional three-stone fires for cooking (81.3% of rural fuelwood users, as shown in Table IV.6).[4] This cooking method has shown efficiencies of 17% in the only series of measurements conducted in the country (Dutt et al., 1989).

Few estimates of fuelwood use by mixed fuelwood-LPG users are available. Available data indicate average unit consumption ranging from 1.7 to 1.8 kg/cap/day for SEMIP (1988; see also Table IV.7) and 1.3-1.7 kg/cap/day in two case studies (Table IV.4). Fuelwood savings in these households amount to between 24% (SEMIP, 1988) and 8-37% (Masera and Navia, 1993) of fuelwood unit consumption by fuelwood-only users. In this report we assume 25% fuelwood savings in mixed fuelwood-LPG households, for an average of 1.5 kg/cap/day fuelwood unit consumption (Table IV.3).

Unit consumption of wood water heaters is estimated to be 1.1-1.3 kg/cap/day. The most common fuel for these heaters is *combustible,* a mixture made out of sawdust and kerosene. *Combustible* is sold in 300 g bags and is commercialized in local grocery stores through informal channels.

Using the saturation values calculated in the previous section, we estimate an overall household fuelwood demand of 21.1 million ton/yr, which is roughly equivalent to 34.6 million m^3/yr.

Energy demand

Translating fuelwood consumption into energy figures is another source of discrepancy in rural energy studies. Official sources in Mexico use 4400 kcal/kg (18.4 MJ/kg) (SEMIP, 1990), which is close to the oven-dry heat content of fuelwood (Appendix I). However, rural inhabitants use wood that is only air-dried. A more accurate estimate of fuelwood heat content should therefore account for the reduction in wood energy arising from wood humidity (Appendix I). In this study we use 16 MJ/kg for the heat content of fuelwood, which assumes 20 MJ/kg for the oven-dry heat content and a 20% humidity (typical of two days of storage, which has been found in some villages (Masera et al., 1989).

Including peri-urban areas, average household fuelwood unit consumption is estimated to be 59.6 GJ/yr (70.5 GJ/yr for rural households) for an overall household fuelwood energy demand of 334 PJ/yr. The rural sector accounts for 73% of total household demand (Table IV.3). Energy demand for wood water heaters is roughly 10% of the total. The estimated fuelwood consumption represents 46% of total residential energy use in Mexico for 1990.

[4] However, in Baja California and other states of northern Mexico the use of stoves (usually small modifications to the three-stone fire to partially enclose the fire) is quite common.

Fuelwood End Uses

Estimates of fuelwood consumption and saturation by end use are virtually non-existent. Past studies have been oriented toward energy supply, and therefore paid little attention to an analysis by end uses. Understanding the end-use structure of fuelwood consumption is also difficult because the same device (the three-stone fire) is commonly used simultaneously for cooking, water heating, and in some cases, even for space heating.

The available information shows that, by far, cooking is the dominant fuelwood end use. Virtually all users in rural areas use fuelwood for cooking (98.8%) and about half, for cooking alone (Table IV.7). The remaining fuelwood end uses are complementary to cooking. Thirty-four percent of households that cook with fuelwood also reported using the three-stone fire for heating water, and 7.1% use it for boiling drinking water. Less than 2% of households reported using fuelwood for space heating and cooking. Virtually no households reported use of fuelwood for water heating purposes alone or for space heating alone – not even in regions with cold winters.[5] About 1% of households burn *ocote*[6] for lighting in addition to the use of fuelwood for cooking (Table IV.2).

Regarding end-use unit consumption, a detailed analysis for one village (Cheranatzicurin) reveals that out of an overall demand of 1.9 kg/cap/day (including households that use fuelwood for lighting) 81% is used for cooking (52.6 GJ/hh/yr), 14% for lighting, and 5% for water heating (Table IV.8).

Within cooking, tortilla making may account for 40% of total fuelwood use or 57% including the preparation of *nixtamal*[7] (Table IV.9). The specific fuel consumption for tortilla making, including making of *nixtamal*, ranges from 24 to 38 MJ/kg. Cooking beans is a very energy-intensive task requiring from 130 to 225 MJ/kg (Table IV.9) . Cooking tasks involve a series of low- and high-power tasks requiring a range of temperatures from low (82 °C) to high (250 °C or greater). In general, two main meals are prepared every day, one in the morning (7-10 A.M.) and the other in the late afternoon (5-8 P.M.).

Water heating for bathing was found to represent a fuel consumption of only 0.1 kg/day (Table IV.8), which probably underestimates consumption given that in the village analyzed there was an extreme scarcity of water. Water is usually heated in a 5-liter vessel over the three-stone fire and later mixed with cold water.

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[5] It should be noted, however, that the use of fuelwood for cooking indirectly provides space heating in most cases. In cold regions, for example, the boiling of water for tea or coffee on winter nights is done more for providing space heating than for the meal itself.

[6] *Ocote* is a resinous part of pine wood. It is burned for lighting in households without access to electricity. Small pieces of *ocote* are also commonly used to start the fire for cooking.

[7] *Nixtamal* is prepared by cooking grains of corn with water and a small quantity of limestone over a low flame.

The diversity of rural Mexico in terms of climate, socio-economic and cultural conditions, and natural resource endowment makes extrapolating the unit consumption values for Cheranatzicurin to the whole country difficult. However, qualitative data from different studies confirm the stated trends: dominance of cooking in overall fuelwood demand, importance of tortilla making among cooking tasks, and early morning and evening meals.

Socio-Economic Differences in Fuelwood Use

Fuelwood markets

In rural Mexico fuelwood markets are still not highl developed. About 85% of fuelwood users still collected their wood in 1987, with regional averages ranging from 80% to 96% (Table IV.10). Fuelwood collection requires from 0.5 to 2.9 h/hh/day, and collection distances range from 1.9 to 10.3 km. Approximately one-fifth of rural households use pack animals for fuelwood collection (Table IV.11).

Wood collection rates, the amount of wood collected in a determined period of time, and therefore the amount of time devoted to wood collection, vary by a factor of 3 to 6 according to the person in charge of collection (children, women, or men) and the means available for carrying the wood (pack animals or trucks) (Table IV.12). A time-budget study for Cheranatzicurin village shows that fuelwood collection might represent from 20% to 29% of total household work devoted to human activities requiring intensive physical work (Masera et al., 1989).

Purchase of wood is more common in urban and peri-urban areas and in areas with acute fuelwood scarcity or the presence of rural industries using biofuels (the central valleys in Oaxaca State, Patzcuaro Lake, and Michoacan State). Households that use fuelwood and LPG also depend more on fuelwood purchases than fuelwood-only users. As villages integrate more into the market economy, there has been a trend toward expansion of fuelwood markets; however, the very limited purchasing power of most rural residents limits the rapid "commoditization" of wood.

Fuelwood prices show important variations at the local level. By 1987, average fuelwood prices at a regional level ranged from 0.5 to 5.7 MEX$/MJ with an overall mean of 2.5 MEX$/MJ. In contrast, country-average LPG and kerosene prices were 3.4 and 6.1 MEX$/MJ (Table IV.13).[8] Fuelwood purchases represented about 25% of total household expenditures in domestic fuels, with regional averages ranging from 15-40% (Figure IV.6).

Information is insufficient to ascertain the historical evolution of fuelwood prices or the most influential factors in their evolution. Evidence from case studies suggests that in selected regions fuelwood prices have experienced a real increase in recent years. In the Purepecha region of

[8] Figures are in 1987 Mexican pesos. The exchange rate was 2227 $MEX/U.S. dollar in 1987.

Michoacan State, for example, fuelwood prices have been related to market prices of alternative uses for fuelwood. In this region, increased competition for wood wastes from the paper industry caused a doubling in fuelwood prices in a few months.

Socio-economic aspects

The use of fuelwood (i.e., the total amount and type of wood consumed, the person in charge of collection, access to alternative fuels, and the share of fuelwood in total household energy use) presents marked differences by socio-economic groups (Figure IV.7). In general, the share of fuelwood in total energy use is higher in poorer households since high-income families have more access to modern fuels. Average household fuelwood consumption tends to decrease slightly as income increases (Figures IV.8 and IV.9). However, there is no simple relationship between fuelwood use and income, since the use of wood is also related to education, access to land and means of transportation, natural resource endowments, cooking practices, and so on. In many villages, the richer use more fuelwood per capita than other income groups (Table IV.14).

The poorest households tend to devote more of either their time or their income to fuelwood collection or purchases. Actual expenditures in fuelwood might represent 10% of total household monetary income and could increase to 20% of total income if the poorest households were to purchase wood instead of collecting it (Table IV.14). The poorest also usually depend more on biofuels that are considered to be of lower quality, such as less preferred tree species or shrubs, and devote more time to fuelwood collection (Table IV.14). The labor of women and children is more intensive in poorer households (Table IV.14).

The correct identification of the differences in fuelwood consumption patterns by socio-economic group is essential for improving the conditions of fuelwood use, because these differences are ultimately reflected in contrasting household priorities and in the possibilities for alternative fuels and technologies.

V. BIOFUEL USE IN SMALL INDUSTRIES

Fuelwood, charcoal, and other biofuels are used extensively in a large number of Mexico's small industries: bakeries, pottery kilns, public baths, brick making, charcoal production, *mezcal* production, and tortilla making, among others. Industries range from very small home-based enterprises to relatively large production units (as in brick making). Most belong to Mexico's informal sector. A significant percentage of rural households, and sometimes entire villages, depend on these industries for their survival. Biofuel-based industries are also common in many urban centers (e.g., Uruapan).

Unfortunately, data regarding biofuel consumption in Mexican small industries are scarce and not very reliable. Economic data are also difficult to find; consequently, little is known about their numbers, the jobs they provide, and their historic evolution.

As shown in Table V.1, small industries tend to be energy-intensive. Between 23 and 32 MJ of wood are required per kilogram of tortillas, from 6.4 to 14.4 MJ per brick, and about 14 MJ per kg flour in bakeries. Home-based pottery kilns use from 13 to 87 GJ/mo/kiln in 6 to 7 months.

Fuelwood demand for pottery kilns is very important in many states of Mexico's central plateau. In Oaxaca's Central Valleys this activity was estimated to account for 40% of total fuelwood use in the region (not considering biofuel use in any other small industries) (Table V.2). In many of these villages fuelwood demand from small industries equals or even surpasses household fuelwood use. Biofuel demand for small industries (fuelwood, sawdust, and charcoal) can also be significant in mid-sized cities, as in the case of Uruapan, Michoacan State (Table V.3).

Charcoal production, particularly for export, has increased dramatically in the last three years, reaching 300,000 m^3/yr in 1990. This figure represents 60% of the legally registered charcoal production in the country (Figure V.1). Charcoal is produced on a relatively large scale in both northern Mexico (Sonora and Tamaulipas states), where it results from the clearing of open forests for pasture lands, and in southern Mexico (Veracruz, Oaxaca, and Chiapas), where it is produced along with other forest-based activities (Table V.2). There are also many small-scale charcoal producers in virtually all states of the country. Charcoal is still used for space heating in many peri-urban areas and for preparing street food in various cities (Navia and Masera, 1992).

From the scarce data available, we estimate a conservative overall biofuel use in small rural industries of between 2 to 3 million tonnes equivalent of fuelwood per year for 1990. Insufficient information about urban demand for biofuels prevents us from deriving a country-wide estimate. The resulting energy demand for biofuel-based, small rural industries reaches 21-31 PJ/yr, or approximately 7% of total fuelwood demand in Mexico (Table IV.3).

VI. HEALTH IMPACTS

Combustion of fuelwood in open fires has been shown to lead to high indoor air pollution levels. Smith (1987) noted that indoor concentration levels of carbon monoxide, formaldehyde, particulates, and benzo(a)pyrene can exceed by 2.5, 8, 25, and up to 2500 times the international standards for these pollutants (see Table VI.1). Prolonged exposure to these high concentrations may cause chronic respiratory illnesses, *cor pulmonale*, acute respiratory infections (ARI) in children, and may increase the risk of the development of cancer in the long term (Smith, 1987).

To date, no indoor air-pollution measurements from fuelwood use have been conducted in Mexico. Indirect evidence from the National Institute of Respiratory Diseases (INER) suggests a positive correlation between women with chronic respiratory illnesses and the use of fuelwood for cooking (Onofre and Perez-Padilla, 1992). Work in this area is urgently needed to ascertain the health consequences of fuelwood use in open fires.

In designing options to remove smoke from the kitchen, analyzing the positive effects of indoor smoke (such as reduction in roof pests or food conservation) and the associated cultural practices is critical. What also should also be taken into account is that families often do not perceive indoor smoke as the most pressing problem compared to other basic household needs (Table VI.2).[9]

VII. ENVIRONMENTAL IMPACTS

The environmental implications of fuelwood use largely depend on the method of fuelwood harvesting. When done on a sustainable basis, fuelwood harvesting provides benefits, like the reduction in the probability of forest fires, reduction in forest pests and diseases, and even the acceleration of tree growth (i.e., acting like a selective pruning) to local forests. Over-harvesting of fuelwood, on the other hand, leads to a wide range of local and global environmental impacts, including forest degradation, soil erosion, changes in nutrient cycles, and emissions of greenhouse gases (Table VII.1).

No simple indicators exist to assess whether fuelwood extraction is made on a renewable basis. Fuelwood extraction by individuals is very different from that used in commercial timber harvesting. For example, peasants usually harvest branches and twigs rather than whole trees, and dead wood is also collected when available. Many of the tree species used for fuelwood are not included in forest inventories because they do not have commercial value.

The conventional procedure for comparing fuelwood demand with the forest's mean annual increment is misleading because: (i) mean annual increment (MAI) estimates usually include only growth of commercial living trees in forested areas, whereas fuelwood comes from a variety of sources – home gardens, trees from fenced and agricultural lands, etc. – in addition to forest lands, non-commercial tree species, and from dead wood; and (ii) fuelwood harvesting might change the tree morphology and growth rate, thus changing the estimated MAI.

In what follows we conduct a preliminary assessment of the environmental impacts of fuelwood use in Mexico, using indirect information available from energy surveys and case studies. We also make a preliminary estimate of the greenhouse gas emissions from fuelwood use that result from different scenarios regarding the sustainability of fuelwood use.

Local and Regional Impacts

Domestic demand for fuelwood has been estimated to be 37 to 38 million m^3 in 1990, with 93% coming from the household sector. This figure is 4.6 times higher than the amount of commercial wood legally harvested in the country (Table VII.2). While both figures are not directly comparable, the large fuelwood demand serves to highlight the importance of this energy source in Mexico's overall wood demand and the need to integrate fuelwood management into rural development strategies.

[9] It should be noted that the ranking of priorities is different for men and women. Men are usually interviewed in rural surveys, with the result that the surveys under-represent women's priorities (in particular, those related to the kitchen and cooking practices).

Household Sector

Evidence from surveys and case studies suggests that non-renewable fuelwood harvesting has been largely a byproduct rather than a cause of deforestation in rural Mexico, at least at a national level. About 86% of SEMIP's rural survey respondents declared they collected dead wood, and only 5.5% obtained it by felling living trees. However, there are important regional differences; in the Central Gulf macro-region, for example, as many as 15.1% of respondents declared they obtained fuelwood from living trees (Table VII.3).

Most fuelwood comes from tree species that are not intensively harvested for timber purposes (e.g., oak, *mezquite, huizache,* and *guasimo*). Use of pines for fuelwood was reported important only in Baja California and the central macro-regions. In this last case, part of the pine wood comes from sawmill wastes (Table VII.4).

This situation might change in the near future. With deforestation rates reaching 670,000 ha/yr in closed forests alone (Table VII.5), the high demand for fuelwood is becoming more difficult to sustain. Almost half of the respondents at the national level declared that the distance for fuelwood collection had increased in their villages and in some macro-regions this percentage reached more than 70% (e.g., in northern Mexico) (Table VII.3). In the Central Valleys and Sierras of the south, macro-region people more frequently use less preferred tree species for fuelwood, as preferred species have become difficult to find (IIE, 1986). This is also the case of villages surrounding the Patzcuaro lake in Michoacan.

The lack of forest inventories for non-commercial tree species and other types of woody vegetation limits the possibilities of a regional assessment of fuelwood scarcity. By compiling the available sources, we can conclude that the regions most affected by fuelwood availability correspond to the relatively densely populated highlands of central and southwest Mexico, which include portions of the states of Veracruz, Chiapas, Oaxaca, Puebla, Guerrero, Michoacan, Mexico State, Morelos, Tlaxcala, Hidalgo, Guanajuato, and San Luis Potosi. Fuelwood scarcity can also be severe in selected regions of northern Mexico.

Small Industries

The environmental impacts of biofuel demand on small industries are also difficult to assess. These impacts vary by type of industry (since they use fuelwood from different tree species and parts of the tree) and by region. The impacts are lower for industries that do not directly compete with household fuelwood use or commercial uses of wood and that are located in regions of adequate forest resources. For example, fuelwood demand for brick-making industries is relatively large, but these industries can use virtually any type of wood wastes (like sawdust). Therefore, they have tended to integrate with sawmills to use their wastes as fuel and thereby reduce the environmental impacts of wood demand (Table V.2).

Pottery making, on the other hand, generally requires pine species for fuel (Table V.2). Because pines are also harvested for timber and resin production, more competition exists for this resource. Many villages with pottery kilns have already exhausted their pine forests. Villagers currently satisfy fuelwood demand through extended markets or through clandestine logging in nearby villages (as is the case of *La Cañada* in Michoacan State). In addition to the negative impacts on the environment, wood shortages have created conflicts among villages for access to fuel.

Charcoal is produced from mezquite and oak. Oak resources are abundant, and commercial harvesting is low in Mexico. Therefore the opportunity exists for sustainable charcoal-production schemes. In some regions, however, charcoal production for export has lead to the clear-cutting of local oak forests (e.g., in the Chiapas highlands). The rise in charcoal exports following the opening of the Mexican economy in recent years requires a closer examination of the environmental implications of this activity which, in addition, is greenhouse gas-intensive.

Global Impacts: Greenhouse Gas Emissions

Combustion of fuelwood produces several greenhouse gases: carbon dioxide (CO_2), carbon monoxide (CO), non-methane organic compounds (TNMOC), methane (CH_4), and nitrous oxide (N_2O), among the most important.

The impacts of fuelwood use on greenhouse gas emissions are complex and still not well understood. A detailed analysis needs to include the complete "fuel cycle": from the harvesting of wood and its impact in the local forests, including soil disturbances to fuelwood combustion at the end use (or at both the production and end-use levels for charcoal use) to the subsequent regeneration of biomass. The time dynamics of the gas emission and absorption processes must also be studied.

In general, net emissions will depend largely on the type of fuelwood management (sustainable or non-sustainable). For sustainable harvesting one might assume no net committed CO_2 emissions (however, net emissions from other greenhouse gases need not be zero; see below). Non-sustainable harvesting should include emissions at the end-use level and those derived from disturbances to the natural ecosystems (like carbon soil emissions). The use of particular time preferences, as reflected in the global warming potential (GWP) of greenhouse gases, will also influence the amount of emissions and the relative impact of each gas.

For fuelwood combustion at the end use, Smith et al. (1991) found that even under sustainable harvesting, incomplete combustion leads to net additions to greenhouse gas emissions from gases other than CO_2. These emissions range from 22-40% of CO_2 emissions, depending on the time horizon selected.

In this study we construct preliminary estimates of greenhouse gas emissions from biofuel use in Mexico as follows: (i) for the household sector we use the emission factors calculated by Smith et al. (1991); and (ii) for small industries we only include CO_2 emissions. For CO_2 emissions the two extreme cases (completely renewable and completely non-renewable fuelwood harvesting) and a best estimate are included.

The analysis indicates CO_2 emissions ranging from 0 to 36 Mton/yr, with a best estimate of 11.3 Mton/yr. Eighty-nine percent of emissions come from the household sector (Table VII.6). Also indicated in the table are the estimated emissions of CO, CH_4, TNMOC, and N_2O. Using the GWP proposed by IPCC (1990), carbon-equivalent emissions of the different gases can be estimated. These amount to 4.3 MtonC/yr using the immediate GWP, with a range of 4.1 to 5.9 MtonC for the different time horizons (Table VII.6).

Net emissions from fuelwood use are estimated to represent approximately 2.4% of total country emissions (these last not including fuelwood, CO, and TNMOC) (Table VII.6). Gross emissions total 13.3 MtonC/yr) or about 8% of the country total.

VIII. TOWARD SUSTAINABLE FUELWOOD-USE PATTERNS IN MEXICO

The current pattern of fuelwood use in the country is clearly not sustainable. The natural resource base from which fuelwood is obtained is shrinking, bringing negative consequences for both rural inhabitants and the environment.

Several trends point to an increasing scarcity of fuelwood in the country in the near future, even without an increase in fuelwood demand. Deforestation rates are still high and the situation of forest resources is critical in many regions of the country. Extended rural poverty, as well as the enormous dispersion of villages and very deep-rooted traditional cooking practices – together with the inability of conventional LPG stoves to perform these tasks – limits the pace of fuel substitution.

At the institutional level, the current changes in agrarian legislation, which provide incentives for the privatization of forest resources, might severely limit access to fuelwood to the poorest households (who largely depend on communal forests for their fuelwood needs). Traditionally used for fuelwood, dead wood and wastes from commercial timber harvesting are now increasing competed for by the paper industry. This trend has resulted in price increases for fuelwood and restricted access to fuelwood resources in some regions (e.g., Michoacan State).

Only an integrated approach that encompasses the whole range of actions, from institutional issues to technical measures, will prove effective in assuring a sustainable pattern of fuelwood use in rural Mexico. Fuelwood concerns urgently need to be incorporated into rural development strategies. Because fuelwood issues focus on problems dealing with human health, the environment, energy, and rural development, they bring about the possibility of building an effective inter-institutional collaboration among the corresponding ministries.

The recent re-opening of the National Program of Wood Energy is a first positive step in this direction. We hope the Program is given sufficient human, technical, and financial resources to respond effectively to the challenges posed by the problem.

A detailed analysis of technical and policy options for improving the conditions of fuelwood use in Mexico is beyond the scope of the present report. Below we examine briefly the main challenges and opportunities for encouraging a sustainable fuelwood use in the household and small-industries sectors.

Household Sector

The two basic actions for encouraging sustainable fuelwood use in Mexico include assuring a renewable fuelwood supply and reducing fuelwood demand.

Assuring a Renewable Fuelwood Supply

Many possibilities exist to assure an adequate fuelwood supply. These range from traditional peasant wood-management strategies and agroforestry schemes to energy plantations (Leach and Mearns, 1988; Munslow et al., 1988). Options that provide several benefits to local people (e.g., that provide food, fodder, and cash, in addition to fuelwood) are the ones that have proved more successful internationally. Institutional issues regarding secure land ownership and the owners' assurance of future benefits are critical to the success of these programs (Agarwal, 1986; Leach and Mearns, 1988).

Reducing Fuelwood Demand

Decreasing fuelwood demand is the most promising policy option in the short term. It can be achieved through fuel substitutions and by increasing fuelwood efficiency.

a. Fuel Substitution

As noted in Section IV, partial substitution of fuelwood with LPG is already occurring in many regions of rural and urban Mexico. However, the use of LPG rarely leads to complete fuel switching in rural areas. Empirical studies show that, on average, only 20-25% of fuelwood is saved by households that also use LPG for cooking (Table IV.3).

One of the major obstacles for complete fuel switching is the inadequacy of current LPG stoves to make tortillas, a central element in peasants' diet. Other factors that limit fuel switching include (a) the dispersion and small size of villages, (b) capital costs of stoves and tanks – currently about US$120-360, or more than one to four Mexican monthly minimum wages, (c) uncertainties in the LPG supply, (d) the existence of brokers, which increases the cost of LPG, and (d) cultural patterns associated with the use of fuelwood, such as preferences regarding food flavor, religious beliefs, etc.

Two additional factors that might limit the possibilities for massive switching to LPG are (a) the imminent large increase of domestic LPG prices (currently about 30% of the U.S. price), which will be set at the international price as a consequence of the signing of the North American Free Trade Agreement; and (b) problems of the LPG supply keeping up with the demand. LPG demand has been increasing at roughly 7%/yr for the last 10 years (SEMIP, 1991); LPG is also the only modern fuel used for cooking and water heating, and is currently promoted as an alternative non-polluting transportation fuel for some of the country's largest cities.

The largest possibilities for switching to LPG thus occur in peri-urban areas. The use of fuelwood in these areas is also proportionally more deleterious to the environment than in the rural sector, since wood more often originates from the cutting of living trees. Actions that can foster the use of LPG include: (a) reducing the capital costs of LPG equipment, which can be achieved by devising some sort of credit mechanisms, by marketing cheap LPG stoves, etc., (b) improving the conditions of LPG supply, and (c) designing stoves appropriate to make tortillas. As subsidies to LPG are removed, other fuels, such as kerosene, should be considered as potential substitutes to fuelwood in the more distant locations.

b. Increasing fuelwood efficiency: Improved cookstoves

The low efficiency of traditional end-use devices provides opportunities for substantial fuelwood savings. Improved cooking stoves (ICS) have been promoted in the country in the past, both at the national (Frausto, 1992) and the local and regional levels (Navia, 1992; ORCA, 1989, among others). At a unit cost of US$16, including only the cost of the device, these stoves have been reported to save about 34% of overall household fuelwood use in field conditions (Dutt et al., 1989; Navia, 1992). The cost of conserved energy is estimated to be 0.1-0.5 ct/kWh (0.3 to 1.5 U.S.$/GJ) (CONAE, 1992).

Lorena-type ICS may save 52% of fuelwood used in tortilla making (Dutt et al., 1989), a task that represents a central concern of rural households facing fuelwood scarcity (see Figure VIII.1). As a result of the high fuelwood savings in tortilla making, ICS may be more attractive for mixed LPG-fuelwood users.

To be successful, stove dissemination programs need to (i) correctly identify users' priorities and needs. Fuelwood savings are usually not the major concern of users; fuelwood supply often has a lower priority than other basic needs. (ii) Be sensitive to regional differences in cooking practices; (iii) understand the multiplicity and complementary nature of fuelwood practices and end uses (for example, the relationship between cooking and space heating); and (iv) promote participatory schemes in the design and dissemination of stoves. It is essential that dissemination programs involve local women.

Dissemination strategies need to be designed according to the needs and possibilities of the specific target populations. Market-oriented schemes might be promoted for peri-urban areas, where cash is more readily available. Institutional approaches could be followed in the poorest rural areas.

Support for R&D in ICS is needed to incorporate health and global environmental (greenhouse gas emissions) concerns in the stoves' design. Priority regions for launching pilot programs include the Purepecha Region in Michoacan State, Oaxaca's Central Valleys and the Mixteca Region, the Chiapas Highlands, and specific regions of the Highlands of Veracruz, Guerrero, and the state of Guanajuato.

Small Industries

A more detailed study is needed to assess the current status and the potential evolution of biofuel demand in Mexico's small rural industries. In the case of charcoal production, the lower production costs in Mexico with respect to Europe and the U.S., and the current opening of the Mexican economy, suggest that a substantial increase in exports might take place in the near future. Some of the major challenges facing the sector include:

(i) the lack of coordination between fuelwood sellers (or the villages that own fuelwood resources) and small industries. In most of the case studies reviewed, no specific actions had been taken to assure the long-term supply of fuel, despite increasing wood scarcity.

(ii) increased competition for fuelwood. Industries that depend on pine fuelwood (like pottery kilns) are facing increasing scarcity because of the depletion of forests and resource competition with the pulp and paper industry (which uses low-quality pine wood).

(iii) the low revenues of local producers. Forced to produce at the lowest possible cost – even at the expenses of the over-exploitation of family labor – and subject to usurary brokers, producers find it very difficult to care for a sustainable management of the natural resource base on which they depend. The low capitalization of most small industries and their poor participation in commercialization channels also limit investments in fuel switching and/or fuel efficiency improvement.

Specific options that might be examined include:

(i) launching eco-production schemes, where concerns about the sustainability of the resource base are integrated into the production and commercialization of the industries' output (pottery, bread, etc.). This option can prove especially attractive in small industries devoted to pottery and other artisan-based production.

(ii) improving efficiency of fuelwood use. As shown in other countries, significant savings are possible through simple design modifications in the different industries (see, for example, Barriga et al., 1992, for the brick-making industry in Ecuador). Fuelwood gasification, including the use of agricultural residues and other schemes, may also be investigated here.

(iii) fuel switching. The cost-effectiveness and challenges of using alternative fuels vary by type of industry. In general, financial incentives, and in many cases, support for alternative commercialization channels, will need to be provided to the industries due to the relatively high investments associated with the use of alternative fuels (e.g., high-temperature LPG ovens for pottery production, etc.)

IX. CONCLUSIONS

Adequately managed, fuelwood and other biofuels can constitute important, renewable, and environmentally sound components of Mexico's future overall energy supply.

In energy terms, fuelwood still represents the main residential fuel in Mexico. We estimate that about 25.6 million people use fuelwood for cooking in the country; 18.7 million of them only use fuelwood for this task. Ninety percent of rural households depend on fuelwood for cooking.

A large number of small industries, mostly belonging to the informal sector, also consume fuelwood and other biofuels (mainly charcoal and sawdust).

Total fuelwood demand was estimated to be 355 PJ/yr (22.2 million ton/yr or 37.0 million m^3/yr) in 1990. About 93% of the total demand goes to the household sector. Most fuelwood for household use comes from non-commercial tree species. In general, the environmental impacts of fuelwood use are proportionally more severe in peri-urban areas and in small industries.

The patterns of fuelwood use, in terms of the amount and type of fuelwood demand, preferred tree species, and fuelwood saturation, show important regional and socio-economic variations. Fuelwood scarcity is critical in many regions, especially in the highlands of central and southern Mexico. Also in some of these regions, the number of fuelwood users has *increased* over the last decade. Places like the Purepecha Region, Oaxaca's Central Valleys, and Chiapas Highlands make up a sizeable household demand and a large biofuel demand from small industries.

With the exception of the critical areas, where demand for fuelwood has a direct impact on forest degradation, fuelwood scarcity should be seen more as a byproduct than as a cause of deforestation. As forest resources are getting scarcer, however, the impact of fuelwood demand on the environment will likely increase. We estimate current gross greenhouse gas emissions of about 13.3 MtonC equivalent per year (including CO_2, CO, CH_4, TNMOC, and N_2O) and net emissions of 4.3 MtonC equivalent per year from fuelwood use in households and small industries.

The limited incomes of most rural residents, the dispersion and small size of most villages, together with the relatively high front-end costs of LPG stoves and their inability to cover traditional cooking practices, specifically tortilla making, limit the extent of fuelwood switching. Very low investment possibilities and the characteristics of the markets for their products also limit the possibilities for fuel switching in most small industries. Fuelwood demand is therefore expected to continue to be high in the medium term. Several actions need to be taken to assure a sustainable fuelwood-use pattern in the future.

Policy Recommendations

(i) *Integrate fuelwood concerns into rural development strategies.*

Rural energy, forest management, and public health programs need to have a fuelwood component. The numerous links between fuelwood use, public health, the environment, and socio-economic development provide good opportunities for the sharing of resources and for a productive inter-institutional collaboration. If this collaboration is to work – as opposed to only increasing the bureaucracy for actually solving the problem – it should combine the best use of existing infrastructure at the village level (e.g., health promoters, local committees for forest protection) with flexible structures for technical and logistic support (e.g., teams of the forestry ministry that can act directly with groups at the grass-roots level). Non-governmental organizations with proven work at the local level should also be supported through these collaborative efforts.

(ii) *Provide the appropriate institutional framework to facilitate the long-term management of forest and fuelwood resources.*

Currently, problems of insecure land tenure, conflicts over boundaries between villages, excessive bureaucracy in forest regulations, disparities between those who own and those who economically benefit from forest resources, extreme poverty of rural inhabitants, and the deterioration of peasant collective institutions for natural resource management, among other factors, encourage a very short-term perspective in the management of forest resources (which has lead to the "mining" of forests). Strong institutional support and specific policies are needed to reverse the stated situation, favoring a sustainable management of forest and fuelwood resources.

(iii) *Improve the existing database on fuelwood use, particularly for small industries.*

The information about fuelwood-use patterns is still fragmented. It is important to have better data regarding the historical evolution of fuelwood-use patterns and prices and a better understanding of the end uses and the regional structure of fuelwood demand. The compilation of basic information is particularly critical for small industries. These biofuel databases should serve to identify critical areas where policy interventions are needed. The database "JURHIATA," created for the present project (Masera, 1993), might serve as a first step in this direction.

(iv) *Launch a national program to disseminate improved cookstoves in rural and peri-urban households.*

Improved cookstoves offer the best possibility for reducing fuelwood demand in the short run. Fuelwood savings might amount to more than 30% with relatively modest investments. Savings in tortilla making can amount to more than 50%. The national programs might be preceded by pilot projects that identify the areas best suited to stove dissemination (in particular, those regions where fuelwood use is a priority problem for local households) and that select the appropriate cookstoves designs and dissemination strategies.

(v) *Encourage fuel substitution in peri-urban centers.*

Partial fuel switching to LPG is already occurring in most peri-urban areas of Mexico. Fuel switching can be fostered by improving the reliability of the LPG supply and reducing the associated capital investments needed. The design of inexpensive LPG stoves that could be used for tortilla making, e.g., stoves that have a sufficiently large burner to place a *comal,* might accelerate the adoption and acceptance of these stoves among local households. Kerosene stoves, currently very scarce in Mexico because of the subsidies to LPG, but which might become competitive as LPG reaches the international price, may also be considered as potential options for villages and small towns where extending the LPG network is very expensive.

(vi) *Assure an adequate and renewable fuelwood supply.*

Different schemes, including energy plantations, agroforestry, and living fences, might be tested here, according to the particular physical and socio-economic conditions and the characteristics of the demand (households or small industries). In general, those schemes that provide a multiplicity of benefits for local users are likely to be the most successful.

(vii) *Increase support to R&D activities in bioenergy.*

The current financial and institutional support is insignificant and clearly insufficient given the problems and challenges associated with the use of these sources. Research priorities include the health and environmental implications of fuelwood demand, design of improved fuelwood-using devices for residential and industrial end uses, biogasification schemes (producer gas and biogas), and integrated energy farms, among some of the most promising options.

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TABLE III.1

MEXICAN HOUSEHOLDS: GENERAL INDICATORS

Indicator	**National**	**Urban**	**Rural**[a]
Demographic (1990)[b]			
Population (million)	81.1	57.6	23.3
Dwellings (million)	16.0	12.3	3.9
Persons/dwelling	5.1	4.7	6.0
Growth rates 1980-1990			
Population	2.0 %	2.7 %	0.4 %
Dwellings	2.3 %	2.6 %	1.7 %
Persons/dwelling	-0.4 %	0.0 %	-1.1 %
Average Income			
Number of minimum wages[c]	1.6	1.8	0.97
Poor[d]	30 %	23 %	43%
Indigent[d]	10 %	6 %	19 %
Income distribution[e]			
Lowest income quintile	3.0 %	4.0 %	3.5 %
Highest income quintile	52.0 %	48.0 %	54.0 %
Average expenditure in energy[c]			
1989	9.0 %	7.3 %	13.1 %

Notes: Adapted from Masera et al. (1992a).

a. "Rural" are all villages with less than 2500 inhabitants.

b. Population figures taken from INEGI, 1980 and 1990.

c. Figures for average income and average expenditures in energy taken from Gutiérrez-Elizarrarás (1990); the minimum wages in mid-1989 was 8640 $MEX/day (Elizalde, 1990).

d. From CEPAL, 1990. "Indigent" are those who do not fulfill their food needs. "Poor" are those who do not satisfy their basic needs (including non-food related).

e. Data for income distribution taken from INEGI, 1983. Figures indicate the proportion of total income represented by the quintiles of lowest and highest incomes, respectively. For example, the population quintile of lowest income only received 3% of total national income.

TABLE III.2

REGIONAL DISTRIBUTION OF RURAL POPULATION
MEXICO 1990

Macroregion	States	Population 1990	Percentage of total	AAGR 1980-90
North Central	San Luis Potosí, Zacatecas	1,588,170	6.8	-0.06%
Baja California	Baja California, Baja California Sur	220,160	1.0	-0.82%
North	Chihuahua, Coahuila, Durango	1,402,129	6.0	-0.68%
North Gulf	Nuevo Leon, Tamaulipas	673,956	2.9	-1.64%
North Pacific	Sonora, Sinaloa, Nayarit	1,485,058	6.4	-0.48%
Central Pacific	Aguascalientes, Colima, Guanajuato, Jalisco, Michoacán	4,021,600	17.3	0.35%
Central	Querétaro, Hidalgo, Puebla, Tlaxcala, Morelos, México, D.F.	4,842,612	20.8	-0.20%
South Pacific	Chiapas, Guerrero, Oaxaca	4,993,112	21.4	1.70%
Central Gulf	Tabasco, Veracruz	3,482,539	15.0	0.54%
Yucatán Penninsula	Campeche, Quintana Roo, Yucatán	580,630	2.5	1.45%
COUNTRY		**23,289,966**	100.0	0.34%

Source: Adapted from INEGI (1980 and 1990)

TABLE IV.1

RECENT ESTIMATES OF HOUSEHOLD FUELWOOD USE IN MEXICO

Estimate	Energy use (PJ/yr)	Volume (million m^3/yr)
Cervantes et al. (1984) Guzmán et al. (1985)	402	32
SEMIP (1988)	293	n.a.
Masera et al. (1992a)	246	23.2
SEMIP (1991)	296	n.a.
INIFAP (Castillo et al. 1989)	n.a.	17
This study Including small industries	334 355-365	34.6 37-38

TABLE IV.7

FUELWOOD SATURATION BY END USE

End Uses	Cooking	Water Heating	Space Heating	Lighting	Boiling Drinking Water	Total Saturation End use
Cooking	49.8%	33.7%	1.6%	1.0%	7.1%	98.8%
Water Heating		0.7%	0.1%	--	--	39.8%
Space Heating			0.1%	--	--	6.0%
Lighting						2.0%
Boiling Drinking Water						7.1%

Notes: Each cell shows the saturation of fuelwood users for different pairs of end uses (i.e.. only cooking, cooking and water heating, cooking and space heating, etc.). The last column shows the total saturation of the end use (i.e., the number of househoulds that use fuelwood for each particular end use, either for the end use alone or in combination with other end uses). Total percentages do not add up because some households use fuelwood for more than two end uses simultaneously, i.e., cooking, water heating and space heating (3.8%); cooking, water heating, and lighting (0.6%); and cooking, water heating, and heat for agro-processing (0.6%).

TABLE IV.2

RURAL FUELWOOD AND L.P.G. SATURATION BY REGION

Region	Fuelwood (%)	Only fuelwood (%)	Only LPG (%)
North Central	80.9	19.7	18.9
Baja California	66.3	9.0	29.5
North	93.5	30.4	6.4
North Gulf	70.6	40.6	29.3
Central Pacific	87.4	23.9	9.1
Central	96.3	32.0	3.3
South Pacific	97.5	68.9	1.5
Central Gulf	91.8	48.1	7.8
Yucatán Pen.	96.6	84.2	3.1
North Pacific	70.4	9.5	29.3
COUNTRY	90.7	39.4	8.6

Source: Masera (1993), from a re-processing of SEMIP's rural energy survey (SEMIP, 1988).

TABLE IV.6

SATURATION OF WOODBURNING COOKING DEVICES

Region	Three-stone Fire (%)	Stove (%)
North Central	49.6	46.2
Baja California	86.6	10.3
North	6.4	93.2
North Gulf	92.5	7.0
Central Pacific	55.3	39.8
Central	97.1	0.4
South Pacific	99.0	0.0
Central Gulf	98.7	1.2
Yucatán Pen.	96.9	2.3
North Pacific	94.6	5.4
COUNTRY	81.3	17.1

Notes: The word "Stove" refers here to any change relative to three-stone fires. Source: Masera (1993), from a re-processing of SEMIP's rural energy survey.

TABLE IV.3

BIOFUEL USE IN RURAL MEXICO
(PJ/yr)

	Urban	Rural	Total
Household (PJ/yr)	**91**	**243**	**334**
Population 1990 (million)	57.6	23.3	81.1
Household size	4.7	6.0	5.1
Total w/o water heaters	69.2	230.1	299.3
Fuelwood alone	50.3	172.7	223.0
Satur. (%)	7%	63%	23%
UC (kg/cap/day)	2.0	2.0	2.0
UC (GJ/hh/yr)	55.2	70.5	59.6
Fuelwood and LPG	18.9	57.4	76.3
Satur. (%)	4%	28%	11%
UC (kg/cap/day)	1.6	1.5	1.5
UC (GJ/hh/yr)	44.1	52.9	44.7
Water Heaters	21.5	13.3	34.7
Satur. (%)	5%	8.6%	6%
UC (kg/cap/day)	1.1	1.3	1.2
UC (GJ/hh/yr)	34.9	39.7	36.5
Small Industries (PJ/yr)	**n.d.**	**21-31**	**21-31**
Charcoal		1.7	1.7
Other Industries	n.d.	19.3-29.3	19.3-29.3
TOTAL (PJ/yr)	**91**	**264-274**	**355-365**
TOTAL (10^{12} Kcal/yr)	**22**	**63**	**85**

Notes:
UC: unit consumption.
Only domestic consumption of charcoal is included (i.e., production minus exports plus imports).

TABLE IV.4

HOUSEHOLD FUELWOOD UNIT CONSUMPTION ESTIMATES FROM SURVEYS AND CASE STUDIES

Estimate	Unit Consumption (kg/cap/day)	Unit Consumption (kg/hh/mo)	Notes
Fuelwood-only users			
Surveys			
Oaxaca-Guerrero	2.8	540-553	IIE (1986) low-income group; no direct measurements.
Northeast of "Sierra de Puebla"	2-4	n.a.	SARH(1981); direct measurements
National Average	2.4-2.5[a] (1.7-5.7)	426-450[a] (299-1012)	SEMIP (1988); no direct measurements
Case studies			
Amatlán, Mor.; San Jerónimo Tulijá, Chis.	1.5-3.5	540-720	IIE (1983); one week daily measurements
La Guacamaya, Mich.	3.1	558	Grupo Energética (1984); one week daily measurements
Jaracuaro; Huancito, Mich.	1.8-2.0 [b]	275-278	Masera and Navia (1993); one week daily measurements
Cheranatzicurin Village, Mich.	1.9 [b]	342	Masera et al. (1989); daily measurements for one week during a year.
Purificación Tepetitla; Santa Catarina, Mexico St.	2.1-2.3	n.a.	Evans (1984); no direct measurement
Mixed Fuelwood-LPG Users			
National average	1.7-1.8	303-314 (200-536)	SEMIP (1988); no direct measurement
Jaracuaro; Huancito, Mich.	1.3-1.7	175-280	Masera and Navia (1993); one week daily measurements

Notes: a. The first figure is a simple average, the second a region-weight average; b. weighed average (using equivalent adults).

TABLE IV.5

REGIONAL DIFFERENCES HOUSEHOLD FUELWOOD UNIT CONSUMPTION

Region	Fuelwood-only users (kg/mo)	Mixed Fuelwood and LPG users (kg fuelwood/mo)
North Central	299.0	198.6
Baja California	1012.1	358.6
North	552.5	408.5
North Gulf	350.4	275.8
Central Pacific	341.4	268.1
Central	305.1	229.1
South Pacific	710.2	536.4
Central Gulf	262.2	224.6
Yucatán Penninsula	380.1	295.0
North Pacific	485.5	243.8
NACIONAL	426.4	313.8

Source: Masera (1993). Data from rural energy survey by SEMIP (1988).

TABLE IV.8

FUELWOOD USE BY END USE
Cheranatzicurin Village

End Use	Device	Unit Consumption (kg/cap/day)	Unit Consumption (kg/hh/mo)	Unit Consumption (GJ/hh/yr)
Cooking	Three-stone fire	1.5	270	52.6
Water heating	Three-stone fire	0.1	18	2.9
Lighting	Burning *ocote*	0.26	48	7.7

Source: Adapted from Masera et al. (1992a) and Masera (1990).

TABLE IV.9

FUELWOOD USE BY COOKING TASKS
SELECTED CASE-STUDIES

Task	Fuel Use		Characteristics of the Task			Energy Use
	Per Capita (kg/day)	Specific Consumption (kg fw/kg nixt.)	Temp (oC)	Power	Time of Day	(GJ/hh/yr)
Cheranatzicurin Village[a]						
Tortilla Making	0.70	1.5				24.6
Tortillas	0.65	1.2	250	high	7-10; 15-19	1.8
Nixtamal	0.05	0.3	82	low		22.8
)ther	0.80	n.a.	95	variable	7-10;16-20	28.0
Total Cooking	1.50	n.a.				52.6
Santa Catarina/ Purification Tepetitla[b]						MJ/kg
Tortilla Making		2.4				38.4
Beans		14.1				225.6
Jaracuaro Village[c]						
Tortilla Making		1.9				30.4
Nixtamal		0.4				6.4
Beans		8.5				136.0

Notes: a. From Masera (1990);
b. From Evans (1984);
c. From Masera and Navia (1993). Energy use calculated using 16 MJ/kg. For beans, specific consumption refers to kg of fuelwood/ kg of raw beans. Fuelwood consumption is given in kg wet (air dry)wood (i.e., in the conditions used by rural inhabitants).

TABLE IV.12

LABOR REQUIREMENTS BY FORM OF ACCESS TO FUEL

CHERANATZICURIN VILLAGE

Fuel Collected [a]	Hours/ collection/day	Collection days/week	Hours/cap day	Collection rate (kg/hr)
Women	3	3	1.3	8
Children	3	3	1.3	4
Men with pack animals	5	1	0.7	14
Men with trucks	8	0.1	0.4	23

Notes: a. From Masera (1990). Data were taken from a sample of 24 households.

TABLE IV.14

SOCIAL DIFFERENCES IN FUELWOOD CONSUMPTION PATTERNS [a]

CHERANATZICURIN VILLAGE

A. Labor and Fuel Use

			Labor Use			
			Wood collection			
Income Group [b]	Percentage village households	Household activities[c] (hr/cap/day)	(hr/cap/day)	% total activity	Fuelwood use (kg/cap/day)	LPG use (% hh)
I	12	4.9	1.3	27	1.8	0
II	61	5.1	1.3	25	1.6	0
III	10	4.0	1.0	25	1.6	5
IV	10	4.0	1.0	25	1.6	5
V	5	24	0.7	29	1.6	20

B. Form of Obtaining Fuel [d]

	Collected (%)			Purchased		Fuel use by type (%)	
Income Group	Men w/ animals	Men w/ trucks	Women & children	% households [e]	% income[f]	Only pine and oak	Various
I	0	02	100	0.3	20	0.8	100
II	0	01	661	343	10	346	66
III	100	00	0.0	0.0	10	100	0
IV	34	33	0.0	330	55	666	34
V	17	33	33	17	3	66	34
VI	0	100	04	0.7	2	100	0

Notes:

a. From Masera (1990). Data taken from a sample of 22 families. Figures correspond to the year 1987.
b. Higher roman numeral indicates higher household income.
c. Includes: water and fuelwood collection, clothes washing, and tortilla making.
d. All figures are percentage of total households in each income group.
e. Includes households that purchase fuelwood in a non-systematic basis.
f. Refers to the percentage of household income that would be devoted to fuelwood purchases in the theoretical (or actual) case that all fuelwood needed to be purchased.

TABLE IV.10

FORMS OF OBTAINING FUELWOOD
(% households)

Region	Collection (%)	Purchase (%)	Purchase and use LPG (%)
North Central	81.5	18.5	17.7
Baja California	92.8	4.4	3.5
North	96.0	4.0	3.2
North Gulf	94.8	5.1	3.2
Central Pacific	80.8	15.6	11.2
Central	84.1	15.9	10.6
South Pacific	79.6	20.3	11.3
Central Gulf	87.9	12.1	5.3
Yucatán Pen.	93.2	6.4	1.1
North Pacific	81.2	18.8	16.5
NACIONAL	84.5	15.2	10.0

Source: Masera (1993). Data from SEMIP's rural energy survey.

TABLE IV.11

LABOR USED FOR FUELWOOD COLLECTION

Region	Fuelwood collection (hr/hh/day)	Use of draft animals * (%)	Animal Work * (hr/day)	Fuelwood collection distance (Km)
North Central	2.9	24.5	2.6	4.3
Baja California	0.9	1.2	0.1	4.8
North	1.7	54.5	1.7	4.1
North Gulf	1.7	26.4	1.6	2.8
Central Pacific	0.7	21.9	1.8	4.8
Central	0.9	20.7	1.2	1.9
South Pacific	1.2	22.7	1.0	3.9
Central Gulf	0.5	9.2	0.9	2.0
Yucatán Pen.	1.4	15.7	0.6	2.4
North Pacific	0.7	3.1	0.3	10.3
NACIONAL	1.1	20.8	1.3	3.8

Note: Only households that collect wood are included. * Indicates the percentage of households respect to those that collect fuelwood. Source: Masera (1993), data from SEMIP's rural energy survey.

TABLE IV.13

AVERAGE PRICES FOR COOKING FUELS

(MEX pesos 1987)

Region	Fuelwood ($/kg)	LPG ($/kg)	Kerosene ($/l.)	Fuelwood ($/MJ)	LPG ($/MJ.)	Kerosene ($/MJ.)
North Central	51.3	154.2	226.3	3.21	3.02	5.80
Baja California	31.3	155.7	222.3	1.96	3.05	5.70
North	7.6	231.9	257.2	0.48	4.55	6.59
North Gulf	47.5	144.4	216.8	2.97	2.83	5.56
Central Pacific	91.4	182.3	216.4	5.71	3.57	5.55
Central	32.5	177.3	225.4	2.03	3.48	5.78
South Pacific	19.3	156.9	253.7	1.21	3.08	6.51
Central Gulf	19.5	173.5	247.1	1.22	3.40	6.34
Yucatán Pen.	54.5	212.8	252.3	3.41	4.17	6.47
North Pacific	39.2	160.7	244.4	2.45	3.15	6.27
COUNTRY	39.9	174.6	237.4	2.49	3.42	6.09

Source: Masera (1993), obtained by the re-processing of the rural survey by SEMIP. The exhange rate in 1987 was 2227 MEX$/U.S. dollar.

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