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Woodfuel as an Energy Resource in
Developing Countries

by

V. Susan Bogach

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A thesis submitted to the Faculty of
Graduate Studies and Research in partial
fulfilment of the requirements for the
degree of

Master of Arts in
International Affairs

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ABSTRACT

Access to energy is a primary determinant of development on an individual or national scale. Wood from planted trees is probably the cheapest source of energy in many countries. Wood production, conversion and utilization is labor intensive and low in foreign exchange cost.

Fuel wood will be a viable energy source in the future only if trees are planted on a sufficient scale and if traditional ways of harvesting, converting and utilizing woodfuels are made more efficient.

While technical solutions to woodfuel problems have been identified, social and institutional barriers to implementing woodfuel programs remain. However, there are signs of increased willingness to act on fuelwood programs. Relating fuelwood problems to high priority energy problems makes it more likely that governments will take action than if the problem is seen as one of rural development or the environment.

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V. Susan Bogach

Introduction

The most widely overlooked impact of the fivefold increase in oil prices ... is the fact that what had been the most feasible substitute for firewood, kerosene, has now been pulled even farther out of reach of the world's poor than it was.

Erik Eckholm, "The Other Energy Crisis: Firewood", 1975

On a global scale, it appears that the current rate of afforestation in the developing world is running at less than 10 per cent of the rate needed to make a meaningful impact on the rural energy crisis by the turn of the century.

John Spears, "Wood as an Energy Source: The Situation in the Developing World", 1978

This crisis affects not only the individual who cannot obtain enough fuel on a sustained basis, but leads to a deterioration of the soil fertility and water carrying capacity ... governments must increase planting on hillsides and farms while at the same time investing themselves in energy plantations for industry and urban areas. Without such commitment from governments, the time may come when tropical man becomes an endangered species because he has destroyed his own habitat.

Keith Openshaw, "Woodfuel and the Energy Crisis: Problems and Possible Solutions", 1981

Throughout history, fuelwood has played a fundamental role in energy supply. Up to 1850, wood furnished most of the world's useful energy.¹ In many developing countries, wood is still the major indigenous energy source for households and small scale industry.

Woodfuels have long been regarded as traditional fuels used only in the subsistence sector. Development planners tended to assume that these fuels would be replaced by inexpensive, convenient and modern energy sources such as petroleum products, as development occurred. Traditional fuels were ignored in energy studies and planning.

Today, new attention is being paid to woodfuels. The shift from woodfuels to modern energy sources has been partially reversed because of the drastic increase in prices of petroleum products and electricity. For the first time, development planners are recognizing that woodfuels will continue to play an important role in energy supply in the future and that forecasts and policies must cover the energy system as a whole (both traditional and commercial fuels).

Oil importing developing countries are facing a whole new set of problems created by the increases in oil prices over the 1973-1980 period. While the prices have dropped in the short term, many countries still have substantial balance of payments deficits even at current price levels. The petroleum potential of these countries is largely unknown. Therefore, emphasis is now being placed on making maximum use of

indigenous energy resources in order to minimize the outflow of foreign exchange and to ensure security of supply of vital energy.

Wood obtained from forests, household gardens, and scattered trees and bushes is now an important energy source for households, commercial establishments and industries. High oil prices² are opening the way for increased use of woodfuels - fuelwood and charcoal as well as more convenient modern forms such as woodchips, pellets and methanol.

However, forest resources in developing countries are shrinking rapidly. If action is not taken soon and on a large scale, supplies will dwindle to the point where wood is no longer a viable energy source in many countries.

Access to energy is one of the fundamental determinants of development on an individual or national level. There is no substitute available for woodfuel in many areas of the world except for dung and agricultural residues. Diversion of these organic materials from enriching the soil to use as fuel can have serious environmental consequences. For many third world families, fuel is one of the basic needs which is becoming most difficult to meet.

The purpose of this study is to examine the potential role of wood as an energy source, and the need for government policy measures in order to ensure that wood resources can make an important contribution to energy supply. A number of questions must be answered in this analysis: (i) What is the current and potential role of wood as an energy source? (ii) How serious are woodfuel supply problems? (iii) How do cur-

rent methods of woodfuel exploitation result in supply problems? (iv) What measures could be taken to alleviate or prevent woodfuel scarcity? (v) What is the role of government and major aid agencies in implementing these measures?

These questions will be discussed in seven chapters. The importance of woodfuel as an energy source is discussed in Chapter One. Chapter Two outlines the future role that could be played by wood as an energy source, if supplies were adequate. The gravity of the current supply situation and its consequences is evaluated in Chapter Three. Chapter Four contains an analysis of current systems of fuelwood supply and utilization in order to discover the roots of supply problems. Chapter Five indicates the kinds of policy measures and the magnitude of expenditure needed to make an impact on the problem. In Chapter Six, the role of governments and major aid agencies in implementing these measures is examined. Chapter Seven draws together the major conclusions of the study.

The analysis relates mainly to the group of oil importing developing countries, since most of these countries have limited resources of modern energy. However, it must be remembered that this group includes countries as diverse as Brazil, a near super power with extensive remaining tropical forests, and Chad, a tiny country in Africa with a GNP per capita of \$140 U.S. in 1978 and serious problems with desertification.

Any serious analysis of fuelwood supply and demand must be made on a very localized basis. However, it is useful to make a broad survey of the problem for several reasons. First, it indicates the global extent of a problem that has tended to be regarded as a local one. And, second, it reveals that there are common threads running through the woodfuel situation in very different parts of the world.

Notes -- Introduction

1. Eugene Ayres and Charles A. Scarlott, Energy Sources -- the Wealth of the World, (New York: McGraw-Hill Book Company Inc., 1952), p. 27.
2. Oil prices have recently dropped from \$34 US to \$29 US and the pressure on OPEC may force prices down again in the short run. However, it is important to remember two things. First, even at \$25 per barrel in 1983 US dollars, oil is four and one-half times as expensive, in real terms, as it was in 1973, before the "energy crisis". Second, an economic recovery on a world scale could push oil prices up again.

Chapter I

Current Role of Woodfuel in Developing Countries

There is a great deal of diversity in the energy situation of developing countries. One has only to think of China, a major producer of oil and coal; Brazil, a heavy user of imported oil; and Kenya, where 75 per cent of all energy is estimated to be supplied by wood.

There is, however, one generalization that applies to all countries other than India or China.¹ Their economies are heavily dependent on wood and/or oil. Oil supplied almost 70 per cent of the modern energy needs of these developing countries, compared to 50 per cent for industrialized ones and 30 per cent for Eastern Europe.² In developing countries petroleum products are used to fuel cooking stoves and heaters, vehicles, industrial processes, and electricity generators.

But while petroleum fuels the modern sector, the transition to modern energy has been made only partially in many countries. Traditional fuels, especially wood, are still very important. Fuelwood and charcoal are widely used in the home for cooking, space heating, and lighting. They are also used in a multitude of small industries: in the processing and drying of agricultural products (such as tobacco, sugar, and tea), in brick and tile making, and in metal working. (See Table 1).

Table 1

Uses of Fuelwood and Charcoal

<u>Household</u>	<u>Cottage Industries</u>	<u>Industrial and Service Sectors</u>
cooking	textile washing & dying	baking
space heating	baking	cassava drying
lighting	brewing alcohol	tea drying
ironing	blacksmith	fish curing
curing meat	fish curing	tobacco curing
steam baths	meat curing	brown sugar production
water heating	palm oil production	brick making
protection from insects & animals	sweet making	ceramic production
	jewellery making	cement making
	cheese making	metal processing
	candle making	blacksmith
	drying agricultural products	railways
	cigarette making	sawmills
	soap making	restaurants
	laundries	canteens
		lime production
		salt production
		potash production
		tile production
		paper production
		lumber drying
		road construction

Sources: Keith Openshaw, "Woodfuel—a Time for Reassessment", Natural Resources Forum 3, (1978), p. 35-51.

D.C. Donovan, "Research Trials in Rural Nepal", Institute of Current World Affairs (Hanover, N.H. : Unpublished paper, 1980).

In a few countries (such as Brazil, India, and Malaysia), charcoal made from wood is a major modern fuel in the iron and steel industry, where it replaces metallurgical coke as a thermochemical reductant in the production of pig iron.

But while a few modern industries use woodfuels, most wood is burned in open fires, traditional stoves, ovens, boilers, and kilns.

Difficulties in Measuring Woodfuel Use

Data on woodfuels is notoriously bad for several reasons. Wood is collected, utilized and traded on a highly localized basis. It does not pass through any commercial organization like a petroleum distribution company or an electrical utility.

Establishing a data base for fuelwood consumption requires well designed, regular field surveys to establish the number and types of users of woodfuel, the purposes for which woodfuel is used, the average dry weight consumed per user in a given time period for a particular use, and the source of the woodfuel.

Such surveys, in practice, are extremely difficult to carry out. The problems are numerous and include: the lack of standard units of measurement for sale of woodfuel or charcoal (measures vary by locality); the fact that the proportion of solid wood contained in any stack is variable; the difficulty of measuring the average volume of fuel used by those who gather wood (estimates are often made by using an artificially defined, "bundle" that may or may not reflect the average size bundle gathered by a man, woman and child in a particular

area); the fact that many different types of wood from many different trees are used making it very difficult to relate volume to weight and energy content; the highly variable moisture content of wood; and the biases that may be introduced by lack of trust and understanding between the interviewer and the interviewee.

It is not impossible to carry out a thorough and accurate analysis of fuelwood use in a particular household or foundry, etc. However, the detailed measures required are prohibitive when the exercise is carried out on a national or even regional scale. Therefore, survey data must always be regarded as approximate.

On the production side, the extent, density, productivity and rate of destruction of natural forest areas in many parts of the world have not been well documented. As Erik Eckholm stated,³

... Any discussion at present of global forest resources and trends must be based on a concoction of subjective observations and surveys of varying quality. (Emphasis mine).

Data that is needed includes an accurate assessment of the extent of natural and man-made closed and open forests, their density, the rate of annual growth, the rate at which forest resources are being destroyed as a result of commercial exploitation and the spread of agriculture, and the amount of fuelwood produced as a byproduct of commercial exploitation and land clearing.

Given the fact that our estimates of the rate of consumption of fuelwood and forest products may be out as much as a factor 20 for an individual country;⁴ that we do not know how much of this demand is supplied by household or non-forest wood resources; that we do not have an accurate assessment of the resource base of forests in most countries; and that we have little data on the rate of destruction of forests to create agricultural or grazing land; it is impossible to make an accurate analysis of the fuelwood situation.

2. The Energy Profiles of Selected Countries

Figure 1 (based on data contained in Appendix 1) indicates the diverse energy profiles of developing countries according to data obtained from national reports presented to the U.N. Conference on New and Renewable Energy Sources (UNERG). The author selected a number of countries whose national reports contained detailed data on energy consumption. The estimate of energy consumption from these reports is not necessarily the same as that given in the U.N. World Energy Supplies publication or in the F.A.O. Yearbook of Forest Products, since data was compiled directly by government officials.

In this group of countries, wood is least important in Jordan, a high income oil importing country in the Middle East with an economy based totally on oil. It is most important in Kenya, a low income oil importing country whose energy consumption is 75 per cent wood.

Figure 1
A COMPARISON OF PER CAPITA ENERGY REQUIREMENTS
IN SELECTED COUNTRIES

Even in countries with a relatively diverse industrial base and a number of energy sources, such as Brazil and Peru, wood plays an important role (approximately one quarter of all energy).

The energy use profile of a country depends on much more than its level of wealth. Some of the other factors to be considered include resource endowment, distribution of income, social structure, and structure of the economy. Figure 1 indicates that it is difficult to generalize about energy use in the developing world other than to say that wood and/or oil dominate energy supply to an unusually large degree.

3. How Important are Woodfuels as an Energy Source?

One and one half billion people, over a third of the world's population, are estimated to rely on wood for their basic energy needs. An estimated 75 to 85 per cent of all the wood burned for fuel in developing countries is used in the home.⁵

According to the latest estimates by the F.A.O., recorded production of fuelwood and charcoal in the developing world was 1.4 billion cubic metres in 1978. (See Table 2). In energy terms, this is equivalent to 2.25 billion barrels of oil, or 75 per cent of oil consumption in the developing world, with a current value of \$65 billion US.⁶ This is a straight comparison in terms of the energy value, unadjusted for the fact that wood is utilized with approximately one third the efficiency of oil products.

Recorded production of fuelwood and charcoal represented

Table 2
Fuelwood in World Energy Consumption in 1978

Population (millions)	Total fuelwood a/ (millions of m ³)	Energy b/ equivalent of fuelwood (millions of gigajoules)	Commercial energy c/ (millions of gigajoules)	Fuelwood (percentage of total) d/ %
World	4 258	14 720	256 594	5.4
Developed World	1 147	1 363	205 115	0.7
Developing World	3 111	13 357	51 479	20.6
Africa	415	3 318	2 415	57.9
Asia	2 347	7 478	37 558	16.6
Latin America	349	2 557	11 306	18.4

a/ Includes wood for charcoal.

b/ 1M³ equals 9.4 gigajoules

c/ 1mt coal equals 29.3 gigajoules

d/ Not including other sources of non-commercial energy in some regions.

Source: U.N. Conference on New and Renewable Energy Sources, "Report of the Technical Panel for Fuelwood and Charcoal on its Second Session", A/Conf 100/DC/34, Feb. 25, 1981.

85 per cent of the total volume of wood removed from the forest in developing countries in 1978. Wood cut for production of pole, pit-props, sawnwood, panel products and paper products accounted for only 15 per cent of the annual cut, on average. Wood is far more important as a fuel than as a building material or source of paper. This is almost the reverse of the situation in the developed countries where fuelwood and charcoal amount to 10 per cent of the total roundwood cut.

Table 3 (summarized below) contains a country-by-country estimate of the contribution of woodfuels to total energy supply, based on official (F.A.O.) figures.⁷ Of the 114 countries listed in the table, woodfuel supplies over one quarter of all energy in 62 countries with a total population of nearly 1.5 billion.

Degree to which Fuelwood Supplies Dom. Energy Needs (%)	No. of Countries	Population Living in these countries (million)	% Total
0 - 4	36	309.5	10
5 - 24	15	1,153.9	38
25 - 49	21	1,209.2	40
50 - 74	15	91.9	3
75 - 100	24	261.9	9
		<u>3,026.4</u>	<u>100</u>

Note: Botswana and Swaziland were not included in this table because of incomplete data.

There are some countries where wood is not important as a fuel, either because it is not available or because the population is wealthy enough to have made the switch to modern energy sources. Wood is not important throughout North Africa and the Middle East, which is a virtual desert; in the wealthier countries of Latin America, such as Venezuela, Chile, and

Table 3

Role of Fuelwood in Energy Supply of Developing Countries

	1978 FAO Est. Fuelwood Cons. (million m ³) (1)	1978 FAO Est. Fuelwood Cons. (millions Gigajoules) (2)	1978 Total Commercial Energy (million Gigajoules) (3)	% Total Energy Supplied by Fuelwood (2 ÷ (2+3))
Africa				
+ Algeria	1.3	12.2	373.0	3
+ Angola	7.1	66.7	38.5	63
Benin	2.3	21.6	5.6	79
Botswana	0.7	6.6	-	-
Burundi	0.9	8.5	1.4	86
Cameroon	7.5	70.5	23.6	75
C.A.R.	2.4	22.6	2.4	90
Chad	3.4	32.0	2.8	92
+ Congo	1.9	17.9	5.9	75
+ Egypt	0.1	0.9	537.5	..
Eq. Guinea	0.4	3.8	1.0	79
Ethiopia	23.8	223.7	17.0	93
+ Gabon	1.2	11.3	28.9	28
Gambia	0.3	2.8	1.8	61
Ghana	10.5	98.7	52.1	65
Guinea	2.9	27.3	12.7	68
Guinea Bissau	0.4	3.8	1.3	75
Ivory Coast	5.3	49.8	55.3	47
Kenya	14.7	138.2	60.6	70
Liberia	1.8	16.9	21.3	44
+ Libya	0.5	4.7	137.1	3
Madagascar	5.2	48.9	20.0	71
Malawi	4.8	45.1	8.3	84
Mali	3.0	28.2	5.5	84
Mauritania	0.6	5.6	8.2	41
Mauritius	.	.	10.7	..
Morocco	2.9	27.3	160.4	15
Mozambique	9.9	93.1	43.9	68
Niger	2.7	25.4	5.6	82
+ Nigeria	80.6	757.6	213.9	78
Zimbabwe (Rhodesia)	7.0	65.8	117.6	36
Rwanda	4.6	43.2	2.4	95
Senegal	2.9	27.3	25.3	52

Table 3 (continued)

	(1)	(2)	(3)	(2 ÷ (2 + 3))
Sierra Leone	2.5	23.5	9.4	71
Somalia	3.4	32.0	10.0	76
Sudan	27.5	258.5	85.1	75
Swaziland	0.5	4.7	-	-
Tanzania	39.0	366.6	31.7	92
Togo	1.0	9.4	6.8	58
+ Tunisia	1.9	17.9	96.7	16
Uganda	18.7	175.8	18.1	91
Upper Volta	4.4	41.4	4.7	90
Zaire	18.5	173.9	56.1	76
Zambia	5.5	51.7	75.9	41
Sub-total	336.5	3,163.1	2,396.1	57

Mexico, Central America & Caribbean

Barbados	0.1	0.9	8.0	10
Belize	0.1	0.9	2.7	25
Costa Rica	2.4	22.6	34.9	39
Cuba	1.5	14.1	345.6	4
Dominican Rep.	1.7	16.0	69.7	19
El Salvador	2.9	27.3	35.1	44
Guadeloupe	..	..	8.1	..
Guatemala	5.1	47.9	50.4	49
Haiti	3.5	32.9	8.0	80
Honduras	3.0	28.2	27.9	50
Jamaica	..	..	113.0	..
Martinique	..	..	11.2	..
+ Mexico	7.2	67.7	2,714.5	2
Nicaragua	2.1	19.7	36.3	35
Panama	1.6	15.0	53.0	22
+ Trinidad	..	..	164.9	..
St. Lucia	..	..	1.2	..
	31.2	293.3	3,684.5	8

Table 3 (continued)

	(1)	(2)	(3)	(2) ÷ (2 + 3)
<u>South America</u>				
Argentina	3.1	29.1	1,448.5	2
+ Bolivia	4.0	37.6	65.9	36
Brazil	119.5	1,123.3	2,686.4	
Chile	3.1	29.1	317.3	
Colombia	21.1	198.3	531.1	
+ Ecuador	1.9	17.9	115.7	13
French Guiana	..	..	5.2	..
Guyana	..	..	25.7	..
Paraguay	3.4	32.0	16.9	65
+ Peru	2.7	25.4	320.0	7
Surinam	..	..	29.1	..
Uruguay	1.2	11.3	88.5	11
+ Venezuela	8.0	75.2	1,149.4	6
	<u>168.1</u>	<u>1,580.1</u>	<u>6,799.7</u>	<u>19</u>
<u>Middle East</u>				
+ Bahrain	..	..	104.2	..
Cyprus	..	..	35.5	..
+ Iran	2.0	18.8	1,865.5	1
+ Iraq	..	..	228.6	..
Jordan	..	..	46.6	..
+ Kuwait	..	..	237.7	..
Lebanon	.1	0.9	86.5	1
+ Oman	..	..	49.6	..
+ Qatar	..	..	70.0	..
+ Saudi Arabia	..	..	375.6	..
D.M. Yemen	..	..	27.7	..
+ Syrian	.1	0.9	229.5	..
+ U.A.E.	..	..	132.6	..
Turkey	10.3	96.8	1,003.8	9
Yemen	..	..	11.3	..
	<u>12.5</u>	<u>117.5</u>	<u>4,504.8</u>	<u>2.5</u>

Table 3 (continued)

	(1)	(2)	(3)	(2 ÷ (2 + 3))
Far East				
Afghanistan	6.3	59.2	24.8	70
Bangladesh	9.4	85.1	105.5	45
Brunei	.1	0.9	62.7	1
Burma	1.7	16.0	60.1	21
+ China	150.6	1,415.6	22,459.4	6
Hong Kong	0.1	0.9	223.7	..
India	124.2	1,167.5	3,328.8	26
Indonesia	117.7	1,106.4	1,196.7	48
Kampuchea	4.4	41.4	0.9	98
Korea R.P.	5.1	47.9	1,474.8	3
Korea D.P.R.	4.4	41.4	1,351.6	3
Lao P.D.R.	3.2	30.1	6.2	83
Malaysia	6.1	57.3	277.1	17
Mongolia	1.4	13.2	57.3	19
Nepal	10.2	95.9	4.2	96
Pakistan	9.3	87.4	387.1	18
Philippines	24.5	230.3	460.8	33
Singapore	0.1	0.9	168.3	1
Sri Lanka	4.3	40.4	47.6	46
Thailand	17.1	160.7	432.0	27
Vietnam	18.6	174.8	179.9	49
	518.5	4,873.9	33,309.5	12.8
Oceania				
Fiji	..	..	8.4	..
French Polynesia	..	..	2.8	..
Papua New Guinea	5.1	47.9	25.6	65
Samoa	.1	0.9	0.8	53
	5.2	48.8	37.6	56
All Developing Countries	1,072.0	10,076.7	50,732.2	17
Excluding Oil Exporters	656.9	6,174.9	17,417.6	26
+ Oil Exporting Countries				

Source: Authors calculations based on 1978 F.A.O. Forest Products Yearbook and U.N. World Energy Supplies.

Argentina; and in the industrialized economies of South East Asia, including Taiwan and Hong Kong.

It is most important in sub-Saharan Africa where it often supplies over three quarters of all energy requirements, in Central America, and in Asian countries, such as India, Thailand, and the Philippines, where it supplies one quarter to one half of all energy needs.

This picture, based on officially recorded woodcuts, gives a conservative estimate of woodfuels' importance. In addition to amounts reported, an unknown amount of wood is cut in household gardens and other non-forest areas, or cut clandestinely in forests.

Surveys have proven that official figures seriously underestimate woodfuel use. Keith Openshaw, a respected professional who has conducted several woodfuel surveys, believes actual consumption is likely to be double the official estimates, with wider variations in individual countries.⁸

Notes -- Chapter I

1. Coal is the largest single source of modern energy in both India and China, at 60 and 80 per cent.
2. Calculated from U.N. World Energy Supplies, 1973-1978.
3. Erik Eckholm, "Planting for the Future: Forestry for Human Needs", Worldwatch Paper 26, (1978), p. 9.
4. Keith Openshaw, "Woodfuels -- a Time for Reassessment", Natural Resources Forum 3, p. 36.
5. Keith Openshaw, "Woodfuel and the Energy Crisis: Problems and Possible Solutions", paper presented to the Non-governmental Organizations Forum at the U.N. Conference on New and Renewable Energy Sources, Nairobi, 1981.
6. Energy content assumed to be 9.4 GJ/m^3 for wood, 5.83 GJ/barrel for oil. No correction is made for the lower efficiency with which wood is used. The price of oil is \$29 US per barrel.
7. Figures for individual countries are available only from the F.A.O. Yearbook of Forest Products. The figures in this source are lower than the figures used in Table 2. Total woodfuel use in the developing world in Table 2 is 1.4 billion cubic metres, in Table 3 is 1.1 billion cubic metres. Both sets of data come from the F.A.O. and there appears to be no way of reconciling them. Table 2 is the more recent estimate, but there are no back up figures on a country-by-country basis.
8. Openshaw, "Woodfuel and the Energy Crisis", p. 3.

Chapter II

Potential Role of Woodfuels in Energy Supply

Until recently, wood was ignored in energy studies because its use was expected to decrease and eventually disappear as development occurred. According to Erik Eckholm, "Someone extrapolating the trends of the first seven decades of this century might well have expected the continued spread of kerosene and gas at a fairly brisk pace in the cities and rural areas, eventually rendering firewood nearly obsolete."¹ High oil prices and a lengthy global recession have made this view highly questionable and have stimulated new interest in wood.

If supplies were adequate, woodfuel could be expected to contribute to energy supply in the following ways,

- ... the traditional use of wood and charcoal by households and small industry could be expected to continue, and,
- ... woodfuels could be increasingly used to power modern industry and even transport

1. Properties of Woodfuels versus Other Major Energy Sources

The major characteristics of different fuels, including fuelwood and charcoal, are outlined below. Table 4 summarizes the energy content of different fuels.²

a) Coal

Coal is a solid mineral product consisting essentially of carbon, hydrogen, oxygen, sulphur and various other impurities. There are several types of coal with substantially different characteristics.

Anthracite is a hard coal with a high energy and low moisture content. It is used mainly for space heating and steam generation. Bituminous coal falls into three categories: coking coal used to produce metallurgical coke for the iron and steel industry; gas coal used to produce manufactured gas and by-product coke; and steam coal suitable for steam raising and space heating. The energy value of bituminous coal varies greatly. For clean coal, it is generally in the range of 27.2-31.4 Gigajoule (GJ) per metric tonne. But for raw coal sold without processing, it can be as low as 16.7 GJ per metric tonne. Since the energy value of bituminous coal varies greatly, it is always necessary to obtain information on the source and energy content on a case-by-case basis.

Lower grades of coal are used mainly for power generation. Sub-bituminous coal is similar to the poorer grades of bituminous coal -- low in carbon, high in volatile matter and moisture. It has an energy content in the range of 16.7 to 27.2 GJ per metric tonne, with an average of about 18.8 GJ. Brown coal or lignite is young coal that is usually high in moisture and low in energy content (8.4 - 16.7 GJ per metric tonne).

b) Metallurgical Coke

Metallurgical coke is a hard, strong coke used in the iron and steel industry where it performs simultaneously as a chemical agent and as a fuel. Metallurgical coke is produced from coking quality bituminous coal and has a high energy

content of about 28.4 GJ per metric tonne.

c) Petroleum Products

Liquid Petroleum Gases (LPGs) are gaseous at normal temperatures and pressures, but can be liquified at relatively low pressures. They are made up mainly of propane and butane produced from crude oil in a refinery or stripped out of a natural gas processing facility. They are premium products with a very high energy content per unit of weight (45.2 GJ per metric tonne).

Gasoline is a light, high quality petroleum product used mainly in internal combustion engines, with an energy content of 44.0 GJ per metric tonne. Distillate fuel oil is a general classification that covers diesel, gas oil, and light heating oils. It is used mostly in internal combustion engines (diesel, gas oil) or as a domestic heating fuel (light fuel oil). It has an energy content of roughly 42.7 GJ per metric tonne.

Finally, heavy fuel oil (also called residual oil or Bunker C) has a low energy content (41.0 GJ per tonne) and a rather high density. It is used primarily as a boiler fuel in industry, electric power plants and ocean steamers.

d) Woodfuels

Fuelwood is a natural, unprocessed product with a variable but low energy content ranging from 10.9 to 21.3 GJ per metric tonne, with an average of 14.7 GJ for seasoned wood (moisture content of 20 per cent). The moisture content of fuelwood is also variable depending on the species and on the

extent to which the wood has been dried. It is widely used in the household, and to some extent in industry, especially the pulp and paper industry (hog-fuel).

Charcoal is a product made up mainly of carbon obtained by the distillation of wood. It has a relatively high energy content of 28.9 GJ per metric tonne. It is widely used in the household as a domestic fuel, in commercial applications, by small industry and even in the iron and steel industry as a substitute for coke.

Methanol is a liquid fuel that can be produced from organic matter including woody biomass. It can be mixed with gasoline as a fuel for existing internal combustion engines, or used as the sole fuel for specially adapted internal combustion motors. Methanol has an energy content that is about one half of gasoline, but it has a much higher octane rating.

Producer gas consists of carbon monoxide and nitrogen produced by the burning of carbon in a supply of air insufficient to convert it to charcoal. It is a low joule gas that is usually burned in furnaces or cleaned before use in an internal combustion engine.

e) Comparison of Woodfuels to Substitute Fuels

The advantages and disadvantages of woodfuels relative to other fuels is summarized below.

Fuelwood can be burned to generate process heat and steam. It is attractive as a domestic fuel or as a fuel for small rural industry because wood resources are widely dispersed. Therefore, fuelwood is widely available and is

often obtained for free (or at the opportunity cost of the labour used to gather it). It is easy to store and use. No major equipment is required-- it can be burned in an open fire or in very simple enclosures to give low temperature heat.

However, while fuelwood is an adequate fuel for many industrial purposes, the use of fuelwood in industry is often uneconomic for the following reasons: first, its low energy content per unit of weight means greater handling, transport and storage costs; second, wood is not a standard fuel and the characteristics vary between one lot and another, making it difficult to control the temperature and rate of burning in industrial processes.

Charcoal is a much more attractive fuel for household and industrial use than fuelwood. It is virtually smokeless and contains twice as much energy as seasoned fuelwood, on average, by weight. This makes it much easier to handle, transport and use. Charcoal has an energy value that is equivalent to metallurgical coke and to good quality coal.

Charcoal, in fact, was used in many industrial processes in Western Europe until charcoal shortages forced the adoption of coal. Cheap and convenient petroleum products have largely replaced both coal and charcoal throughout the world. However, where charcoal can be made available at a price that is sufficiently below the price of petroleum products to make up for the inconvenience of handling a solid fuel, it is likely to find acceptance.

Table 4

Net Heating Values of Selected Solid
and Liquid Fuels

	GJ/Metric ton	Index, Wood=1.0
Coal - Anthracite	29.3 - 16.7	2.0
- Bituminous	16.7 - 31.4	1.9 - 2.1
- Sub-bituminous	16.7 - 27.2	1.1 - 1.9
- Lignite	8.4 - 16.7	0.6 - 1.1
Metallurgical Coke	28.4	1.9
Petroleum Products		
- LPGs	45.2	3.1
- Kerosene	43.1	2.9
- Heavy Fuel Oil	41.9	2.9
Woodfuels		
- Wood*	10.9 - 21.3 (average 14.7)	1.0
- Charcoal	28.9	2.0
- Methanol	23.9	1.6
Agricultural Residues		
- Bagasse	14.7	1.0
- Corncoobs	19.3	1.3
- Dung	8.8	0.6
- Paddy Husks	13.4	0.9

*Air dry (i.e., 20% moisture content)

Source: Federal Energy Agency, A Handbook of Tables and Conversion Factors for
Combining and Comparing International Energy Data (Washington: June 1977).

Methanol

The main energy use of methanol is to replace some gasoline as a fuel in automotive engines. Methanol/gasoline mixtures of 10-20 per cent have been tried in several countries and have proven satisfactory as long as care is taken with the methanol to prevent water contamination. Pure methanol can be burned by specially adapted engines.

Producer Gas

Producer gas has a low energy value per unit of mass or volume. It is suitable mainly for burning in internal combustion engines and furnaces where high temperatures are not required.

2. Potential for Woodfuel in Traditional Uses

Wood is an adequate fuel for the low temperature heating requirements of households and traditional industries. It is likely to continue to be used until supplies are no longer available, or until an alternative form of energy can be made available at lower cost. What are the alternatives that could displace it in traditional uses in the future?

The normal response to wood shortages in rural areas is to make increasing use of dung and agricultural residues as a supplement or replacement for fuelwood. While the ashes may be returned to the soil after burning, the ash does not create humus as does organic matter and nitrogen is lost. Diversion of organic matter to use as fuel results in impoverishment of the soil. India is a prime example of a country with this problem. Fuelwood supplies are virtually exhausted and the

widespread use of dung as fuel, rather than as fertilizer contributes to the low productivity of Indian farmland.

Biogas is often suggested as an alternative to fuel-wood and charcoal. It is produced from organic material by anaerobic decomposition. The production of biogas normally requires human or animal excrement as feedstock. The gas is produced in a sealed container and then piped under low pressure to power appliances or even internal combustion engines. Small biogas plants are in operation in many countries. China, India, and South Korea have experimented with biogas plants on a large scale.

The advantage of biogas is that dung and other organic matter can be used to produce both fuel and fertilizer rather than one or the other. Biogas is of interest mainly in countries where most families own livestock, since an estimated four to six cattle are necessary to provide enough manure to fuel a biogas plant for a family of six. The biogas plants also require capital and, therefore, are out of reach of subsistence families. Biogas is not likely to play a major role in energy supply in most countries of the third world.³

Solar energy has considerable promise for the future, but its main current application in the developing world is in the drying of agricultural crops. Solar cookers are not likely to be in widespread use for another 20 years. Despite years of experimentation, a solar cooker has not been developed that meets the requirements of women. Two meals of the day,

breakfast and dinner, are cooked at times when there is little or no sunlight. Also, a solar cooker must be used outdoors, which is not the current practice in many areas.

There has been more success in developing solar water heaters, but the capital cost of such a system puts it out of reach of most third world families. Solar water heating may be a substitute for electrical water heating, or water heating with petroleum products, but it is likely to be a substitute for water heating with wood only in commercial establishments and a few households.

Electricity generated from hydropower could provide an alternative to purchased woodfuel for cooking and heating, as well as light. However, the use of electricity requires that an expensive distribution system be put into place and it requires the user to purchase a stove and pay regularly for energy used. Electricity is not available in many areas and its cost would be prohibitive for many families.

Natural gas is an excellent cooking fuel that could theoretically displace some wood use, but it requires an even more expensive distribution system than electricity, and is unlikely to be available as a domestic fuel outside of middle and upper class income areas. It is likely to be used, where available in developing countries, mainly for power generation and by large industrial customers.

It can be expected that coal production in the third world will increase considerably. Coal can be substituted for charcoal or fuelwood in the home or in small industry. But

coal is more difficult to ignite, requires a larger quantity of material in the fire to stay alight, and may give off noxious fumes.⁴ Introduction of coal requires the development of specially designed stoves, with chimneys, and a careful education program.

The most likely alternatives to fuelwood and charcoal are petroleum products, kerosene and Liquified Petroleum Gases (LPGs). Kerosene, a product refined from crude petroleum, is a major substitute for purchased woodfuel in many households. It can be burned in a cheap stove (cost \$20-\$30 US), can be bought in quantities as small as a pint (cost 15¢-20¢ US), and is convenient and easy to use.

LPGs (propane and butane) are sold in metal pressurized containers, normally containing in the range of 10-125 pounds of fuel. LPGs burn more cleanly than kerosene and are often used by middle class households in developing countries to fuel stoves and hot water heaters. The use of LPGs requires a payment of a deposit on the container (in the range of \$25-\$50 US), payment for the fuel (approximately \$2-\$25 US per refill), and purchase of a stove (\$30-\$250 US). The heavy containers must be brought to an LPG dealer to be filled; such dealers are normally located in towns and cities.

A switch to LPGs or, more commonly, to kerosene was the normal response by a wood purchasing family to increased levels of wealth and/or wood shortages. But price increases for petroleum products have been more rapid than price increases for fuelwood and charcoal, so that there is now a

tendency for the reverse to happen. Where there is not a strong preference for woodfuels, there is likely to be movement back and forth between petroleum products and woodfuel depending on the relative prices.

People may continue to buy wood rather than kerosene or propane even when it is more expensive on an energy equivalent basis. Woodfuel can be burned without a stove and wood can be purchased in small quantities daily. For those who live from day-to-day, these factors are important, and people continue to use wood even though they may spend more on fuel in the long-run than people using petroleum products.

There are no satisfactory substitutes to self-gathered woodfuels in rural areas except the use of agricultural wastes and dung. Diversion of this organic matter from the soil often exacerbates ecological damage caused by deforestation.

The most likely alternatives for those purchasing woodfuels are propane and kerosene. But the transition to these fuels is likely to take place only where scarcity and high prices of woodfuels make petroleum competitive. As long as woodfuel supplies are available free or at low cost, they will continue to supply households and traditional industry with the bulk of their energy needs.

3. The Potential for Wood to Supply Modern Energy to Industry and Transport

In some countries, such as the Ivory Coast, woodfuels are plentiful and could supply a larger market than they currently serve. And even in countries with shortages, action

could be taken to increase wood supplies and make wood available for use in modern industry.

Wood can be burned directly, or it can be converted into products that may be more attractive for certain uses -- e.g., charcoal, methanol, producer gas. These products are produced by the thermo-chemical or biological conversion of the elements present in wood, mainly carbon, hydrogen, and oxygen.

a) Direct Combustion in Boilers and Furnaces

Direct combustion is the simplest, most direct, and most traditional way to utilize wood. It can also be the most efficient way to utilize wood, if sophisticated modern technology such as that used in the forest products industry in developed countries is applied.

Wood is not utilized by modern industries in developing countries, with the exception of the iron and steel industry. Its use could be fostered in two ways -- by making wood a more convenient fuel to handle through pre-processing and by utilizing specially designed combustion systems.

i) Pre-Processing

Fuelwood is a heavy and awkward commodity. Pieces of fuelwood are not a standard size and may contain a considerable amount of moisture. Chipping and pelletization are two ways of standardizing the form in which wood is available.

Mobile chippers have been developed to process branches, stems, and tree trunks into standard sized chips that are blown into a waiting truck behind the chipper. The costs of

processing and handling the chips are less than those for split fuelwood. But since chips can still contain a considerable amount of moisture, they cannot be trucked long distances. Chipping is often a preliminary step to the use of wood in wood boilers or furnaces.

Wood pellets are made from wood waste bound together by heat and pressure. They are denser, drier and have a higher calorific value than wood chips, which means that they can be transported over longer distances. They can be substituted directly for coal in boilers and furnaces. The f.o.b. cost of pellets is higher than that of coal, for the same amount of energy, but where coal transport costs are high, it is becoming economic to use pellets.⁵ Pellets have another advantage over coal in that they are virtually sulphur free. Pellets are attractive where it is necessary to utilize wood as fuel in existing boilers, or where wood must be transported a considerable distance.

ii) Specially Designed Combustion Systems

Wood is used as fuel in industry mainly to generate process steam and heat. Three basic approaches exist for efficient combustion of wood for these purposes -- the Dutch oven, the spreader-stoker, and the fluidized bed combustor. In the Dutch-oven system, a heavy bed of wood is placed on a combustion grate and underfire air flows through it. In the more commonly used spreader-stoker system, the fuel is introduced into the firebox above the grate and begins to burn as it falls to the grate. The fluidized bed combustion system

employs a hot bed of inert material such as sand. The wood is fed into the bed and preheated combustion air is fed through the grate below. The abrasive bed material constantly removes the charred surface of the woodfuel, exposing fresh material for oxidation.

These systems have combustion efficiencies in the range of 67-72 per cent, while the standard combustion efficiency for pulverized coal, oil, or natural gas in a well designed boiler is 80-85 per cent.⁶ Since the wood boiler is larger and more expensive, there must be a substantial differential in the cost per energy unit between wood and these alternative fuels to make it economic.

iii) Co-Generation

Spectacular gains in efficiency and cost effectiveness can be achieved if process heat and electricity are produced by combusting the same fuel. There are two basic approaches to co-generation -- the raising of industrial heat plus steam and electricity, and the generation of residential and commercial heat, plus the production of electric power.

Co-generation in industrialized countries is practised mainly in the pulp and paper industry. Requirements to make co-generation attractive include the following: a generating capacity of 1-2 MegaWatt (MW) and preferably 25 MW, and the operation of at least two shifts per day, five days per week.⁷

The application of co-generation in developing countries is limited by the fact that it is attractive only where there is a need for both electricity generation and process

heat, implying the presence of a large commercial or industrial entity and the opportunity to sell surplus power.

b) Conversion of Wood Through Thermo-Chemical Processes

Wood can be converted to charcoal, liquid fuels or gas by the application of heat and pressure in the presence of a catalyst. Some processes, such as pyrolysis (for the production of charcoal), distillation (for the production of methanol) and gasification (to produce gas) have been known and utilized for centuries. However, wood products could not compete with the low cost of coal and oil.

Today, with high energy prices, the possibility of wood plantations based on fast-growing trees, and the possibility of applying modern methods and technology to old processes, a new look is being taken at wood products. These products are especially attractive where wood is needed as a substitute for fuels in existing equipment -- charcoal for metallurgical coke and coal, methanol and producer gas for use in internal combustion engines.

i) Pyrolysis

Pyrolysis is defined as the thermal decomposition of carbonaceous materials in the absence of oxygen. It has been used for hundreds of years to produce charcoal. However, if the by-products of pyrolysis are recovered (liquid and gaseous fuels), the total efficiency of the process can be much improved.

ii) Gasification

Gasification is a high temperature process in the pre-

sence of oxygen that results almost exclusively in gaseous fuels. Gasification to low or medium joule gas in the presence of air is the most efficient conversion process next to direct combustion.

Producer gas consists of carbon monoxide and nitrogen produced by the burning of carbon in a supply of air insufficient to convert it to charcoal. Low joule producer gas has a long history -- it was widely used in the Second World War to power motor cars, especially in Sweden.

There are a number of producer gas plants in operation around the world. The gas can either be burned directly in a furnace or boiler or cleaned before use in an internal combustion engine. The Beijer Institute of Sweden is currently conducting research into the use of producer gas, especially as a fuel for small-scale electricity generation.⁸

Water gas is mainly a mixture of carbon monoxide and hydrogen that may be burned or used as a source of hydrogen for synthesizing methyl alcohol.

iii) Liquid Fuel Production

Methanol and a liquid fuel similar to fuel oil can be produced directly from woody materials through pyrolysis, hydrogenation, or other thermo-chemical processes. The gases from pyrolysis and gasification are crude synthesis gases that can be used to produce methanol, higher alcohols, hydrocarbon liquids and hydrogen by a variety of processes.

The potential of methanol produced from wood has been receiving increasing attention. The United States, Canada,

France, Sweden, and Brazil are all working on methanol technology and testing methanol powered vehicles.

There are no major technological problems with the use of methanol as a supplementary fuel for existing gasoline powered engines. Up to 15 per cent of gasoline can be replaced by methanol without major adjustments to gasoline engines. Specially modified engines can burn pure methanol.

The main problem with methanol use has been the relatively high production cost, estimated in the range of \$1.00 to \$1.25 US per gallon.⁹ Methanol contains just under half the energy value of the equivalent weight of gasoline. With the ex-refinery cost of gasoline at about \$1.00 to \$1.10 US per gallon, methanol is not yet competitive in the U.S. unless it is given special treatment -- such as tax exemptions.

However, recent data from Brazil indicate a production cost for methanol of about 40¢ to 60¢ US per gallon based on a wood price of \$12 per cubic metre, including the cost of transport (100 km).¹⁰ This indicates that methanol production is now becoming economic in Brazil where the average cost for refined oil products ex-refinery is estimated at 85¢ per gallon. Brazil is considering shifting some emphasis from the production of ethanol to the production of methanol.

Methanol has a strong advantage over ethanol because production of methanol need not compete with the production of food. Ethanol is produced from agricultural crops -- plantations for the production of ethanol may encroach on land that could be used for food production. Trees, on the other

hand, can be grown in areas that are marginal for agricultural production; where soils are poor, slopes are steep, or rainfall is minimal.

Methanol holds considerable promise for the near future as a supplement to or substitute for gasoline or diesel in internal combustion engines and for fuel oil in boilers. It will be especially attractive in countries with limited fossil fuel deposits, available land, and a serious balance of payments problem.

c) Brazil: A Strong Example of the Use of Woodfuels for Import Substitution

An example of the degree to which wood and wood derivatives can replace petroleum can be seen in the plans of Brazil. The World Bank and the Brazilian government are preparing a project that has as its objective the substitution of Eucalyptus wood, densified pellets, or charcoal for oil in a number of industries including ceramics, grain drying, food processing, steel manufacture, pulp and paper, and cement. Preliminary studies indicate that this is economic in Brazilian conditions, where there are high growth rates and short rotations.¹¹ The government of Brazil hopes to replace 24 per cent of fuel oil with woodfuels by 1985, which is equivalent to 120,000 barrels of oil per day.¹² In addition, pilot scale methanol plants using gasification techniques are being constructed in Brazil.

Brazil cannot be taken as a typical example of a developing country. It has considerable capacity for development of new technology and industry, and extensive remaining

tropical forests. And even in Brazil, concern is mounting over the rapid exploitation of the forest resources in the Amazon and other areas.

d) Outlook for the Use of Wood in Industry and Transport

Pre-processing of woodfuels, direct combustion of wood, gasification to low and medium Btu gas, and pyrolysis in retorts are all commercial technologies that are economic in some circumstances. (See Table 5). However, barriers remain to their adoption including unfamiliarity with the technology, concern over the adequacy and price of woodfuel supplies in the long-term, uncertainty about the long-term price of alternative fuels, and concern over operating performance.

Production of methanol is still at the pre-feasibility stage. Once this technology is proven to be economic, it may be an attractive route for countries that must import gasoline and are short of foreign exchange. But to produce methanol from wood a country must also have excess land that can be devoted to fuel plantations.

Woodfuels are not likely to make a contribution to industrial or transport energy requirements on the scale of their contribution to household energy uses. Expensive transformations and transportation reduce their competitiveness. But in certain locations and for certain purposes, chips, pellets, methanol or producer gas may be economic, especially when the employment generated and the foreign exchange saved by the production and use of these fuels is taken into account.

Table 5

Estimated Costs of Energy from Some Wood Conversion Systems
(1979 dollars)

<u>Process</u>	<u>\$GJ base (high-low)</u>	<u>Status</u>	<u>Date of Commercial Availability</u>
<u>Direct Combustion</u>			
Steam	4.39 (3.48-6.24)	Commercial	1980
Electricity	21.25 (16.23-30.07)	Commercial	1980
Steam/Electricity	4.96 (3.94-7.08)	Commercial	1980
<u>Gasification</u>			
low joule gas - raw	3.52 (2.36-5.33)	Commercial	1980
- clean	5.42 (3.24-8.56)	Commercial	1980
medium joule gas	5.54 (4.26-9.10)	Laboratory/Pilot	1988
high joule gas (S.N.G.)	13.40 (10.30-20.80)	Concept/Demo	1988
Methanol	16.10 (12.70-24.00)	Concept	1988
<u>Liquification</u>			
PERC to oil	8.60 (6.60-13.00)	Pilot	1990
Pyrolysis to oil	8.85 (5.51-14.48)	Demonstration	1985
<u>Petroleum Products</u>			
Gasoline	5.10 - 6.00		
Diesel	4.87 - 5.40		
Heavy Fuel Oil	3.00		

Source: U.N. Conference on New and Renewable Energy Sources, "Technical Panel on Biomass Energy, Final Report", (13 Jan. 1981). Calculations based on wood price of \$19.60 to \$33.30 per dry ton.

Petroleum Product prices f.o.b. Far Eastern Refineries, Reported March 29, 1983 and corrected back to 1979.

4. Potential Contribution of Woodfuels to Energy Requirements

The author carried out a study of the potential of renewable energy sources in Guatemala as part of a United Nations Development Program project. This study indicated that hydro-power, fuelwood, bagasse and alcohol produced from sugar could all make important contributions to energy requirements.

The study results are summarized in Tables 6 and 7. If woodfuel supplies were increased and new technologies including efficient woodstoves were adopted, wood would continue to be a major fuel in households and small industry, and would contribute approximately 107,000 TeraJoules (TJ) or the equivalent of 5.5 million barrels of petroleum products in the year 2000 (equivalent to almost one quarter of all petroleum needs according to the base year forecast). This would supply just over 30 per cent of all energy requirements in the year 2000.

The importance of wood relative to other energy sources would decrease from its current level of 60 per cent of total energy supply, but it would still be significant. If action is not taken, fuelwood will be extremely scarce by the year 2000.

This analysis applies to only one country. However, the order of magnitude of the estimate could be applied to many of the other countries where woodfuels currently supply 25 per cent or more of total energy requirements.

TABLE 6

ESTIMATE OF MAXIMUM RENEWABLE SCENARIO

Year 2000 A.D.

(Tera-Joules)

	Basic Forecast	S u b s t i t u t i o n s			Maximum Renewable Forecast
		Amount	Substitution	For	
<u>Hydro</u>	57,700	(2,500)	geothermal	hydro	55,200
<u>Petroleum</u>	172,000	(4,800)	wood in industry	petroleum products	
		(11,100)	wood in household	petroleum products	
		(2,000)	biogas	petroleum products	
		(10,400)	alcohol	petroleum products	
		(6,500)	solar	petroleum products	137,200
Bagasse	15,700	---			15,700
Fuelwood	58,300	48,700	fuelwood	petroleum products	107,000
Solar	0	6,500	solar	petroleum products	6,500
Geothermal	0	2,500	geothermal	petroleum products	2,500
Biogas	0	2,000	biogas	petroleum products	2,000
Alcohol	0	10,400	alcohol	gasoline	10,400
	<u>303,700</u>				<u>336,500</u>

Source: Van Meurs & Assoc. Ltd, Final Report on Renewable Energy,
United Nations Development Program Project GUA/74/014,
(March 1981), p. 27.

TABLE 7

ESTIMATE OF MINIMUM RENEWABLE SCENARIO

Year 2000 A.D.

(Tera-Joules)

	<u>Basic Forecast</u>	<u>S u b s t i t u t i o n s</u>			<u>Minimum Renewable Forecast</u>
		<u>Amount</u>	<u>Substitution</u>	<u>For</u>	
Hydro	57,700	(28,850)	Heavy Fuel Oil, Diesel	Hydro	28,850
Petroleum	172,000	(500)	biogas	kerosine propane	
		7,150	kerosine, dom.	wood	
		3,800	kerosine + diesel	wood	
		84,850	diesel, bunker	hydro	
		(3,000)	solar	kerosine, propane	
		2,400	petroleum products	bagasse	
					266,700
Bagasse	15,700	(3,700)	petroleum products	bagasse	12,000
Fuelwood	58,300	(43,135)	petroleum products	dom. wood	
		(15,165)	petroleum products	wood ind.	0
Solar	0	3,000	solar	petroleum products	3,000
Geothermal	0	0			0
Biogas	0	500	biogas	petroleum products	500
Alcohol	0	0			0
					311,050

Source: See Table 6.

Notes -- Chapter II

1. Erik Eckholm, "The Other Energy Crisis", p. 17.
2. The following discussion on characteristics of fuel is based on the Federal Energy Agency, A Handbook of Tables and Conversion Factors for Combining and Comparing International Energy Data (Washington: June 1977).
3. For an analysis of the problems regarding introduction of biogas see Andrew Barnett, Leo Pyle and S.K. Subramjan, Biogas Technology in the Third World: A Multidisciplinary Review (Ottawa: I.D.R.C., 1978), p. 92-95.
4. Gerald Foley and Adriane van Buren, "Coal Substitution and Other Approaches to Easing the Pressure on Woodfuel Resources", paper prepared for the Second Meeting of the Technical Panel on Fuelwood and Charcoal, U.N. Conference on New and Renewable Energy Sources, (Rome, December, 1980).
5. Nigel Smith, Wood: An Ancient Fuel with a New Future, Worldwatch Paper 42 (January 1981).
6. David A. Tillman, Wood as an Energy Resource (Academic Press: New York, 1978), p. 99-100.
7. Ibid., p. 144-148.
8. Bjorn Kjellstrom, Producer Gas 1980, The Beijer Institute (Stockholm: International Foundation for Science, 1981).
9. "How Costs of Emerging Technologies Compare in Constant 1979 Dollars", Oil and Gas Journal, (June 23, 1980), p. 81.
10. Companhia Energetica de Sao Paulo, "Methanol from Wood in Brazil", undated.
11. World Bank, "Review of Bank Financed Forestry Activity for Fiscal Year 1981", (Washington: 1981), p. 10.
12. Ministry of Mines and Energy of Brazil, Brazilian Energy Model (Sao Paulo: 1981), p. 13.

Chapter III

Current Woodfuel Supply/Demand Situation

Rapidly increasing populations have led to the clearing of forests for agriculture and pasturage and greater pressure on remaining wood resources to supply fuelwood, fodder, and building materials. Increasing reference has been made in forestry literature to the "fuelwood crisis", the "poor man's energy crisis", and to the serious problem of deforestation in tropical regions.¹

What is the evidence? A comparison of the total consumption of wood with the total annual production of wood in the world's forest is meaningless for a number of reasons. First, much of the remaining tropical forest is located in remote regions, far from the centres of concentrated demand for fuel (for example, the Amazon regions of Ecuador, Peru, and Brazil). The resources available in these forests are not practical sources of fuels.

• Second, the forests are not the only source of supply for woodfuels. Wood is gathered in household gardens, and from areas of scattered trees and bushes that are not classified as forests. No one has adequate measurements of the production of such non-forest wood resources.

Third, the data on consumption and production of wood in general are poor in quality. No significant conclusions can be made on the basis of inaccurate quantitative data.

There are, however, a number of studies that have tackled an assessment of woodfuel supply problems. None of them succeeds totally, but a brief examination of their methods and

conclusions does indicate the magnitude of the problem.

1. F.A.O. Map of the Fuelwood Situation in the Developing World

The F.A.O. has addressed itself specifically to fuelwood supply problems in a recent study done for the Technical Panel on Fuelwood and Charcoal of the U.N. Conference on New and Renewable Energy Sources.²

In their study, the fuelwood situation in different areas of the world is stratified into four classifications:

Acute Scarcity Situation -- zones or countries where existing wood resources have been depleted to the point where populations are no longer able to obtain sufficient fuelwood even by overcutting.

Deficit Situations -- zones or countries where populations are still able to meet minimum fuelwood needs but only by cutting in excess of sustainable supply.

Prospective Deficit Situations -- zones or countries where supplies still exceed demand in 1980, but which will move into a deficit situation by the year 2000 if present trends continue.

Satisfactory Situations -- zones or countries where for the area as a whole there will still be adequate supplies by the year 2000 although there may be localized shortages.

The stratification was done by comparing estimated supplies and needs in 1980 and the year 2000. An estimate was made of supplies by estimating the area of existing productive forests, woodlands, scrublands, plantations, and rural woodlots. The resulting estimates were multiplied by estimated mean average fuelwood productivity to result in an estimate of total fuelwood availability. This in turn was multiplied by an accessibility ratio to give an estimate of total

accessible fuelwood resources in 1980 and in the year 2000.

This wood supply was compared to fuelwood requirements which were obtained by multiplying an estimated wood using population by the mean average fuelwood need per person.

Forecasts to the year 2000 are based on a continuation of current trends in plantation establishment, forest management, and depletion of wood resources.

This study states that, today, one hundred million people cannot obtain sufficient fuelwood to meet even minimal needs. A further billion people live in situations of growing deficit where minimum needs are met at the cost of depleting current resources. (See Table 8).

If present trends continue, by the year 2000 2.4 billion people will be facing fuelwood shortages. Appendix 2 contains more detail on the results of the study.

Areas of current acute scarcity include parts of the following countries: Upper Volta, Nigeria, Tanzania, Sudan, Burundi, Lesotho, Rwanda, Swaziland, Afghanistan, India, Nepal, Pakistan, Bolivia, Peru, El Salvador, and Haiti. Areas of current deficit where the forest capital is being depleted are spread even more widely throughout the world.

The methodology used in this study is a reasonable one. The results, however, are dependent on the quality of the data used. The data available for making estimates of fuelwood supplies and requirements on a highly localized basis is very poor. Few forests in developing countries have been inventoried.

Table 8
Populations Involved in Fuelwood Deficit Situations^{1/}
(million inhabitants)

Region	1980						2000	
	Acute Scarcity		Deficit		Prospective Deficit		Acute Scarcity or Deficit	
	Total	Rural	Total	Rural	Total	Rural	Total	Rural
Africa	55	49	146	131	112	102	535	464
Near East and North Africa			104	69			268	158
Asia Pacific	31	29	832	710	161	148	1 671	1 434
Latin America	26	18	201	143	50	30	512	342
Total	112	96	1 283	1 052	323	280	2 986	2 398

^{1/} The table indicates the total population and the population with a predominant rural type of energy consumption (total population less urban centres over 100 000 inhabitants); these are the estimated populations living in the areas under the identified fuelwood situations.

N.B.: This table is a revision of Table 2 of the Final Report of the Technical Panel on Fuelwood and Charcoal.

Knowledge about the extent of wood resources in household gardens and scattered on farmland and grazing land is virtually non-existent. And estimates of fuelwood consumption per capita are not reliable.

The results of the study for many areas can then be questioned. However, the overall conclusions of the study do indicate the direction and magnitude of fuelwood problems.

2. World Bank, Renewable Energy Task Force Study, Developing Countries Fuelwood Supply/Demand Analysis, 1978-2000

This study is one which was carried out by the World Bank as part of its studies on the potential of renewable energy to contribute to energy requirements in the developing world.³

The methodology used in the study can be derived from the tables in Appendix 3. First, estimates were obtained of current population, and current fuelwood use, by country. From these figures, an average figure for fuelwood consumption per capita can be calculated.

This average fuelwood consumption per capita was then applied to the total projected population in the year 2000, in order to calculate projected fuelwood consumption in the year 2000. The task force then assumed that some substitution of other renewable fuels for fuelwood would take place as well as some conservation due to more efficient use. The combined effect is to reduce projected fuelwood consumption by 10 to 40 per cent. The remainder of the projected fuelwood consumption (residual fuelwood demand) will have to be supplied from

wood resources.

An estimate of the ability of the natural forest to supply this demand is made based on the total area of natural forest and "guesstimates" made by World Bank staff. An estimate is then made of the amount of residual fuelwood demand that must be met by plantations and of the rate of planting needed to achieve that objective. This rate is then compared to actual current rates of planting. The analysis is summarized in Table 9.

The study indicates that there is a need for a five-fold increase worldwide in the level of plantations being established for fuelwood production. In Africa and individual countries in other regions, the factor of increase needed is much higher.

The rather simplistic approach taken in the study can be criticized for a number of reasons. First, there are many assumptions that are no more than guesses, such as the percentage reduction in fuelwood needs caused by conservation and substitution, and the "guesstimates" of availability of wood from natural forests.

Also, the origin of some of the figures for fuelwood consumption is mysterious. For Guatemala, as an example, consumption figures are not taken from the F.A.O. Forest Products Yearbooks, from F.A.O. studies, from a recent survey, or from official government figures. The figure used is much too low according to any of these sources. (See Appendix 3 for country data).

Table 9

WORLD BANK
RENEWABLE ENERGY TASK FORCE STUDY
DEVELOPING COUNTRIES FUELWOOD SUPPLY/DEMAND ANALYSIS¹
1980-2000

Summary

REGION	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Popu- lation in 1980 Mil- lions	Projected Population in Year 2000	Current Fuel- wood Consump- tion Million m ³	Pro- jected Fuel- wood Consump- tion Million m ³	Alter- native Fuel Substiti- tion Million m ³	Net Fuel- wood Require- ment (10 of Col 7)	Natural Forest Supply (11 of Col 7)	Area of Natural Forest Million ha	Area of Plantations to be Established (12 of Col 7)	Present Area of Fuel- wood Plantations Million ha	Balance of New Plantations to be Established (13 of Col 7)	Col (13) less Col (12) million ha	Actual Current Annual Fuel- wood Planting Program to Year 2000 million ha	Actual Current Annual Fuel- wood Planting Program to Year 2000 million ha	Factor to be increased to achieve Col (15)	
EAST AFRICA	192	109 238	347	155	281	22	217	332.7	20	157	9.8	174	9.7	490	31	15
WEST AFRICA	163	114 183	297	102	191	21	146	94.8	20	120	9.3	63	9.3	465	30	16
SOUTH ASIA	929	478 954	1432	162	371	23	263	132.9	28	227	15.8	980	14.8	740	267	3
EAST ASIA AND PACIFIC	367	206 348	554	183	290	29	186	211.0	35	142	6.5	1201	5.7	285	83	3
EXTRA	56	42 53	95	12	23	32	14	5.8	8	13	1.5	270	1.2	60	13	5
LATIN AMERICA & CARIBBEAN	337	191 176	577	209	379	22	256	236.6	20	202	12.2	1091	11.4	580	140	4
	2044	1140 1952	3902	823	1535	24	1084	1513.8	21	861	25.1	3779	52.1	2670	546	5

^{1/} This analysis refers to plantations or on farm tree planting specifically for production of fuelwood. It excludes investment in 'other' forestry projects part of which would also produce fuelwood.

Again, while the figures can be questioned, the broad picture cannot. There is a desperate need for the establishment of new fuelwood resources, especially in Africa.

3. Local Signs of Supply Problems

Ultimately, fuelwood shortages are site-specific and must be assessed at the local level. Only fragmentary evidence is available to indicate the state of wood supply, but this evidence points to growing shortages.

Evidence of fuelwood shortages on an individual or local level includes:

- ... a lengthening amount of time required to gather wood in rural areas,
- ... supplementing of fuelwood with agricultural wastes that would normally have been returned to the soil,
- ... changes in dietary patterns such as cutting back on the number of meals cooked or eliminating foods with long cooking times,
- ... woodfuel prices that rise faster than prices for other commodities,
- ... the trucking of woodfuels to market over long distances.

Evidence on these points is scattered and incomplete, but in many locations such as Upper Volta, Central Tanzania, the Andean highlands, Nepal, parts of India, some areas of Haiti, and much of the Sahel, evidence of fuelwood shortage has been recorded.⁴

4. A Classification of Countries According to Degree of Fuelwood Scarcity

Putting together the evidence from the F.A.O. study,

the World Bank study, and scattered references in the literature to local shortages, it is possible to make a rough classification of countries that identifies those countries where woodfuel plays an important role in energy use, but where woodfuel supply is or will soon become a serious problem.

First, the countries where recorded woodfuel supplies more than five per cent of all energy needs are identified as those where action is most critical. These countries are classified according to the current fuelwood supply situation -- one where no problems are foreseen, where deficits are forecast in the future, or where acute scarcity or deficits now exist.

Again, because fuelwood supply is a local problem, a situation of scarcity or deficit may exist in one part of a country while there may be a surplus of forest resources in another part of the country. Similarly, in some of the countries where fuelwood plays a minor role, there are areas where fuelwood use is important and scarcities exist (Peru, Ecuador, China, and Pakistan).

Table 10 summarizes this classification of countries. Countries in an especially critical situation are those where fuelwood supplies more than 25 per cent of all energy needs and fuelwood deficits or scarcities exist.

For oil-importing countries in this classification, the situation is urgent. Most African countries fall into this category, along with Central American countries such as Guatemala and El Salvador, South American countries including

Table 10

Classification of Developing Countries by
Degree of Dependence on Wood and by
Degree of Woodfuel Shortage

Wood Supplies 5 - 24% of all Energy			
	No. Problems Foreseen	Prospective Deficits	Acute Scarcity or Deficit
Africa		+ Tunisia	
Mexico, Central America and Caribbean	Panama	Barbados	Dominican Rep.
South America	+ Venezuela	Uruguay	Chile + Ecuador + Peru
Middle East		Turkey	
Far East	+ Malaysia	+ Burma	+ China Pakistan

+ Oil Exporting Countries

Table 10 (continued)

Wood Supplies 25 - 49% of all Energy			
	No. Problems Foreseen	Prospective Deficits	Acute Scarcity or Deficit
Africa	+Gabon Liberia	Ivory Coast Mauritania Zimbabwe	Zambia
Mexico, Central America and Caribbean	Belize Costa Rica Nicaragua		El Salvador Guatemala
South America			Bolivia Brazil Columbia
Far East			Bangladesh India +Indonesia Philippines Sri Lanka Thailand Vietnam

Table 10 (continued)

Wood Supplies 50 - 99% of all Energy		
No. Problems Foreseen	Prospective Deficit	Acute Scarcity or Deficit
Africa	C.A.R.	+ Angola
	+ Congo	Benin
	Eq. Guinea	Burundi
		Cameroon
		Ethiopia
		Gambia
		Ghana
		Guinea
		Kenya
		Lesotho
		Malawi
		Madagascar
		Mozambique
		Niger
		+ Nigeria
		Rwanda
		Senegal
		Somalia
		Tanzania
Central America and Caribbean		Togo
		Uganda
		Upper Volta
		Zaire
		Haiti
Far East		Afghanistan
		Nepal
	Honduras	
	Kampuchea	
	Lao, P.D.R.	

Bolivia, Brazil, and Columbia, and Asian countries such as India, Thailand, and the Philippines.

In total, 39 of the 114 countries examined, representing a total population of 1.48 billion, fall into this category.

5. Consequences of Fuelwood Shortages

The people who use fuelwood and charcoal are those with the least access to wealth and resources. They are subsistence farmers, the urban poor, and those engaged in traditional industries. The consequences of woodfuel shortages to these people are discussed below.

a) Diversion of Agricultural Waste and Dung from Agriculture

For the rural poor, the only alternatives to woodfuel are agricultural and animal wastes. In India, an extreme example where woodfuel is scarce in many areas, 10 per cent of all energy use is derived from burning cowdung cakes, representing a loss from 60 to 80 million tons of organic matter to the soil per year. Worldwide, the use of manure as fuel is estimated to reduce the potential food grain production by some 20 million tons, enough food to nourish 100 million people.⁵

In some situations, biogas could provide an alternative solution since methane and fertilizer could be produced from the dung that is currently burned.

In areas where families do not have access to animal dung, the only alternative is agricultural wastes, such as corn stalks and cobs, coffee and nut husks. Where such wastes

would normally be returned to the soil, productivity is reduced because the soils are denied recycled nutrients and conditioners. Even if the ash is returned to the soil, nitrogen and organic matter would still be missing.

b) Increased Use of Imported Petroleum Products

While most fuelwood is still used by those who gather it, the commercialization of fuelwood and charcoal is spreading. For those who buy woodfuels, the most likely alternatives are kerosene, propane, and electricity. As credit arrangements become widespread in developing countries, it will be easier and more economical to invest in a stove that uses commercial fuels. Spiralling fuelwood prices and irregular availability will eventually force a switch to kerosene and propane.

The F.A.O. forecasts that 2.4 billion people will be experiencing fuelwood shortages in the year 2000 if current trends continue unchecked. If even one half of these people were to shift to a reliance on petroleum products, demand for petroleum products would increase by a minimum of 1.9 million barrels per day.⁶

Total oil use in oil-importing developing countries in the year 2000 is predicted to be 13 million barrels per day, of which six million barrels per day will be supplied from domestic sources.⁷ The additional demand quoted above will have to be supplied mainly by imports. If 80 per cent. of the total were to be imported, the total cost at current oil prices (\$29 US per barrel) would be \$44 million per day or approximately \$16 billion per year in 1983 US dollars.

c) Effects on the Well-Being of Families

People now have to spend increasing amounts of human energy or real income in order to maintain a very low level of wood energy utilization.

There is little hard data on the effects of woodfuel scarcity on the health of both rural and urban poor. But the effects are quite apparent. They include the necessity to reduce the number of cooked meals; changes in diet to foods that may require less cooking time, and which may have less nutritional value; the inability to use firewood to provide heat to the young, old, and sick in cold climates; and the deepening poverty resulting from the diversion of income or productivity to the purchase or gathering of fuelwood.⁸

The burden of fuelwood is only part of the cycle that weighs down poor families in both rural and urban areas in developing countries. Distribution of land, resources, skills, and wealth are certainly more fundamental issues. However, the cycle must be broken somewhere and woodfuel offers one part of the solution. For the urban poor, the ability to buy fuelwood or charcoal at reasonable prices would free resources for other purposes. For the rural small landholding poor, planting scattered or bordering trees on agricultural land can provide fuelwood and contribute to increased fertility and a better cycle of water availability.

d) Contributing to Deforestation

It is important to understand the relationship between deforestation and fuelwood use. Fuelwood use is not the primary

cause of deforestation in most areas, but is a contributing factor, especially in areas already cleared for agriculture.

The typical pattern of forest exploitation by rural dwellers in developing countries is as follows. As population grows, people begin to migrate from fertile valleys to surrounding foothills and mountainsides. Forests are cleared to free land for cultivation. Branches are cut from the remaining trees for feed and fodder and eventually the trees themselves are cut. The first rains begin the process of erosion, run-off increases and causes flooding in the valleys. Food production is reduced and more land must be cleared.⁹

Clearing of tropical forests results in the same sort of cycle. Much of the land cleared is not suitable for agriculture. There is no accumulation of humus, the storehouse of minerals. All nutrients are in the forest foliage. When the forest is removed, so are the nutrients. Farmers must move on every few years, clearing a new patch of land and leaving behind impoverished soil.

In arid lands, cattle and goats are often a source of livelihood and increasing herds can lead to desertification. Their grazing and fires started to encourage new growth on exhausted grasslands may eventually destroy the limited forests that exist. The few remaining trees and shrubs are taken to meet the heavy demand for fuelwood and fodder.

There is also a destructive cycle at work in the supply of wood to urban areas.

5 (The producer of charcoal or fuelwood systematically clears, legally or otherwise, areas of woodland and forest radiating from urban centers until the point is reached when it either becomes uneconomic to transport the charcoal (or fuelwood) or the raw material supplies are exhausted.¹⁰

The areas surrounding urban centers are also intensively cultivated for agricultural purposes. The combination of these heavy pressures can result in the eventual creation of virtual deserts around urban centers.¹¹

These patterns of land and forest use are inherently destructive. The concept of renewing the forest to ensure future wood supplies and protect the fertility of the soil is not incorporated into local practice. The uncertainty and poverty of life focuses concern on today's needs: food, shelter, and firewood. These cycles lead inevitably to the destruction of forests whenever there is extensive human habitation.

Where woodfuel use contributes to deforestation, it can be considered as partly responsible for environmental degradation. A joint report of the World Bank and F.A.O. describes some of the consequences that can be measured economically:

The extent of damage due to excessive deforestation in upland areas of developing countries has been well documented. The evidence of flooding in the Indus River system in Pakistan, for example, has been far higher in the past twenty-five years than in the previous sixty. Increased flooding, partly attributable to denudation of catchment areas has led to silting of dams and canals in Pakistan's irrigation system. Flood damage below the deforested Himalayan catchment areas of Northern India has affected an area averaging 6 million hectares per year for the last 10 years, and the cost of crop losses and repairs to flood damage has averaged about U.S. \$250 million per year.¹²

6. Is There a Crisis?

A shortage of fuelwood is much more than an energy problem. As wood scarcity becomes severe in rural areas, dung and agricultural residues are diverted from agriculture to supplement woodfuel. More time is spent on gathering wood and less on productive activities. As woodfuel prices rise in urban areas, people are forced to divert an increasing share of income to energy needs. Small industries that relied on wood as a cheap fuel are no longer able to operate. The supply of wood is therefore critical to the well-being of individuals, industries and national economies in much of the developing world.

Is there a global fuelwood crisis? To some extent this question is misleading. First, a crisis is defined as a critical stage at which further events are determined. The oil crisis of 1973/74 fits this definition. The structure of world oil markets was permanently changed with producer country governments taking decisive control over oil prices.

The term when applied to fuelwood is less obviously apt. The woodfuel situation in many areas has been deteriorating for centuries; there is no sharp, sudden break to mark a crisis.

Also, since the market for fuelwood is limited to a few hundred miles, there are no immediate global repercussions of supply problems. The people affected are isolated from one another and from the industrialized world.

However, on the basis of all available evidence, wood-fuel supply shortages are widespread and growing, affecting increasing numbers of people.

According to the F.A.O. study, there are about sixteen countries where acute scarcity at local levels is widespread. There are an additional 34 countries where deficits in supplies now exist and the situation is likely to be critical by the year 2000. Development planners in all these countries must be concerned with acting now, before it is too late. In this sense, there is a real crisis. It will take time to educate people about the importance of trees, to change the age old perception that wood is a "free" good, like air.

Notes -- Chapter III

1. See Erik Eckholm, "Planting for the Future: Forestry for Human Needs", Worldwatch Paper 26, (1978); John Spears, "Wood as an Energy Source: the Situation in the Developing World", paper presented to the 103rd Annual Meeting of the American Forestry Association (Washington:1978); J.E.M. Arnold, "Wood Energy and Rural Communities", Natural Resources Forum 3 (1978), p. 229-252.
2. F.A.O., "Map of the Fuelwood Situation in Developing Countries", (Rome: 1981), presented at the U.N. Conference on New and Renewable Energy Sources, Nairobi, 1981.
3. World Bank, "Renewable Energy Task Force Study, Developing Countries Fuelwood Supply/Demand Analysis, 1978-2000", unpublished tables (Washington: 1981).
4. See Eckholm, "Planting for the Future", p.21-22; Spears, "Wood as an Energy Source", p. 5-7 ; Arnold, "Wood Energy", p. 237-238
5. Spears, Ibid., p. 5.
6. Assumes 1.2 billion people using one cubic metre of wood per year per capita, on average, with an energy content of 9.4 GJ/m^3 , replaced by kerosene used three times as efficiently with an energy content of 5.57 GJ/barrel.
7. A.P.H. Van Meurs, Modern Petroleum Economics, (Ottawa: Van Meurs and Associates Ltd., 1981), p. 770.
8. See Arnold, "Wood Energy"; Spears, "Wood as an Energy Source"; DEVRES, "The Socio-Economic Context of Fuelwood Use in Small Rural Communities", Aid Evaluation Study No. 1, (August 1980).
9. F.A.O., Forestry for Rural Communities, (Rome: 1978), p. 7-8.
10. Keith Openshaw, "Woodfuel -- a Time for Re-assessment", Natural Resources Forum 3, (1978), p. 43.
11. Some analysts talk of virtual deserts created around cities by fuelwood use. However, this is generally true only where the creation of small farms or pasturage lands has already largely denuded the landscape of trees.
12. World Bank/F.A.O., "Forestry Research Needs in Developing Countries -- Time for a Reappraisal?", paper for the 17th IUFRO Congress, Kyoto, Japan (August 1981), p. 5.

Chapter IV

The Current System of Woodfuel Supply, Conversion and Utilization

An understanding of the way in which fuelwood is harvested, converted to charcoal, and utilized as fuel is fundamental to identifying problem areas that are resulting in woodfuel shortages.

1. Wood Supply: Current Practices

There are three main supply routes for woodfuel from tree to user. First, wood that is collected by the individual end user. Second, wood that is collected for commercial sale or for conversion to charcoal. And third, wood that is grown and processed by industry for its own use.

a) Wood Collected by the End User

Most of the wood used for fuel in the home is gathered by a family member, outside the money economy. Wood requirements for cooking and space heating using traditional methods are considerable. Estimates range from half a cubic metre to two and one quarter cubic metres per person a year,¹ with an average of one cubic metre per person annually. For a family of six, this amounts to three to fourteen cubic metres per year, or 1.5 to 6.5 cords per year.

At the upper end of the scale, the task facing the women and children who collect wood is daunting. It is comparable to a North American heating his home with wood and obtaining his yearly supply with his bare hands, a machete and a small axe, making a round trip of up to 20 kilometres on foot with each heavy load of cut wood.

In some areas, such as Central Java, Indonesia, household gardens supply over one half of all fuelwood needs,² which minimizes the labourious task of collecting wood. But in most cases, wood is collected from trees on family land and from scattered trees and bushes, or forests, on communally or publically owned land.

Access to wood resources can vary greatly even among families living in the same area. Government regulation and private ownership of land are constraints on access to wood. Wherever fuelwood is scarce and private property rights exist, they tend to be more strictly enforced. Those who do not own land or whose wood resources have run out, resort to collecting wood from publically owned land. Pressure on publically owned land and forests then increases since few forestry services have the resources to enforce government regulations.

Publically owned wood resources are seen as a "free" good. This is the classic case of the "tragedy of the commons": where wood is gathered on publically owned land and resources are scarce, it benefits each individual to collect the maximum possible, but it is to the advantage of no single individual to plant trees to ensure the long-run sustainability of the resources. Very few trees are planted in developing countries to produce fuel.

Wood collection begins near the home, but people will travel as far as five to ten kilometres, one way, to obtain wood. When the distance to the nearest wood resource is greater than 15 kilometres, the use of wood drops off drastically.³

Women and children use few tools and gather mainly dead-wood, branches, twigs, bark, and stumps. When wood is in short supply, they also gather non-woody tissues such as fresh twigs, leaves, and even grasses.

Where distances are great or where trees must be cut down to obtain wood, men participate in collecting wood supplies. The tools they use, a machete or lightweight axe, limit the size of the trees that can be harvested. A common sight in many developing countries is a large tree with all of its branches lopped off to a height of 15 to 20 feet above the ground.

Human heads and backs transport most wood from the place of collection. Women carry loads in the range of 10 to 35 kilograms, while men carry as much as 50 kilograms in a single load.⁴ Heavy loads are common where distances are long, in order to minimize the frequency of trips.

Burros, donkeys, horses, and even bicycles are sometimes used to transport wood, although this is more common where wood is being collected for commercial sale.

The job of collecting wood for a family may be a light or arduous one depending on the situation. Women of the Nyakyusa tribe in Tanzania are reported to spend between two and five and one half days a month searching for fuel. However, in some parts of central Tanzania, a family member must spend between 20 to 25 days a month in wood collection. Reports from northern Ghana indicate collection times of 10 days a month, from Gujarat, India, 11 days a month, and from Nepal,

15 to 19 days a month. (See Table 11).

The wide variations in collection times reflect a number of factors, including the collector's access to fuelwood resources, the wood requirements of the family (as determined by family size, cooking habits, and the degree to which wood is used for space heating and light), the efficiency of the collector, and the degree to which other tasks or socializing are done at the same time.

Wood is becoming scarce in some unexpected places. In some parts of the once heavily forested Himalayan foothills of Nepal, it takes an entire day to collect sufficient amounts of fuelwood and fodder. One generation ago it required only an hour or two.⁵

Reports are scattered and there are no times series data, but wherever studies have been done, the task of collecting wood is becoming more arduous.

This is cutting into the time people can devote to other productive tasks. Women have less time for agriculture, sewing, weaving, and cooking. Men must increasingly bear the double burden of agricultural production and firewood collection. And children may have to spend much of the day foraging for fuelwood, rather than attending school or studying.

Eventually, no amount of labour will procure sufficient fuelwood and people are forced to use dung and agricultural wastes for fuel, or to purchase fuel.

Table 11

Time Spent in Gathering Woodfuel

Various Locations

Location	Reported Length <u>250-300 days/yr.</u>	Reported Length Converted to Days/Year	Rating in Order of Time Required
		250 - 300	1
Central Tanzania			
Kwemzitu tribe, Tanzania	11 hours/week	72	7
Nyakyusa tribe, Tanzania	4-10 hours/week	26 - 65	8
Mbere tribe, Kenya	2½-10 hours/week	16 - 65	8
Boulenga, Upper Volta	4½ hours/day	200	3
East Pasil, Phillipines	½-4 hours/day	22 - 180	4
Peru	½-1 day/week	26 - 52	9
Gujarat, India	3 hours/day	137	5
Nepal	1½-5 hours/day	68 - 228	2
Tallensi tribe, Northern Ghana	1 day for 3 days supply,	122	6

Sources:

- J.E.M. Arnold, "Wood Energy and Rural Communities", Natural Resources Forum 3 (1979) p. 237.
- DEVRES, "The Socio-Economic Context of Fuelwood Use in Small Rural Communities", AID Evaluation, Special Study 1 (August 1980) p. 29-31.
- World Bank, "Sociological Aspects of Forestry Project Design", AGR Technical Note #3, (November 1980) p. 25.

b) Wood that is Commercially Sold

Wood is often called a "non-commercial" fuel, a term that is becoming questionable. While much wood is still collected by the user, a growing amount is being sold or converted to charcoal for sale. There is not much data on the degree to which wood is commercialized, but a recent Guatemalan study indicated that 40 per cent of all wood using households purchased most of their wood supplies.⁶

In a Haitian village, 70 per cent of all households purchase fuelwood from time to time.⁷ In Senegal, it is estimated that a third of the fuelwood consumption is in urban areas where virtually all wood and charcoal is purchased.⁸

The collection, transport, and sale of fuelwood provides seasonal employment for an estimated four million people (10 per cent of the population) in Andhra Pradesh, India.⁹

Wherever charcoal is widely used, there is a substantial market for woodfuels, since charcoal is generally produced for sale. There is no data worldwide on the usage of charcoal, but data for certain countries indicates that charcoal accounts for as little as three per cent of total woodfuel use (Tanzania) or as much as 46 per cent of total use (Thailand). (See Table 12). In 1979, Arnold estimated that charcoal production could account for as much as 15 per cent of wood use in the developing world.¹⁰

Commercially traded wood, including wood converted to charcoal, could therefore easily account for as much as 25 per cent of woodfuel use in the third world. And its use is

Table 12

The Pattern of Consumption of Woodfuels
in Selected Countries

Country	Year	Average Use of Woodfuel per Capita/Year (cu. m.)	Charcoal as a Percent of Total Woodfuel Use (%)
Gambia	1973	1.61	26
India	1970	0.38	...
Kenya	1960	1.00	6
Lebanon	1959-63	0.17	37
Sudan	1962	1.66	42
Tanzania	1960-61	1.14	...
	1968-69	2.29	3
Thailand	1970	1.36	46
Uganda	1959	1.53	...

Source: J.E.M. Arnold, "Wood Energy and Rural Communities",
Natural Resources Forum 3, (1979), p. 233.

growing at a faster rate than non-commercial use.

The combination of urbanization and scarcity of wood resources is converting wood to a commercial commodity. Where wood is difficult to collect, even those in rural areas who can afford it will purchase wood or charcoal.

Since the collection and distribution systems for commercial fuelwood and charcoal are different, they will be discussed separately.

i) Fuelwood

Commercial fuelwood collectors work full-time or part-time gathering and cutting wood, mainly on communally or publically owned land. They sell or barter wood at the roadside, from their homes, or at markets. These small-scale operators use a minimum of tools and operate similarly to people collecting wood for their own use.

Wood vendors or brokers in larger villages and cities own trucks or hire agents with trucks to travel through the countryside to buy wood at the roadside from individual collectors. These vendors also obtain wood through large-scale harvesting, as a result of land clearing for agriculture, pasturage, or construction projects, such as dams or roads. Other sources of wood include the regular pruning of trees in fruit orchards or shade trees in plantations, and leftover wood from logging operations.

A fuelwood dealer or an intermediary may obtain a licence or contract to harvest the wood. He usually hires local labour for the job and pays a royalty to the owner of the

trees. In this case, the tools used may include crosscut saws, axes, and even chainsaws. The wood is carried to the roadside by labourers or animals, and is trucked to depots for sale in small or large urban areas.

The cost of such an operation can be substantial, as an analysis of a case from Guatemala will show. The cost per cubic metre of hardwood delivered to the vendor in Guatemala was 15 dollars US in 1979. Almost half of the cost was due to transport: loading the wood onto trucks, transporting it 70 to 100 kilometres and unloading it at the vendor's depot. (See Table 13).

Fuelwood is not a cheap commodity in many countries. In 1978, the price per cubic metre in selected locations ranged from a low of three dollars US in the forest to \$40 to \$50 for fuelwood delivered in the cities. (See Table 14). Just for comparison, the price of a cubic metre of split wood, delivered, in the state of Maine during the 1977/78 season ranged from \$17 to \$34 US.¹¹

Prices are rising rapidly. The retail price in Guatemala City rose from \$23 US per cubic metre for hardwood to \$30 between 1979 and 1980.¹² Part of this increase may be due to profiteering, but it also reflects higher handling and transport costs.

ii) Charcoal

The costs of handling and transporting charcoal are lower than those for wood, since one ton of charcoal contains as much energy as two tons of seasoned wood or four tons of

Table 13

Two Examples of the Cost of Collection and Delivery of
Wood for Commercial Sale in Guatemala, 1979

Process	Tools Utilized		Distance Transported (km)		Time Taken (man-hrs/solid m ³)		Cost (\$/solid m ³)	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Cutting, Splitting	axe machete	axe machete	N/A	N/A	8.7	10.2	2.10	2.45
Stacking, Transport to Road	human labor	human labor	1.5	0.5	N/A	N/A	2.50	1.90
Loading, Unloading	human labor	human labor	N/A	N/A	4.2	2.6	2.15	1.80
Transport	1966, 6 ton truck	1977, 7 ton truck	70	100	1.8	1.7	5.30	4.60
Other costs (20% above)	N/A	N/A	N/A	N/A	N/A	N/A	2.25	2.15
Total Costs							14.30	12.90
Profit							0.70	2.10
Price Paid by Distributor							15.00	15.00

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Source: Data collected by author.

Table 14

Selected Prices for Fuelwood in Nine Countries

Over Time
(U.S. \$/m³)

Country	Explanation	Year									
		1965	1967	1969	1970	1971	1973	1974	1976	1977	
Bangladesh	Retail in Dacca		18.30							29.40	
Burma	Retail in Rangoon	4.30								9.90	
Cameroon	Retail in Yaoundi					6.10				14.50	
India	Wholesalt at Ou Hack (Orissa)			7.30						22.90	
Indonesia	Local market price				1.30					3.20	
Madagascar	Retail in Tanarive					8.60		14.20			
Pakistan	Retail in Karachi	16.90						30.20			
Philippines	Domestic wholesale	26.50								46.00	
Senegal	Retail in Dakar							30.20		29.50	

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Source: F.A.O., Forest Product Prices 1960-1978, F.A.O. Forestry Paper (Rome: undated)

green wood. Therefore, even though charcoal costs more to produce, it can be delivered more cheaply to market when wood resources are far from the point of sale.

People in urban environments and industries that must purchase fuel often prefer charcoal to fuelwood because it is easier to handle and it burns more cleanly, steadily, and longer.

Most charcoal is produced on a small scale by individuals or small groups of charcoal makers. The most common method of production uses pits in the earth or mounds.

The charcoal producers gather a large quantity of wood, usually from communally or publically owned land. Large pieces of hardwood are often said to make the best charcoal. The wood is stacked in a pit or on the ground, fired, and covered with earth and a mixture of other materials to carbonize. Access to air is restricted to control the rate of burning. After several days, the charcoal is uncovered, removed, and packed into sacks. Since the charcoal is produced near the wood resources, the sacks must be transported by human labour or on the backs of animals to the nearest road.

At the roadside, the sacks of charcoal may be sold to drivers of passing vehicles, transported by animal, bicycle, bus, or truck to market, or carried to the producer's home for sale. Long distance transport of charcoal by road, and occasionally by rail or water, is common. There are reports of it being transported 150 kilometres in Kenya, 300 kilometres in Sudan, and up to 600 kilometres in Thailand.¹³

Prices vary widely and are rising wherever they are not controlled. The price per tonne in selected locations in 1978 ranged from less than \$50 US to \$350 US. (See Table 15). As the price for petroleum products rises, it becomes economic to produce charcoal from distant sources and from fuelwood produced in plantations as discussed below.

c) Wood that is Produced and Used by Industry

There are, as yet, only a few examples of industries in developing countries that grow, harvest, and process wood-fuels for their own use. The outstanding example is the iron and steel industry of Brazil, where charcoal was used to supply the equivalent of 20 million barrels of oil in 1979.¹⁴ Charcoal is used to replace coke as a thermo-reductant in the production of pig iron.

Companies such as the Companhia Siderurgica Belgo-Mineira have integrated the production of charcoal into their operations.¹⁵ Through an associated company (the Cia Agricola e Florestal Santa Barbara), a forested area of about 150 thousand hectares was established by 1979.

In 1979, the 1.2 million cubic metres of charcoal produced from 1.92 million cubic metres of wood, which was harvested from planted eucalyptus forests, supplied 60 per cent of the fuel needs of Belgo-Mineira steel plants. The goal is to double this production in five years.

The collection and delivery systems used by the company are mechanized. Trees are cut and split using chainsaws. The split wood is loaded into trucks and unloaded at batteries of

Table 15

Selected Prices for Charcoal in 13 Developing Countries Over Time

(\$/m.t.)

Country	Explanation	Year							
		1966	1967	1969	1970	1971	1975	1976	1977
Brazil	Delivered to consumer industry	--	--	--	22.10	--	--	--	44.80
Burma	Retail price in Rangoon	--	94.60	--	--	--	--	--	121.70
Cameroon	Retail price in Yeounde	--	--	--	--	127.00	--	--	240.00
Indonesia	Average local market price for charcoal from natural forests	--	--	--	30.10	--	--	--	90.40
Madagascar	Retail price in Tananarive	--	--	31.50	--	--	--	--	46.00
Morocco	Retail price in Casablanca	--	--	--	--	58.40	--	--	120.20
Pakistan	Retail price in Karachi	53.40	--	--	--	--	--	96.50	--
Philippines	Wholesale price for upland species	--	--	25.60	--	--	--	--	82.70
Surinam	FOB export price, 4% moisture content	--	--	--	--	--	94.00	--	104.00
Togo	Retail price in Lome	--	56.90	--	--	--	--	--	121.30
Tunisia	Retail price in Tunis	--	--	--	--	31.00	--	--	53.60
Turkey	Retail price in Istanbul	--	61.90	--	--	--	--	229.90	--
Zambia	Retail price (regulated)	--	--	--	68.00	--	--	--	61.60

Source: See Table 14.

brick-domed kilns by forest loaders.

The company says the ratio of green wood to charcoal is nearly optimal at between three and four to one by weight. Tars and gases produced in the carbonization process are being recovered as substitutes for fuel oil in the company's plants.

The cost of producing charcoal in such an operation is estimated at \$2.85 to \$3.65 per gigajoule, \$68 to \$88 per ton, in 1977, including the cost of growing the trees. It is interesting to compare the production costs of industrial charcoal in Brazil to those of Senegal, where charcoal is produced in earth pits. (See Table 16). If only the cutting, hauling, and conversion costs are considered, the production cost in Brazil is 20 to 30 per cent lower despite higher wage rates. This may be due to the higher degree of efficiency in conversion and mechanization.

Large companies in other countries are beginning to look at charcoal as a fuel. INCO Limited is considering the use of charcoal to replace up to 400,000 barrels of fuel oil per year in its nickel plant in Indonesia.¹⁶ Charcoal utilization for iron ore reduction was also considered in Liberia.¹⁷

2. Utilization of Woodfuels: Current Practices

An estimated 75 to 85 per cent of all woodfuel used in the developing world is burned in inefficient open fires or traditional stoves to provide heat for cooking, space heating, light, and protection.

Most third world families that use fuelwood cook over an open fire shielded by stones. This fire may be built on the

Table 16

Comparison of Estimated Costs of Production
of Charcoal, Senegal and Brazil (\$/GJ)

	<u>Senegal</u> <u>(1978)</u>	<u>Brazil^{a/}</u> <u>(1977)</u>	<u>Brazil^{b/}</u> <u>(1977)</u>
Cost of growing wood	0	2.80	2.17
Cost of cutting and hauling	N/A	.73	.57
Cost of conversion	<u>N/A</u>	<u>.11</u>	<u>.11</u>
Subtotal Cost/Cutting and Conversion Only	1.03	.84	.68
Total Cost at Production Site	1.03	3.64	2.85
Rate of pay for labor (\$/man-month)	40	80+	80+
Efficiency of conversion, dry weight basis	20%	32%	42%
Efficiency of conversion, energy basis	27%	41%	53%

Source: Meta Systems Inc., "Potential for Fuelwood and Charcoal in the Energy Systems of Developing Countries", prepared as a U.S. input to the Technical Panel on Fuelwood and Charcoal of the U.N. Conference on New and Renewable Energy Sources, (October 1980), p. III-20. Table modified using data from p. III-18 for the cost of growing wood.

ground, or on elevated surfaces, ranging from adobe blocks to barrels filled with earth. In most countries, there are also a wide variety of different types of stoves that have been constructed by local artisans (See Appendix 4). The efficiency of an open fire or traditional stove is generally in the range of 5 to 10 per cent.

Recent studies have shown, however, that the efficiency of a three-stone fire is dependent on the care with which it is tended. In a well-tended, shielded, open fire the efficiency can be as high as 15 to 20 per cent.¹⁸ But this is still well below the efficiency of 70 per cent for a modern North American natural gas stove, 40 per cent for a small propane stove, or even 30 to 35 per cent for a kerosene stove.

Charcoal is burned in small inexpensive clay or metal cooking stoves that hold only one pot. These stoves are more efficient than woodstoves, often in the range of 15 to 30 per cent.¹⁹ But again, there is room for improvement.

Wood and charcoal are also utilized inefficiently in traditional industries. Brick, lime, and pottery production, for example, are all based on traditional, inefficient kilns. There is little data on the consumption of wood in traditional industries.

3. Net Energy Efficiency of Current Woodfuel Supply/Demand Routes

The overall efficiency of wood supply/demand routes is extremely low in current systems. Net energy efficiency is calculated by subtracting the energy expended in each phase

of the supply and utilization process (harvesting, transport, conversion, and utilization) from the energy content of the wood. Detailed calculations are made in Appendix 5 and summarized in Table 17 for the different supply routes.

The largest part of the energy expended in each case is related to the low conversion efficiency of wood to charcoal and/or the low end use efficiency of wood or charcoal when burned in an open fire or traditional stove. Losses in combustion are 90 - 95 per cent when wood is burned directly in an open fire. Losses in charcoal combustion are 72 per cent in conversion in an earth kiln and 19-24 per cent in utilization in a traditional stove for a total of 91-96 per cent.

Therefore, direct burning of wood in an open fire involves just as great a loss of energy as the production and burning of charcoal, assuming that both are trucked 50 km to market. At greater distances, charcoal would begin to have an advantage.

The collection of wood directly by the end user requires the greatest expenditure of human energy. Collecting wood in an average supply situation requires over 0.5 units of food energy for each unit of net energy obtained. In other words, only a small energy surplus is generated by the human labour expended.

These estimates are highly dependent on assumptions about end use and conversion efficiencies. In Chapter V, the ways in which the net energy output of the supply/demand balance can be increased will be discussed.

Table 17

Net Energy Efficiencies for Different Supply/Demand Routes for Woodfuels in Current Situations

	Energy Cost in GJ/1000 GJ Wood		
	<u>Self-Collection</u>	<u>Commercial Wood</u>	<u>Commercial Charcoal</u>
Harvesting or Collection	36	6	6
Conversion	n/a	n/a	724
Transport	n/a	19	2
Combustion	950-900	950-900	235-194
	986-936	975-925	967-926
Net Energy Delivered	14-64	25-75	33-74
Net Energy Efficiency (%)	1.4-6.4	2.5-7.5	3.3-7.4

4. Summary

Wood resources are now being mined rather than used on a sustainable basis. Wood is treated as a free good by those who collect it for their own use. The contribution of trees to soil retention, water supply, and productivity is not realized by many subsistence farmers. Most commercial wood gatherers or charcoal producers also collect fuelwood from public land. The cost of growing wood is not included in the fuelwood or charcoal price.

Maintaining the supply of wood is assumed to be outside the responsibilities of individuals; few trees are planted for fuel to replace those that are cleared for agricultural production, timber production, fuelwood, charcoal, or building poles.

Utilization of woodfuels is for the most part tradition bound and inefficient as is the conversion process from fuelwood to charcoal. An average rural household in a developing country uses about half as much wood for cooking as a Canadian family would use to heat a large house with fuelwood over a winter.

Rapidly growing populations burning large amounts of wood and requiring more and more agricultural lands, combined with the attitude that wood is free will result in growing fuelwood shortages.

Notes -- Chapter IV

1. Arnold, "Wood Energy", p. 233.
2. Ibid., p. 236.
3. Spears, "Wood as an Energy Source", p. 3.
4. DEVRES, "The Socio-Economic Context", p. 30.
5. Eckholm, "The Other Energy Crisis", p. 7.
6. V.S. Bogach, A Fuelwood Policy for Guatemala, study carried out for the UNDP (Project GUA/74/014, January 1981).
7. Frederick J. Conway, "A Survey of the Fuelwood Situation in Haiti", AID Mission to Haiti (1979), p. 3-7.
8. World Bank, "Republic of Senegal Forestry Project Staff Appraisal Report", (Washington, Jan. 15, 1981), p. 5.
9. C.V. Konda Reddy, "Prosopis juliflora, the Precocious Child of the Plant World", Indian Forester, 104:1 (January 1978), p. 16.
10. Arnold, "Wood Energy", p. 234.
11. Elizabeth Swaine, Maine Firewood Study: Final Report for the Period November 1978 -- 15 January 1980, prepared for the U.S. Department of Energy and the Maine Office of Energy Resources, D.O.E./ET/15437--4, p. 79.
12. Bogach, A Fuelwood Policy, Table 5-3.
13. Patrick C. Fleuret and Anne Fleuret, "Fuelwood Use in a Peasant Community: A Tanzanian Case Study", Journal of Developing Areas, (July 1978); DEVRES, op. cit., p. 75.
14. Ministry of Mines and Energy of Brazil, "Brazilian Energy Model", (May 1981), p. 13.
15. The following information is taken from correspondence with the Non-Ferrous and Steel Industry Council of the Government of Brazil and from information provided by the Companhia Agricola e Florestal Santa Barbara.
16. Author's correspondence with INCO.
17. Atlanta, "Charcoal Utilization for Iron Ore Reduction in Liberia", Prefeasibility Study, 1978.

18. Bogach, A Fuelwood Study, p. 4-13; Meta Systems Inc.,
"Potential for Fuelwood and Charcoal in the Energy Systems
of Developing Countries", U.S. Input to the Technical Panel
on Fuelwood and Charcoal, U.N. Conference on New and Renew-
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(October 1980), p. III-39.
19. Arnold, "Wood Energy", p. 237.

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Chapter V

Potential Improvements in Woodfuel Supply or Utilization

There are a number of ways to ensure that wood remains a viable fuel by preventing or rectifying fuelwood shortages. These approaches include increasing the supply of wood resources, improving the efficiency of conversion of wood to charcoal and improving the efficiency of utilization of fuelwood and charcoal. •

1. Improvements in Fuelwood Supply

Woodfuel supply can be increased in several ways, including,

- a) better management of existing forests to improve yields,
- b) creation of new wood resources,

a) Forest Management

In much of the industrialized world, a balance has been struck between agricultural and forest land. The management, protection, and regulation of forest resources is the responsibility of government.

Techniques such as rapid reforestation of cut-over areas, conversion of stands to faster growing species, site drainage, fertilization, regular thinning, and protection of the forest from fire, disease and insects are used to raise the productivity of the natural forest. These techniques are applied

mainly on publically owned land or on land controlled by forest industries, and are paid for from the revenues generated by the lumber industry and the consolidated tax revenue of the government.

Most developing country governments also have national forest services. However, in the developing as in the industrialized world, forest management and conservation have a low priority, since they do not generate short-term revenue.

Knowledge about forest resources is sketchy. The extent, density, productivity, and rate of destruction of forest resources have not been well documented. For example, in Africa less than 10 per cent of the area classified as forest has been inventoried even once.¹ Forest policy is often being made on the basis of subjective observation even in developed countries.

Good forest management includes strict control of cutting on both public and private lands, and incentives to reforest and invest in forest industries. Because of the lack of funds, trained personnel and power, national forestry services are not able to adequately enforce existing regulatory legislation, or to develop and update legislation.

Given the small scale, clandestine nature of much of the cutting and the fact that the vast majority of land is often privately owned, regulations are difficult to enforce. Even in many industrialized countries, where considerable resources have been devoted to forest management, it has proven impossible to control cutting on privately owned land.

In some countries, incentives to reforest take the form of deductions against income tax payable. This form of incentive will only work with large industries and landowners. Where forests are in the hands of small land-holders or are publically owned, such incentives are meaningless.²

Where incentives may be appealing to invest in reforestation, the lack of technical personnel is often an insurmountable obstacle. There are few foresters and forest technicians in developing countries operating in the private sector who have the competence to carry out a plan for afforestation or reforestation.

The major problems with respect to forest management are:

- ... private or communal ownership of forest resources that makes regulation difficult,
- ... the small scale and clandestine nature of forest exploitation that makes it difficult to control,
- ... a lack of power and resources in national forest services that makes it difficult to develop and enforce policies,
- ... a lack of qualified personnel to work in both the private and public sector.

The first two factors are quite intractable, but there is some potential for improved forest management. First, adequate knowledge of forest resources needs to be acquired through more satellite surveys and forest inventories. Also, new techniques need to be developed to measure forest resources, since the old ones were designed to measure only

conventional forest products rather than the total biomass.

Second, training of foresters and forest technicians needs to be expanded and oriented more toward woodfuel problems and less toward industrial utilization of the forest. Third, by tying deforestation into wood shortages and petroleum imports, forestry agencies may be able to benefit from the current concern about energy to get more resources and larger budgets.

Fourth, forest services can improve woodfuel supply by ensuring that maximum use is made of all wood for which cutting licences are granted. Waste wood from logging operations and wood from land clearing is often burned rather than being transported to distant markets. This wood could be transformed into charcoal and shipped to market.

The Sri Lanka State Timber Corporation is carrying out such a program. During the past few years, Sri Lanka's foresters have been clearing the giant Mahaveli forests to create new, irrigated croplands. The 25 million tons of wood that the forest will yield over the next five years is a long way from towns and villages, and is too expensive to transport. The State Timber Corporation together with an American company will convert the wood into charcoal in efficient portable steel kilns. Charcoal will be sold within 200 km of the kilns; some to individuals, some to industry, including possibly the Sri Lanka Cement Corporation, and some may be exported. Fast growing Eucalyptus trees will be planted on 14,000 hectares of the cleared land to replace the wira.

trees that originally made up the forest.³

Adequately staffed, well-funded forestry services with a strong extension arm are the basic building blocks on which forestry programs must develop. Where they exist, management of forest exploitation, at least with regard to public lands or large projects, becomes a realistic possibility.

Even with improved management, the world's accessible natural forests could not produce enough woodfuel to satisfy the demand.⁴ Therefore, it will be necessary to create more wood resources by planting trees.

b) Creation of New Wood Resources

Tree planting has usually been restricted to government forestry agencies that send out teams to reforest publically owned land. Aid agencies have sponsored some of these tree planting projects.

The success of traditional afforestation and reforestation projects has not been great, especially when measured against the scale of program needed. The costs of traditional reforestation programs are generally estimated at \$250 to \$1,000 US per hectare. The lower end of the scale applies to low budget national programmes, whereas the higher end applies to projects such as those of the World Bank that include high overheads.

The high cost of this type of project is a barrier to carrying out reforestation at more than a token level. The cost cannot be recovered by the government except in terms of long-term benefits to the environment and local populations.

Most developing countries have great difficulty in finding the budget for traditionally recognized needs such as education and health care services. Investing a large amount of money in projects that will yield non-monetary returns in the long-run is not a priority, unless there is a crisis.

Reforestation programs have also run into trouble because they are not supported by local populations. The lands that are chosen for reforestation may have been previously used by local people for pasturage, recreation, or some other purpose. They may perceive that the planting of trees is not to their benefit, and they may be correct in this assumption, especially if the area is designated as a forest reserve with restricted access.

Unless local people believe that they will ultimately benefit by having access to the wood products from the trees, they are likely to be hostile to reforestation. There are a number of stories of people sabotaging seedlings by cutting them down or allowing animals to eat or trample them.⁵

Virtually all governments carry out reforestation programs, but the total area of new forest is small. The total amount of reforestation in developing countries is estimated at 546,000 hectares in 1980, about one fifth of the level that the World Bank feels is needed to make any significant impact on fuelwood and charcoal supply problems or on deforestation.⁶

If governments are serious about deforestation and fuelwood problems, new approaches must be tried that are less of

a drain on their budgets, and that benefit local people directly so that their co-operation is obtained.

Village Woodlots

Village woodlots are one such alternative that was much publicized in the 1970s. In village woodlot schemes a plot of land is set aside for the planting of trees to provide a permanent source of fuel, building poles, and fodder. The seedlings are usually provided to the village for free, and the villagers themselves plant and tend the trees with the help of the extension arm of the forest service.

Such schemes, however, have not been universally successful. Some villages do not have sufficient publically owned land to set aside areas for forestry without affecting other needs. Many villages have no tradition of co-operative action. Also, the problems of distribution are foreseen by the population. They are reluctant to participate if they feel that the government or some rich villager will get all the benefits.

The forest products from village woodlots are sometimes sold, with the proceeds going to an objective set by the village council.⁷ This eliminates the distribution problem, but, it means the fuelwood supply to the villagers is not improved.

Village woodlot programs also require considerable organization that must be done by government or aid agencies. While the cost of planting and tending trees is low, the cost of organization, promotion, and extension tends to be high.

In South Korea, village woodlot programs have been highly successful. The South Korean programs have often been held up as an example of successful reforestation. But village woodlots have been unsuccessful in Gujarat (India), Tanzania, Upper Volta, and Niger.⁸ The World Bank is now recognizing that village woodlots may not be an appropriate vehicle for supplying fuelwood in many rural environments. The following comment was made on a program funded by CIDA in Niger: "effective local participation in reforestation has been throttled by an exclusive reliance ... on a community woodlot system ill-suited in the socio-political context to serve as a vehicle for reforestation."⁹

It seems that village woodlots are appropriate only in certain situations: Where there is a tradition of community action to solve problems, where sufficient land is available, or where many villagers are landless peasants who would otherwise have no access to wood.

Family Woodlots

Family woodlots on individual land holdings may have more universal applicability than village woodlots. They offer more tangible and direct incentives for participation. In such programs, extension services provide seeds or seedlings to individual farmers for planting as field borders, on roadsides, near the home, or even for interplanting with crops.

Two constraints on such planting that are often mentioned are competition for land with food crops and the need

to wait several years before being able to harvest trees. Still, many of the fast growing leguminous species, such as Prosopis and Leucaena actually enhance crop production, improving the micro-climate by pumping up chemicals from layers of soil that are inaccessible to annual crops, fixing nitrogen and improving water retention. It is estimated that up to 15 per cent of agricultural land could be devoted to the planting of trees without adversely affecting crop production.¹⁰ These species can also be harvested as soon as one year from the date of planting. The shortening of the period to harvest may be critical in encouraging small farmers to participate in the program.

In Malawi, a World Bank mission reported that many small farmers were collecting seeds of species such as Cassia siameca, Gmelina, Eucalyptus, and sowing these seeds in their homestead gardens. A similar experience was reported from Kenya in the 1950s (Swynnerton Plan in the Kericho area with Mauritius thorn and wattle).¹¹

The provision of a range of seeds to local farmers along with extension services is an extremely low cost option for providing people with fuel. The World Bank estimates that in its Uttar Pradesh project, the cost of establishing one hectare of farm forest was about \$135 per hectare for seedlings, plus the farmers own labour. Planting by individual farmers was proceeding faster than expected. The World Bank Review of Bank Financed Forestry Activity for 1981 states:

... self help on farm planting is likely to be the cheapest and most effective way to ensure rural afforestation on a large scale in many countries.¹²

In many areas, the production and distribution of seedlings could be done on a commercial basis, since the cost per unit is low. Assuming a conservative production of 20 m³ per hectare, consumption of 0.5 to 2.25 m³ per person per year, and an average family size of six, it would be necessary for each family to plant 0.15 to 0.75 hectares at a cost for seedlings of \$20.25 US to \$101.25. Costs could be reduced even further by distribution of seeds, rather than seedlings.

This approach is most useful where there are subsistence farmers who own or have long-term rights to the produce from a particular plot of land. Where small farmers are sharecroppers, where there are nomadic peoples, where many people are landless labourers, or in arid or cold areas where conditions are not suitable for the use of fast growing species of trees, this approach will not reach the people who need the most help. But in many areas, the only way out of the current energy dilemma is for farmers to become self-sufficient in fuel and to incorporate the growing of trees into their agricultural activities.

There have been few programs that have tried this approach and the results are not yet in, but the early results from World Bank projects indicate that it could provide the key to low cost, large-scale planting programs.

Commercial Fuelwood Plantations

The idea of plantations to produce wood and, possibly charcoal, for sale is relatively new. But with current high prices for wood and evidence that high prices are due to increasing scarcity combined with high transport costs, there is scope for the commercial production of wood as fuel.

The growing of trees as a small-holder cash crop is becoming more attractive. In Gujarat, hundreds of small farmers have switched to growing Eucalyptus as a cash crop; in the Philippines, farmers are growing a variety of trees including Leucaena for the production of leaf meal, fuel, and fodder; in Malawi, small farmers have been collecting their own seed and establishing woodlots for the production of fuelwood and building poles.¹³ The World Bank is now encouraging such small farmers as part of many of their projects.

Plantations are just becoming economic, but in order for them to make a rate of return that is sufficient to justify investment, they must be organized efficiently -- from planting through to delivery of the final product. When dealing with a low value, high bulk product it is especially important that harvesting, handling, and transport costs be minimized.

The optimal mix of equipment and labour needs to be carefully assessed for large-scale production of wood. A comparison of harvesting methods indicates that a man with a chainsaw is about seven times as productive as a man with a machete and axe. The annual cost of one skilled worker

operating a chainsaw is in many countries well below the cost of seven man-years of unskilled labour. The use of a chainsaw can reduce the costs of harvesting and processing wood substantially. Costs may also be lowered by using other equipment, such as a hydraulic splitter.

Transport and handling account for a large part of the total cost of wood as was shown in the earlier Guatemalan example. One of the reasons costs were so high is that expensive trucks and drivers were standing idle for six out of ten hours, while they were being loaded and unloaded by hand. More efficient handling practices are critical to the economics of fuelwood production in plantations.

Many of the studies on the economics of fuelwood plantations base their calculations on the value of stumpage, assuming that harvesting will continue to be done using traditional inefficient methods. Plantation operations can generate a higher rate of return if they are considered as integrated systems, from planting of trees to delivery of wood to large customers and wood vendors.

Recent estimates show that wood plantations can produce a sufficient rate of return to justify public, and in some cases, private investment.¹⁴

It is difficult to generalize, but based on one source the cost for standing wood can be estimated at \$0.75 to \$4.40 per giga-joule in 1978 US dollars. The upper end of the range applies to the particularly difficult conditions in the Sahel. Harvesting costs range from 25¢ to 85¢ US 1978, while trans-

port costs range from 0.2¢ to 2.2¢ per GJ/km.¹⁵

Assuming the plantation is 50 km from the market, this would mean a total cost of \$1.10 to \$6.35 US 1978 dollars per gigajoule, or \$10.35 to \$60 US per cubic metre. All except the high end of this range (more than \$50 US) are within the band of 1978 wood prices.

How do these prices compare to those for petroleum? Current crude prices are about \$29 US per barrel. The price of a barrel of kerosene landed in an urban centre is about \$41 US in 1981 dollars. This is equivalent to \$7 per GJ. Assuming that wood is used with 10 per cent efficiency and kerosene with a 30 per cent efficiency, the delivered price of wood would need to be below \$2.26 US per GJ in 1981 dollars in order to be competitive.

Assuming an inflation rate of nine per cent per year, the cost of supplying wood in 1981 dollars ranges from \$1.42 to \$8.22 per GJ (not including retail costs). Unless the efficiency with which wood is used is improved, only those costs at the lowest end of the scale are truly competitive. However, if the end-use efficiency is doubled, the cost of wood can rise to \$5.30 per GJ and still be competitive.

A calculation of the profitability of a commercial fuel-wood plantation in Guatemala was made based on conservative assumptions of annual production of 15 m³/hectare/year, an eight year rotation, a distance of 50 km to market, and a wholesale price of \$20 US per cubic metre in 1980 dollars (\$2.12 per GJ). This calculation indicated a rate of return

of over 15 per cent and a pay-out time of 12 years.¹⁶

Such an investment is not commercially attractive when the cost of borrowed money is well over 12 per cent. However, if a substantial part of the necessary capital can be obtained from low interest sources, such as the World Bank or the OPEC Fund, such plantations are quite economic.

The economics of any particular plantation will depend mainly on the annual growth rates attainable, the distance from market, and the future price of wood.

Plantations have the advantage of being self-financing, of generating employment, and of creating a small-scale decentralized industry. To the extent that continued woodfuel supply prevents a switch to kerosene or propane, foreign exchange is saved. And wood plantations will have beneficial effects on soil and water retention in the local area. Fuelwood plantations need not compete for agricultural land since trees can be grown on marginal land, or on land that has been damaged by deforestation and erosion. Production from managed plantations is much higher than the production from natural forest areas as can be seen in Table 18.

But examples of large-scale production of fuelwood or charcoal in plantations for the urban or industrial market are few. The main example is Brazil, which was discussed in Chapter IV.

There is probably more knowledge about optimal silvicultural methods for commercial plantations for the production of fuelwood in Brazil than in any other country. But this

Table 18

Estimates of Yields in Natural
Stands and Plantations

<u>Country</u>	<u>Plantation Yield</u> <u>(m³/ha/year)</u>	<u>Yield with Natural</u> <u>Regeneration</u> <u>(m³/ha/year)</u>
Malawi	13	1
Brazil (Minas Gerais)	13	4.5
Shei - Sahelian Zone	3	0.2
Sudanian Zone	8	1
Thailand (Northeast)	17	0.6

Source: Meta Systems Inc., «Potential for Fuelwood and Charcoal in the Energy Systems of Developing Countries» U.S. input to the Technical Panel on Fuelwood and Charcoal. United Nations Conference on New and Renewable Energy Sources. 1980. p. III-6.

knowledge is mainly of Eucalyptus grown to supply charcoal to one large consumer, in Brazilian conditions.

In order to encourage entrepreneurs and governments to establish commercial fuelwood plantations, there is a need for pilot scale operations in various countries with different species. The development of low cost methods for soil preparation and planting and the ability to predict the growth rates of different species under varying conditions is critical to the spread of such plantations, as is the development of low cost harvesting and handling methods.

Most important is the availability of financing for plantations since concessional terms may be needed to encourage projects, at least initially.

c) Summary of Wood Supply Improvements

The primary method of increasing fuelwood supply in developing countries is to increase wood resources by planting trees, especially fast growing species. But government reforestation programs are simply too expensive to be carried out on the scale needed. Village woodlot schemes have run into social and organizational problems in many areas.

There are several routes available for increasing the scale of tree planting in the developing world that have a good chance of success because they do not require vast amounts of government expenditure. These routes are the supply of seed and seedlings of fast-growing species, such as Leucaena and Prosopis, to small farmers and the establishment of commercial fuelwood plantations to supply wood or charcoal to urban markets.

The first scheme can be funded by government money, either on a non-recoverable or recoverable basis (i.e., seedlings and seeds can be distributed for free or sold). The second approach would have private or state entities setting up a commercial enterprise, which would be especially economic if based on low cost capital.

2. Improvements in the Conversion of Wood to Charcoal

Charcoal is the solid residue remaining when wood is pyrolyzed under controlled conditions. Control is exercised over the entry of air so that the wood does not burn away to ashes, but instead decomposes chemically to form charcoal. The process produces not only charcoal, but tarry residues, ash, combustible gases, tars, a number of chemicals including acetic acid and methanol, and a large amount of water given off as vapor.

Traditional earth pit or mound methods of charcoal production, as described in Chapter IV, are highly inefficient. About 20 to 30 per cent of the original energy contained in the wood is retained in the charcoal. By dry weight, the production ratio is generally in the order of 1 to 1.5 units of charcoal per 10 units of wood. Using metal or brick kilns, the ratio of charcoal to wood by weight could be raised to two to three units of charcoal per 10 units of wood. (See Table 19 for a comparison of different methods of charcoal production).

Several portable steel kilns have been devised with developing countries in mind. These kilns, however, have not

Table 19

A Comparison of Kilns and Retorts

Type	Total Cycle	Investment (U.S. 1976 \$)	Output (percent of air dried wood)	Life of Device
Earth Stack	5 days - 3 months	-	8-12	One firing
Pit Kiln	1 week (for 23 steres capacity)	100-200 (for digging, masonry lining and cover- ing with sheet metal)	12-15	1 to 2 years
Portable Metal Kiln	2 to 3 days	1500-2500	15-20	2 to 3 years
Masonry Kiln	7 to 10 days (for 30 stere capacity)	1000-2000	15-22	5 to 10 years
Continuous Kiln or Retort (Lambiotte type)	10 hours	300,000 to 3,000,000	20-25	20 to 30 years

Source: Edmund Uhart, Charcoal Industry in the Sudan,
U.N. Economic Commission for Africa
(Addis Ababa, 1976).

been widely adopted for a number of reasons,¹⁷ including

- ... Cost. At a cost of \$1,000 US per kiln, most charcoal producers cannot afford to purchase a steel kiln.
- ... Convenience. Wood must be cut into small pieces and loaded over the top rim of the kiln, a laborious and time-consuming process. In contrast, using traditional methods, large logs can be used without processing.
- ... Maintenance. Hot spots can damage the kiln when it is made from low cost steel. Also, repair services for the kiln may not be available locally.
- ... Performance. The action of wind and rain can slow down the reaction and result in a decrease in the efficiency of the kiln. More partially carbonized wood is produced and the advantage of the steel kiln over traditional methods is reduced.

Brick kilns have also not been widely adopted for a number of reasons including,

- ... Cost. Brick kilns also have a capital cost of over \$100 US.
- ... Portability. Brick kilns can be moved, but only as a result of considerable labour in dismantling, transporting, and reconstructing the kiln.
- ... Scale. Brick kilns are generally larger than earth or portable steel kilns.

In general, brick kilns are most suitable where they can be situated nearby a source of wood (e.g., plantation) that can be utilized on a sustained basis for a considerable period of time.

It may be more practical to try to improve the yield of traditional earth pit kilns than to try to introduce kilns with a high capital cost. At least one authority, Booth, argues that the differences in efficiency between the tra-

ditional methods and the brick or steel kiln are not significant, and only the use of retorts would make a marked difference to wood requirements.¹⁸

Sophisticated continuous retorts can produce three tons of charcoal per 10 tons of wood; a production efficiency that is near the maximum theoretical limit. Retorts make use of the heat of pyrolysis that is normally wasted so that once the initial charge is made, pyrolysis is accomplished without burning additional wood. Where retorts are used, it is also possible to economically recover some of the byproducts of the process. The tar can be used as a substitute for fuel oil, while the gases can be used as fuel in a conventional thermal power station.

As more charcoal is produced on a larger scale, for example from commercial plantations, the use of more efficient kilns and even retorts will become practical. Village co-operative projects could also make use of this equipment. Where more efficient equipment is in use, wood requirements for charcoal production would be cut by a factor of one half to two thirds.

3. Potential for Improvements in Wood Utilization

Conservation of energy in the industrialized world has moved much faster than expected, spurred on by steadily increasing oil prices. Similarly, more efficient utilization of woodfuels could substantially reduce wood requirements. Since an estimated 75 to 85 per cent of all wood is burned in inefficient stoves in the household, emphasis must be placed on

this sector. What is the potential for improved efficiency?

a) Woodstoves

Woodstoves have been developed that are claimed to save up to two thirds of the wood needed to cook in a three stone fireplace.¹⁹ Therefore, a key element in any woodfuel supply strategy is the promotion of fuel efficient stoves. This approach generally receives no more than a paragraph in the writings of those concerned with fuelwood supply problems.

There are two reasons for this lack of emphasis on stoves. First, woodfuel programs are mainly in the hands of foresters who place primary emphasis on their area of expertise -- growing trees and managing forest resources. Second, the adoption of stoves on a wide scale would require decisions by millions of individual households. Conservation efforts throughout the world are hampered because governments are unwilling to take on the task of educating the public to make informed choices.

However, where efforts have been made to introduce efficient stoves, they have been largely unsuccessful. Why have there been so few success stories?

First, most stove projects have been isolated efforts carried out by voluntary agencies with few resources. The development of the the much publicized Lorena stove during its first three years, for example, was estimated to have taken place on a budget of \$7,000 US per year.²⁰

A high turnover in volunteers means that experience is rarely carried from one project to the next. It is difficult

to exchange information about different stove models since no common methodology exists for assessing the functionality and efficiency of stoves.²¹ The wheel is being constantly reinvented. The designers and promoters of woodstoves are still amateurs tackling a complex social problem.

Second, the design criteria and the methods used to assess a stove relative to these criteria have been misdirected. There seems to be an attempt to find "the" most efficient stove design when what is really needed is a mix of stove designs that may not be the ultimate in efficiency, but meet people's needs in areas such as convenience and ease of use. Local women must be involved in the design and testing process to ensure that their needs are met.

Third, stove selection and promotion has focussed mainly on user-built stoves rather than trying build up local-scale industries for production of simple stoves. The "appropriate technology" model of development and diffusion has been followed. This model involves a strong element of "do it yourself" with local people actively participating in the development and introduction of new technology. Mud or clay stoves are often considered most appropriate because they are constructed with local materials by the user. Diffusion is primarily through the demonstration effect of seeing a successful stove in use.

Harrison makes a persuasive argument that the "appropriate technology" model is appropriate in the fields of

health, education, and water supply, but that it is a mistake to apply it to the field of household technology.²² It is not always desirable or practical for the user to build his own efficient woodstove. And the demonstration effect is insufficient to ensure the spread of technology at the village level.

A fourth reason for the lack of success of improved stove projects is that they have usually been targeted to rural populations. Subsistence farmers are not in a position to easily adopt a new innovation -- they are living on the margin and have to be conservative. Until any new device has proven its worth, they will be unlikely to adopt it, especially with respect to the preparation of food, one of the most tradition bound areas of human activities.

Collected wood is "free" in most rural areas and the benefits of a more efficient stove may not be enough to offset even the low cost of a self-built mudstove, unless there is an acute scarcity of wood.

There is an even more fundamental reason why rural households may not adopt efficient woodstoves. Open fires have uses other than cooking, specifically space heating, and providing light and protection. Some woodstoves give off sufficient heat to warm a room, but no closed woodstoves will provide light. Therefore, promotion of a closed stove may not be an appropriate strategy in rural areas. Instead, efforts could be concentrated on improving the efficiency of the open fire; for example, through the use of a grate which would

allow the fire to be enclosed by stones.

There are a number of reasons why urban households are more likely to be receptive to efficient woodstoves. First, urban families are often paying out a large share of income for fuel and have an immediate incentive to conserve. From Table 14, the price of fuelwood ranged from \$3.20 to \$46.00 US per cubic metre in 1977, with an average of \$22.20 US. The cost of the six cubic metres per year needed to supply an average family's fuel needs would then be \$133 US. If wood use could be cut by even a minimum of 25 per cent, the annual saving would amount to \$33 US. If a stove could be paid for by monthly payments spread out over two years, then a stove in the price range of \$30 to \$60 US is economic; and this is based on the price of wood in 1977. Using a conservation estimate of an average increase in wood prices of 10 per cent, a stove with a current price of \$40 to \$90 US would now be economic.

In addition to having a strong economic incentive to conserve wood, urban families are more likely to use fuelwood solely for cooking. The side benefits of an open fire, light and space heat, may be less important.

A logical approach to stove promotion might be to establish stove industries aimed initially at the urban market, eventually moving into rural areas once an initial degree of acceptance has been obtained in the easier to break into urban market.

Where wood scarcities truly exist, and prices are high,

people are likely to adopt an efficient wood cookstove if it meets all their needs, if it is cost effective, and if credit is made available to allow the purchase price to be spread over several years. Where wood resources are gradually being depleted, but no acute shortage of woodfuel exists, other motivations will have to be found, such as convenience and prestige.

b) Charcoal Stoves

Charcoal is already used in various types of equipment, such as the "jiko" with an efficiency estimated at 15 to 30 per cent. Improved charcoal burners have been designed that save up to 50 per cent of fuel.²³ In Kenya, such improved jikos are available commercially, but do not seem to have caught on. The obvious reason is a price that is two to three times the price of a regular jiko. Other difficulties exist, however, such as the fact that the improved jiko was more difficult to light. Also, no strong promotional campaign has taken place.

The same factors apply to the improved charcoal stove as to the improved woodstove with a few differences: charcoal must be burned in some sort of apparatus so the initial step to a burner or stove has already been taken; charcoal is normally purchased so that there is an economic incentive to use an efficient stove; and efficient charcoal stoves can be constructed more cheaply than woodstoves. For these reasons, it should be somewhat easier to promote improved charcoal stoves than improved woodstoves.

FIGURE 1a
LORENA STOVE

c) Other Methods of Improving Efficiency of Wood Use in the Home

There are a number of ways of increasing the efficiency of wood as a fuel. One relates to the moisture content of the wood. This is one of the few properties of wood that man can control. Simply drying wood prior to use can result in wood savings of up to 15 per cent. Figure 2 shows the rapid improvement in the utility of wood as fuel as it becomes progressively less moisture laden. Seasoned or air-dried wood normally has a moisture content of 20 to 30 per cent on a dry-weight basis.

The extent to which wood is dried prior to use is not known. It is likely that all users prefer dry wood because it is easier to burn and produces less smoke. However, in areas where wood is scarce, it is difficult to store wood for long enough to allow it to dry out thoroughly before use.

Cooking habits can also have some impact on wood requirements. The use of lids for pots, pans, and other cooking utensils can reduce the amount of wood needed to boil or simmer food by reducing heat loss. Also, vessels with curved bottoms have been shown in tests to be more efficient than vessels with flat bottoms. Even the material of the cooking vessel can have an impact on efficiency. For example, aluminum has been shown to be more efficient than brass in cooking pots.²⁴

d) Summary of Potential Utilization Improvements

The only woodstove projects that are being carried out on a broad scale are those of the World Bank and U.S. AID. Research in the area of woodstoves is being funded as part of

Figure 2
Moisture Content of Wood

Net heating value and net energy delivery capacity of wood as a function of moisture content.

Source: David A. Tillman, Wood as an Energy Resource, (New York: Academic Press, 1978).

World Bank projects in Burundi, Malawi, India (Upper Pradesh), Gujarat, Nepal, Mali, Niger, and Upper Volta. But Bank programs are still at a research stage.²⁵ U.S. AID has a large regional project in Central America to test efficient stoves.

In all of these programs, there has been too much emphasis on design and efficiency testing of woodstoves and not enough emphasis on finding ways of rapid diffusion. A persuasive argument is made by Harrison for what he calls the "social marketing" approach to diffusion.²⁶

He argues that energy saving devices can be spread in the developing world by entrepreneurs, with effective marketing and distribution systems, and using the mass media and advertising to attract customers. A small-scale, labour intensive industry could be set up to manufacture efficient stoves. Aggressive marketing campaigns could follow using ads on radios and on billboards. The stoves could even be sold at subsidized prices, if the government recognizes the social importance of reducing woodfuel consumption. An example of how such a project would work is given by Harrison: in areas where charcoal is the main fuel efforts could be concentrated on a moveable fuel efficient charcoal stove made of scrap iron, giving it a name like the Superjiko, backing it with a multimedia campaign, and licensing blacksmiths who have proved they can make it.

Widespread use of efficient wood and charcoal stoves could result in a decrease in woodfuel requirements of 25 to 50 per cent. Promotion of such stoves is the fastest and most permanent way to improve the woodfuel supply situation.

4. Impact of Improvements in Fuelwood Supply/Demand
on Net Energy Efficiencies

The figures of net efficiencies for woodfuel supply/demand in developing countries can be compared with similar figures for other fuels in Table 20. The net energy efficiency factors for coal and oil in industrial uses are more than triple the maximum efficiency factors for wood in Table 17.

Improvements in current systems can substantially improve net energy efficiencies for woodfuels. Table 21 summarizes the data in Appendix 5 on net energy efficiencies, using assumptions that reflect the suggested improvements in supply and utilization systems. Comparing Table 21 to Table 17, the energy cost of each route is less and the net efficiency higher in the improved system.

For the rural wood collector, access to trees planted within 0.5 km of the house will cut down greatly the time and energy needed to search for and transport wood. In comparison to Table 17, the food energy expended through human labour would be cut to one-twelfth of the previous energy needed, and the yield may be increased by as much as a factor five through increased end use efficiency.

For commercial fuelwood from plantations, energy costs of harvesting are greater because oil products powering machinery have been substituted for human labour. Transport energy cost is less because of more efficient organization and handling. Most important, end use efficiency is substantially higher leading to an overall increase in net energy efficiency

Table 20

Net Energy Efficiency Factors for Different Fuels

Stage in Supply/ Demand System	Energy Cost Per Operation (GJ/1000 GJ)		
	<u>Wood</u>	<u>Coal</u>	<u>Oil</u>
Extraction*	25	21	40
Transport**	22	2	..
Conversion	n/a	n/a	70
Combustion***	900-300	700-200	650-150
Total	947-347	723-223	760-260
Net Energy Delivered	53-653	277-777	240-740

*Extraction process is more mechanized and energy intensive than in Table 18.

**Transport distance is 50 miles.

***High energy costs reflect use in domestic applications (fireplaces for wood, kerosene stoves for oil, and coalpots for coal). Low costs reflect use in a high efficiency boiler.

Source: Adapted from David A. Tillman, Wood as an Energy Source, Academic Press (New York 1978), p. . .
Refinery use of fuel changed to reflect worldwide average, a range of combustion efficiencies used to reflect different applications.

Table 21

Net Energy Efficiencies for Different Supply/Demand
Routes for Woodfuels if Improvements are Implemented

Energy Cost in GJ/1000 GJ Wood			
	<u>Self-Collection</u>	<u>Commercial Wood</u>	<u>Commercial Charcoal</u>
Harvesting or Collection	2	11	11
Conversion	n/a	n/a	469
Transport	1	14	4
Combustion	900-750	900-750	372-213
	903-750	925-775	856-697
Net Energy Delivered	97-247	75-225	144-303
Net Energy Efficiency	9.7-24.7	7.5-22.5	14.4-30.3

of a factor three.

An even more dramatic increase occurs in the net energy efficiency of charcoal because the energy costs of conversion and end use have been substantially reduced resulting in a net energy efficiency increase of a factor four. In fact, the net energy efficiency is higher for charcoal than for fuelwood, even for a transport distance of 50 kilometres.

But net energy efficiencies are of limited value. Choices among different fuels are based on the price of the fuel, delivered to the user, the combustion efficiency of the fuel, and its availability. If the price differential is great enough, wood may be the preferred fuel despite a very low net energy efficiency. Improvements in net energy efficiency are of importance mainly because they result in a lowering of the cost per effective unit of energy, and because they make the fuel a more viable choice among different options.

5. An Example of the Cost and Potential Impact of an Integrated Woodfuel Program

Where woodfuel deficits exist on a wide scale, it is necessary to carry out an integrated program to improve supply. An example of such a program was developed for Guatemala as part of a UNDP energy project in 1979/80.²⁷

A detailed study indicated that the total growing stock in Guatemalan forests was estimated at 254 million cubic metres in 1979.²⁸ The annual growth was estimated at 5.2 million cubic metres per year, while annual withdrawals were estimated at 12.9 million cubic metres per year. With an annual deficit of

of 7.7 million cubic metres, the rate of deforestation is approximately three per cent per year. If fuelwood use continues to increase with population and nothing is done to increase fuelwood supplies, the forests would virtually disappear by the year 2000, as shown in Figure 3.

However, with the introduction of woodstoves at the rate of 50,000 per year, the establishment of 30 commercial fuelwood plantations (average size 15.75 sq. km. and average production of 27,000 cubic metres per year) each year from 1981 to 1990, and the distribution of seedlings free or at cost at an average rate of 30 million seedlings a year, the situation can be dramatically improved.

The deficit between annual growth and withdrawals that must be supplied by the destruction of the natural forest would be reduced greatly. The introduction of stoves would decrease fuelwood demand by five million m^3 in the year 2000. Because the destruction of forest resources would be reduced, annual growth in the natural forest would increase by almost one million cubic metres. By 2000, production from plantations would reach 8.1 million cubic metres per year, while production from the distribution of seedlings would amount to 4.1 million cubic metres per year.

Sixty per cent of all wood using households would be using fuel-efficient woodstoves by 2000. A total of 4,725 sq. km. of plantations covering 6.5 per cent of the land of Guatemala (excluding the Peten) would be in place. Approximately 400,000 rural Guatemalan families would have been supplied

FIGURE 3
IMPACT OF SUGGESTED MEASURES
ON FUELWOOD SITUATION
IN GUATEMALA

Source: V.S. Bogach, «A Fuelwood Policy for Guatemala», Study carried out for the UNDP, 1981, p. I-21.

with enough seedlings to meet all of their fuelwood needs.

Fuelwood demand and supply in 2000 is made up of the following elements: one million families using an efficient stove with a total demand of 5.1 million cubic metres supplied by commercial fuelwood plantations; 0.6 million families using an open fire for a total demand of 6.1 million cubic metres of which 4.1 million cubic metres comes from planted seedlings, while two million cubic metres comes from natural forest or other natural resources; and a total demand of 3.4 million cubic metres from small industries of which three million cubic metres is supplied from commercial plantations, 0.4 million cubic metres from the natural forest. An additional 1.6 million cubic metres of timber is extracted from the natural forest.

The net result of this policy is that fuelwood would remain a viable fuel in Guatemala. Its use would be more convenient because of the widespread use of stoves and an improved distribution system. Pressure on the natural forest would be eased.

The goals of establishment of plantations, stove distribution and seedlings distribution do not seem unrealistic if the government were to make a strong commitment to such a policy.

The total expenditures on the program are outlined in Table 22. The stove project requires an investment of approximately five million dollars and shows a rate of return of 25 per cent, making it an attractive venture on a commercial basis.²⁹

Table 22

Cost of Fuelwood Program Outlined
for Guatemala

	millions 1980 U.S. \$		
	<u>Investment in Stove Project</u>	<u>Investment in Plantations .</u>	<u>Expenditure on Distribution of Seedlings</u>
1981	5	30	0.7
1982	-	30	1.4
1983	-	30	2.1
1984	-	30	2.7
1985	-	30	3.1
1986	-	30	3.4
1987	-	30	3.8
1988	-	30	4.1
1989	-	30	4.1
1990	-	30	4.1
1991	-	-	3.4
1992	-	-	2.7
1993	-	-	2.1
1994	-	-	1.4
1995	-	-	1.0
1996	-	-	0.7
1997	-	-	0.3
1998	-	-	-
1999	-	-	-
2000	-	-	-
	5	300	41

The investment in commercial plantations amounts to 1980 US \$300 million over the period 1981-1991, an average of 1980 US \$30 million per year. The commerciality of the plantations depends on the yield, location, and the price obtained for wood. Assuming a yield of 15 cubic metres/hectare/year, a transport distance of 50 km and a price at the distributor of 1980 US \$20 per cubic metre, a plantation would have a rate of return of over 15 per cent, making it an attractive investment on the basis of partial or total financing with low interest loans from the World Bank or other international lenders.

Distribution of an average of 30 million seedlings at a cost of eight cents per seedling, including extension service costs, would amount to an average of US \$2.4 million per year, or 1980 US \$41 million over the period. Even if the seedlings are to be given away, the total cost of this program is very small in comparison to the potential benefit. To provide one family with enough seedlings to become self-sufficient would cost 1980 US \$100.³⁰

There may even be a possibility of recovering part of the costs of this program through sale of the seeds or seedlings, at cost or at a subsidized price.

Almost all of the cost of the program is, therefore, recoverable except for the opportunity cost of using capital in projects which involve a degree of risk (market for stoves, growth rate of trees, labour and equipment cost of plantations).

The analysis indicates several things,

... stove projects have an extremely low capital cost in relation to their effectiveness,

- ... it is possible to design woodfuel projects so that much of the expenditure is recoverable,
- ... even if none of the investments were recoverable, the total cost of the program is approximately \$350 million US spread out over a 20 year period. The average annual cost per person now using fuelwood is 1980 US \$3.00.

While an investment of \$350 million over 20 years is a large one, it can be put into perspective by looking at planned expenditures on hydro-electrical projects over the same period. INDE, the government owned electricity supply company, has long-term plans to spend over \$3 billion on hydro-electrical generating plants from 1977-2000.

It is difficult to generalize from the Guatemalan situation to the global one since the necessary expenditures will depend on the severity of fuelwood shortages and the mix of policies that are implemented. However, if the costs outlined above can be taken as a rough guide, it would be necessary to spend approximately 1980 \$4.5 billion per year to the year 2000.

6. Summary

Elements of a strategy to resolve fuelwood supply problems have been identified. The approaches can be summarized as follows. First, fuelwood supply can be increased by better management of existing forests, and the creation of new wood resources through village woodlots, farm woodlots (or agro-forestry) and commercial fuelwood plantations. Second, new techniques can be adopted to reduce losses in the conversion of wood to charcoal. And third, improvements can be made in

the efficiency with which wood is finally used through the adoption of efficient wood and charcoal stoves and various other improvements in handling wood and in cooking techniques.

It is possible to draw up a plan for any country incorporating a mix of these approaches. The author drew up such a plan for Guatemala and calculated that the investments needed to carry it out amounted to US \$3 per person per year over a 20 year period. And this cost is recoverable from sales of wood and stoves. The technical and economic barriers to implementation of such a program are not prohibitive.

The reasons why such programs have not been carried out in many countries are discussed in Chapter VI.

Notes -- Chapter V

1. F.A.O. Secretariat Note, "Providing Forestry Sector Data Appropriate to National Situations", 5th Session African Forestry Commission (Accra: April 1978) p. 7.
2. Bogach, A Fuelwood Policy, p. 3-15.
3. "Sri Lanka's Energy Problem Comes Out of the Woods", New Scientist, (13 August 1981) p. 409.
4. Spears, "Wood as an Energy Source", p. 12; Arnold, "Wood Energy", p. 246.
5. Raymond Noronha, "Why is it so difficult to grow fuelwood?", Unasylva 33 (1981) p. 4-12.
6. World Bank Renewable Energy Task Force Study, "Developing Countries Fuelwood Supply/Demand Analysis, 1980-2000", (June 1980) p. 1.
7. Noronha, "Why is it so difficult?", p. 8.
8. Ibid., p. 4-12.
9. Ibid., p. 6.
10. Openshaw, "Woodfuel and the Energy Crisis", p. 10.
11. World Bank, "Review of Bank Financed Forestry Activity for Fiscal Year 1981", (Washington: unpublished, July 1982) p. 10.
12. Ibid., p. 13.
13. Ibid., p. 9.
14. Bogach, "A Fuelwood Policy", Chapter V; World Bank, "Staff Appraisal Report, Malawi Wood Energy Project" (Feb. 8th, 1980).
15. Meta Systems, Potential In Fuelwood and Charcoal, p.
16. Bogach, "A Fuelwood Policy", Chapter V.
17. Harry Booth, "Charcoal in the Energy Crisis of the Developing World", F.A.O. unpublished paper (December 1979).
18. Ibid., p. 12.
19. G. de Lepelier et al., A Woodstove Compendium, prepared for the Technical Panel on Fuelwood and Charcoal, U.N. Conference on New and Renewable Sources of Energy, (Nairobi: August 1981).

20. Personal conversation with Donald Wharton in Quetzaltenango, Guatemala, 1979.
21. Stephen Joseph, working with the Intermediate Technology Group, has done much to develop such a methodology, but his work is just beginning to become widely known.
22. Paul Harrison, "Appropriate technology: how can it reach the villages?", New Scientist, (Nov. 20, 1980) p. 523.
23. Meta Systems, Potential for Fuelwood and Charcoal, p.
24. Government of India, National Buildings Organization, "A Study on the Efficiency of Chulaha", Technical and Research Report 17 (unpublished report, no date given).
25. World Bank, "Review of Bank Financed", p. 16.
26. Harrison, "Appropriate Technology", p. 524.
27. Bogach, "A Fuelwood Policy", Chapter 1.
28. This calculation excludes the province of Peten which is a jungle province too remote from the center of population to serve as a source of supply. It also assumes that all fuelwood comes from forest resources, which is an oversimplification.
29. It is assumed that the stove would be paid for on credit, with monthly installments of nine dollars US.
30. These calculations are based on a survival rate of 50 per cent.

Chapter VI

Implementing Integrated Woodfuel Programs

1. Experiences With Large Scale Programs

While many developing countries are facing serious deforestation and woodfuel supply problems, only a few of them have implemented large scale programs to resolve or prevent these problems. The countries that have tackled forestry problems on a large scale are China, Korea, and India in the state of Gujarat.

a) China

In China, national forest cover was increased from less than 5 per cent in 1949 to 12.7 per cent in 1978, through the mass mobilization of rural communities to plant and tend trees.¹ This implies an increase of 72 million hectares of forest. Reidar Person makes a more conservative estimate of the establishment of 30 to 60 million hectares of new forest over the past quarter century.²

Little information is available on the nature of the program carried out by the Chinese government. However, because the political organization under which this program took place is unique, it is generally not taken as an example to be followed by other countries.

b) South Korea

In South Korea, according to figures of the government, more than one third of the national land area is stocked with trees that are less than fifteen years old.³ This resulted

from a series of measures introduced by the government in 1973, as follows,

- ... Forestry law and institutions were strengthened and their status raised.
- ... A strong extension and publicity campaign was created to inform the rural population of the need to restore forest cover to the land and to adopt fuel saving equipment and practices.
- ... Regulations forbidding the raking of leaves, grass, and litter within forest areas were enforced.
- ... A national reforestation scheme was introduced to create a fuelwood plantation for each village, the work to be carried out by the villagers themselves.⁴

This program has been widely publicized as a successful model for other countries.

c) Gujarat

The third example of a serious woodfuel program was implemented by the state government of Gujarat in India. This program began in 1969, with a two-part campaign -- first, to provide a demonstration effect by planting trees on government-owned roadsides and canal sides, and second, to conduct an extensive public information and self-help campaign. The publicity campaign included films, posters and tree planting contests, planting of trees in school grounds, industrial estates and government compounds, and annual tree planting ceremonies. Seedlings and extension services were provided at no cost by the government to individuals. The program has been such a success that the 50 million seedlings distributed in 1980 were insufficient to meet the demand. Distribution will rise to 100 million seedlings in 1982.

However, a complementary village woodlot program begun in 1974 has lagged behind the individual planting program for a number of reasons, including inequalities within villages, problems with land tenure and availability, labor shortages during the crop planting season, and less than total government support.⁵

d) Malawi

Malawi has just embarked on a woodfuel program with the support of the IBRD⁶ (International Bank for Reconstruction and Development). This program, begun in 1980, has a total budget of US \$13.8 million. It consists of the following components,

- ... a pilot program for the establishment of a network of 88 nurseries, each producing 100,000 seedlings per year to be sold to the public,
- ... establishment of 12,900 hectares of government operated plantations that would sell fuelwood and poles to meet mainly the commercial and industrial demand,
- ... strengthening of the Wood Energy Division which would carry out a number of studies and surveys to monitor the situation and would also implement the project,
- ... charcoal production trials to investigate more efficient methods of charcoal production and marketing,
- ... establishment of an energy unit to investigate more efficient ways of using wood and alternate sources of energy.

The project is only the pilot stage of what could develop into a much larger project if it is successful. The seedlings produced would be sufficient to supply the fuelwood needs of less than 10,000 families, according to project documents.

It is not clear in the proposal what use will be made of publicity campaigns. Since the main component of the project

is designed to encourage individuals to plant seedlings on their property, the inclusion of such a component is vital. Without a publicity campaign heavily backed by a government commitment of extension services and support, the program cannot succeed. This project will certainly provide an important test case of an internationally financed, integrated woodfuel program.

e) A Comparison of the Programs

The programs described above all tended to focus on fuel-wood supply. The Chinese program was one of multi-purpose reforestation. The Korean and Indian ones were mainly oriented to increasing woodfuel supplies through the planting of trees and improving the overall ecology for food production by increasing tree cover on agricultural lands. The Malawi project is very specifically oriented to increasing production of woodfuel and poles. A minimal component is included on overall woodfuel policy and on increasing the efficiency of use of woodfuels.

None of these programs can really be described as an integrated woodfuel program of the type described in Chapter V. However, the experiences gained with tree planting and with mobilization of public support are quite useful in analyzing the implementation of integrated woodfuel programs.

2. Elements of an Ideal Woodfuel Program

Even though the woodfuel situation varies, sometimes greatly, from country to country, it is possible to make an outline of the elements of an ideal woodfuel program. Below is an outline based partly on the successful experiences des-

cribed in the previous section and partly on the analysis of solutions to woodfuel problems in the previous chapter.

- i) A strong political commitment by government.
- ii) A program design that ensures public participation.
- iii) A strong organizational structure with clearly defined responsibilities.
- iv) A public awareness campaign.
- v) A solid effort by government to encourage the development of small-scale industries around the program.

a) Political Commitment

A clear common factor in all of the successful programs described in the previous section is a strong political will on the part of governments to resolve woodfuel or forestry problems. This political commitment was backed up by the allocation of financial and human resources to the program. Since organizational, technical, administrative, and managerial skills are extremely scarce in many developing countries, governments must be strongly motivated to initiate such a program.

In China, the program was developed, financed, and carried out internally. In Korea and Gujarat, the programs were originally developed and financed internally, but when they proved successful, the IBRD stepped in with additional funding.

In the case of the Malawi program, the staff of the World Bank played a large role in defining the project and the project is being financed by the IBRD. It remains to be seen whether the commitment of the government to the program is serious enough to make the program a success.

b) Design of the Program

A program needs to be designed to meet the needs of all woodfuel users: subsistence farmers, tenant farmers, landless labourers, the urban poor, and small rural industries. When participation is required, all potential participants need to have a strong personal incentive to take part in the program by receiving direct benefits.

This means that governments need to design a program that is carefully tailored to the situation in their respective countries. Factors that need to be considered are the social characteristics of the population, settlement patterns, land tenure arrangements, livestock holdings, attitudes to trees, and organizational arrangements.⁷

The components of a project were defined in Chapter V to consist of the following,

Improving fuelwood supplies through

- better management of existing resources
- creation of new resources through
 - ... individual planting
 - ... village woodlots
 - ... commercial plantations

Improving efficiency of conversion and use through

- more efficient kilns
- more efficient cookstoves
- more efficient equipment for small industry

There are problems involved with the implementation of each of these elements that include such factors as impermanent land tenure arrangements that are a disincentive to tree planting, social and economic inequalities in villages that work against communal woodlots, and adherence to traditional ways of cooking that prevent the adoption of efficient stoves.

Anticipating and devising innovative methods of getting around these difficulties is an essential part of the design of any project. This requires a thorough knowledge of current patterns of woodfuel use and supply and an intensive investigation of the potential problems that can be anticipated by using imagination, by reading the literature, and by consulting people who have experience in carrying out similar projects.

Providing credit, subsidies and even free services and advice is an important part of a woodfuel program. Care needs to be taken to ensure that people have access to the resources needed to implement the program effectively.

It is also necessary to ensure that the benefits from the program are distributed equitably. At the same time, it must be recognized that the elite of a community will most likely be the first persons to experiment with new technology such as woodstoves, or take the risk of planting valuable land with unfamiliar tree species. These people, however, may provide the crucial bridge for wider participation in the project.

When the desire to participate spreads to the poorer population, they need to be given priority in the allocation of resources from the program. This is being done in the Gujarat program where people with land holdings of under two hectares are given priority in seedling distribution.⁸

Poor people will probably have to participate in a program for several years before they come to believe in its benefits.

c) Organizational Structure

A strong organizational structure must be set up where responsibilities are clearly defined in respect to objectives. This organizational structure needs to cut across the traditional departmental frameworks. The co-operation of a number of ministries and governmental and non-governmental entities will be required. Ministries that have an important role to play include agriculture (which normally includes forestry), industry, finance, and energy. Government agencies that extend credit to small business and farmers also need to be involved along with local governments, agricultural co-operatives, women's groups, and so on. However, while all of these entities need to be involved, there must be clear direction from a central body with overall responsibility for the program.

d) Public Awareness Campaign

People need to be motivated to participate in the program by a public awareness campaign. This strategy is similar to the social marketing approach described by Harrison.⁹ Individuals must become aware of how they can benefit directly by planting and tending trees, and by using more efficient stoves. They must also become aware of the facilities that exist to help them carry out these activities, and of how they can get access to these facilities.

The campaign in Gujarat can provide a good example of what is needed: films, ads on billboards, radio advertisements, and extension workers travelling the countryside to speak to schools, womens' groups, co-operatives, and at public meetings.

As an awareness of the economic benefits of woodfuel programs spreads through the population, gradually, especially in the young, a heightened woodfuel consciousness may develop, similar to the energy consciousness that is now developing in the industrialized world as a result of the combination of conservation campaigns and high energy prices.

e) Encouraging the Development of Small Scale Industries Around the Program

The entire woodfuel program as described above could be carried out by government agencies using government departments, forestry agencies, government extension services, and so on. It may be necessary to create new institutions such as special government corporations similar to petroleum companies or electrical utilities for fuelwood supply. An example of such a corporation is the Sri Lankan State Timber Corporation, which is actively involved in the production of wood and charcoal and the sale of fuel efficient stoves. Such companies could be partially or wholly government owned and operated, and could be an instrument for implementing woodfuel policies.

Since the administrative resources of most governments are already stretched thin, governments could also choose to implement policies partly through encouraging investment in small-scale woodfuel projects such as nurseries, commercial woodfuel plantations, and the production of efficient woodstoves and wood utilization equipment.

Because the social benefits are not taken into account by the private sector, and its discount rate is higher than

the government's, incentives may be needed. These incentives could be similar to those offered to new industrial projects, such as special tax exemptions or writeoffs for investments in and income from woodfuel projects. Governments could also provide financing or loan guarantees and could even remove some of the risk by contracting to buy the product at an agreed-upon price. Fuelwood production companies could be allowed to lease government land on a profit-sharing basis. Finally, governments could provide infrastructure as they sometimes do for industrial projects.

f) Comparison of Woodfuel Programs and Conservation Campaigns

There are many parallels between woodfuel programs in developing countries and conservation campaigns in industrialized countries. Both are trying to motivate a large number of individuals to make decisions that will result in extending the life of energy resources and in increasing energy self-sufficiency for the nation as a whole.

Conservation campaigns have shown that the decision to conserve is mainly an economic one. That is, people conserve energy when it clearly benefits them economically. As the cost of heating oil rises, people turn down their thermostats.

Government campaigns in this case primarily consist of informing people about ways to conserve energy without radical changes in lifestyles. Energy ministries also help people to conserve by publishing data on the energy consumption of consumer goods, such as cars and appliances, and by subsidizing the installation of insulation in homes.

When people are purchasing wood or where wood is in extremely short supply, there is no doubt that people are already conserving wood. The government's role can be to make people aware of ways to increase wood supplies and reduce wood consumption, and to subsidize these actions where people would otherwise be unwilling to take them, just as industrialized countries have done in their conservation programs.

3. Why Have So Few Governments Implemented Woodfuel Programs?

As noted in Section 1, only China, Korea, India, and Malawi have made or are making serious attempts to resolve woodfuel problems. What of the other countries that are shown in Chapter II to have critical woodfuel problems?

Most of these countries have general reforestation programs, directed by their forestry services. The level of planting under these programs is grossly inadequate as shown in Appendix 3.

In addition, aid agencies are sponsoring reforestation, afforestation, and woodfuel projects on a small scale in most countries. These are often offshoots of general forestry or agriculture projects, or of industrial forestry projects. Their scale is too small in relation to needs. An examination of IBRD supported projects, which tend to be large in relation to those of other agencies, shows that in 1980 and 1981 the following projects were approved, ¹⁰

Gujarat - planting of 71,000 hectares over five years plus establishment of nurseries, number and production unspecified.

Upper Volta	- strengthening of forestry institutions plus the establishment of 1,925 hectares of woodlots over five years.
Malawi	- establishment of 19,000 hectares of woodlots over five years (including individual planting).
Nepal	- establishment of 12,000 hectares of woodlots and rehabilitation of 39,000 hectares of existing forest over five years.
Rwanda	- establishment of 5,000 hectares of fuelwood and pole plantations over five years, plus nurseries, number and production unspecified.
Bangladesh	- planting of 15,000 acres of mangrove annually in years 1,2, and 3, 25,000 acres annually in years 4 and 5. Production to be utilized for both fuelwood and timber.
Senegal	- establishment of 5,000 hectares of tree plantations over a five year period.
Philippines	- general reforestation of 31,500 hectares over a five year period.
Madagascar	- establishment of 18,500 hectares of industrial plantations over a three year period.

Table 23 summarizes for the above countries annual planting levels in government reforestation programs and IBRD sponsored projects in relation to the level of planting required as estimated by the World Bank Task Force on Renewable Energy (See Appendix 3). The combined level of planting is 50 to 85 per cent below required levels for this group of countries.

There are, of course, other aid agencies sponsoring fuelwood and reforestation projects in different countries that add to the number of hectares being planted, but their contribution will not make up the difference shown in Table 23.¹¹

Planting is only one aspect of woodfuel programs. Action

Table 23

Comparison of Current Planting Levels of
Government and IBRD Sponsored Programs
in Comparison to Required Levels

(hectares/year)

	<u>Gov't Programs</u>	<u>IBRD Programs</u>	<u>Total Programs</u>	<u>Required Level</u>
Upper Volta	1,500	385	1,885	15,000
Malawi	2,500	3,800	6,300	10,000
Nepal	5,000	2,400	7,400	25,000
Rwanda	1,500	1,600	3,100	10,000
Bangladesh	10,000			85,000
Senegal	2,000	1,500	3,500	15,000
Philippines	12,000	6,300	18,300	35,000
Madagascar	2,000	6,000	8,000	10,000

on improving efficiency of conversion and end use of woodfuels is even less advanced. There are a number of reasons why governments have not implemented woodfuel programs, including

- a) the low priority given to the basic needs of the rural sector by development planners,
- b) the fact that fuelwood is seen as an old-fashioned, backward fuel,
- c) the need for long-term financing that must compete with other priority uses for capital,
- d) the massive scale of the action needed and requirements for administrative, managerial, and technical skills,
- e) the lack of success with previous projects.

These reasons are discussed further below.

a) Low Priority of Basic Needs

The development strategy followed by most countries has been one of import substitution, with a heavy emphasis on the development of local large-scale industries. This also led to a focus on urban issues versus rural issues, a focus that comes naturally to a government where most officials live in the modern, urban world.¹² The problems of subsistence farmers, tenant farmers, and landless labourers, the people who most often face woodfuel supply problems, are not high on the political agenda of most governments.

If the problem is seen from the standpoint of environmental degradation, again this is not a high priority. Only when food production is seriously affected or when woodfuel availability is linked to petroleum imports is the attention of government planners likely to be caught.

b) Perception of Woodfuel as a Backward Fuel

According to Noronha, "To many governments of developing countries, the cry for investment in fuelwood resources is a step backward in the pursuit of progress."¹³ Until the surge in oil prices in the 1970s, it was widely expected that wood would be rapidly replaced by cheap petroleum products as income levels rose. However, per capita income levels have risen slowly or not at all since 1973, while the price of petroleum products has increased spectacularly.

There is now little doubt that commercial energy sources will remain beyond the reach of much of the world's population, as discussed in Chapter II. But to be asked now to emphasize wood as a domestic energy resource is to be asked to recognize that traditional rural lifestyles will continue unchanged, to be condemned to being backward forever.

It is especially upsetting for officials from developing countries to be told by international aid agencies and governments of industrialized countries to emphasize wood as an indigenous fuel. Development planners are therefore reluctant to allocate resources to woodfuel programs, even though they are unable to propose alternative sources of energy for those people now using woodfuels.

c) The Need for Long-Term Programs and Financing

Fuelwood projects require a long-term commitment of funds. Most programs would require a time horizon of 10 to 20 years to take effect. The money for projects would have to be taken from current resources or borrowed from bilateral or

multilateral aid agencies.

The demands on current revenue in most countries are already greater than the funds available. Providing even minimal levels of educational and health services is difficult. This means funds would need to be borrowed.

Most countries must borrow long-term capital for a number of purposes including the construction of infrastructure such as transportation networks, communications systems, and electrical generating and distribution facilities. They also must often guarantee or obtain loans for industrial projects, and for petroleum exploration and development by national oil companies.

Government planners will almost always place higher priority on obtaining funds for the above kinds of projects than for a risky and untested woodfuels program.

Additionally, the traditional design of reforestation programs do not offer the possibility of recovering costs. Government reforestation or village woodlot programs can be looked at as investments in public welfare, but they are also a long-term drain on government revenues. The last thing developing countries want is an extra, long-term financial burden.

d) The Massive Nature of the Programs Needed

Most countries need to initiate large-scale programs to counter the result of centuries of neglect of forest resources. The scale of action needed can be illustrated by the Guatemalan

example described in the previous chapter.¹⁴ This program required the diffusion of 30 million seedlings to rural families, the establishment of plantations on over 6 per cent of the national territory, and the sale of 50,000 efficient stoves per year. The total cost of the project over 20 years was US \$350 million.

Commitment to such a program requires the allocation of manpower, resources, and revenues beyond the capacities of most developing countries.

e) The Lack of Success of Previous Projects

The degree of success of national reforestation programs, and of projects such as village woodlots initiated by foreign aid agencies, has not been great. There have been many more failures than successes.

The essence of the problems in woodfuel projects can be defined as a less than total commitment on the part of the governments involved in terms of allocating financial and human resources to the programs; design problems related to a lack of experience in managing such projects; and lack of participation of local people in the projects.

Government planners have become skeptical about woodfuel projects since so few of them have achieved their objectives. Therefore, even when funds and resources are available for woodfuel projects, planners will be reluctant to commit them to programs that appear to have a dubious chance of success.

4. Prospects for Increased Government Action on Woodfuel Problems

While developing countries have grown wary of or have not shown much interest in woodfuel programs, there are a number of reasons why they may begin to initiate action on woodfuel problems in the near future. These reasons relate to the renewed interest in agriculture as a prime mover of development, the link between woodfuels and petroleum products, the recognition that woodfuel programs can be economic, and the increased funds being made available by aid agencies for woodfuel projects.

a) Recognition of the Importance of Agriculture in Development

Development via industrialization has proven to be a rocky road for many countries. In some countries, it has created serious problems that are exacerbated by current high oil prices and the world recession. For example, Brazil achieved steady growth rates of 10 per cent per year in the early 1970s based on industrial development. But balance of payments constraints have now forced Brazil to reappraise its development strategy and to look for new ways to generate economic growth.

Brazil's new triple-pronged strategy is to promote the development of agriculture at a faster pace than industry, to do everything possible to increase exports, and to develop alternative indigenous energy sources (including fuelwood, charcoal, and methanol from wood) as quickly as possible.¹⁵

As countries are forced by balance of payments problems to recognize the importance of indigenous energy sources and by growing populations to see the importance of agriculture,

they may allocate more resources to woodfuel programs that contribute to both agricultural and energy self-sufficiency.

b) Woodfuels as Substitutes for Petroleum Products

Purchased fuelwood, charcoal, methanol, and producer gas are all substitutes for petroleum products. The potential contribution of woodfuels as petroleum replacements is substantial.

It was estimated earlier that even if one half of the 2.4 billion people forecast to be experiencing woodfuel shortages by the year 2000 were to switch to petroleum products, the total additional cost for imported petroleum would be US \$16 billion annually, at current oil prices.¹⁶

Even if one's focus is on the oil crisis, it is therefore important to increase woodfuel supplies so that this shift will be minimized. To this extent, the woodfuel situation can benefit from association with the broader problem of petroleum supply.

c) Woodfuel Programs Can Be Economic

Woodfuel programs can be designed so that the investments made by government can be recovered, partially, completely, or even with a healthy rate of return.

In many countries, programs can be designed to include the sale of seed or seedlings, commercial production of fuelwood and charcoal, and sale of efficient stoves and commercial equipment.

Such projects can generate a healthy rate of return,¹⁷ especially if they are financed on the basis of low interest

loans such as those available from the OPEC Fund for energy projects. In fact, investment in woodfuel can be much more attractive than investment in a highly risky petroleum exploration venture.

d) Increased Funding by Aid Agencies

The interest of major multilateral and bilateral aid agencies is relatively recent. The key year is 1978, when the Eighth Annual World Forestry Congress was held with the theme of "Forests for People". In the same year, both the World Bank and the FAO made major policy statements on rural forestry problems in developing countries.¹⁸

This was followed by increased funding commitments, especially by the World Bank which allocated, as part of its general energy program US \$425 million to woodfuel projects over the period 1981-1985 (See Table 24).¹⁹ FAO and US AID are among other agencies that have recently increased funding for woodfuel programs.

The total amounts allocated for woodfuel programs do not come near the total of one billion dollars per year estimated to be required by the UNERG Technical Panel on Fuelwood and Charcoal, or the \$4.5 billion estimated to be necessary in Chapter V. But it is doubtful whether even the amounts available can be absorbed by developing countries.

Therefore, aid agencies need to encourage governments to take an interest in woodfuel problems. This can be done in a number of ways, such as maintaining the high profile of the

issue by continuing to organize conferences and meetings that highlight woodfuel concerns, as was done at the Djakarta conference and at the U.N. Conference on New and Renewable Energy Sources. They can also publicize the woodfuel programs that they sponsor. Wherever possible, fuelwood issues could be made an integral part of general energy policy and planning work funded by agencies.

Perhaps the most effective way to give emphasis to woodfuel programs is to do what the World Bank has done, i.e., to allocate a larger share of forestry aid funds to woodfuel programs.

Aid agencies can also ensure that any woodfuel programs that they carry out are integrated into a general plan of action. Isolated, piecemeal projects of the type carried out to date have limited effect. Projects need to be designed to ensure that the momentum of the project is carried forward, either into a new phase or into a replication of the project.

Aid agencies, however, can only play a supplementary role in suggesting, organizing, and developing projects. Woodfuel programs must be suggested by developing country governments.

Table 24: CURRENT AND DESIRABLE WORLD BANK ENERGY LENDING PROGRAMS,
FY 1981-85

(Million current US dollars)

	Current		Desirable	
	Lending Program	Total Project Cost	Lending Program	Total Project Cost
<u>Coal and Lignite</u> /a	840	4,270	2,000	7,350
<u>Oil and Gas</u>				
Predevelopment	1,020	2,610	2,410	5,850
Oil Development /b	1,755	5,900	3,320	12,150
Gas Development /c	1,210	3,250	2,270	5,875
	<u>3,985</u>	<u>11,760</u>	<u>8,000</u>	<u>23,875</u>
<u>Refineries</u>	150	400	1,000	3,100
<u>Renewables</u>				
Fuelwood	425	850	1,100	2,200
Alcohol	200	2,100	650	4,550
	<u>625</u>	<u>2,950</u>	<u>1,750</u>	<u>6,750</u>
<u>Electric Power</u>	7,590	37,950	11,000	47,450
<u>Industrial Retro-</u> <u>fitting</u>	0	0	1,250	3,825
TOTAL	<u>13,190</u> /d	<u>57,330</u>	<u>25,000</u> /d	<u>92,350</u>
Bank Share of Total Project Cost (percent)		23		27

/a Includes coal gasification projects.

/b Includes heavy oil projects.

/c Includes methanol.

/d Does not provide for any lending to China.

Note: On completion, the projects included in the Current Lending Program are estimated to produce (or in the case of electric power and industrial retrofitting projects, to save) energy equivalent to 1.62 million barrels of oil per day (mbdoe) or 5.3 percent of the developing countries' projected energy consumption in 1990. The corresponding estimates for the Desirable Lending Program are 2.9 mbdoe and 9.5%, respectively. Refineries, which add substantially to the value of petroleum products but not to energy output or savings, are excluded from the calculation.

Notes - Chapter VI

1. Noronha, "Why is it so difficult to grow fuelwood?", p. 5.
2. Quoted in Eckholm, "Planting for the future", p. 40.
3. Ibid., p. 42.
4. FAO, "Case Study No. 2, "Village Fuelwood Plantations in Korea", FAO Forestry Paper 17, Supplement 1 (Rome: FAO, 1979).
5. Noronha, "Why it it so difficult ...", p. 7-8.
6. World Bank, "Malawi: Phase II of a National Rural Development Program (Wood Energy Project)", Staff Appraisal Report (Washington: World Bank, Feb. 8, 1980).
7. Noronha, "Sociological Aspects of Forestry Design", p. 11-40.
8. World Bank, "Annual Report on Bank Financed Forestry Activity, FY 1981", p. 9.
9. See Chapter V, p. 114.
10. This information was taken from "Review of Bank Financed Forestry Activity" for FY 1980 and 1981 (World Bank, Internal Memoranda).
11. For an extensive, if somewhat dated list of aid-funded forestry, see United States, Department of Agriculture, Forest Service, Forestry Activities and Deforestation Problems in Developing Countries, Report to Office of Science and Technology, Development Support Bureau, US AID PASA No. AG/TAB-1080-10-78 (June 1980).
12. This is not a problem unique to developing countries. Farmers and the rural sector in industrialized countries are also not a prime focus of government policies.
13. Noronha, "Why is it so difficult ...", p. 9.
14. See Chapter V, p. 122.
15. "Brazil has three pronged strategy for dealing with debt burden", The Globe and Mail, November 16, 1981, p. B6.
16. See Chapter III, p. 57.
17. See Chapter V, p. ; the World Bank's "Review of Bank-Financed Forestry Activity" FY 1980, which shows a rate of return of 18 per cent for a Bangladesh forestry project; and the Review for FY 1981 quotes rates of return as high as 27 per cent for farm forestry (p. 13).

18. World Bank, "Forestry Sector Policy Paper" (Washington: World Bank, February 1978); FAO, "Forestry for Rural Communities" (Rome: FAO 1978).
19. The World Bank would like to spend US \$1 billion on woodfuel projects if it is able to obtain additional funding. However, American opposition to the creation and funding of the proposed World Bank Energy Affiliate has made it virtually certain that additional funds will not be obtained.
20. Quoted in V.S. Bogach, "The U.N. Conference on New and Renewable Energy Sources: Summary of the Proceedings and Documentation Relating to Fuelwood and Charcoal", National Research Council, Division of Energy Research and Development (Ottawa: NRCC, December 1981), p. 37.

Chapter VII

Summary: Woodfuel as a Key Energy Resource

Over one and one-half billion people are estimated to rely on wood to supply their basic energy needs. If petroleum prices remain high and wood supplies are adequate, the traditional use of wood as energy will continue and expand. Woodfuels, if available, could also play a small but significant role in supplying the energy needs of modern industry and transport.

Since most developing countries are net importers of oil and their petroleum resources are largely unknown, it makes economic sense to maximize the use of indigenous wood resources.

But forest resources in many developing countries are shrinking rapidly because of uncontrolled exploitation and destruction. In 39 of the 56 countries where wood supplies over 25 per cent of all energy requirements, there are widespread areas of acute scarcity or deficit. In another eight countries, there are likely to be deficits by the year 2000.

Few trees are planted by individuals or governments to replace those that are cleared for agricultural production, timber production, fuelwood, charcoal, or building poles. In the context of many countries, wood is not a renewable resource. It is being mined rather than utilized on a sustainable basis.

Rapidly growing populations hungry for agricultural land and for more and more wood, combined with the perception that wood is free, will create increasing woodfuel shortages.

Because of the long lead time needed to implement woodfuel programs, the situation is becoming critical. Development

planners in all these countries need to be concerned with acting now, before it is too late. If action is not taken, the quality of life of those people who depend on wood for energy will deteriorate, the capacity to produce food will decrease as a result of deforestation and consequent soil erosion, and negative impacts will permeate the economic system of each country.

Technical solutions to woodfuel supply problems have been identified. These include increasing wood resources through better management of existing forests, the creation of new wood resources, especially through agroforestry in rural areas, and commercial wood plantations. They also include more efficient conversion of wood to charcoal, and more efficient utilization of woodfuel in the home and small industry. Efficiency improvements can have the fastest impact on reducing wood requirements and pressure on wood resources.

But action on woodfuels has in most countries been confined to small isolated projects funded by aid agencies. Few countries have embarked on a serious program to resolve woodfuel problems.

There are many reasons for this reluctance that relate to the low level of political power of woodfuel users; the perception of wood as a traditional, backward fuel; the need for long-term programs and financing; the massive scale of the programs needed; and the lack of success in early woodfuel programs.

Action on woodfuel problems is also being blocked by two other current and critical issues -- a worldwide recession that is cutting into export earnings, and balance of payments deficits caused by expensive oil imports.

The focus of most countries is on the more immediate oil-related balance of payments problems. This was made clear at the U.N. Conference on New and Renewable Energy Sources, where resistance to the high profile of fuelwood and charcoal was expressed by some delegates.

Many of the speakers from developing countries stressed their concern with obtaining adequate supplies of conventional fuel, especially oil, in the short-term. This attitude was expressed most strongly by the Industry Minister of Zimbabwe in his address to the conference,

Zimbabwe is deeply concerned that new and renewable sources of energy should not be made the energy of the poor countries leaving the conventional sources to satisfy the insatiable appetites of the industrialized countries who already consume a disproportionate quantity of the world's energy resources.

Developing countries must perform the difficult act of deftly juggling short-term needs (oil) and long-term needs (development of other sources of energy). They face the onerous task of making sure their modern industrial sectors have adequate oil supplies, and of ensuring, at the same time, that poor people in the traditional sectors have access to reliable woodfuel supplies.

Since supplying both types of energy requires major investments and capital is scarce, there are difficult decisions

to be made.

These energy policy decisions will be made by the governments of developing countries. It is up to government planners to decide which needs will be met among the many that have priority.

Now that an awareness of the importance of woodfuel problems is growing, and that governments are being forced by balance of payments problems to recognize the potential importance of indigenous woodfuels as alternatives to expensive imported petroleum products, governments may allocate more resources to woodfuel programs. They are beginning to see that this would contribute to both agricultural and energy self-sufficiency. Aid agencies are encouraging this growing willingness to engage in woodfuel programs by making more funds available for them.

It is not too late to prevent widespread woodfuel shortages and the deterioration of living standards that will accompany them. If governments allocate enough administrative, managerial, and financial resources to the problems, and if international agencies continue to provide more financial and technical support, woodfuel problems can be resolved over the next 10 to 20 years.

As long as woodfuel shortages were perceived as a forestry issue, i.e., just another environmental problem, there was not much chance of government action. But now that deforestation and woodfuel shortages are being seen as an energy issue with important economic effects, developing countries may be motivated to embark on effective reforestation and woodfuel supply programs.

Appendix 1

Examples of Energy Requirements in
Selected Developing Countries

Appendix 1

Examples of Energy Requirements in Selected Developing Countries

(Total = Thousands of tonnes of oil equivalent and per capita = tonnes of oil equivalent)

	Jordan, 1980		Egypt, 1981		Thailand, 1978/79	
	Total	Per Capita	Total	Per Capita	Total	Per Capita
<u>Modern</u>						
Oil	1,840	0.58	13,600	0.33	9,582	0.22
Natural gas	-	-	-	-	-	-
Coal	-	-	-	-	262	0.01
Hydro	-	-	3,400	0.08	991	0.02
Alcohol	-	-	-	-	-	-
Sub-total	1,840	0.58	17,000	0.41	10,835	0.25
<u>Traditional</u>						
Wood	-	-	n/a	n/a	11,322	0.26
Charcoal	-	-	n/a	n/a	806	0.02
Bagasse	-	-	n/a	n/a	4	-
Agr. residues	-	-	n/a	n/a	n/a	n/a
Draught animals	-	-	n/a	n/a	12,132	0.28
Sub-total	-	-	3,000	0.07	22,967	0.52
Total	1,840	0.58	20,000	0.48		

Appendix 1 (continued)

Brazil, 1978

Peru, 1979

Guatemala, 1979

	Brazil, 1978		Peru, 1979		Guatemala, 1979	
	Total	Per Capita	Total	Per Capita	Total	Per Capita
<u>Modern</u>						
Oil	45,862	0.38	6,200	0.36	1,537	0.23
Natural gas	-	-	1,200	0.07	-	-
Coal	4,781	0.04	325	0.02	..	..
Hydro	10,130	0.09	800	0.05	23	..
Alcohol	1,266	0.01	-	-	-	-
Sub-total	62,039	0.52	8,525	0.50	1,560	0.23
<u>Traditional</u>						
Wood	20,676	0.17			1,945	0.29
Charcoal	2,559	0.02	3,026	0.18	..	..
Bagasse	5,243	0.05	-	-	178	0.03
Agr. residues	n/a	n/a	698	0.04	n/a	n/a
Draught animals	n/a	n/a	n/a	n/a	n/a	n/a
Sub-total	28,478	0.23	3,724	0.22	2,123	0.31
Total	90,517	0.76	12,250	0.72	3,683	0.54

Appendix 1 (continued)

	Sudan, 1979/80		Kenya, 1979	
	Total	Per Capita	Total	Per Capita
<u>Modern</u>				
Oil	1,106	0.06	1,677	0.11
Natural gas	-	-	-	-
Coal	-	-	11	..
Hydro	51	..	352	0.02
Alcohol	-	-	-	-
Sub-total	1,157	0.06	2,040	0.13
<u>Traditional</u>				
Wood	3,534	0.20	7,000	0.45
Charcoal	306	0.02		
Bagasse	-	-	n/a	n/a
Agr. res.	70	..	n/a	n/a
Draught animals	44	..	n/a	n/a
Sub-total	3,954	0.22	7,000	0.45
Total	5,111	0.29	9,040	0.58

Sources: National Papers to U.N. Conference on New and Renewable Energy Sources, Nairobi, 1981. Except Thailand; Geoffrey Barnard and Sermpot Ratasuk, "The Potential for Wood Energy in Thailand" Thailand Institute of Scientific and Technological Research, (June 1980): and Guatemala; V.S. Bogach, "A Fuelwood Policy for Guatemala", study carried out for the U.N.D.P. (GUA/74/014, January 1981).

APPENDIX 2

Data from Annex to FAO, Map of the Fuelwood
Situation in Developing Countries, presented at U.N.
Conference on New and Renewable Sources of Energy

POPULATIONS INVOLVED IN FUELWOOD DEFICIT SITUATIONS ^{1/}
(million inhabitants)

Region	1980						2000	
	Acute Scarcity		Deficit		Prospective Deficit		Acute Scarcity or Deficit	
	Total	Rural	Total	Rural	Total	Rural	Total	Rural
Africa	55	49	146	131	112	102	535	464
Near East and North Africa			104	69			268	158
Asia Pacific	31	29	832	710	161	148	1 671	1 434
Latin America	26	18	201	143	50	30	512	342
Total	112	96	1 283	1 052	323	280	2 986	2 398

^{1/} The table indicates the total population and the population with a predominant rural type of energy consumption (total population less urban centres over 100 000 inhabitants); these are the estimated populations living in the areas under the identified fuelwood situations.

N.B.: This table is a revision of Table 2 of the Final Report of the Technical Panel on Fuelwood and Charcoal.

AFRICA SOUTH OF SAHARA

Unit	Situation in 1980					Prospective Situation in 2000	
	Populations depending mainly on fuelwood	Fuelwood			Total Fuelwood Balance	Populations depending mainly on fuelwood	Total Fuelwood Balance
		Needs	Availability	Balance			
	million inhabitants	m ³ /inhabitant/year			million m ³	million inhabitants	million m ³
<u>Acute Scarcity</u>							
Arid and sub-arid areas	13.1	0.5	0.05 to 0.1	-0.45	-6	19	-10
Mountainous areas and islands	35.7	1.4 to 1.9	0.5 to 0.7	-1.1	-40	55	-70
<u>Deficit</u>							
Savannah areas	131.4	1 to 1.5	0.8 to 0.9	-0.5	-66	215	-150
<u>Prospective Deficit</u>							
Savannah areas	65	1 to 1.5	1.8 to 2.1	+0.7	+45	112	-35
High forest areas	36.5	1.2 to 1.7	1.8 to 2	+0.5	+20	63	-5
<u>Satisfactory</u>							
High forest areas	6.2	1.2 to 1.5	5 to 10	over 4	+50	9	+50

PAR EAST ASIA

	Situation in 1980						Prospective Situation in 2000	
	Populations depending mainly on fuelwood	Fuelwood			Total Balance	million m ³	Populations depending mainly on fuelwood	Total Fuelwood Balance
		Needs	Availability	Balance				
Unit	million inhabitants	m ³ /inhabitant/year				million m ³	million inhabitants	million m ³
<u>Acute Scarcity</u>								
Mountainous areas Himalayas	29	1.3 to 1.8	0.2 to 0.3	-1.3	-38	-60	46	-60
<u>Deficit</u>								
Plains, mainly Indo-Gangetic in northern Asia	297	0.2 to 0.7	0.15 to 0.25	-0.30	-90	-146	487	-146
Plains and islands in South East Asia	412	0.3 to 0.9	0.2 to 0.3	-0.30	-120	-265	662	-265
<u>Prospective Deficit</u>								
Other fast-growing population areas	148	0.5 to 0.9	0.7 to 0.8	+0.05	+7	-48	239	-48
<u>Satisfactory</u>								
Korea	21	0.3 to 0.9	1	+0.4	+8	+12	29	+12
High forest areas	129	0.9 to 1.3	1 to 6	+2.4	+309	+283	218	+283

LATIN AMERICA

	Situation in 1980					Prospective Situation in 2000	
	Populations depend- ing mainly on fuelwood	Fuelwood			Populations depend- ing mainly on fuelwood million inhabitants	Total Fuelwood Balance million m ³	
		Needs m ³ /inhabitant/year	Avail- ability	Balance			
							Total Balance million m ³
Unit	million inhabitants	m ³ /inhabitant/year			million inhabitants	million m ³	
<u>Acute Scarcity</u>							
Andean Plateau	2	0.95 to 1.6	0.2 to 0.4	- 2	3.5	- 4	
Arid areas in west- ern South America and densely popu- lated areas	16	0.6 to 0.9	0.1 to 0.3	- 9	28	-15	
<u>Deficit</u>							
Populated semi-arid areas and Andean zones.	143	0.7 to 1.2	0.6 to 1	- 36	260	-117	
<u>Prospective Deficit</u>							
Less populated sub- tropical and temper- ate areas	30	0.5 to 1.2	1.9 to 2.3	+ 36	50	+ 15	
<u>Satisfactory</u>							
Areas with abundant forest resources	38	0.5 to 1.2	2.5 to 10	+ 5.5	64	186	

APPENDIX 3

Data from World Bank Renewable Energy Task Force,
Developing Countries Fuelwood Supply/Demand Analysis

RENEWABLE ENERGY TASK FORCE STUDY
DEVELOPING COUNTRIES FUELWOOD SUPPLY/DEMAND ANALYSIS

1980-2000

[Excluding fuelwood likely to be produced as a by-product of "other" multipurpose forestry lending]

COUNTRY	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
LATIN AMERICA																						
Mexico	70	24	104	132	9	15	30	10	30.0	10	9	0.4	10	0.4	20	5.6	4	25	25	5	30	15.0
Costa Rica	2	2	1	3	2	3	30	2	1.5	5	2	0.1	1	0.1	5	1.0	5	5	5	5	10	5.0
El Salvador	5	4	5	9	2	3	30	2	1.0	5	2	0.1	-	0.1	5	1.0	5	5	5	5	10	5.0
Guatemala	7	6	6	12	4	6	30	4	4.0	5	4	0.2	-	0.2	10	1.0	10	5	5	5	10	5.0
Honduras	4	4	3	7	2	2	30	1	6.0	5	1	0.1	-	0.1	5	2.0	3	10	10	5	15	7.5
Nicaragua	3	2	3	5	2	3	30	2	6.4	5	2	0.1	-	0.1	5	1.0	5	5	5	5	10	5.0
Dominican Republic	-	1	-	1	2	3	30	2	2.0	5	2	0.1	1	0.1	5	0.5	10	5	5	5	10	5.0
Haiti	6	4	6	10	3	4	30	3	8.1	11	3	0.1	-	0.1	5	1.0	5	5	5	5	10	5.0
Brazil	116	210	326	536	250	250	30	170	350.8	25	130	8.7	700	6.0	400	100.0	42	100	100	20	120	60.0
Peru	18	23	6	29	5	8	20	6	60.0	20	5	0.2	6	0.2	10	5.0	2	20	20	5	25	12.5
Chile	11	13	2	15	3	5	40	3	20.0	10	3	0.1	200	Already self-sufficient								
Venezuela	15	23	3	26	6	9	40	5	44.0	15	4	0.2	10	0.2	10	2.0	5	-	-	5	5	2.5
Ecuador	8	8	7	15	1	2	30	1	20.0	20	1	0.1	2	0.1	5	2.0	3	20	20	5	25	12.5
Colombia	27	34	8	42	22	35	30	25	60.0	20	20	1.0	20	1.0	50	10.0	5	20	20	5	25	12.5
Guyana	Less than 1	1	-	1	-	1	25	1	18.0	80	-	-	1	0				-	-	2	-2	
Jamaica	2	2	1	3	-	1	25	1	0.2	-	1	0.1	2	0.1	5	1.0	5	5	5	5	10	5.0
Surinam	Less than 1	-	1	1	-	1	25	1	14.0	80	-	-	1					-	-			
Trinidad	1	1	1	2	-	3	30	1					1					-	-			
Paraguay	3	3	2	5	2	3	30	2	21.0	80	1	0.1	2	0.1	5	1.0	5	5	5	5	10	5.0
Uruguay	3	3	2	5	-1	2	40	1	0.5	11	1	0.1	30	0.1	5	1.0	5	5	5	5	10	5.0
Argentina	27	27	5	32	6	10	40	6	60.0	20	5	0.2	100	0.1	5	2.0	2	20	20	5	25	12.5
Bolivia	5	4	5	9	5	8	20	6	10.0	20	5	0.2	3	0.2	10	2.0	5	10	10	5	15	7.5
Panama	2	2	1	3	1	2	20	1	4.0	10	1	0.1	1	0.1	2	1.0	3	10	10	5	15	7.5
Sub-Totals	327	331	176	577	292	379	32	356	236.6	20	202	12.2	1091	11.4	500	139.5	4	260	260	112	392	195.8

RENEWABLE ENERGY TASK FORCE STUDY

DEVELOPING COUNTRIES FUELWOOD SUPPLY/DEMAND ANALYSIS

1980-2000

[Excluding fuelwood likely to be produced as a by-product of "other" multipurpose forestry landings]

COUNTRY	(1)	Urban	(2)	Total	(3)	Current Fuelwood Consumption	(4)	Projected Fuelwood Consumption	(5)	Alternative Fuelwood Substitution	(6)	Net Fuelwood Requirement	(7)	Area of Plantations Needed	(8)	Area of Plantations Needed	(9)	Balance of New Plantations	(10)	Col (11)	(11)	Col (12)	(12)	Col (13)	(13)	Actual Output	(14)	Factor	(15)	Target Planting Area	(16)	Cost of Additional Wood	(17)	Cost of Additional Wood	(18)	Cost of Additional Wood	(19)	Cost of Additional Wood	(20)	Cost of Additional Wood	(21)	Cost of Additional Wood
SOUTH ASIA																																										
India	694	322	485	1037	93	225	30	158	10	142	10.0	600	9.4	470	200.0	2	200	300	30	250	125.0																					
Pakistan	42	40	85	145	15	40	30	30	5	28	2.8	100	2.7	135	25.0	5	50	50	25	75	37.5																					
Burma	35	22	33	55	12	25	20	20	60	6	0.5	100	0.4	20	2.0	10	20	20	10	30	15.0																					
Nepal	14	2	20	22	8	14	14	14	20	9	0.5	10	0.5	25	5.0	5	15	15	5	20	10.0																					
Sri Lanka	15	8	12	20	4	7	20	6	3.4	20	0.1	20	0.1	5	5.0	-	25	25	5	30	15.0																					
Bangladesh	89	34	119	153	30	60	20	40	5	38	1.2	150	1.7	85	10.0	8	50	50	2	52	27.5																					
Sub-Totals	279	478	254	1432	162	271	23	245	26	227	13.8	980	15.8	740	267.0	30	340	340	100	440	230.0																					
EAST ASIA AND PACIFIC																																										
Cambodia	6	3	9	12	3	6	20	5	11.0	30	0.2	1	0.2	10	0.5	20	5	5	5	10	5.0																					
Laos	4	2	4	6	2	4	10	4	11.0	35	0.1	-	0.1	5	0.5	14	5	5	5	10	5.0																					
Vietnam	52	28	51	79	16	30	35	20	11.5	25	0.7	50	0.6	30	8.0	4	30	30	5	35	17.5																					
Thailand	48	17	59	76	15	24	30	16	20.0	25	0.6	25	0.6	30	12.0	3	20	20	5	25	12.5																					
Philippines	51	41	42	83	20	35	35	25	12.0	20	0.8	60	0.7	36	12.0	3	25	25	5	30	15.0																					
Indonesia	151	71	150	221	107	164	35	100	71.0	15	3.6	400	3.2	140	50.0	3	60	60	5	65	32.5																					
Malaysia	13	8	12	20	6	7	40	4	23.0	45	0.1	10	0.1	5	0.2	25	5	5	5	10	5.0																					
Fiji	Less than 1	-	1	1	1	1	20	3	1.0	40	0.1	-	0.1	5	0.3	16	5	5	5	10	5.0																					
Papua New Guinea	3	1	4	5	4	7	30	5	42.0	45	0.1	5	0.1	5	0.3	16	5	5	5	10	5.0																					
Korea	38	35	16	51	2	10	40	4	6.5	20	0.2	650	0.1	285	83.3	2	135	135	40	175	87.5																					
Sub-Totals	347	204	248	254	182	270	23	186	81.0	33	5.3	1201	5.7	285	83.3	2	135	135	40	175	87.5																					
E.M.E.A.																																										
Yemen A. R.	6	4	6	10	1	2	30	1	11.1	11.1	0.1	-	0.1	5	0.2	25	5	5	5	10	5.0																					
Yemen, P.D.R. of	2	1	2	3	1	2	20	1	11.1	11.1	0.1	-	0.1	5	0.1	50	5	5	5	10	5.0																					
Afghanistan	22	11	26	37	5	9	30	6	0.1	11.1	0.3	-	0.3	15	1.0	15	5	5	5	10	5.0																					
Tunisia	6	4	3	9	2	4	40	2	0.7	20	0.4	40	0.3	15	2.0	7	30	30	5	35	17.5																					
Morocco	20	20	16	36	3	6	40	4	5.0	20	0.4	200	0.4	20	10.0	2	20	20	10	40	20.0																					
Sub-Totals	54	42	53	95	12	22	22	14	5.8	8	1.2	270	1.2	60	13.2	95	25	25	20	115	62.5																					

including fuel oil to be produced as a by-product of "other" multipurpose forestry landings.

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DEVELOPING COUNTRIES FUELWOOD SUPPLY/DEMAND ANALYSIS/
1980-2000

Summary

Region	Country	Year	Production (1)	Projected Production (2)	Current Production (3)	Pre- ferred Production (4)	Actual Production (5)	Area of Cultivated Land (6)	Irrigated Land (7)	Total Population (8)	Area of Cultivated Land (9)	Irrigated Land (10)	Total Population (11)	Area of Cultivated Land (12)	Irrigated Land (13)	Total Population (14)	Area of Cultivated Land (15)	Irrigated Land (16)	Total Population (17)	Area of Cultivated Land (18)	Irrigated Land (19)	Total Population (20)	Area of Cultivated Land (21)	Irrigated Land (22)	Total Population (23)	Area of Cultivated Land (24)	Irrigated Land (25)	Total Population (26)	Area of Cultivated Land (27)	Irrigated Land (28)	Total Population (29)	Area of Cultivated Land (30)	Irrigated Land (31)	Total Population (32)	Area of Cultivated Land (33)	Irrigated Land (34)	Total Population (35)	Area of Cultivated Land (36)	Irrigated Land (37)	Total Population (38)	Area of Cultivated Land (39)	Irrigated Land (40)	Total Population (41)	Area of Cultivated Land (42)	Irrigated Land (43)	Total Population (44)	Area of Cultivated Land (45)	Irrigated Land (46)	Total Population (47)	Area of Cultivated Land (48)	Irrigated Land (49)	Total Population (50)	Area of Cultivated Land (51)	Irrigated Land (52)	Total Population (53)	Area of Cultivated Land (54)	Irrigated Land (55)	Total Population (56)	Area of Cultivated Land (57)	Irrigated Land (58)	Total Population (59)	Area of Cultivated Land (60)	Irrigated Land (61)	Total Population (62)	Area of Cultivated Land (63)	Irrigated Land (64)	Total Population (65)	Area of Cultivated Land (66)	Irrigated Land (67)	Total Population (68)	Area of Cultivated Land (69)	Irrigated Land (70)	Total Population (71)	Area of Cultivated Land (72)	Irrigated Land (73)	Total Population (74)	Area of Cultivated Land (75)	Irrigated Land (76)	Total Population (77)	Area of Cultivated Land (78)	Irrigated Land (79)	Total Population (80)	Area of Cultivated Land (81)	Irrigated Land (82)	Total Population (83)	Area of Cultivated Land (84)	Irrigated Land (85)	Total Population (86)	Area of Cultivated Land (87)	Irrigated Land (88)	Total Population (89)	Area of Cultivated Land (90)	Irrigated Land (91)	Total Population (92)	Area of Cultivated Land (93)	Irrigated Land (94)	Total Population (95)	Area of Cultivated Land (96)	Irrigated Land (97)	Total Population (98)	Area of Cultivated Land (99)	Irrigated Land (100)	Total Population (101)	Area of Cultivated Land (102)	Irrigated Land (103)	Total Population (104)	Area of Cultivated Land (105)	Irrigated Land (106)	Total Population (107)	Area of Cultivated Land (108)	Irrigated Land (109)	Total Population (110)	Area of Cultivated Land (111)	Irrigated Land (112)	Total Population (113)	Area of Cultivated Land (114)	Irrigated Land (115)	Total Population (116)	Area of Cultivated Land (117)	Irrigated Land (118)	Total Population (119)	Area of Cultivated Land (120)	Irrigated Land (121)	Total Population (122)	Area of Cultivated Land (123)	Irrigated Land (124)	Total Population (125)	Area of Cultivated Land (126)	Irrigated Land (127)	Total Population (128)	Area of Cultivated Land (129)	Irrigated Land (130)	Total Population (131)	Area of Cultivated Land (132)	Irrigated Land (133)	Total Population (134)	Area of Cultivated Land (135)	Irrigated Land (136)	Total Population (137)	Area of Cultivated Land (138)	Irrigated Land (139)	Total Population (140)	Area of Cultivated Land (141)	Irrigated Land (142)	Total Population (143)	Area of Cultivated Land (144)	Irrigated Land (145)	Total Population (146)	Area of Cultivated Land (147)	Irrigated Land (148)	Total Population (149)	Area of Cultivated Land (150)	Irrigated Land (151)	Total Population (152)	Area of Cultivated Land (153)	Irrigated Land (154)	Total Population (155)	Area of Cultivated Land (156)	Irrigated Land (157)	Total Population (158)	Area of Cultivated Land (159)	Irrigated Land (160)	Total Population (161)	Area of Cultivated Land (162)	Irrigated Land (163)	Total Population (164)	Area of Cultivated Land (165)	Irrigated Land (166)	Total Population (167)	Area of Cultivated Land (168)	Irrigated Land (169)	Total Population (170)	Area of Cultivated Land (171)	Irrigated Land (172)	Total Population (173)	Area of Cultivated Land (174)	Irrigated Land (175)	Total Population (176)	Area of Cultivated Land (177)	Irrigated Land (178)	Total Population (179)	Area of Cultivated Land (180)	Irrigated Land (181)	Total Population (182)	Area of Cultivated Land (183)	Irrigated Land (184)	Total Population (185)	Area of Cultivated Land (186)	Irrigated Land (187)	Total Population (188)	Area of Cultivated Land (189)	Irrigated Land (190)	Total Population (191)	Area of Cultivated Land (192)	Irrigated Land (193)	Total Population (194)	Area of Cultivated Land (195)	Irrigated Land (196)	Total Population (197)	Area of Cultivated Land (198)	Irrigated Land (199)	Total Population (200)	Area of Cultivated Land (201)	Irrigated Land (202)	Total Population (203)	Area of Cultivated Land (204)	Irrigated Land (205)	Total Population (206)	Area of Cultivated Land (207)	Irrigated Land (208)	Total Population (209)	Area of Cultivated Land (210)	Irrigated Land (211)	Total Population (212)	Area of Cultivated Land (213)	Irrigated Land (214)	Total Population (215)	Area of Cultivated Land (216)	Irrigated Land (217)	Total Population (218)	Area of Cultivated Land (219)	Irrigated Land (220)	Total Population (221)	Area of Cultivated Land (222)	Irrigated Land (223)	Total Population (224)	Area of Cultivated Land (225)	Irrigated Land (226)	Total Population (227)	Area of Cultivated Land (228)	Irrigated Land (229)	Total Population (230)	Area of Cultivated Land (231)	Irrigated Land (232)	Total Population (233)	Area of Cultivated Land (234)	Irrigated Land (235)	Total Population (236)	Area of Cultivated Land (237)	Irrigated Land (238)	Total Population (239)	Area of Cultivated Land (240)	Irrigated Land (241)	Total Population (242)	Area of Cultivated Land (243)	Irrigated Land (244)	Total Population (245)	Area of Cultivated Land (246)	Irrigated Land (247)	Total Population (248)	Area of Cultivated Land (249)	Irrigated Land (250)	Total Population (251)	Area of Cultivated Land (252)	Irrigated Land (253)	Total Population (254)	Area of Cultivated Land (255)	Irrigated Land (256)	Total Population (257)	Area of Cultivated Land (258)	Irrigated Land (259)	Total Population (260)	Area of Cultivated Land (261)	Irrigated Land (262)	Total Population (263)	Area of Cultivated Land (264)	Irrigated Land (265)	Total Population (266)	Area of Cultivated Land (267)	Irrigated Land (268)	Total Population (269)	Area of Cultivated Land (270)	Irrigated Land (271)	Total Population (272)	Area of Cultivated Land (273)	Irrigated Land (274)	Total Population (275)	Area of Cultivated Land (276)	Irrigated Land (277)	Total Population (278)	Area of Cultivated Land (279)	Irrigated Land (280)	Total Population (281)	Area of Cultivated Land (282)	Irrigated Land (283)	Total Population (284)	Area of Cultivated Land (285)	Irrigated Land (286)	Total Population (287)	Area of Cultivated Land (288)	Irrigated Land (289)	Total Population (290)	Area of Cultivated Land (291)	Irrigated Land (292)	Total Population (293)	Area of Cultivated Land (294)	Irrigated Land (295)	Total Population (296)	Area of Cultivated Land (297)	Irrigated Land (298)	Total Population (299)	Area of Cultivated Land (300)	Irrigated Land (301)	Total Population (302)	Area of Cultivated Land (303)	Irrigated Land (304)	Total Population (305)	Area of Cultivated Land (306)	Irrigated Land (307)	Total Population (308)	Area of Cultivated Land (309)	Irrigated Land (310)	Total Population (311)	Area of Cultivated Land (312)	Irrigated Land (313)	Total Population (314)	Area of Cultivated Land (315)	Irrigated Land (316)	Total Population (317)	Area of Cultivated Land (318)	Irrigated Land (319)	Total Population (320)	Area of Cultivated Land (321)	Irrigated Land (322)	Total Population (323)	Area of Cultivated Land (324)	Irrigated Land (325)	Total Population (326)	Area of Cultivated Land (327)	Irrigated Land (328)	Total Population (329)	Area of Cultivated Land (330)	Irrigated Land (331)	Total Population (332)	Area of Cultivated Land (333)	Irrigated Land (334)	Total Population (335)	Area of Cultivated Land (336)	Irrigated Land (337)	Total Population (338)	Area of Cultivated Land (339)	Irrigated Land (340)	Total Population (341)	Area of Cultivated Land (342)	Irrigated Land (343)	Total Population (344)	Area of Cultivated Land (345)	Irrigated Land (346)	Total Population (347)	Area of Cultivated Land (348)	Irrigated Land (349)	Total Population (350)	Area of Cultivated Land (351)	Irrigated Land (352)	Total Population (353)	Area of Cultivated Land (354)	Irrigated Land (355)	Total Population (356)	Area of Cultivated Land (357)	Irrigated Land (358)	Total Population (359)	Area of Cultivated Land (360)	Irrigated Land (361)	Total Population (362)	Area of Cultivated Land (363)	Irrigated Land (364)	Total Population (365)	Area of Cultivated Land (366)	Irrigated Land (367)	Total Population (368)	Area of Cultivated Land (369)	Irrigated Land (370)	Total Population (371)	Area of Cultivated Land (372)	Irrigated Land (373)	Total Population (374)	Area of Cultivated Land (375)	Irrigated Land (376)	Total Population (377)	Area of Cultivated Land (378)	Irrigated Land (379)	Total Population (380)	Area of Cultivated Land (381)	Irrigated Land (382)	Total Population (383)	Area of Cultivated Land (384)	Irrigated Land (385)	Total Population (386)	Area of Cultivated Land (387)	Irrigated Land (388)	Total Population (389)	Area of Cultivated Land (390)	Irrigated Land (391)	Total Population (392)	Area of Cultivated Land (393)	Irrigated Land (394)	Total Population (395)	Area of Cultivated Land (396)	Irrigated Land (397)	Total Population (398)	Area of Cultivated Land (399)	Irrigated Land (400)	Total Population (399)	Area of Cultivated Land (400)	Irrigated Land (400)	Total Population (400)	Area of Cultivated Land (400)	Irrigated Land (400)	Total Population (400)	Area of Cultivated Land (400)	Irrigated 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1/ This analysis refers to plantations or on farm tree planting specifically for production of fuelwood. It excludes investment in 'other' forestry projects part of which would also produce fuelwood.

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June 1988

Column (12). *Yield*—per hectare, as adjusted by the Mexican Rice $\bar{Y}$. Since in many countries the statistics do not separate *landed* from *other* $\bar{Y}$, and *landed* $\bar{Y}$ is generally higher than *other* $\bar{Y}$, the $\bar{Y}$ used in this column is made up of the *landed* $\bar{Y}$ for all countries except in 30 per cent of the remaining area of multi-purpose plantations.

Column (13). *Cost*—Column (11) times Column (12) figure rounded.

Column (14). *Cost*—Column (13) divided by 20 (the number of years in the period 1961 - 2000).

Column (15). *Pay* and *Net* Mexican Rice based on similar assumptions regarding *landed* percentage as in Column (11) above except in those countries for which detailed information on *landed* planting area is already available.

APPENDIX 4

Examples of Designs of Wood and Charcoal Cookstove

Selected From A Woodstove Compendium

by G. de Lepelierre et al,

Eindhoven University of Technology,

Eindhoven, The Netherlands,

August 1981

Traditional Three Stone Fire

Modified Three Stone Fire with Grill

Modified Keren Charcoal Stove, Indonesia

Traditional Indonesian Ceramic Charcoal Stove

Metal Bucket with Ceramic Liner,
Traditional Thai Stove for Wood or
Charcoal

Traditional Indonesian Ceramic
Woodstove

Traditional Bangladesh Chula

Junadagh Mud Chula for Wood

Traditional Cast Iron
South African Woodstove

Lorena Mudstove - Wood Cookstove
developed in Guatemala

APPENDIX 5

Calculation of Net Energy Efficiency
of Woodfuel Utilization

Appendix 5

Calculation of Net Energy Efficiency of Woodfuel Utilization

The efficiencies of extraction, transportation, conversion, and utilization must be considered in calculating net energy efficiencies. The energy cost involved in the supply process can be calculated as follows,

$$EC = C_i$$

where

EC is the energy cost

C_i is the energy cost of harvesting or collection

C is the energy cost of transport

C is the energy cost of conversion

C is the energy cost of combustion

The net energy efficiency can be calculated as follows,

$$NEE = \frac{FVh - EC}{FVh}$$

where

NEE = Net Energy Efficiency

EC = Energy cost as defined above

FVh = Original fuel value contained in the wood

This calculation is similar to an accounting one.

It is of limited use since the factors involved in choices between energy sources relate more to relative energy prices than to efficiencies. However, the calculation does indicate the tremendous potential for increases in efficiency throughout the supply/demand system, especially at the conversion and utilization stage.

The analysis that follows is based on somewhat arbitrary, but realistic assumptions. Three different examples are taken to reflect the current situation. First, that of a person gathering wood for use in an open fire (Table 1).

Second, that of a person purchasing wood from a vendor for use in an open fire (Table 2). Third, that of a person purchasing charcoal from a vendor for use in a traditional stove (Table 3).

Then, a calculation is made of the effect of the recommended improvements in the supply system on net energy efficiencies. Table 4 represents the situation of a person able to collect wood on his own property or in a community woodlot within 0.5 km of his house, for use in an open fire or improved stove, Table 5 represents the net efficiency if a person purchases plantation produced wood for use in an open fire or improved stove. Finally, Table 6 indicates the net efficiency of the use of charcoal produced in retorts and burned in an improved stove.

General Assumptions

1. One cubic metre of wood has an energy value of 9.4 GJ, one oven-dry kg of wood contains 14.7 MJ, one kg. charcoal contains 25 MJ.
2. Gross energy input of human labour is assumed to be equal to the daily intake of food of 8.44 MJ per person. Energy input to human labour includes all people, with each adult assumed to support one child. One year of human labour then requires 6.16 GJ ($8.44 \text{ MJ} \times 365 \times 2$) of food energy.

Table 1

Net Energy Efficiency of Utilizing 1000 GJ
of Self-Collected Fuelwood in an Open Fire

(GJ)

Energy Cost of Collection and Transport (Food Input to Human Labour)	36.0
Energy Cost of Combustion	950 - 900
Total Energy Cost	<hr/> 986 - 936
Net Energy Delivered	14 - 64
Net Energy Efficiency (%)	1.4 - 6.4

Assumptions Table 1

- a) From Table 10, labour spent in wood collection for one family ranged from 22 to 300 days per year, with an average of 120 days or .33 years equivalent to 2.03 GJ. Assuming an average wood consumption of one cubic metre per person per year and a family size of six people, this would amount to 36.0 GJ of food energy per 1000 GJ of wood collected.

$$\frac{1000 \text{ GJ}}{6 \times 9.4 \text{ GJ}} \times (2.03) = 36.0$$

- b) Wood is burned in an open fire with an efficiency of 5 to 10 per cent.

Source: Author's estimate.

Table 2

Net Energy Efficiency of Utilizing
1000 GJ of Purchased Fuelwood

(GJ)

Energy Cost of Harvesting (Food Energy Input to Human Labour)			3
Energy Cost of Transport to Roadside (Food Energy Input to Human Labour)			3
Energy Cost of Transport to Market (50 km.) (Food Energy Input to Human Labour)			1
Petroleum			18
Sub-total			19
Energy Cost of Combustion	950	-	900
Total Energy Cost	975	-	925
Net Energy Delivered	25	-	75
Net Energy Efficiency (%)	2.5	-	7.5

Assumptions Table 2

- a) Harvesting of wood requires 10.9 hrs/cubic metre of wood (using an axe and machete) or 1159 hrs for 1000 GJ, equivalent to 0.41 yr of human labour or 2.5 GJ per 1000 GJ of wood.
- b) Transport of wood 1.5 km to road using human labour takes 12 hrs/cubic metre of wood or 2.7 GJ per 1000 GJ of wood.
- c) Wood is transported a distance of 50 km; the return trip takes 3 hours plus 6 hours of loading and unloading. Team involved in transport is 3 people, a driver and two helpers. Truck carries 5 cubic metres of wood. Labour is $\frac{9 \text{ hours}}{\text{person}} \times 3 \text{ people} = 5.4 \text{ hours/cubic metre}$ or 1.2 GJ/1000 GJ of wood.
- d) Truck gets 15 km per gallon of gasoline. Round trip of 100 km requires 6.67 gallons, or .159 barrel, or .82 GJ total, .165 GJ per cubic metre or 17.5 GJ/1000 GJ wood.
- e) Combustion efficiency -- same as Table 1.

Source: Author's estimate.

Table 3

Net Energy Efficiency of Utilizing 1000 GJ of
Fuelwood After Conversion to Charcoal Using
Traditional Methods

(GJ)

Energy Cost of Harvesting & Collecting Food Input to Human Labour	2
Energy Cost of Transport to Kiln Food Input to Human Labour	3
Energy Cost of Conversion Food Input to Human Labour	1
Losses	723
Sub-total	724

Energy Cost of Transport to Market (50 km)
Food Input to Human Labour

Petroleum	2
Sub-total	2

Energy Cost of Combustion at
15 - 30 per cent Efficiency

235 - 194

Total Cost

966 - 925

Net Energy Delivered

34 - 75

Net Energy Efficiency (%)

3.4 - 7.5

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Table 4

Net Energy Efficiency of Using 1000 GJ of
Wood from Family Woodlot Within 0.5 km
of Home

(GJ)

Energy Cost of Harvesting			
Food Energy for Human Labour			2
Energy Cost of Transport			
Food Energy for Human Labour			1
Energy Cost of Combustion			
(Efficiency 10-25%)	900	-	750
Total Energy Cost	903	-	753
Net Energy Delivered	97	-	247
Net Energy Efficiency (%)	9.7	-	24.7

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Table 5

Net Energy Efficiency in the Utilization of
1000 GJ of Fuelwood from a Commercial
Plantation (GJ)

Energy Cost of Production	
Weeding and Planting	..
Energy Cost of Harvesting	
Food Input to Human Labour	3
Petroleum	11
Sub-total	14
Energy Cost of Transport	
Food Input to Human Labour	4
Petroleum	14
	18
Energy Cost of Combustion	
(Efficiency 10-25 per cent)	900 - 750
Total Energy Cost	932 - 782
Net Energy Delivered	68 - 218
Net Energy Efficiency (%)	6.8 - 21.8

Assumptions Table 5

- a) Energy cost of seedling production and planting is less than 0.1 GJ per 1000 GJ of wood produced because of the fact that this operation is done only once, but production continues for three rotations from one planting. This large yield from a single operation reduces the energy cost of this phase to an insignificant amount.
- b) Harvesting wood in a plantation requires 12 man years and 500 barrels of diesel for total production of 27,000 cubic metres, assuming the use of chain saws and a cable yarding system. A swing saw and power cutter are used to process the wood.
- c) Transporting the wood a distance of 50 km to market requires 19 man years and 610 barrels of diesel per year for an annual production of 27,000 cubic metres.

Source: V.S. Bogach, An Energy Policy for Guatemala, Ch. 5.

Table 6

Net Energy Efficiency of Utilization of 1000 GJ
of Charcoal Produced from Plantation Wood in
Efficient Retorts

Energy Cost of Seedling Production and Planting	..		
Energy Cost of Harvesting			
Food Input to Human Labour	..		
Petroleum	11		
Sub-total	11		
Energy Cost of Conversion			
Food Input to Human Labour	1		
Losses of Wood Supply	468		
Sub-total	469		
Energy Cost of Transport			
Food Input to Human Labour	1		
Petroleum	4		
Sub-total	5		
Energy Cost of Combustion (Efficiency of 30 to 60 per cent)	372	-	213
Total Energy Cost	860	-	701
Net Energy Delivered	140	-	299
Net Energy Efficiency (%)	14.0	-	29.9

Assumptions Table 6

- a) Costs of planting and harvesting are the same as in Table 5.
- b) Ratio of conversion in 5 cubic metres of wood per ton of charcoal or 25 GJ of charcoal per 47 GJ of wood.
- c) Labour required for conversion is .004 man years per ton of charcoal or .085 man years per 1000 GJ of wood converted.
- d) It is assumed that by-products are not recovered.
- e) The energy expense of transport can be calculated with reference to Table 5. One GJ of wood weighs 77 kg (assuming an average weight of 725 kg/cubic metre). One GJ of charcoal weighs 39 kg (assuming 25.5 GJ/ton). Charcoal produced has an energy value of 532 GJ and a weight of 21.28 tons in comparison to a total weight carried in Table 5 of 77 tons. Therefore, energy costs of transport are 0.28 those in Table 5.
- f) Combustion efficiency is assumed to be doubled by use of more efficient equipment.

Source: Information from the Cia Agricola e Florestal Santa Barbara and author's estimates.

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