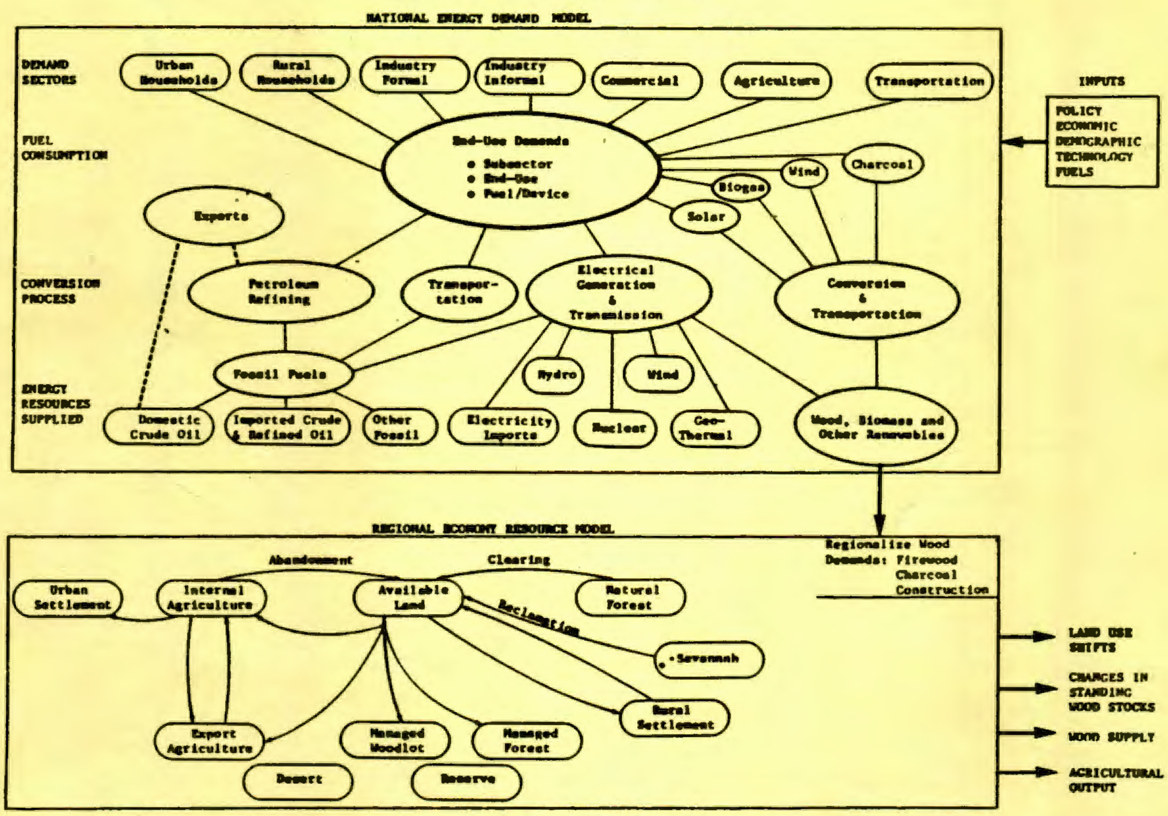
LEAP

LDC ENERGY ALTERNATIVES PLANNING MODEL

A Description

LEAP MODEL - GENERAL STRUCTURE



October, 1981

ENERGY SYSTEMS RESEARCH GROUP, INC.
Boston, Massachusetts 02109

E S R G

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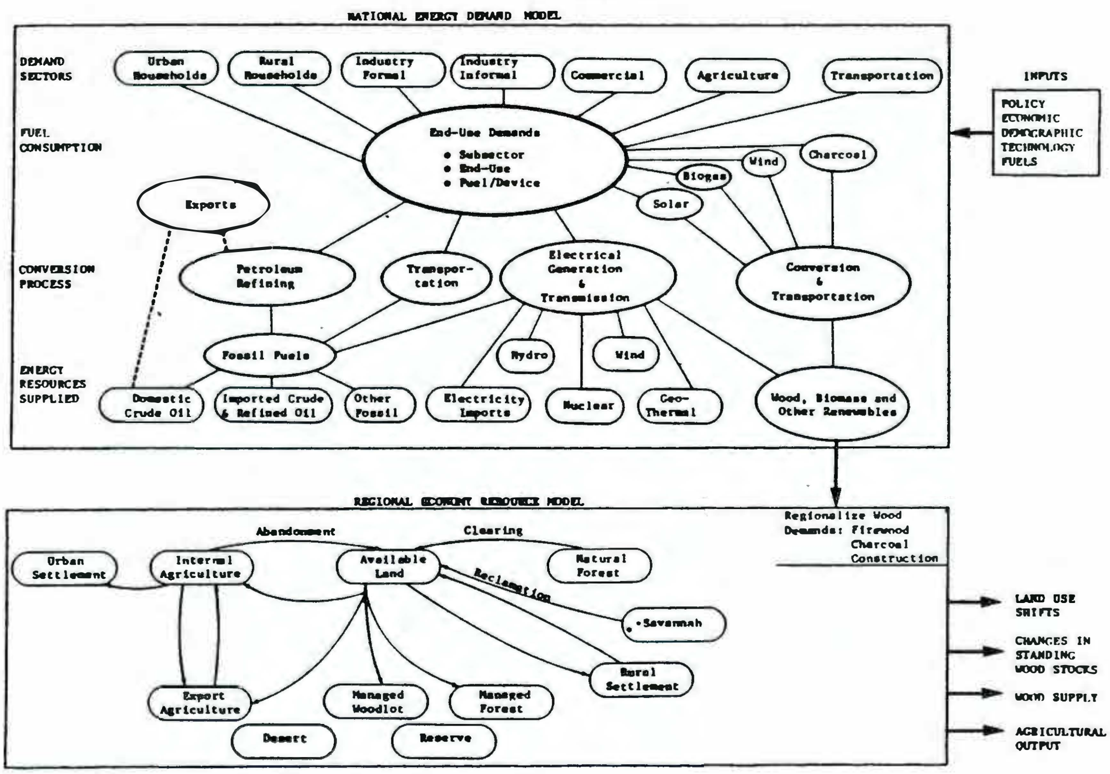

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APPENDIX D

THE LEAP MODEL

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1. INTRODUCTION

1.1 Overview

ESRG has created a computer model for the evaluation of energy policy and planning options in developing countries. The LDC Energy Alternative Planning (LEAP) Model* is designed as a flexible and accessible tool to enable planners and decision-makers in specific countries to identify and quantify the long-range implications of energy policy alternatives.

The analyst may develop pictures of the time evolution of energy supply and demand balances, import requirements, land use impacts, and electric power plant capacity needs that could be expected under alternative policy and planning frameworks. A number of policy variables may be explored in constructing interesting long-term energy scenarios. Among these are:

- wood supply increases (e.g., long term programs to increase the production of managed woodlots, reforestation projects, urban greenbelts)
- domestic oil production (e.g., increased refinery capacity or domestic crude extraction)
- efficiency improvements (e.g., cooking stoves, charcoal kilns, private automobiles, industrial boilers)

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*Prepared for an investigation of long-range energy prospects for Kenya with an emphasis on the fuelwood cycle, under sponsorship of the International Institute for Energy and Human Ecology (the Beijer Institute) of Sweden. The results presented here are preliminary and for illustrative purposes only.

- fuel switching (e.g., charcoal to petroleum products, fossil fuels to electricity)
- electric system planning (e.g., alternative capacity program impacts)
- land use (e.g., mix between use of high potential land for food, fuel, export crops)
- non-conventional sources (e.g., solar heating, wind driven irrigation, biogas applications)
- increasing agricultural productivity (e.g., mechanization irrigation)
- settlement schemes

The model structure allows for considerable freedom in the specification of long-range energy scenarios according to the time frame of interest, the detailed consumption patterns appropriate for the country analyzed, the linkages to primary energy sources, demographic and economic growth projections, electric generation system characteristics, petroleum supply assumptions, land use, wood availability, and so forth.

The LEAP model provides quantitative indications of likely future trouble spots in a country's energy system, the promising areas for policy intervention, and the magnitude of the effects of alternate policy objectives. Moreover, policies affecting agricultural patterns and yields can be assessed to determine impacts on domestic food supply and import requirements. The model can serve as an aid for planners attempting to ensure that their country's future can sustain long term economic and social development strategies and goals.

1.2 Model Structure and Data Requirements

The LEAP model consists of two major components:

I. An Energy Demand Forecasting Model

II. A Resource and Land-Use Projection Model.

The basic structural linkages embodied in the model are displayed diagrammatically in Figure 1, below.

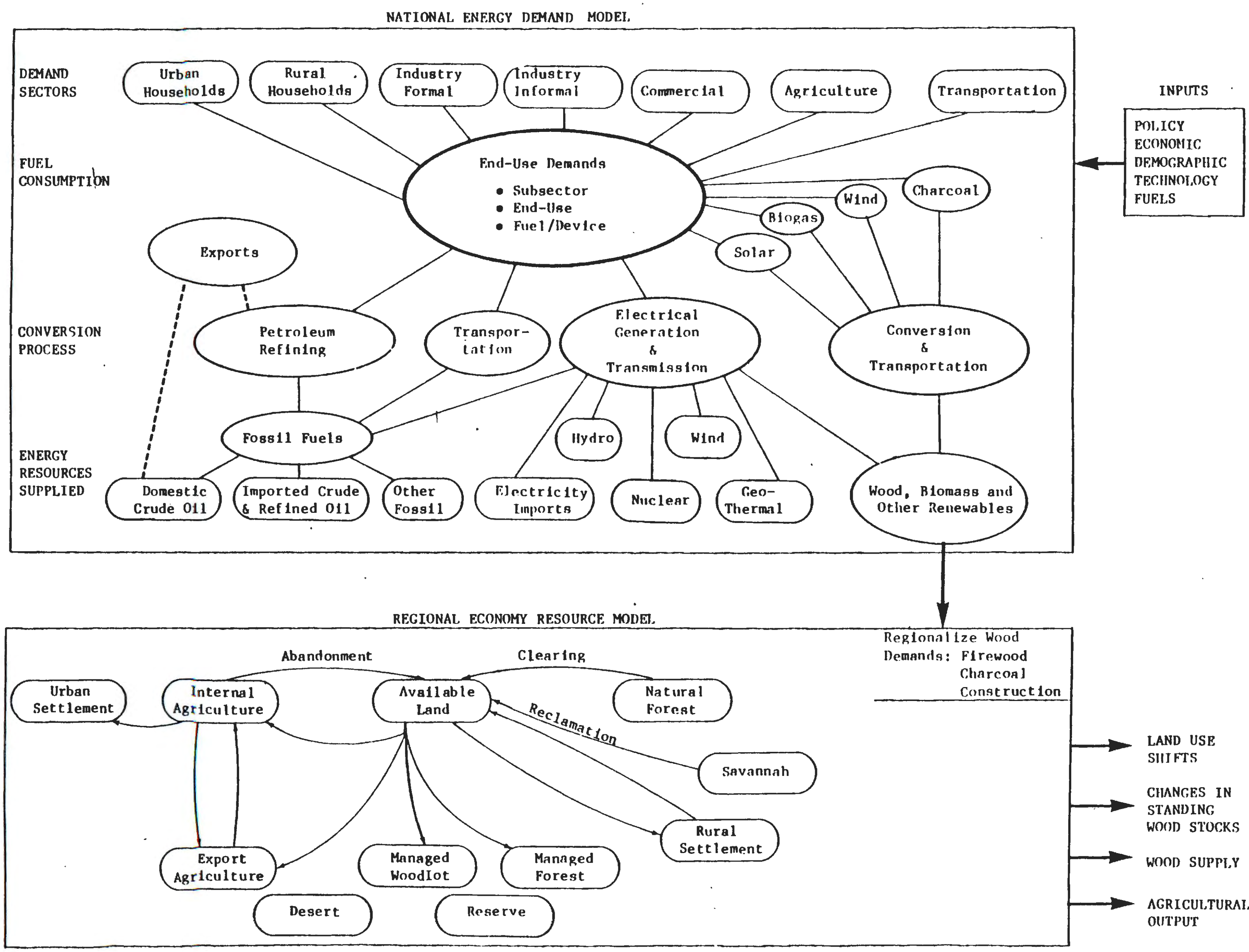
The energy Demand Model is based upon a flexible user-defined set of sectors, subsectors, end-uses, devices, and fuel types. For example, analysis could include such sector/subsector components as Urban Households (Income,...), Rural Households (Income,...), Large Industry (Steel, Chemicals,...), Informal Industry (Brewing, Brick Making,...), Commercial (Offices, Hotels,...), Agriculture (Sugar, Maize,...), Transportation (Private Ground, Rail,...).

The end-use device and fuel specification could include, for example: cooking (jiko/charcoal, stove/wood, stove/electric), water heating (furnace/oil), lighting (lamp/kerosene, electric) in households; process thermal (boiler/oil, furnace/electric), feedstocks (wood, petroleum), motor drive (pumps/electric) in the industrial sector; cultivation (mechanical/diesel, animal/draft), irrigation (diesel pump, wind pump), drying (enhanced solar, biogas) in the agricultural sector, and so on.

The model also embodies linkages from end-use fuels to primary energy resources through various user-specified conversion processes, such as transportation, transmission and distribution, electric generation, oil refining, charcoal production, etc. For example, end-use fuels could include diesel, kerosene,

Figure 1

LEAP MODEL - GENERAL STRUCTURE



natural gas, wood, charcoal, electricity, coal, residual oil, biogas, while primary energy resources could include petroleum, coal, wood, crop residues, natural gas, geothermal, hydro.

Actual end-use consumption levels are calculated on the basis of appropriate measures of sectoral and subsectoral activity (e.g., number of households, steel output, agricultural production, vehicle-kilometers). The time evolution of these activity measures, as well as end-use, device, and fuel mixes will determine the forecast of final energy and primary resource demands. Ultimately, then, these demands are linked to the demographic and economic projections embodied in the model. Device and conversion process efficiencies can change over time to account for new stocks of equipment, operating changes, or policy interventions.

The Resource Model is based primarily on land-use patterns and production characteristics. The land related data is organized into a hierarchy based upon region, zone, and landtype. Landtype specification could include settlement, agriculture, natural forest, reserves, uncropped grazing, pastoral desert, etc., as well as a variety of wood resource schemes such as rural woodlots, urban greenbelts, and managed forests. The breakdown could be more detailed as appropriate, for example, to break out different crop categories (e.g., food/non-food; domestic/export). Regions can be specified flexibly in both type and number to represent, for example, provincial divisions. Zones within regions are also flexibly specified to represent, for example, ecological zones (e.g. high potential, medium potential, semi-arid, arid) or economic planning districts. Landtype categories and characteristics can also be specified as the user wishes.

Land-use shifts over time can be evaluated to account for changing settlement patterns, expansion (or contraction) of agricultural activities (e.g. tradeoffs between production for export and for domestic consumption), and wood resource enhancement projects. Agricultural productivity can be specified on a region/zone/landtype basis and can be allowed to change over time. Wood resources, including both stocks and annual yields can be specified for each region/zone/landtype. These resources are matched with national and regional demands as they evolve, and appropriate allocation and harvesting is modelled. The cutting of standing stocks, reduction of annual yields, and regrowth of stocks is also represented. Also included are inter-regional charcoal transactions and the accessibility of wood resources on various landtypes.

Finally, the LEAP Resource Model calculates the time evolution of regional wood resources and wood harvests (both annual yields and standing stocks), and tracks the supply/demand balances, identifying shortfalls and surpluses. Agricultural production is also calculated and compared with requirements, and forecasts of agricultural imports and exports are developed.

For each model, the full input data is echoed back in a special output report to aid the user in reviewing scenario assumptions and diagnosing the results. The size and nature of the data base employed in actual application may flexibly reflect the unique set of national conditions and the planning scenarios the user wishes to evaluate.

The LEAP models provide a variety of output reports, of which both the number and the degree of detail can be specified by the user. For the Demand Model these include information on the time evolution of primary and secondary fuel demands on a sectoral basis, electric generation, petroleum refining, and import/export conditions, and wood resource requirements in both energy and physical units. For the supply model reports on the time evolution of regional and zone-specific land uses, agricultural production and import/export conditions, and regional wood resource allocation, standing stock, and surplus/shortfall conditions. These reports are presented and described in the following sections.

2. DEMAND MODEL

2.1 Description

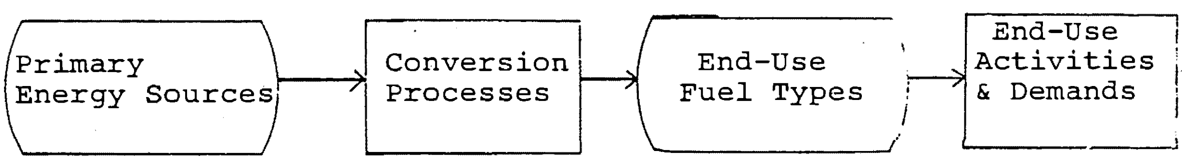
The LEAP Demand Model provides a very flexible mechanism for the calculation of a country's energy demands over time. The basic structure of this model is tied to the physical flows and uses of energy. As such, the demand component of the LEAP system belongs to the same family as the Brookhaven Reference Energy System and AL-EDIS energy demand models, with many of the same advantages. However, LEAP has more extensive capabilities than those models, with an inherent time dimension and greater flexibility in defining the energy flow structures. Further, as we shall see, the LEAP integrates the demand-side simulations with comprehensive land use/resource model components.

There are two major components of the energy flow structure as used in the LEAP Demand Model:

1. The specification of end-use activities and their fuel uses;
2. The specification of the conversion processes from primary energy to end-use fuel types.

Schematically this is shown in the following diagram:

Figure 2
ENERGY FLOW STRUCTURE



While this diagram represents the direction of flow of energy resources, in practice, the computer model begins at the most disaggregated device/fuel use level and builds back towards aggregate primary energy resource requirements.

In our discussion we shall first review the end-use demand structure. It is based on a hierarchy of four levels: 1) Sector, 2) Subsector, 3) End-use, 4) Device/Fuel. By defining the components of these categories, current and future energy demands can be characterized. For example, one might define a sector as "Urban Households," a subsector as "High Income," and end-use as "Cooking," and devices for this end-use as "Electric Range," "Gas Stove," "Wood Stove" "Charcoal Jiko," etc. Another example could be "Industrial" sector, "Steel" subsector, "Process Thermal" end-use, and devices such as "Oil Boiler," "Electric Arc Furnace," "Coal Boiler," etc. Then as the magnitude of these components change over time, the associated energy consumption also changes. Thus by incorporating forecasts of demographic changes, income shifts, end-use saturation device efficiencies, fuel mix, economic output, process components, equipment fuels, etc., one can predict the energy demand consequences.

The definitions of these demand categories is entirely flexible and determined by the user when the demand data is analyzed and entered. There is no pre-defined set of categories that must be chosen from, but rather the categories are defined as the data file is created. Indeed, one can select any language for the category designation, although the printed reports currently have headingsin English.

There is also a great deal of flexibility in specifying the conversion processes. The results of the end-use calculations are the total demands for various end-use fuels (the types are user defined). These end-use fuel demands are then transformed by a variety of user defined conversion/distribution processes into demands for primary energy sources (also user defined). Two special conversion processes, electrical generation and oil refining, have their own special characteristics and data requirements. Fuelwood and biomass regional allocations and primary supply analyses are treated in the Land Use/Resource model described in the next section.

The skeletal structure of the Demand Model is shown in Figure 3. Table 1 provides a suggestive list of typical sector, subsector, end-use and device/fuel type specifications. A schematic of the basic relationships of the demand model and energy flows was shown in Figure 1.

TABLE 1

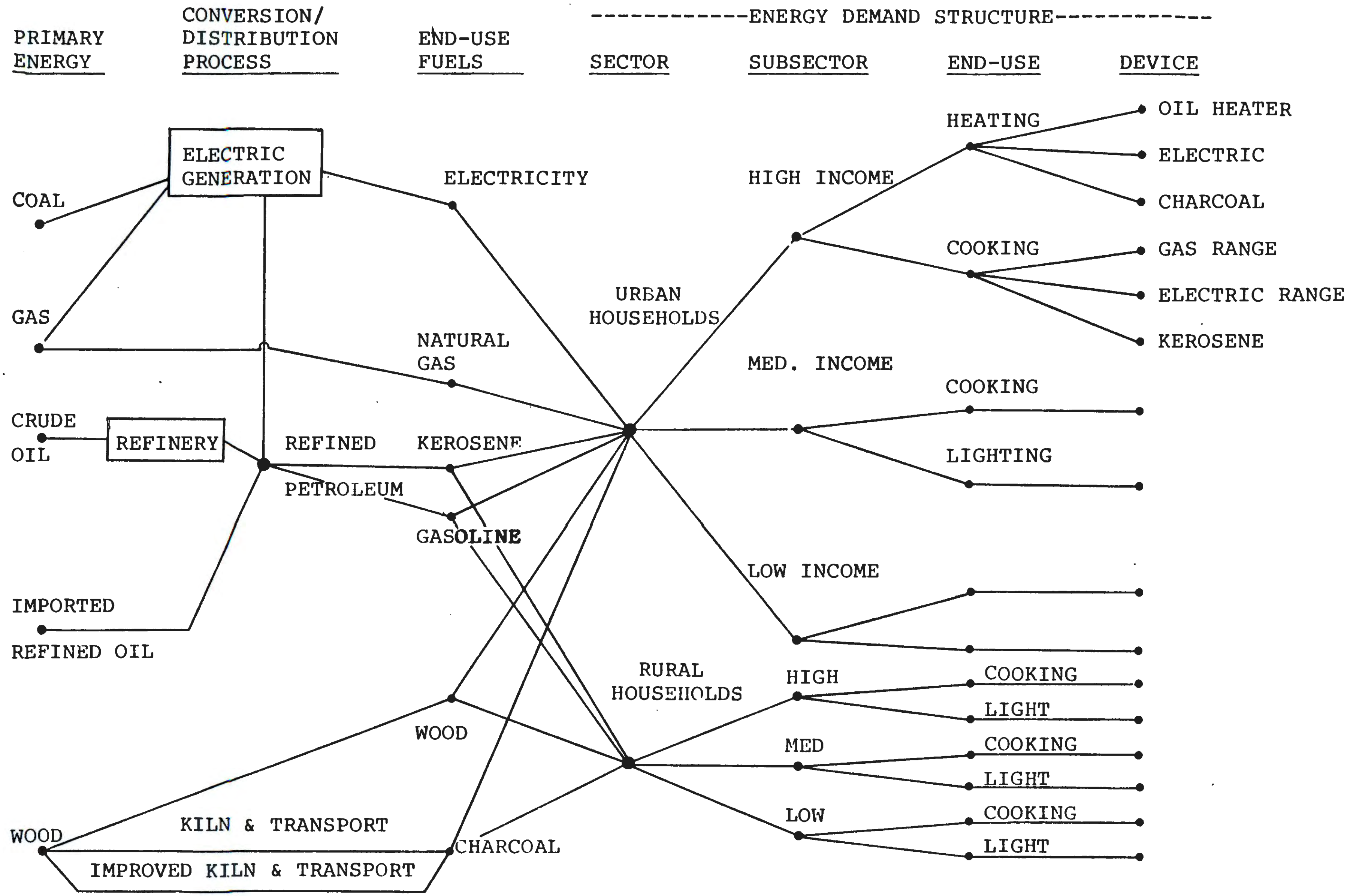
REPRESENTATIVE DEMAND HIERARCHY CATEGORIES*

Sector	Subsector	End-Use	Device/Fuel
Urban Households	High Income Medium Income Low Income	Cooling Lighting Water Heating Space Heating Cooking	Wood Stove Charcoal Stove Electric Light Kerosene Light Electric Stove Air Conditioner Electric Water-heater
Rural Households	High Income Medium Income Low Income	Cooking Water Heating Space Heating Lighting	Wood Stove Charcoal Stove Kerosene Stove Kerosene Light Gasoline Stove
Industry	Rubber Machinery Steel Stone etc.	Process Mechanical Drive Lighting Feedstocks	Coal Boiler Oil Boiler Wood Furnace Electric Motor Solar Collectors
Agriculture	Small Farm by Crop Type Large Farm by Crop Type Export by Crop Type	Cultivation Harvesting Irrigation Drying	Tractors, Petrol Tractors, Diesel Pump, Oil Pump, electric Pump, Wind Dryers, Solar

*The categories are neither compulsory nor exclusive and may be suitably selected for a particular study.

Figure 3

SAMPLE STRUCTURE OF LEAP DEMAND MODEL*



*Demand categories, fuel and conversion types, and branching characteristics are for illustration only; arbitrary numbers and types of linkages could be constructed by the user.

Looking at this diagram from right to left, we see the hierarchical demand structure moving from device, to end-use, to subsector, to sector, and ultimately to the national sum of all sectors. Associated with each level of this hierarchy is an activity measure (e.g., number of households, fraction in an income group, fraction which have space heating, fraction which use oil heaters). As one moves down a branch to an end-use device, these activity measures, which may change over time, are multiplied to arrive at a physical measure of the end-use stock (e.g., the number of refrigerators, wood stoves, etc.). These are then multiplied by the energy use per device, to get the end-use energy associated with this particular combination of activities. Changing the activity level of any element in this link produces a change in the energy demand. After the energy for each end point is calculated in this fashion, the fuel requirements are then aggregated back up the structure to the total end-use fuel demands. All of this may be displayed in greater or lesser detail in the printed model reports.

The end-use fuel demands are then related to primary energy requirements by means of various conversion linkages. For each end-use/fuel category, at least one conversion must be defined to relate it to a primary energy source. More than one conversion linkage may be defined, each contributing a portion of a given end-use fuel requirement at specified efficiencies. An example of the former would be a mix of kiln technologies used in charcoal production. As with the rest of the demand-side structure, the conversion specifications may also change over time. In addition one further characterizes electrical generation conversions to primary fuels over time in terms of current and future generation capacities, fuel types, and efficiencies.

2.2 Setting up a Demand Scenario

The first step in using the demand model for a country or regional study is to define the elements of the various categories, which then determine the structure of the model. These cateogies are as follows:

1. End-Use Fuel Types
2. Primary Energy Sources
3. Energy Conversion Processes
4. Electrical Generation Processes
5. Demand Categories: sectors, subsectors, end-use, device/fuel types.

By defining these elements, one creates a demand model tailored to the particular requirements of the region and policy investigation. The model can be easily expanded by adding new elements to the various categories or by changing old ones. In the following sections we will go through each of these categories.

1. The End-Use Fuel Types are specified first, since these definitions are used in developing data for several of the other categories. One lists the fuel types in a logical

order, assigning an index number and a name to each fuel type. The index numbers are used in the other categories to refer to this fuel type, and the assigned names will appear in the output reports. The fuel types will be listed in the output in the same order as used for this list. Table 2 provides such a list arrayed as input data for the LEAP Demand Model.

TABLE 2

END-USE FUEL CATEGORIES

```
*SECONDARY
1,'WOOD FUEL'
2,'CHARCOAL'
3,'BIOMASS/CROP RESIDUE'
4, 'WOOD INDUSTRIAL'
5,'GASOLINE'
6,'BOTTLED GAS'
7,'PARAFFIN'
8,'DIESEL'
9,'SPIRIT'
10,'JET FUEL'
11,'OTHER AVIATION FUEL'
12,'RESIDUAL OIL'
13,'COAL'
14,'ELECTRICITY'
15,'BAMBOO'
16,'OTHER'
17,'PETROL'
18,'SAWDUST'
19,'MAIZE'
20,'METHANOL'
21,'SOLAR'
0 /
```

2. The Primary Energy Sources are treated like the end-use fuel types in that they are used in specifying other categories. As before one needs an index number and a name. In addition, one specifies for wood and oil a conversion to

to physical units, to convert from a commom generic energy unit (currently gigajoules) for some of the output reports. This is done by selecting the appropriate physical measure, say million tonnes, and calculating the number of generic energy units in this physical measure. These two data items are then included as part of the primary energy source data. As with end-use fuel types, the order that one selects will be used in the various model reports. Table 3 provides a set of primary energy source data inputs.

TABLE 3

PRIMARY ENERGY CATEGORIES

```
*PRIMARY
1, 'FUEL WOOD', 16.3E6, 'MILLION TONNES'
2, 'WOOD FOR CHRCOAL', 16.3E6, 'MILLION TONNES'
3, 'WOOD FOR INDUST.', 16.3E6, 'MILLION TONNES'
4,'REFINED OIL' , 6.13E6, 'MILLION BBL'
5,'IMPORTED CRUDE' , 6.13E6, 'MILLION BBL'
6,'DOMESTIC CRUDE' , 6.13E6, 'MILLION BBL'
7.'HYDRO' ,0, ' '
8,'GEOTHERMAL' ,0, ' '
9,'ELEC. IMPORTS' , 0,' '
10,'WIND' , 0, ' '
11.'COAL'. 0, ' '
12,'BIOMASS', 0,' '
13,'SOLAR', 0,' '
0 /
```

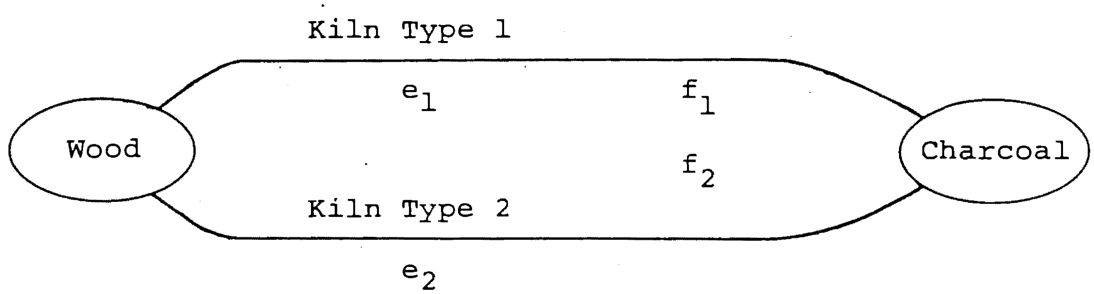
3. Energy Conversion Processes are used to link end-use and primary energy types. Each end-use fuel type (except electricity) must be linked to one or more primary sources. A link is defined in the backwards direction from the end-use type to the primary type. A certain fraction of an end-use

fuel is provided by each of the linking processes. These fractions are used to calculate the flow through specific processes and the primary energy requirements. Each process is also assigned an efficiency which determines how much primary energy is lost in the conversion.

To understand this better, let's consider the following example where the end-use fuel charcoal is produced from wood using two types of kilns of different efficiencies.

Figure 4

CHARCOAL TO WOOD CONVERSION



The fraction of the charcoal produced by the kiln types are f_1 and f_2 respectively. The user must specify these fractions for the Base, Mid and End index years to represent changes over time. (We will return to the procedures for time indexing below.) In any given year the sum of the fractions associated with an end-use fuel should sum to one. The processes also have efficiencies e_1 and e_2 respectively. Thus if C were the energy demand for charcoal, the demand for wood to produce charcoal, W, would be

$$W = \frac{f_1 \times C}{e_1} + \frac{f_2 \times C}{e_2}$$

One can have an indefinite number of processes associated with an end-use energy type linked to one or more primary energy categories. (The fractions though should sum to one.) This is done by specifying conversion processes with the following information: end-use fuel index, primary energy index, process name, supply fractions for three index years, process efficiency. Table 4 shows a sample report of a set of energy conversion process data.

4. Electrical Generation is a special type of energy conversion which requires a unique type of data to characterize the production of electricity. One first gives the name of the generation type, then the generating capacity in Megawatts for the three index years, then the maximum capacity factor for this type, then the index for the primary energy source used, and finally the efficiency of this generation process. The sequence of this list determines the priority which is used for electrical generation in meeting a given demand. This simulation can be used to approximate the consequences of economic dispatch or other considerations governing the availability and allocation of electrical generating facilities. The model takes the electrical

TABLE 4

ENERGY CONVERSION PROCESSES -- DATA INPUT REPORT

-END USE FUEL-	-PRIMARY SOURCE-	--PROCESS--	FRACTION - YEAR: 1980	1990	2000	PROCESS EFFICIENCY
WOOD FUEL	FUEL WOOD	WOOD TRANSPORT	1.00	1.00	1.00	1.000
CHARCOAL	WOOD FOR CHRCOAL	KILN	1.00	1.00	1.00	0.250
CHARCOAL	WOOD FOR CHRCOAL	IMPROVED KILN	0.0	0.0	0.0	0.400
BIOMASS/CROP RES	BIOMASS	COLLECTION	1.00	1.00	1.00	1.000
WOOD INDUSTRIAL	WOOD FOR INDUST.	WOOD TRANSPORT	1.00	1.00	1.00	1.000
GASOLINE	REFINED OIL	DISTRIBUTION	1.00	1.00	1.00	0.950
BOTTLED GAS	REFINED OIL	DISTRIBUTION	1.00	1.00	1.00	0.950
PARAFFIN	REFINED OIL	DISTRIBUTION	1.00	1.00	1.00	0.950
DIESEL	REFINED OIL	DISTRIBUTION	1.00	1.00	1.00	0.950
SPIRIT	REFINED OIL	DISTRIBUTION	1.00	1.00	1.00	0.950
JET FUEL	REFINED OIL	DISTRIBUTION	1.00	1.00	1.00	0.950
OTHER AVIATION F	REFINED OIL	DISTRIBUTION	1.00	1.00	1.00	0.950
RESIDUAL OIL	REFINED OIL	DISTRIBUTION	1.00	1.00	1.00	0.950
COAL	COAL	DISTRIBUTION	1.00	1.00	1.00	0.950
BAMBOO	BIOMASS	COLLECTION	1.00	1.00	1.00	0.950
OTHER	BIOMASS	COLLECTION	1.00	1.00	1.00	0.950
PETROL	REFINED OIL	DISTRIBUTION	1.00	1.00	1.00	0.950
SAWDUST	BIOMASS	COLLECTION	1.00	1.00	1.00	0.950
MAIZE	BIOMASS	COLLECTION	1.00	1.00	1.00	0.950
METHANOL	BIOMASS	CONVERSION	1.00	1.00	1.00	0.900

requirement in a given year and then goes down this list, generating as much electricity available and needed from each type until the total demand is met. If there is insufficient indicated capacity then the model can warn of a shortage or add additional makeup capacity as needed. The generation energy requirements associated with conversion are then added to the appropriate primary energy category after transmission/distribution, refining, etc, processes are accounted for. Table 5 shows an echo report of a set of input data characterizing electrical generation. The model allows for user specification of current and future capacity mix, fuel types, and conversion efficiencies, some of which may be subject to policy intervention.

5. The oil resource treatment in LEAP requires that data be provided on current and future refinery capacity, domestic oil extraction, exported refined petroleum products, and refinery efficiency. The model then calculates supply/demand balances over time and estimates requirements for imported crude and refined petroleum, exported crude, and the level of refinery capacity utilization. Figure 5 shows this diagrammatically, with accompanying notes defining the magnitudes of the various flows. The full array of end-use petroleum based fuel demands are aggregated over all sectors to provide the basis for the supply/demand comparison. Table 6 shows a data report of a set of input data for characterizing petroleum supply and refining activity.

TABLE 5

----------- ELECTRICAL GENERATION PROCESSES ---- DATA INPUT REPORT -----------

GENERATION PROCESS	GENERATION CAP. (MW) 1980	1990	2000	MAXIMUM CAP. FACT.	PRIMARY SOURCE	CONVERSION EFFICIENCY
UGANDA IMPORTS	30.	30.	30.	0.960	ELEC. IMPORTS	1.000
HYDRO POWER	300.	420.	630.	0.300	HYDRO	1.000
GEOTHERMAL	0.	30.	30.	0.800	GEOTHERMAL	0.400
COMBUST. TURBINE	26.	50.	80.	0.100	REFINED OIL	0.200
DIESEL	23.	0.	0.	0.100	REFINED OIL	0.200
OIL STEAM	93.	93.	93.	0.640	REFINED OIL	0.250

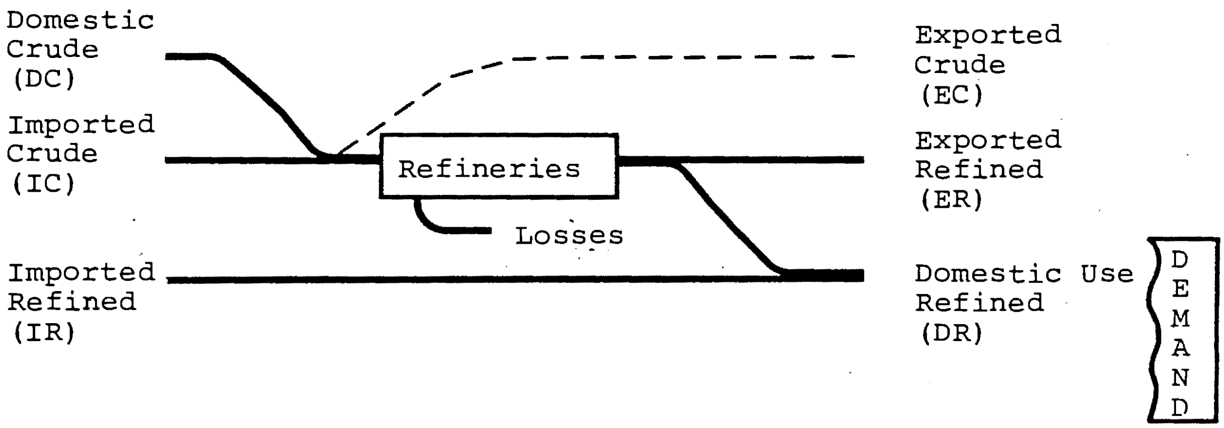
TABLE 6

---- PETROLEUM REFINING & RELATED DATA ----

	1980	1990	2000	
REFINERY CAPACITY	25.5	25.5	25.5	(MILLION BBL/YR)
REFINERY EFFICIEN.	0.97	0.97	0.97	
EXPORTED REFINED	6.8	6.8	6.8	(MILLION BBL/YR)
DOMESTIC CRUDE	0.0	0.0	0.0	(MILLION BBL/YR)

Figure 5

Petroleum Balances



In a given year projected exports of refined petroleum products (ER), projected refinery capacity (RC) and projected domestic crude production (DC) are estimated from exogenous inputs. Domestic use of refined petroleum products (DR) is calculated by the LEAP Demand Module.

(1) Total refined petroleum requirements ER+DR is compared with refinery capacity RC minus losses which are proportional to refinery throughput. If sufficient capacity exists,

$$RC(1-\alpha) \geq ER+DR, \quad (\alpha = \text{loss factor})$$

then the amount of imported crude is calculated

$$IC = (ER+DR)/(1-\alpha) - DC$$

If the refinery is operating at less than full capacity increased exports of refined products can be input.

If sufficient domestic crude is available then exports of crude are calculated:

$$EC = DC - (ER+DR)/(1-\alpha)$$

(2) If refinery capacity is insufficient to meet requirements then refined petroleum imports are calculated:

$$IR = ER+DR - RC(1-\alpha)$$

In this case imported crude is

$$IC = RC/(1-\alpha) - DC$$

or exported crude is

$$EC = DC-RC/(1-\alpha)$$

6. The Demand Categories are the most important part of the model. It is here that the societal, economic, demographic, and behavioral activities and their relationships with energy use are specified; it is also here where the characteristics of energy using activities and devices are represented. Finally, it is here where a large variety of forecast scenarios (including policy interventions) can be specified with regard to devices, fuel mix, efficiency improvements, etc.

First the demand categories use a hierarchical structure of the following form:

1. Sector
2. Subsector
3. End-Use
4. Device/Fuel

This structure serves to provide an order for the demand data and calculations, and all entries must fit somewhere into this structure. An example of this was shown in Figure 2 where the "Urban Household" sector has "High, Medium and Low Income" group Subsectors, with "Heating" and "Cooking," End-Uses, with a different variety of Devices associated with each End-Use. There is complete flexibility in defining the Sectors, the Subsectors within a Sector, the End-Uses within a Subsector, and the Devices associated with an End-Use. Each category may have as many subcategories as desired.

The only restriction is that the hierachy be complete, so that each Sector must have at least one Subsector, each Subsector one End-Use, and each End-Use one Device. Other that these restrictions, the structure is freely defined and one may add or delete elements as required.

The data for each element of the demand hierarchy contains the following items: level index number, element name, element activity levels for the three index years, a power of ten scaling factor for the activity levels, the activity level label. For the Device level, we also need the end-use fuel index number, and the unit device annual consumption in standard energy units.

The activity levels are the key to the demand calculations and may represent a variety of different things (that the activity units and levels are specified). For example, in a Sector, the activity may represent the number of households, or the number of people, or the number of businesses, or the number of employees, all depending on how the structure is set up. The Subsector activities may represent fractions of the Sector activity levels, or something else consistent with the Sector activity definitions. The End-use activities might represent the saturation of that End-use in that Subsector, and the Device activities might represent the fraction of that End-use which use the device.

The fuel use is specified at the Device level in terms of annual unit usage (<u>e.g.</u>, gigajoules of charcoal per household stove). The total consumption in any given year for this device is product of this unit consumption and the associate activity levels up through the hierarchy as explained earlier. One advantage of this structure is that it allows one to change the elements singly or in combination and observe the results. Table 7 provides a set of data inputs characterizing the demands for energy at the sector/subsector/end-use/device levels. Table 8 provides a listing of the various types of demand data we have discussed.

TABLE 7

------ END USE CHARACTERISTICS ---- DATA INPUT REPORT ----

SECTOR / SUBSECTOR / ENDUSE / DEVICE	ACTIVITY MEASURES FOR THE YEARS 1980	1990	2000	UNITS OF MEASURE ACTIVITY	ANNUAL DEVICE FUEL CONSUMPTION GIGA-JOULES	FUEL T[illegible]
1 URBAN HOUSEHOLD	0.35	0.71	1.43	MILLION HSH		
1. 1 INCGROUP 1	0.15	0.08	0.02	FRACTION		
1. 1. 1 COOK/WATHEAT/SPH	1.00	1.00	1.00	SATURATION		
1. WOOD	0.82	0.82	0.82	FRACTION	[illegible]	WOOD FUEL
2. CHARCOAL	0.65	0.65	0.65	FRACTION	1.249E+01	CHARCOAL
1. 1. 2 COOKING	0.18	0.18	0.18	SATURATION		
1. PARAFFIN	1.00	1.00	1.00	FRACTION	1.900E-01	PARAFFIN
1. 1. 3 LIGHTING	0.94	0.94	0.94	SATURATION		
1. PARAFFIN	1.00	1.00	1.00	FRACTION	2.970E+00	PARAFFIN
1. 1. 4 OTHER	0.18	0.18	0.18	SATURATION		
1. CHARCOAL	1.00	1.00	1.00	FRACTION	1.023E+01	CHARCOAL
1. 2 INCGROUP 2	0.27	0.23	0.17	FRACTION		
1. 2. 1 COOK/WATHEAT/SPH	0.95	0.95	0.95	SATURATION		
1. WOOD	0.40	0.40	0.40	FRACTION	2.550E+01	WOOD FUEL
2. CHARCOAL	0.85	0.85	0.85	FRACTION	2.206E+01	CHARCOAL
1. 2. 2 COOKING	0.54	0.54	0.54	FRACTION		
1. PARAFFIN	1.00	1.00	1.00	FRACTION	3.560E+00	PARAFFIN

TABLE 8

SUMMARY OF DATA CATEGORIES

I. End-Use Fuel Types
   1. Sequential Index Number
   2. Fuel Type Name

II. Primary Energy Sources
   1. Sequential Index Number
   2. Energy Source Name
   3. Conversion Factor for Physical Units
   4. Name of Physical Units

III. Energy Conversion Processes
   1. Index of End-Use Fuel Types
   2. Index of Primary Energy Source
   3. Name of Process
   4. Fractions of the End-Use Fuel Produced by this process in the Base, Mid and End Years
   5. Process Conversion Efficiency

IV. Electric Generation Processes
   1. Name of Process
   2. Generating Capacity (MW) in the Base, Mid and End Years
   3. Maximum Capacity Factor
   4. Primary Energy Type Index
   5. Generating Efficiency

V. End-Use Demand Descriptions
   1. Hierachy Level Index
   2. Activity Name
   3. Activity Levels in the Base, Mid, and End Years
   4. Activity Level Scaling Factor
   5. Activity Level Name

Following are for the Device level only:

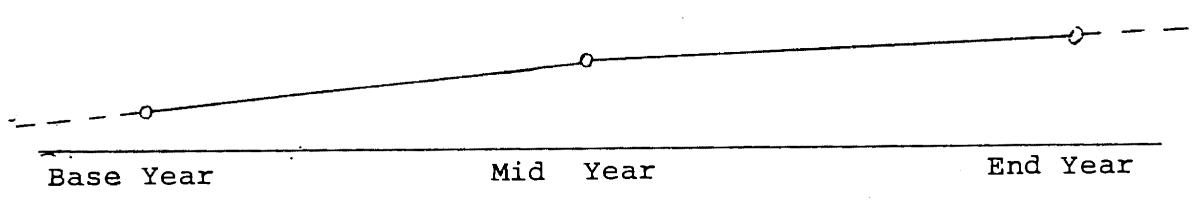
   6. End-Use Fuel Type Index
   7. Unit Energy Consumption

2.3 Specification of Time-Varying Input Data

Some of the input data used in the model have a time dimension. For example, activity levels, end-uses, device saturations, fuel mixes, conversion processes, and equipment efficiencies change over time. Rather than specifying a date and a value for each occurrence of this type of data, a more general procedure is used. In setting up the model for a particular case, three years are selected to be representative for all the time dependent data. These years are the Base, Mid and End years respectively. Then when one enters time varying data, one enters three times corresponding to the values in each of these years. These index years are selected in accordance with the time span of the investigation and the years for which data and projections are available. When the model needs variable values for intermediate years, it linearly interpolates the values of the two nearest index years. The model can be run past the end years, but this must be done with caution to avoid extensive extrapolation.

Figure 6

DATA INTERPOLATION



The linear interpolation of time dependent data does not, of course, mean that the model results are themselves linear. Since the model results are both the product and sum of a variety of factors, rather complex behavior may be exhibited. For example, consider charcoal used for urban cooking. The number of urban households changes over time, as does the distribution of income groups, as might the fractions which use charcoal for cooking, as might the average efficiency of the cooking devices. The charcoal usage is then the product of all these changes summed over all the urban households. Moreover, charcoal use in other sectors, will also contribute. Finally, insofar as charcoal contributes, through conversion using kilns, to the total requirement for wood resources, changes in the conversion process over time affects the time evolution of requirements for primary wood resources allocated to charcoal demands. These clearly need not be a linear interpolation of the usages in the two nearest index years.

The concludes the general discussion of the Demand Model and the data requirements. More discussion of setting up a study will be found in the case study Section 4. A further description of specific data requirements and computer code structure will be found in Section 5.

2.4 Demand Model Reports

This section will display samples of the output produced by the Demand Model. In doing this we will proceed from the most general to the most specific.

Table 9 presents an all-Sector summary of the end-use fuel consumption over time. It provides an overview of which fuels are being used. Table 10 gives this same type of information for each sector. This table shows the contribution of each sector to the total national demand and the distribution of fuel uses within each sector. Further detail of the demands can be obtained from the annual profiles (an example is given in Table 11) which can be selected to show the annual consumption down to the 1) Sector, 2) Subsector, 3) End-use, 4) Device/ Fuel level.

Other tables provide information on electrical generation (Table 12), and oil import/exports and refinery activity (Table 13). A final set of tables report on the primary energy resources required both in common energy units (Table 14), and, where appropriate, in physical units (Table 15).

TABLE 9

NATIONAL SUMMARY OF END-USE FUEL CONSUMPTION (MILLIONS OF GIGA-JOULES)

YEAR	1980	1985	1990	1995	2000
ALL SECTORS FUEL					
WOOD FUEL	140.0	163.9	187.8	219.6	251.0
CHARCOAL	13.4	19.1	25.1	36.5	48.4
BIOMASS/CROP RES	4.2	4.7	5.2	5.8	6.4
WOOD INDUSTRIAL	13.2	19.8	26.4	40.3	54.1
GASOLINE	0.0	0.0	0.0	0.0	0.0
BOTTLED GAS	0.4	0.6	0.8	1.2	1.5
PARAFFIN	6.5	8.6	10.8	14.8	18.9
DIESEL	20.1	26.7	33.2	45.8	58.4
SPIRIT	0.0	0.0	0.0	0.0	0.0
JET FUEL	11.9	17.7	23.6	35.2	46.8
OTHER AVIATION F	0.0	0.0	0.0	0.0	0.0
RESIDUAL OIL	23.4	35.1	46.8	70.4	94.0
COAL	1.3	2.1	2.8	4.5	6.1
ELECTRICITY	4.1	5.9	7.8	11.5	15.2
BAMBOO	0.0	0.0	0.0	0.0	0.0
OTHER	0.0	0.0	0.0	0.0	0.0
PETROL	21.0	27.4	33.8	44.4	55.0
SAWDUST	0.0	0.0	0.0	0.0	0.0
MAIZE	3.4	4.2	5.1	6.2	7.5
METHANOL	0.0	0.0	0.0	0.0	0.0
SOLAR	0.0	0.0	0.0	0.0	0.0
GRAND TOTAL:	262.9	335.9	409.3	536.1	663.3

TABLE 10

------- SUMMARY OF END-USE FUEL CONSUMPTION BY SECTOR (MILLIONS OF GIGA-JOULE

SECTOR / YEAR	1980	1985	1990	1995	2000
URBAN HOUSEHOLD					
WOOD FUEL	3.5	4.9	5.9	8.2	10.0
CHARCOAL	7.3	11.3	15.6	24.0	32.9
PARAFFIN	1.7	2.7	3.6	5.6	7.5
ELECTRICITY	1.2	2.0	2.8	4.3	5.9
PETROL	0.3	0.5	0.7	1.2	1.6
SECTOR TOTAL:	14.0	21.3	28.7	43.3	58.0
RURAL HOUSEHOLD					
WOOD FUEL	136.1	158.5	181.0	210.2	239.4
CHARCOAL	5.2	6.4	7.6	9.5	11.5
BIOMASS/CROP RES	4.2	4.7	5.2	5.8	6.4
PARAFFIN	3.6	4.2	4.9	5.7	6.6
MAIZE	3.4	4.2	5.1	6.2	7.5
SECTOR TOTAL:	152.4	177.9	203.8	237.5	271.5
AGRICULTURE					
DIESEL	6.6	7.1	7.5	8.1	8.6
ELECTRICITY	0.6	0.6	0.7	0.7	0.8
PETROL	1.0	1.1	1.2	1.2	1.3
SECTOR TOTAL:	8.2	8.8	9.4	10.0	10.7
INFORMAL INDUSTR					
WOOD FUEL	0.4	0.6	0.8	1.2	1.6
CHARCOAL	1.0	1.4	1.9	2.9	3.9
BIOMASS/CROP RES	0.0	0.0	0.0	0.0	0.0
PARAFFIN	0.1	0.1	0.1	0.2	0.3
DIESEL	0.0	0.0	0.0	0.0	0.0
RESIDUAL OIL	0.0	0.0	0.0	0.0	0.0
ELECTRICITY	0.0	0.0	0.0	0.1	0.1
PETROL	0.0	0.0	0.0	0.1	0.1
SAWDUST	0.0	0.0	0.0	0.0	0.0
SECTOR TOTAL:	1.5	2.2	3.0	4.5	6.0
LARGE INDUSTRY					
BOTTLED GAS	0.2	0.3	0.4	0.5	0.7
PARAFFIN	0.9	1.4	1.8	2.7	3.6
RESIDUAL OIL	16.9	25.5	34.0	51.3	68.6
COAL	1.3	2.1	2.8	4.5	6.1
ELECTRICITY	1.7	2.7	3.6	5.6	7.6
SECTOR TOTAL:	21.0	31.8	42.6	64.6	86.6

(Partial Results)

TABLE 11

---- PROFILE OF END-USE FUEL CONSUMPTION IN THE YEAR 1990 ----

DEMAND CATEGORY	ACTIVITY	MEASURE	FUEL USE MILLION GIGA-JOULES	FUEL TYPE
1 URBAN HOUSEHOLD	0.71	MILLION HSH	28.68	SECTOR TOTAL
1. 1 INCGROUP 1	0.08	FRACTION	2.23	SUBSECTOR TOTAL
1. 1. 1 COOK/WATHEAT/SPH	1.00	SATURATION	1.96	ENDUSE TOTAL
1.WOOD	0.82	FRACTION	1.51	WOOD FUEL
2.CHARCOAL	0.65	FRACTION	0.46	CHARCOAL
1. 1. 2 COOKING	0.18	SATURATION	0.00	ENDUSE TOTAL
1.PARAFFIN	1.00	FRACTION	0.00	PARAFFIN
1. 1. 3 LIGHTING	0.94	SATURATION	0.16	ENDUSE TOTAL
1.PARAFFIN	1.00	FRACTION	0.16	PARAFFIN
1. 1. 4 OTHER	0.18	SATURATION	0.10	ENDUSE TOTAL
1.CHARCOAL	1.00	FRACTION	0.10	CHARCOAL
1. 2 INCGROUP 2	0.23	FRACTION	5.77	SUBSECTOR TOTAL
1. 2. 1 COOK/WATHEAT/SPH	0.95	SATURATION	4.47	ENDUSE TOTAL
1.WOOD	0.40	FRACTION	1.57	WOOD FUEL
2.CHARCOAL	0.85	FRACTION	2.89	CHARCOAL
1. 2. 2 COOKING	0.54	FRACTION	0.31	ENDUSE TOTAL
1.PARAFFIN	1.00	FRACTION	0.31	PARAFFIN
1. 2. 3 LIGHTING	1.00	SATURATION	0.60	ENDUSE TOTAL
1.PARAFFIN	0.98	FRACTION	0.60	PARAFFIN
2.ELECTRICITY	0.04	FRACTION	0.00	ELECTRICITY
1. 2. 4 OTHER	0.41	SATURATION	0.39	ENDUSE TOTAL
1.CHARCOAL	1.00	FRACTION	0.39	CHARCOAL
1. 3 INCGROUP 3	0.36	FRACTION	10.24	SUBSECTOR TOTAL
1. 3. 1 COOK/WATHEAT/SPH	0.98	SATURATION	7.75	ENDUSE TOTAL
1.WOOD	0.31	FRACTION	1.97	WOOD FUEL
2.CHARCOAL	0.94	FRACTION	5.78	CHARCOAL
1. 3. 2 COOKING	0.69	SATURATION	0.66	ENDUSE TOTAL
1.PARAFFIN	0.93	FRACTION	0.59	PARAFFIN
2.PETROL	0.07	FRACTION	0.07	PETROL
1. 3. 3 LIGHTING	1.00	SATURATION	0.99	ENDUSE TOTAL
1.PARAFFIN	0.84	FRACTION	0.95	PARAFFIN
2.ELECTRICITY	0.21	FRACTION	0.04	ELECTRICITY
1. 3. 4 OTHER	0.58	SATURATION	0.82	ENDUSE TOTAL

TABLE 12

------- ELECTRICAL GENERATION FOR INTERNAL CONSUMPTION' (MW CAPACITY & GWH GENERATION)

TYPE / YEAR	1980	1985	1990	1995	2000
UGANDA IMPORTS					
CAPACITY (MW)	30.	30.	30.	30.	30.
GENERAT. (GWH)	252.	252.	252.	252.	252.
HYDRO POWER					
CAPACITY (MW)	300.	360.	420.	525.	630.
GENERAT. (GWH)	788.	946.	1104.	1380.	1656.
GEOTHERMAL					
CAPACITY (MW)	0.	15.	30.	30.	30.
GENERAT. (GWH)	0.	105.	210.	210.	210.
COMBUST. TURBINE					
CAPACITY (MW)	26.	38.	50.	65.	80.
GENERAT. (GWH)	23.	33.	44.	57.	70.
DIESEL					
CAPACITY (MW)	23.	12.	0.	0.	0.
GENERAT. (GWH)	20.	10.	0.	0.	0.
OIL STEAM					
CAPACITY (MW)	93.	104.	168.	331.	498.
GENERAT. (GWH)	253.	583.	943.	1858.	2792.
-TOTAL ELECTRIC-					
CAPACITY (MW)	472.	559.	698.	981.	1268.
GENERAT. (GWH)	1336.	1930.	2553.	3757.	4980.

TABLE 13

---------- SOURCES AND USES OF OIL ---- SUMMARY FORECAST (MILLION BARRELS) ---------

YEARS	1980	1985	1990	1995	2000
SOURCES					
IMPORTED CRUDE	22.5	26.3	26.3	26.3	26.3
INTERNAL CRUDE	0.0	0.0	0.0	0.0	0.0
IMPORTED REFINED	0.0	2.7	9.2	22.2	35.2
USES					
INTERNAL DEMAND	15.0	21.4	27.9	40.9	53.9
EXPORT REFINED	6.8	6.8	6.8	6.8	6.8
EXPORT CRUDE	0.0	0.0	0.0	0.0	0.0
REFINERY LOSS	0.7	0.8	0.8	0.8	0.8
REFINERY CAPACITY	25.5	25.5	25.5	25.5	25.5

TABLE 14

------ ENERGY SUPPLIED FOR INTERNAL CONSUMPTION (MILLIONS OF GIGA-JOULES

SOURCE / YEAR	1980	1985	1990	1995	2000
TOTAL WOOD	206.9	260.2	314.7	405.8	498.5
FOR FIREWOOD	140.0	163.9	187.8	219.6	251.0
FOR CHARCOAL	53.7	76.5	100.5	145.9	193.4
FOR INDUSTRY	13.2	19.8	26.4	40.3	54.1
TOTAL OIL	95.0	135.0	174.8	254.3	334.1
IMPORT. REFINED	0.0	16.9	56.7	136.1	215.9
IMPORTED CRUDE	95.0	118.2	118.2	118.2	118.2
DOMESTIC CRUDE	0.0	0.0	0.0	0.0	0.0
HYDRO	2.8	3.4	4.0	5.0	6.0
GEOTHERMAL	0.0	0.9	1.9	1.9	1.9
ELEC. IMPORTS	0.9	0.9	0.9	0.9	0.9
WIND	0.0	0.0	0.0	0.0	0.0
COAL	1.4	2.2	3.0	4.7	6.4
BIOMASS	7.8	9.1	10.5	12.4	14.3
SOLAR	0.0	0.0	0.0	0.0	0.0
TOTAL SOURCES:	314.8	411.8	509.8	684.9	862.1

TABLE 15

FOSSIL & BIOMASS ENERGY SUPPLIED FOR INTERNAL CONSUMPTION (PHYSICAL UNITS)

	1980	1985	1990	1995	2000
FUEL WOOD MILLION TONNES	8.6	10.1	11.5	13.5	15.4
WOOD FOR CHRCOAL MILLION TONNES	3.3	4.7	6.2	9.0	11.9
WOOD FOR INDUST. MILLION TONNES	0.8	1.2	1.6	2.5	3.3
REFINED OIL MILLION BBL	0.0	2.7	9.2	22.2	35.2
IMPORTED CRUDE MILLION BBL	15.5	19.3	19.3	19.3	19.3
DOMESTIC CRUDE MILLION BBL	0.0	0.0	0.0	0.0	0.0

3. RESOURCE MODEL

3.1 Description

The LEAP Resource Model complements the Demand Model by providing forecasts of land-related resource levels based on land-use patterns. For example, the model calculates agricultural production for both internal consumption and export. The model also calculates regional wood production for fuel (charcoal and fuelwood) and construction purposes and automatically keeps track of the standing wood stock.

Both food and wood resource supply/demand balances are tracked over time, depending upon such factors as changes in national and regional demographic land-use patterns, in agricultural productivity, in food consumption levels, in stocks and yields of wood resources on different landtypes, and in wood resource policy measures. Such policy measures could include a variety of projects varying in magnitude, timing, location, and wood production characteristics. Some examples are rural woodlots, urban greenbelts, managed forest plantations, and agro-forestry schemes. Ecological factors governing location and wood production characteristics (e.g. species) can be taken into account. The model also employs additional locational factors to measure the impact of wood resource accessibility and inter-regional charcoal transactions on regional and national supply/demand balances.

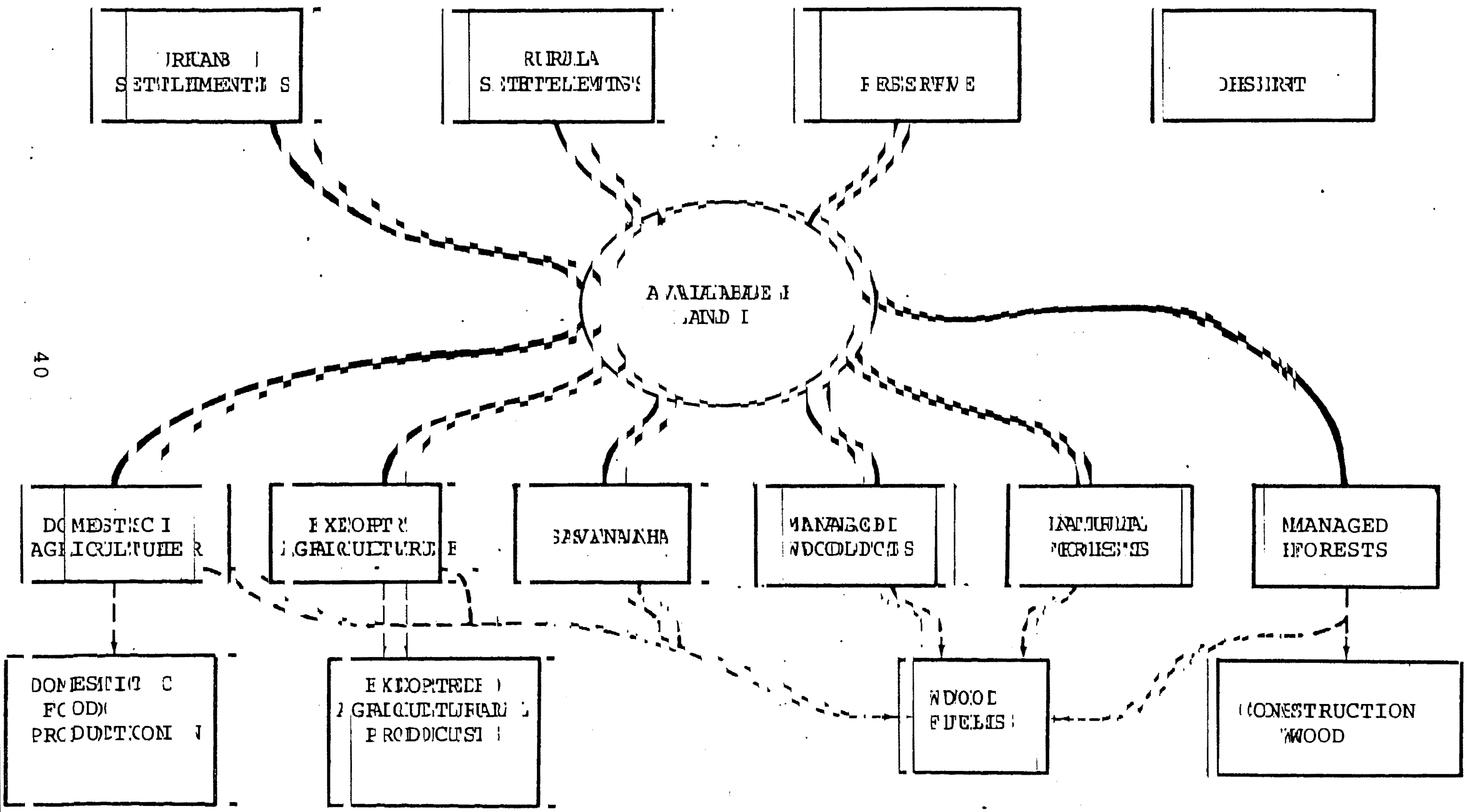
Shortfalls and surpluses can be estimated as they evolve, and appropriate land use policies (including, e.g., wood resource projects or settlement schemes) can be identified.

The LEAP Resource Model can be employed on a 'stand-alone' basis or through interaction with the Demand Model. Fuelwood, charcoal, and construction wood demands associated with Demand Model scenarios may be automatically passed to the Resource Model or may be created by the user. The use may also independently create his own wood demand data files. Figure 7 shows the overall structure of the Resource Model.

The structure of the Resource Model is based on the land areas devoted to various uses. The basic form is a three-level hierarchy of: 1. Region, 2. Zone, and 3. Land Type. This structure was chosen to correspond with generally available land data. For example, the first level could correspond to the primary administrative subdivisions of a country, typically provinces or districts. This second level typically corresponds to ecological zones within a province based, for example, on the annual rainfall. This has the advantage of allowing for more precise modelling of agricultural and wood resource production characteristics. The third level is for the various land types, generally based on land usage such as small farming, grazing, natural forest, etc. As in the case of the Demand Model, one can name and

Figure 7

TYPICAL LAND USE RELATIONSHIPS IN THE RESOURCE MODEL



Solid lines represent possible shifts of one land use to another.
Dotted lines represent land related resource production.
Land may be converted from one use to another through the implicit "Available Land" category.

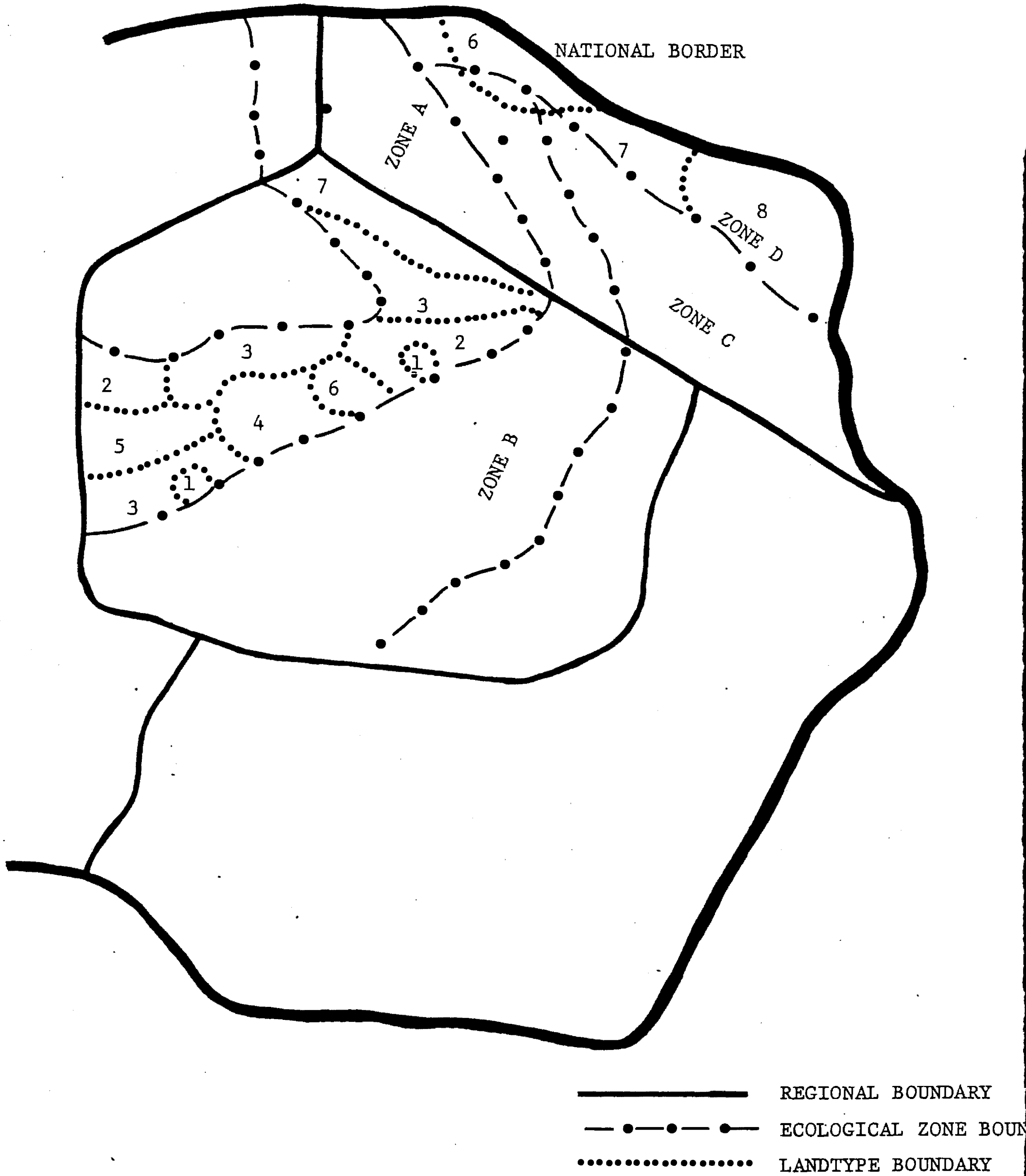
specify those various categories as appropriate. An illustration of the land demarcations is shown in Figure 8 below.

In estimating the supply of wood and agricultural resources, the LEAP model employs a land-use submodel. The competing functions of a set of specified landtypes within the country of interest provides the dynamic structure for the evaluation of the time evolution of resources. This dimension of the analytic framework of the model is important since both the physical requirements for food and fuel and the economic implications of food and fuel imports (and exports) often place competing pressures on land use and land-use policies in developing countries. Moreover, demographic pressures, both directly through settlement patterns and indirectly through food and fuel requirements, can be modelled. Finally, the structure of the land-use submodel allows for flexibility in evaluating the impact of alternative land use policies, varying in type, magnitude, and timing, which affect agricultural and wood resource production and settlement patterns.

The set of landtypes can be specified in as much detail as desired or appropriate. An example of such a set is given below in Table 16.

Figure 8

SAMPLE LAND DIVISIONS



LANDTYPES				ZONES
E.G.	1. urban settlement	5. uncropped	E.G.	A. High Potential
	2. small farms	6. reserves		B. Medium Potential
	3. large farms	7. savannah		C. Semi-Arid
	4. natural forest	8. desert		D. Arid

TABLE 16

EXAMPLE OF LANDTYPE SET

Natural Forest
*Managed Forest
*Woodlot Plantation
*Urban Greenbelt
Urban Settlement
Rural Settlement
Small Farm Domestic Food
Small Farm Export Food
Small Farm Domestic Non-Food
Small Farm Export Non-Food
Large Farm Domestic Food
Large Farm Export Food
Large Farm Domestic Non-Food
Large Farm Export Non-Food
Grazing
Uncropped Agricultural Land
Savannah
Reserves
Water Bodies
Patoral
Desert

*policy projects

Of course, other divisions might be appropriate depending upon the country and planning issues of interest. For example, different types of natural forest may be modelled to account for the variety of dominant tree species and their characteristics. The agricultural categories may be specified to account for the variety of crops, or to track land tenure conditions. For any given landtype demarcation, it is necessary that sufficient detail be provided in order that the sources of wood and crops be adequately identified for the LEAP analysis.

The set of zones could be chosen as desired, e.g., a small set for convenience or a large set for greater ecological or development planning specificity. A convenient set of ecological zones could be (1) High Potential, (2) Medium Potential, (3) Semi-Arid, and (4) Arid, based primarily on annual rainfall.

The Resource Model operates on the basis of three fundamental sets of processes: (1) land conversions, (2) wood resource supply conditions, and (3) resource allocations to meet demands. Land conversions are treated through both exogenous inputs (wood projects, expansion of agriculture) and automatic calculations in the model (settlement expansion). Supply conditions are treated primarily through the available stocks and annual yields on a region/zone/landtype basis. This depends upon the supply/demand interaction itself. The allocation of wood resources, through both harvesting of annual yields and cutting of stocks (where necessary) in accessible lands, is modelled on a regional basis, taking local fuelwood and charcoal demands, inter-regional charcoal exchanges, and national construction wood demand into account. This allocation, in turn, can affect the conditions of wood resource supply as a result of stock cutting, and the consequent reduction of yields, and as a result of regrowth of depleted stocks when annual yields exceed demand. Each of these processes are illustrated in the set of figures which are discussed below.

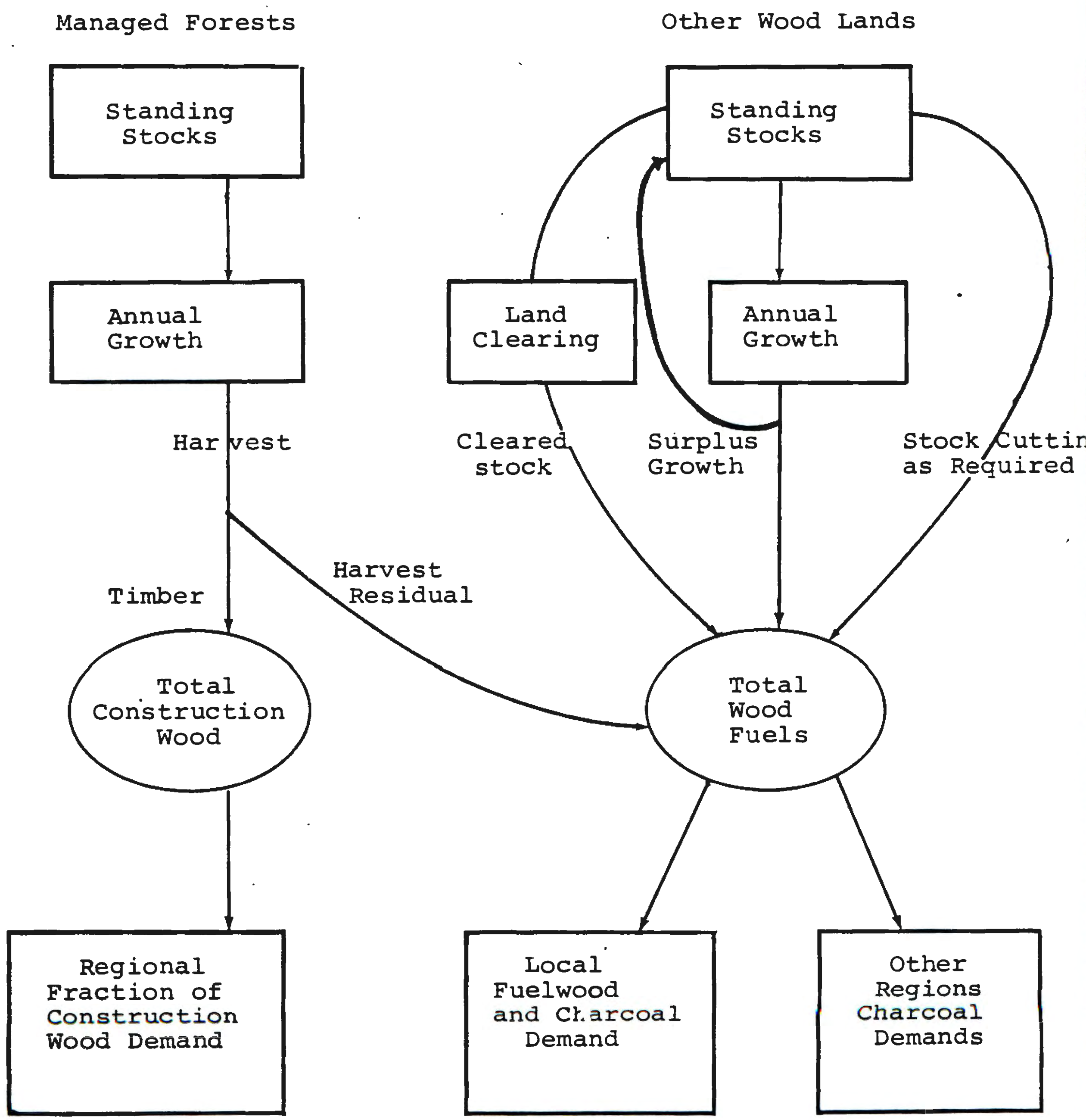
Figures 9 and 10 show in more detail, the specific relationships for wood supply within a region. Managed forests are harvested to supply construction wood demand, with the residual made available for local fuel use. Land clearing from forest conversions provides an additional source of wood fuel. Then the accessible wood growth is used as required to meet demand. If there is surplus growth, then depleted stocks will be replenished; otherwise the accessible standing stock will be cut as required to meet the demand. Figure 10 shows this process in more detail for forests.

3.2 Setting Up Basic Resource Data

The Resource Model has associated with it two major categories of data: 1) Basic and 2) Scenario data. The Basic data is used to define the base year characteristics

Figure 9

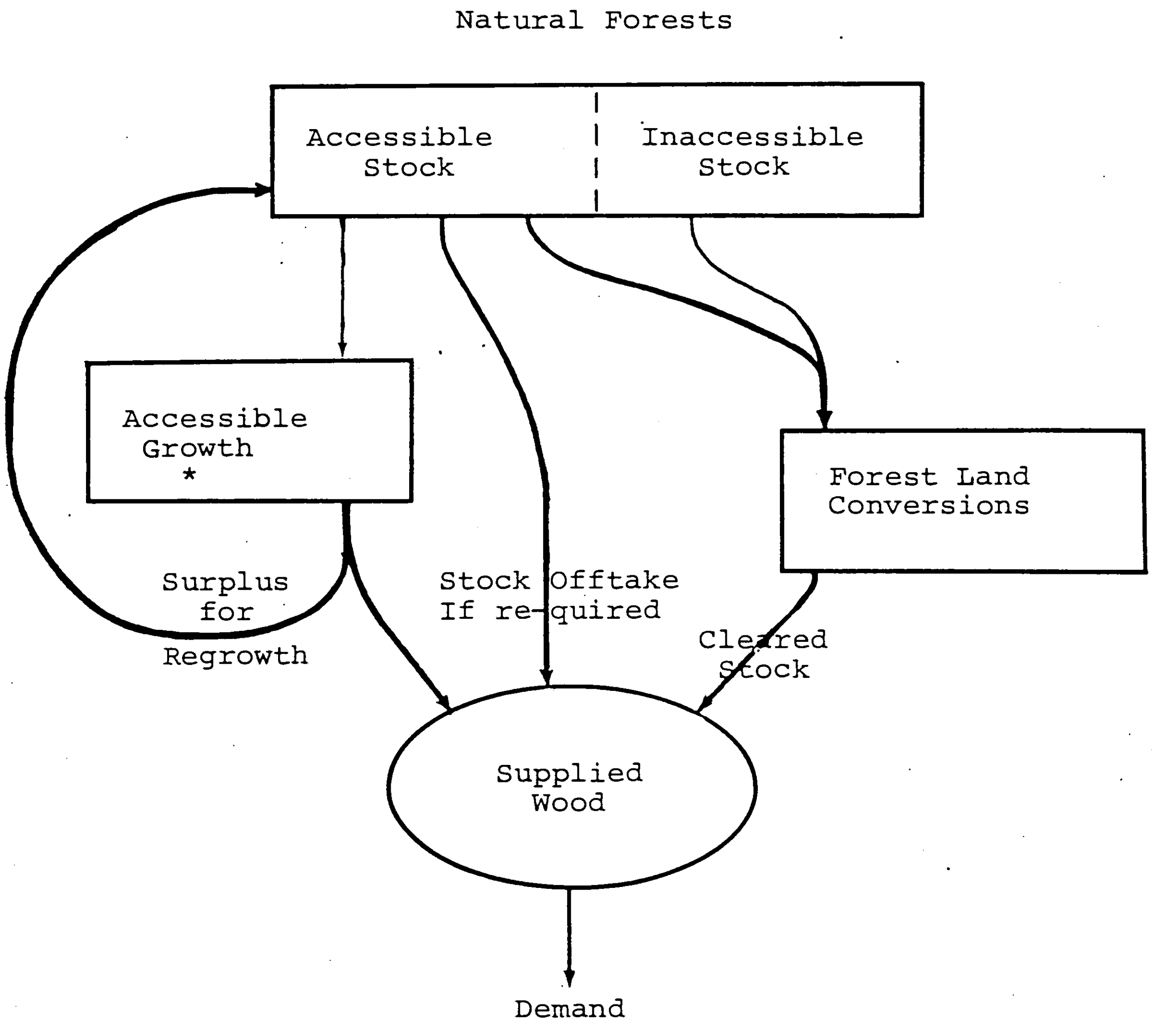
INTER-REGIONAL WOOD RESOURCE FLOWS



Annual growths are a function of the standing stocks.

Figure 10

NATURAL FORESTS WOOD SUPPLY



*For some forest types, the growth is a nonlinear function of the stock.

of the country or area under investigation in terms of land areas and productivities. The Scenario data is used to define alternative futures based, for example, on population growth, agricultural productivity changes, and a variety of other policy variables. These two types of data will be discussed in this and the next section.

In using the Resource Model one must decide how the country is to be divided into regions, zones, and landtypes. As mentioned, useful division would be administrative boundaries for regions, ecological/rainfall characteristics for zones, and land-use categories for landtypes. Other categories could be used as appropriate.

Once these divisions are determined, three separate lists are created of the regions, zones, and landtype names, along with the index numbers for each. Those three lists then serve to define a three-dimensional matrix of possible land categories. In reality, not all regions have or will have land in all zones, and not all landtypes will actually exist in all zones. Only the non-zero combinations are entered as data.

The collection of land-related data to fill this matrix requires determining the area of each region and zone, and the landtype areas within each region-zone combination. If the landtype produces either wood or agricultural products, additional data is also required. For wood production, one needs to know the fraction of the wood resources in each land area that is accessible for harvest, the annual wood yield and the current standing stocks per land unit. For agricultural production, one needs to know the average annual production per land unit, either in relative or absolute terms. Note here that one advantage of using ecological classifications for zones is that the land type characteristics for the same zones in different regions tend to be very similar. A summary listing of the "Basic" data requirements are shown in Table 17. A report of sample input data is displayed in Table 18.

3.3 Setting up the Resource Scenario Data

The "Basic" data function is to capture the geographic and physical character of the country or region under investigation and to initialize the data set. Off of this basic "photograph" of the land-use and resource characteristics, a number of "motion pictures" of the country's resource can be developed based, among other variables, on assumptions about policy inputs. The set of data influencing this evolution of the land-use and resource characteristics constitutes the "Scenario" data.

The Scenario data is somewhat more complex than the Basic data since it incorporates the time dimension, as well as providing for the analysis of a variety of policy alternatives. However, because normal default values are established for most data, one must only confront as much complexity as is needed for a particular analysis.

TABLE 17

BASIC DATA CATEGORIES

A. Base Data

1. Country (or Area) Name
2. Base Year
3. Land Unit Label
4. Land Unit Scale

B. Regions

1. Index Number
2. Name

C. Zones

1. Index Number
2. Name

D. Land Types

1. Index Number
2. Name
3. Symbolic Name

E. Land Data

1. Region Index
2. Zone Index
3. Land Type Index (or Symbolic Name)
4. Area
5. Wood Accessibility
6. Annual Wood Growth
7. Standing Wood Stock
8. Annual Agriculture Production

Optional

TABLE 18

**** DATA INPUT REPORT - COUNTRY DATA FOR KENYA ****

WESTERN PROVINCE	AREA	WD ACC	WD GRW	WD STK	A PROD
HIGH POTENTIAL					
SETTLEMENT URBAN	3.00	0.0	0.0	0.0	0.0
BUILT ENV. RURAL	4.00	0.0	0.0	0.0	0.0
SML FRM DOM FOOD	322.00	1.00	1.00	20.00	0.70
SML FRM DOM N-FD	10.00	1.00	1.00	20.00	0.90
SML FRM EXP FOOD	20.00	1.00	1.00	20.00	0.80
SML FRM EXP N-FD	2.00	1.00	1.00	20.00	1.00
LRG FRM DOM FOOD	1.00	0.80	0.50	10.00	1.00
LRG FRM DOM N-FD	1.00	0.80	0.50	10.00	0.20
LRG FRM EXP FOOD	6.00	0.80	0.50	10.00	1.10
LRG FRM EXP N-FD	2.00	0.80	0.50	10.00	1.30
AGRIC UNCROPPED	125.00	1.00	1.00	20.00	0.0
PASTURE	145.00	0.50	1.50	25.00	0.0
FOREST MANAGED	14.00	1.00	8.00	80.00	0.0
FOREST UNMANAGED	71.00	0.60	4.00	80.00	0.0
PLANTAT/WOODLOT	0.0	1.00	20.00	140.00	0.0
RESERVE	15.00	0.0	4.00	80.00	0.0
SMALL FARM WOOD	0.0	1.00	1.00	20.00	0.70
MEDIUM POTENTIAL					
SML FRM DOM FOOD	0.0	1.00	0.65	12.00	0.50
LRG FRM DOM FOOD	0.0	0.80	0.40	8.00	0.65
SEMI-ARID					
SML FRM DOM FOOD	0.0	1.00	0.50	6.00	0.35
LRG FRM DOM FOOD	0.0	0.80	0.30	4.00	0.50
ARID					
SAVANNAH BUSH	50.00	0.30	0.30	6.00	0.0
SAVANNAH GRASS	32.00	0.30	0.30	6.00	0.0

NYANZA PROVINCE	AREA	WD ACC	WD GRW	WD STK	A PROD
HIGH POTENTIAL					
SETTLEMENT URBAN	16.00	0.0	0.0	0.0	0.0
BUILT ENV. RURAL	6.00	0.0	0.0	0.0	0.0
SML FRM DOM FOOD	421.00	1.00	1.00	20.00	0.70
SML FRM DOM N-FD	15.00	1.00	1.00	20.00	0.90
SML FRM EXP FOOD	20.00	1.00	1.00	20.00	0.80
SML FRM EXP N-FD	3.00	1.00	1.00	20.00	1.00
LRG FRM DOM FOOD	5.00	0.80	0.50	10.00	1.00
LRG FRM DOM N-FD	3.00	0.80	0.50	10.00	0.20
LRG FRM EXP FOOD	32.00	0.80	0.50	10.00	1.10
LRG FRM EXP N-FD	2.00	0.80	0.50	10.00	1.30
AGRIC UNCROPPED	500.00	1.00	1.00	20.00	0.0
PASTURE	105.00	0.50	1.50	25.00	0.0
FOREST MANAGED	0.0	1.00	8.00	80.00	0.0
FOREST UNMANAGED	0.0	0.60	4.00	80.00	0.0
PLANTAT/WOODLOT	0.0	1.00	20.00	140.00	0.0
RESERVE	90.00	0.0	4.00	80.00	0.0
SMALL FARM WOOD	0.0	1.00	1.00	20.00	0.70
MEDIUM POTENTIAL					
SML FRM DOM FOOD	0.0	1.00	0.65	12.00	0.50
LRG FRM DOM FOOD	0.0	0.80	0.40	8.00	0.65
RESERVE	23.00	0.0	3.00	60.00	0.0

(partial)

The following table lists the various data that can be specified. Those items marked with an asterisk must be in every scenario data set, while the other items are optional. We will first discuss the required data.

Required Data

The start and finish year of the scenario must be specified. The model will then perform annual calculations from the base year to the final year and report the results for the start and finish years as well as for selected years in between.

Although the Base year is specified as part of the Base data set, one must specify Mid and End index years for the time varying data as we saw was required for the Demand model. The Resource model then uses these three index years to interpolate the time dependent indexed data in the same fashion.

Population data must be given for the rural and urban populations in each of the regions for the three index years. This data is used to allocate national wood demands, and calculate food needs over time, as well as to compute requirements for settlement land. The population related calculations are performed relative to base year values and relative to total national population, thus the exact values are not as important as the relative changes.

The regional allocation of wood and charcoal demands proceeds as follows. Fuel wood is assumed to be supplied

TABLE 19

LEAP RESOURCE MODEL

SCENARIO DATA

A. General Scenario Data

*1. Start and Final Years for analysis.
*2. Mid and End Years for indexed data.
*3. Rural Population in thousands by region for each of the index years (Base, Mid and End).
*4. Urban population by region as above.
5. Rural settlement density scale for the three index years.
6. Urban settlement density scale as above.
7. Sources of Rural Settlement Lands.
8. Sources of Urban Settlement Lands.
*9. Base year domestic food consumption (1000 tonnes).
*10. Base year total agricultural production by land type (1000 tonnes). Used for normalization.
11. Future agricultural productivities by land type for the three index years.
*12. Base year per capita caloric intake (calories/day).
13. Caloric consumption scaling factors for the index years.

B. Exogenous Land Conversion Data

1. Region Index
2. Zone Index
3. Land type converted from.
4. Land type converted to.
5. Annual area converted.
6. Starting year of conversion.
7. Final year of conversion.

*Required

from the same region in which it is used. National charcoal demand is allocated to regions proportional to urban population distribution. Final charcoal demand may be met from charcoal produced in other regions than the region of consumption. A specified inter-regional charcoal allocation matrix assigns the charcoal demand for each region to one or more supply regions. Thus each region supplies its own fuelwood, some or all of its charcoal, and may supply charcoal for other regions as well. Construction wood demand is supplied from managed forests. The National demand is allocated to the various regions proportionally to each region's managed forest yield in a given year. Figures 11A and 11B illustrate these various allocation procedures.

Also needed, is the base year domestic food consumption which is used in conjunction with base year food production to calculate initial imports/exports. This is also scaled by future population growth and caloric intake changes to project future food requirements.

Future changes in agricultural productivity, by landtype, may be specified as part of a scenario.

Optional Data

The following optional data allows the creation of a variety of scenarios. The major categories are listed below.

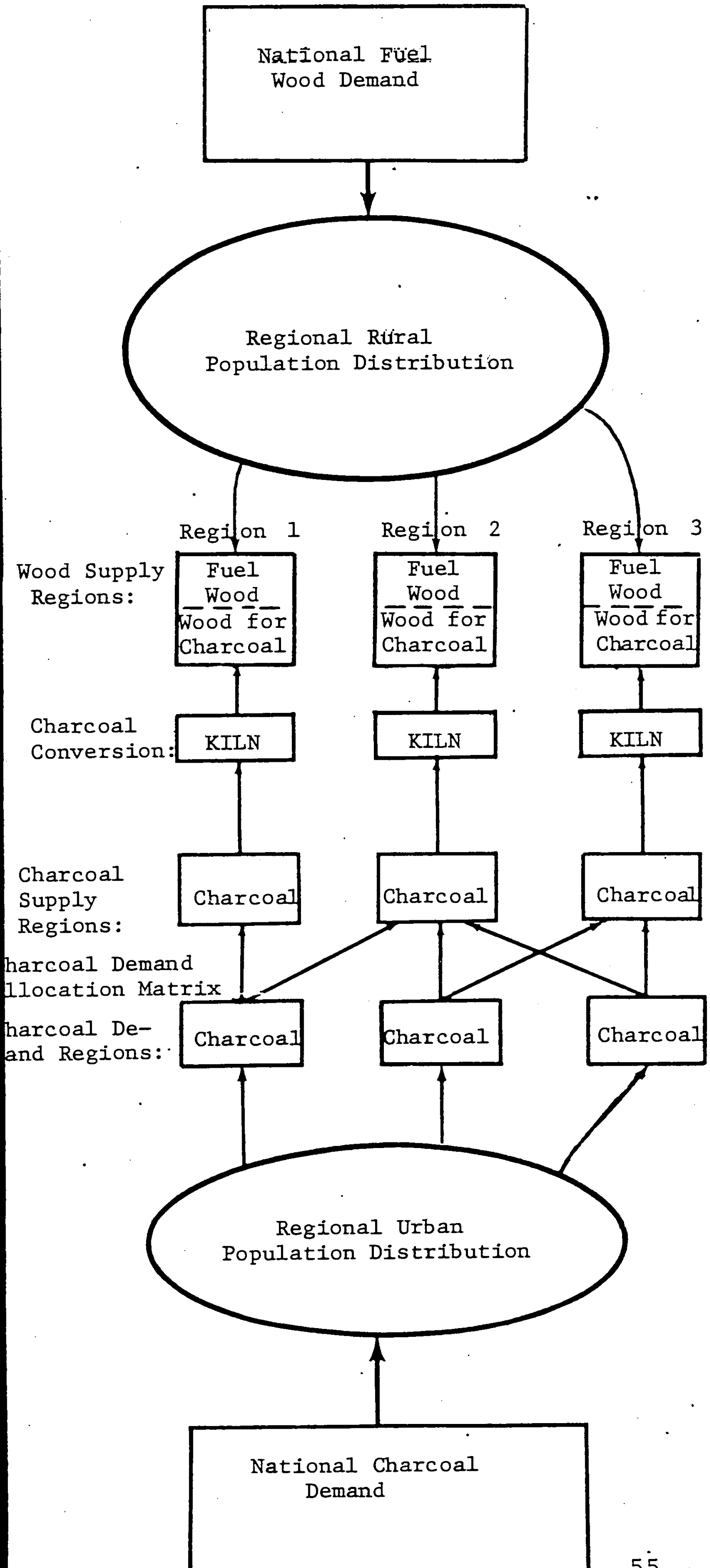


Figure 11A

NATIONAL FUEL WOOD DEMAND

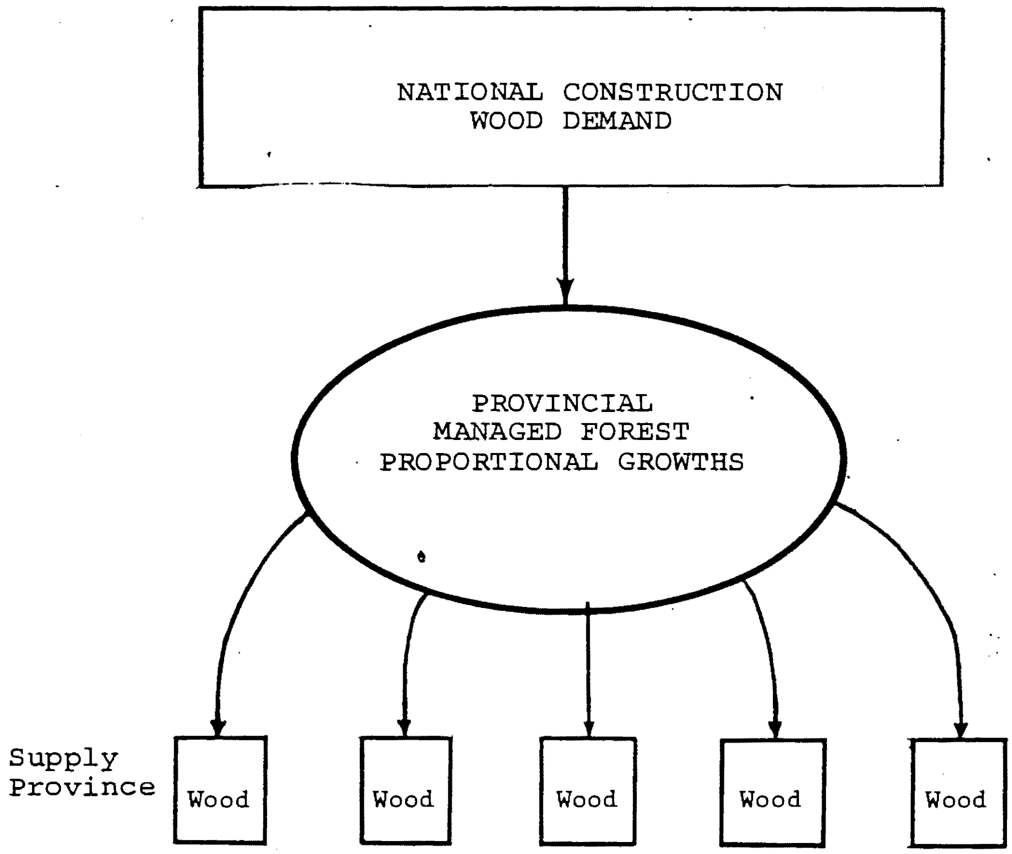
1. The National Fuel Wood Demand is allocated to province based on that province's fraction of the rural population. Fuel wood is assumed to be supplied from the same province it is used in.

2. The National Charcoal Wood Demand is allocated to province based on urban population. Charcoal may be supplied from other places than the province of use. A specified charcoal transportation/allocation matrix assigns the charcoal wood demand from each province to one or more supply provinces.

3. Thus each province supplies its own fuelwood, some or all of its charcoal wood, and may supply charcoal wood for other provinces as well.

Figure 11B

NATIONAL CONSTRUCTION WOOD DEMAND



Construction wood demand is supplied from managed forests. The National demand is allocated to the various provinces based on the current managed forest yield in each province. This demand is allocated proportionally to supply.

(a) Settlement Lands

As urban and rural populations grow, the model normally increases the areas of urban and rural settlement lands by converting contiguous farm lands. One may, however, specify explicitly by region and zone where the new settlement lands are taken from. Additionally, growth of settlement lands may be modified by changes in the settlement density (i.e. an increase in the density reduces the settlement land increase). This is done by specifying an hierarchical order of available landtypes for each region.

(b) Agricultural Production

Data may be provided to characterize projected or targeted changes in agricultural productivities by land type over time. This is performed through a scaling factor specified by landtype and index year used to multiply the base productivity values for that landtype in all regions and zones.

(c) Wood Production

Changes in wood productivities on various landtypes may also be modelled. This is done in a fashion analogous to changing the agricultural productivities.

(d) Land Conversions

Most importantly, conversions from one landtype to another within a given region and zone may be developed as exogenous inputs representing expectations and/or policies. This permits a very wide range of possible scenarios. For example, forest land could be converted to woodlots to increase fuel wood production, uncropped land could be converted to agriculture land for more food production, agricultural land could be converted from one type to another to represent changes in productivities or products. Altogether this provides a very flexible and powerful tool for designing policy scenarios.

3.4 Sample Results

The resource model produces a number of reports which give information about landuse and wood and agricultural production. Table 20 shows a sample landuse forecast for one region (the model produces reports for all regions plus a national summary). This table shows the areas devoted to various landuses for each zone within the region over the time span of the forecast. This report enables one, for example, to see the effects of increasing land required for urban settlement, observe trends in agricultural land usage, determine how much land is available for conversion from one use to another, and identify trouble spots and opportunities with respect to long-range land use patterns.

The model also produces a table summarizing national agricultural production and demands (Table 21). This table shows the land areas devoted to agricultural production, the domestic food production, consumption and import requirements, as well as agricultural exports and other information.

TABLE 20

CENTRAL/NAIROBI LAND USE PROJECTIONS
(1000 HECTARES)

ZONE / LANDTYPE	1980	1985	1990	1995	2000
HIGH POTENTIAL	1019.				
SETTLEMENT URBAN	32.	45.	58.	82.	107.
BUILT ENV. RURAL	5.	6.	6.	7.	7.
SML FRM DOM FOOD	180.	166.	153.	128.	103.
SML FRM EXP FOOD	26.	26.	26.	26.	26.
LRG FRM DOM FOOD	262.	262.	262.	262.	262.
LRG FRM EXP FOOD	60.	60.	60.	60.	60.
LRG FRM EXP N-FD	10.	10.	10.	10.	10.
PASTURE	93.	93.	93.	93.	93.
FOREST MANAGED	44.	44.	44.	44.	44.
FOREST UNMANAGED	202.	202.	202.	202.	202.
UNUSED	105.	105.	105.	105.	105.
ARID	367.				
RESERVE	138.	138.	138.	138.	138.
SAVANNAH GRASS	229.	229.	229.	229.	229.
ALL ZONES	1386.				
SETTLEMENT URBAN	32.	45.	58.	82.	107.
BUILT ENV. RURAL	5.	6.	6.	7.	7.
SML FRM DOM FOOD	180.	166.	153.	128.	103.
SML FRM EXP FOOD	26.	26.	26.	26.	26.
LRG FRM DOM FOOD	262.	262.	262.	262.	262.
LRG FRM EXP FOOD	60.	60.	60.	60.	60.
LRG FRM EXP N-FD	10.	10.	10.	10.	10.
PASTURE	93.	93.	93.	93.	93.
FOREST MANAGED	44.	44.	44.	44.	44.
FOREST UNMANAGED	202.	202.	202.	202.	202.
RESERVE	138.	138.	138.	138.	138.
SAVANNAH GRASS	229.	229.	229.	229.	229.
UNUSED	105.	105.	105.	105.	105.

TABLE 21

****** AGRICULTURAL PROJECTIONS ******

AREAS (1000 HECTARES)	1980	1985	1990	1995	2000
SML FRM DOM FOOD	1717.	2310.	2903.	3455.	4008.
SML FRM DOM N-FD	25.	25.	25.	25.	25.
SML FRM EXP FOOD	179.	179.	179.	179.	179.
SML FRM EXP N-FD	6.	6.	6.	6.	6.
LRG FRM DOM FOOD	618.	938.	1258.	1578.	1898.
LRG FRM DOM N-FD	25.	25.	25.	25.	25.
LRG FRM EXP FOOD	281.	281.	281.	281.	281.
LRG FRM EXP N-FD	24.	24.	24.	24.	24.
TOTAL AGRIC. LAND	2875.	3788.	4701.	5573.	6446.
FOOD SOURCES					
PROD FOR HOME MKT (THOUSAND TONS)	1940.00	2485.33	3190.77	3914.79	4680.11
IMPORTS (THOUSAND TONS)	640.00	799.35	853.40	1269.54	1727.54
FOOD CONSUMPTION					
TOTAL REQUIREMENT (THOUSAND TONS)	2580.00	3284.68	4044.18	5184.33	6407.65
AVER. PER CAPITA (CALORIES/DAY)	2000.	2100.	2200.	2300.	2400.
AGRICULTURE EXPORTS (THOUSAND TONS)	1120.00	1176.00	1232.00	1288.00	1344.00
RELATIVE PRODUCTION (PER LAND UNIT)	1.00	0.91	0.88	0.88	0.88

The model also provides a detailed wood report for each region and the nation as a whole (Table 22). This table gives the standing wood stock and the amount supplied from each wood producing landtype in the region. The total supply is compared with the demand and the shortfall, if any, reported. Also reported is the annual wood growth for the region in each year, and the amount that is accessible for harvest. A final section of this table reports in more detail the components of the demand and the source of supply, for example, whether it is harvested from new growth or cut from standing stock.

These tables provide detailed information for the identification and evaluation of potential problems as well as an aid in developing and testing alternative policies.

TABLE 22

CENTRAL/NAIROBI WOOD REPORT STOCKS AND SUPPLIES (MILLION TONNES)

SOURCE BY LANDTYPE:	1980		1985		1990		1995		2000	
	STK	SUPL	STK	SUPL	STK	SUPL	STK	SUPL	STK	SU
SML FRM DOM FOOD	3.60	0.30	2.68	0.30	1.61	0.29	0.24	0.25	0.0	0.
SML FRM EXP FOOD	0.52	0.04	0.42	0.05	0.27	0.05	0.05	0.05	0.0	0.
LRG FRM DOM FOOD	2.62	0.17	2.21	0.19	1.63	0.20	0.72	0.21	0.52	0.
LRG FRM EXP FOOD	0.60	0.04	0.51	0.04	0.37	0.05	0.17	0.05	0.12	0.
LRG FRM EXP N-FD	0.10	0.01	0.08	0.01	0.06	0.01	0.03	0.01	0.02	0.
PASTURE	2.33	0.11	2.10	0.11	1.77	0.12	1.27	0.12	1.16	0.
FOREST MANAGED	3.52	0.16	3.52	0.25	3.52	0.25	3.52	0.27	3.52	0.
FOREST UNMANAGED	16.16	0.80	14.28	0.96	11.57	1.14	7.38	1.01	6.46	0.
SAVANNAH GRASS	1.37	0.03	1.29	0.04	1.18	0.04	1.00	0.04	0.96	0.
CLEARED LANDS		0.0		0.0		0.0		0.0		0.
--- TOTALS ---	30.82	1.66	27.10	1.93	21.99	2.13	14.38	2.00	12.77	0.
TOTAL DEMAND		1.66		1.93		2.13		2.43		2.
SHORTFALL		0.00		0.00		0.00		0.43		2.
CURRENT ANNUAL GROWTH										
ACCESSIBLE		1.27		1.08		0.82		0.43		0.
TOTAL		1.74		1.55		1.29		0.91		0.

SUPPLY DEMAND BALANCES

WOOD USE CATEGORY -	1980		1985		1990		1995		2000	
	FUEL WOOD	IND/ CONST	FUEL WOOD	IND/ CONST	FUEL WOOD	IND/ CONST	FUEL WOOD	IND/ CONST	FUEL WOOD	IND CONS
DEMAND										
FROM REGION	1.53		1.73		1.94		2.22		2.50	
OTHER REGIONS	0.0		0.0		0.0		0.0		0.0	
TOTAL	1.53	0.13	1.73	0.20	1.94	0.20	2.22	0.21	2.50	0.2
SUPPLIED										
SUSTAINED YIELD	0.95	0.13	0.87	0.20	0.75	0.20	0.18	0.21	0.06	0.2
STOCK DEPLETION	0.59		0.86		1.19		1.61		0.0	
TOTAL	1.53	0.13	1.73	0.20	1.94	0.20	1.79	0.21	0.06	0.2
SHORTFALL	0.00	0.0	0.00	0.0	0.00	0.0	0.43	0.0	2.45	0.0

4. CREATING POLICY SCENARIOS

4.1 Introduction

The first steps towards creating and evaluating policy scenarios have already been described in the preceding sections. These steps lead to the development of what we may call "Base Case" projections of national (and regional) supply/demand balances incorporating sets of assumptions governing the mix of activities (economic, demographic, land-use, etc.) which influence energy supply and demand. It may be useful as well to perform sensitivity runs with adjustments in basic economic/demographic inputs to reflect reasonable uncertainty in those variables. Once this exploration is performed, however, it is convenient to limit the number of Base Case projections employed for further analysis, to a single one if possible, in order to have a benchmark for evaluating and comparing alternative policy scenarios.

The Base Case projections developed using the LEAP Demand and Resource Models can then be used as the point of departure for analysis and evaluation of alternative policy options. The initial step in this process involves a careful examination of the Base Case output reports. This serves to identify the type, timing, magnitude, and location of problems in the supply/demand configuration which are found to arise over the time horizon of the Base Case analysis. The important sectors and fuel types contributing to supply/demand mismatch, e.g. the need for new refinery or electrical generating capacity, the need to expand or intensify agricultural production, the pressure on standing stocks of wood resources, and the requirements for additional sources of wood will emerge from such an investigation. The analyst can then proceed to construct policy scenarios which address these problems.

Policy scenarios can be developed to assess the supply/demand implications of individual measures as well as integrated packages of options. It is useful to begin by testing the sensitivity of results to a variety of promising measures at several levels of implementation. The examination of Base Case results provides guidance in the selection of these measures, and such sensitivity analysis lays the basis for the construction of integrated policy programs which can be designed to effect changes in the character of both supply and demand.

It is useful to consider policies affecting demand and resources separately at first. This is convenient in that it adheres to the general structure of the LEAP model. Moreover, from the policy design standpoint, the demarcation between measures affecting end-use and primary fuel demands principally through technology changes, and options affecting the supply of resources primarily through land-use programs, may be useful. Some measures, however, do not readily fall primarily within either the demand or resource sides of the analysis. Examples of these could include measures affecting demographic patterns, e.g. settlement schemes, and agricultural expansion, both of which have direct consequences for land-use and energy demand. Such measures of necessity require a combined demand and resource analysis.

Among the kinds of policy measures that can be evaluated using the LEAP Model are:

- wood supply increases (e.g., long term programs to increase the production of managed woodlots, reforestation projects, urban greenbelts)
- domestic oil production (e.g., increased refinery capacity or domestic crude extraction)
- efficiency improvements (e.g., cooking stoves, charcoal kilns, private automobiles, industrial boilers)
- fuel switching (e.g., charcoal to petroleum products, fossil fuels to electricity)
- electric system planning (e.g., alternative capacity program impacts)
- land use (e.g., mix between use of high potential land for food, fuel, export crops)
- non-conventional sources (e.g., solar heating, wind driven irrigation, biogas applications)
- increasing agricultural productivity (e.g., mechanization, irrigation)
- settlement schemes.

4.2 Demand Model Policy Scenarios

By examining the Base Case reports provided by the LEAP Demand and Resource models the user can identify opportunities for reducing demands or shifting fuels in order to alleviate the impact of some of the problems that are illuminated by the Base Case projections. Here, for illustration, we shall focus upon the problems of reducing oil imports and reducing wood demand.

As can be seen below in Figure 12, the Base Case projections (see Sec. 2) for oil imports (both crude and refined) for meeting domestic requirements more than triples between 1980 and 2000, increasing from 15.7 million barrels to 54.7 million barrels. The most rapid increases arise in the urban households, large industry, transportation, and commercial sectors. Economic and demographic trends govern the magnitudes of the various sectoral increases, e.g. rural to urban migration. Of these sectors, transportation and large industry dominate overall oil consumption and therefore deserve attention in developing demand policy. While Figure 12 is illustrative of the general sectoral trends, it is necessary to examine the detailed subsector, end-use, and device/fuel information to locate more specifically the major sources of oil demands and the plausible policy options that can reduce these demands.

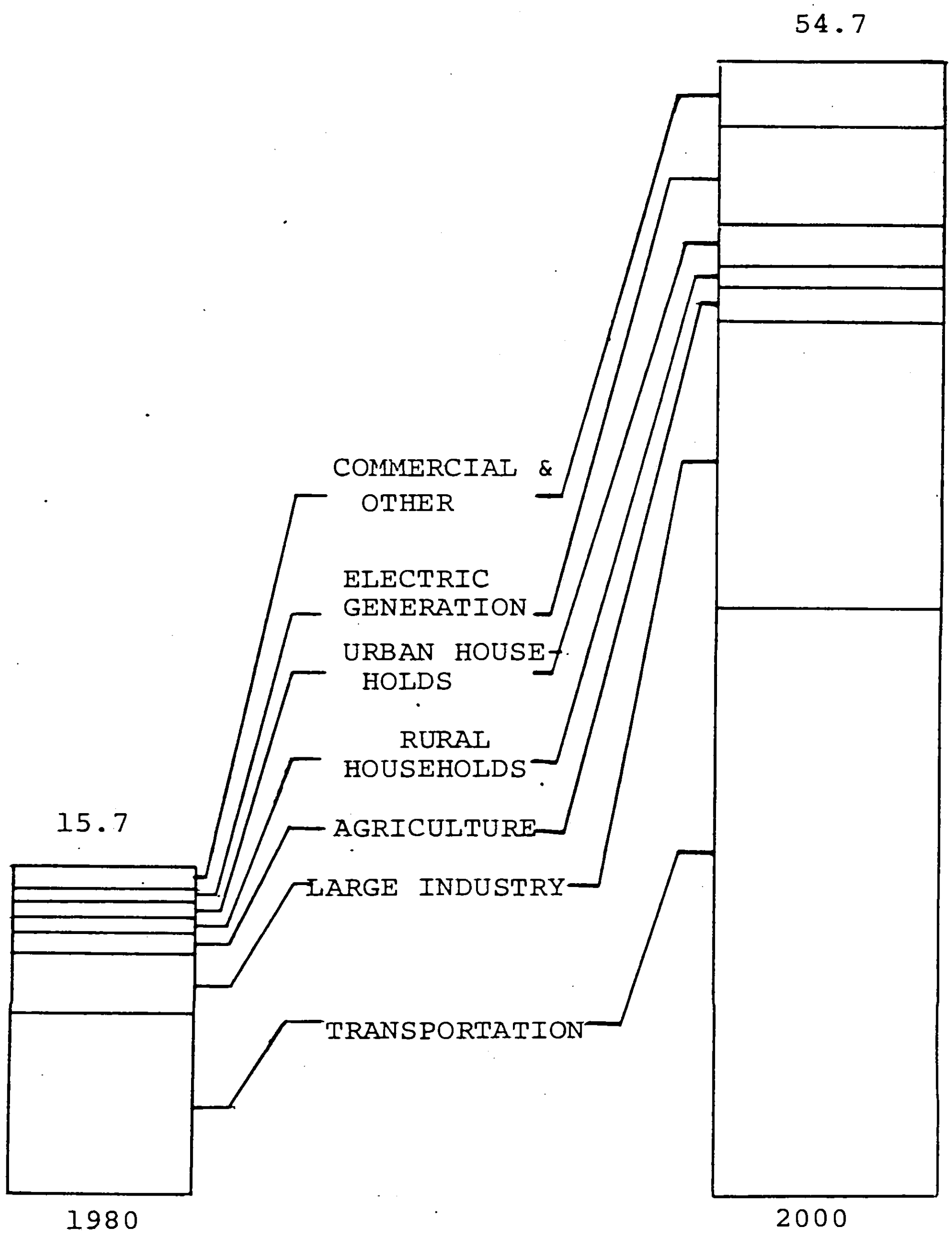
For example, specific subsectors and end-uses can be targeted. These choices can be based upon both their relative contribution to demand, and evaluation of the likelihood of policy effectiveness (e.g., public versus private sector transportation, central versus dispersed technologies). Here we shall restrict such options to those which reduce oil use without reducing the final service at the end-use level. Fuel switching and conversion efficiency improvements will be employed to achieve this end.

The results of Base Case Demand and Resource model projections show that wood resource demands are expected to rise

Figure 12

PETROLEUM IMPORTS FOR INTERNAL DEMAND

BASE CASE



Demands in Million Barrels

rapidly and both shortfalls and standing stock depletion on a regional and national basis can be expected. Figure 13 below, developed from the sample Base Case reports presented in Sec. 2.4 and Sec. 3.4, shows the major trends on a national basis. More regional detail is available in the regional Resource Model reports. Wood resource demands remain dominated by Rural Household demand for fuelwood and Urban Household Demand for charcoal throughout the forecast period. During the 1980-2000 period, demand increases by 250 percent, from 12.7 million tons to 30.6 million tons. The consequence of this is that by the year 2000 a serious shortfall (about half of demand) is shown to arise despite the cutting of standing stocks.

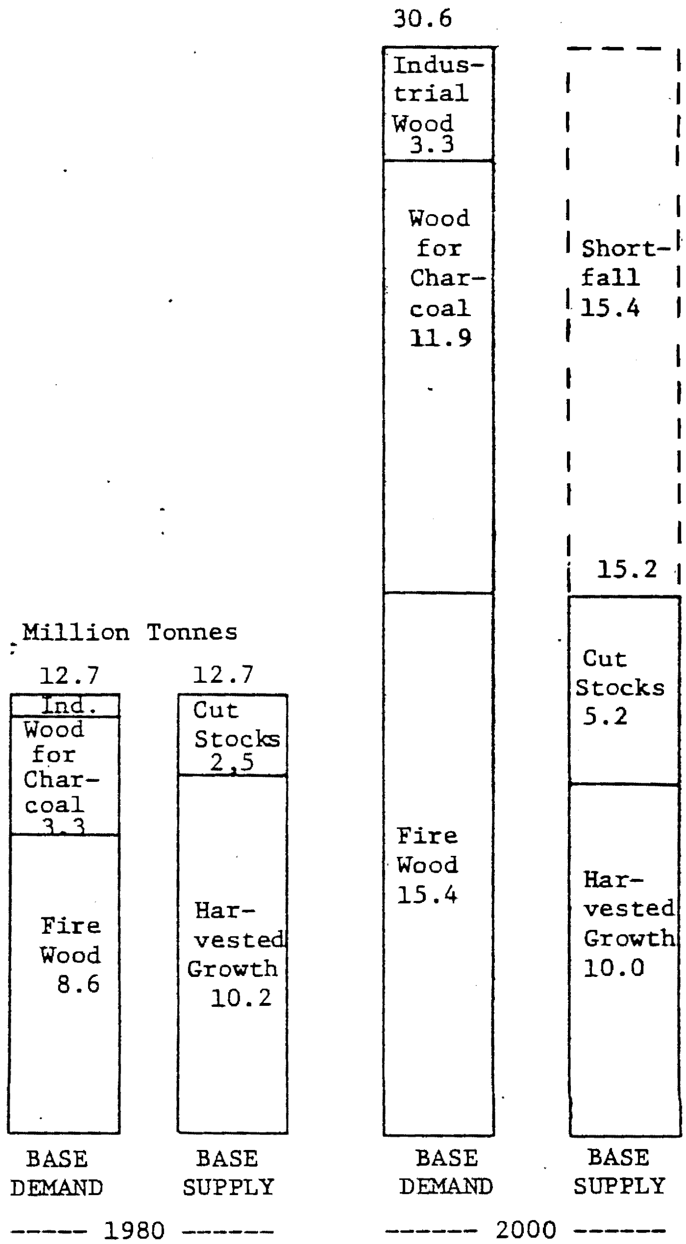
The demand policy program developed here includes the following measures addressing the wood resource supply/demand problems from the demand side only. These measures include:

1. urban households - device improvements
2. rural households - device improvements
3. charcoal kiln improvements
4. transportation improved vehicle mileage
5. electric generator increased efficiency
6. large industry boiler improvement

Figure 13

BASE CASE

SUPPLY AND DEMAND



Demands and Supplies are in Millions of Metric Tons.

The results of the demand policy program are provided in reports identical in format to those shown earlier for the Base Case. To complete this illustration, Figures 14 and 15 below, developed from the Demand Policy Scenario reports, are provided. Note the reduction in oil imports of 15% compared to the Base Case in 2000. Wood shortfall and stock depletion is also reduced by the year 2000, although not in the same proportions as the reductions in demand, due to the regional character of shortfalls. Regions with wood surpluses benefit, not by the reduction of shortfalls, but rather by a reduction of stock depletion.

From these national results, it is apparent that there is a need for more wood supply. But there remains the issue of when and where it is needed. This can be determined by looking at the region specific results. Figures 16 and 17 show graphically the time development of wood supply, demand and shortfall for two regions. The first region is experiencing a severe wood crisis with cutting from the standing stocks providing over a third of the supply in the base year. With stock reduction, future growth potential is decreased, and wood supply ultimately collapses circa 1995 when the last of the available stocks have been cleared. The second region is in much better condition. No substantial cutting of the wood stocks is projected until the early 1990's, and no shortfall at all is anticipated through the year 2000 when the annual growth plus some stock cutting is adequate to meet demand.

Figure 14

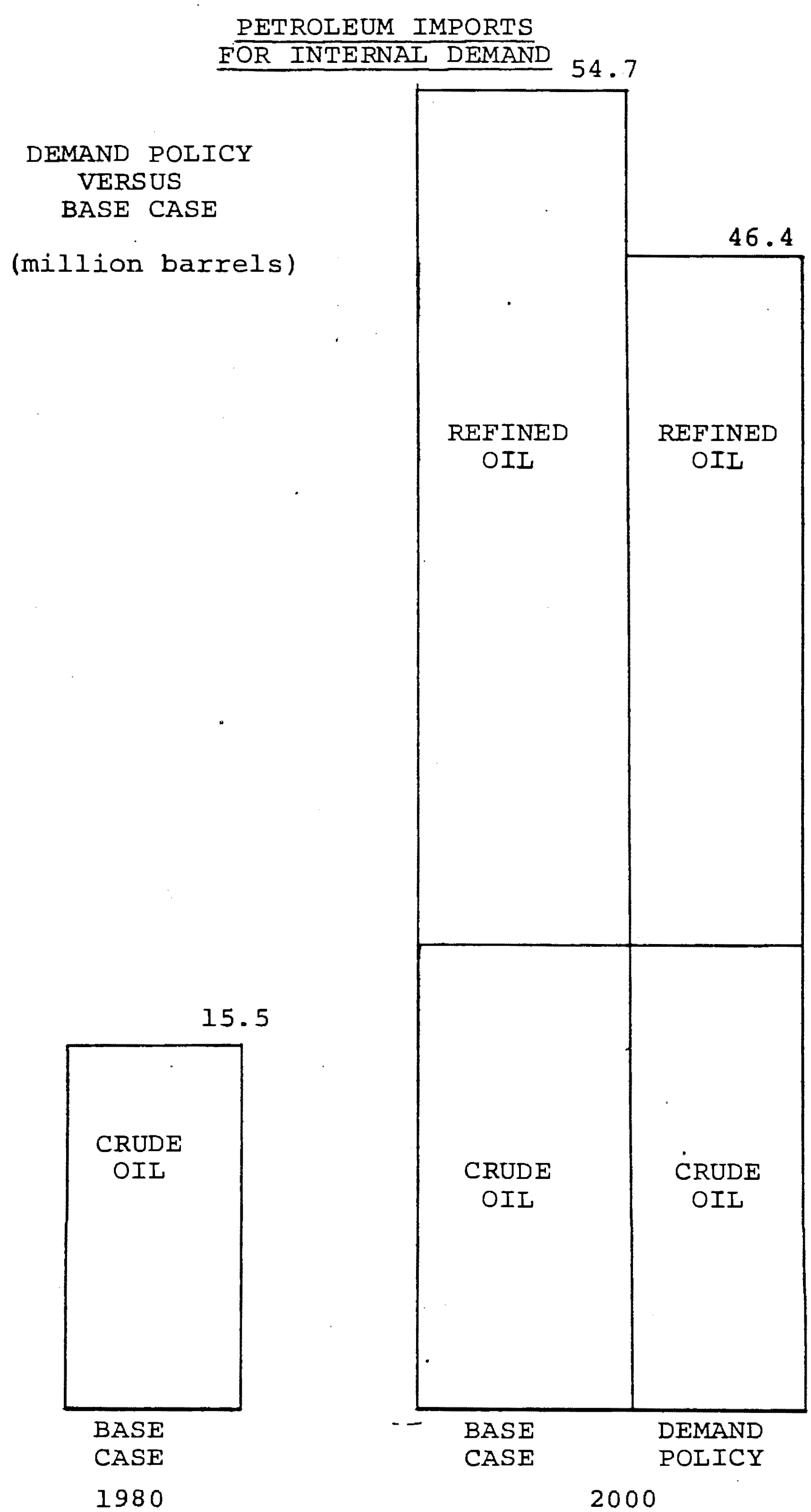
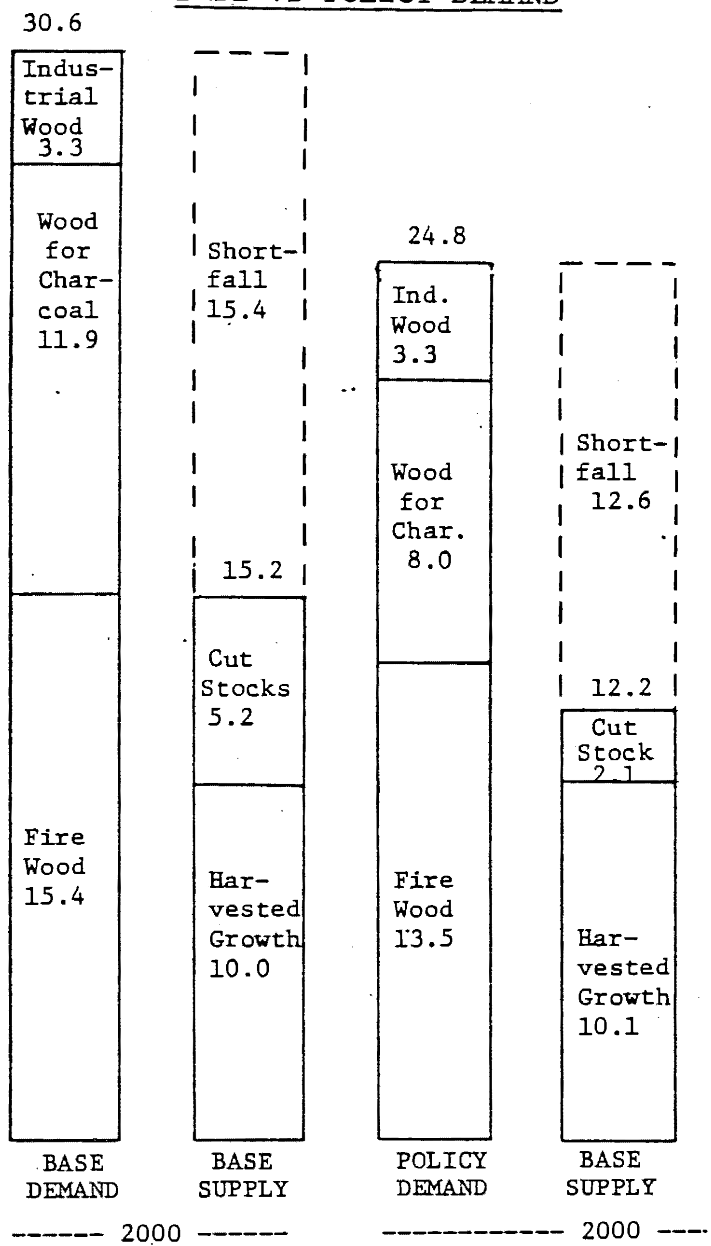

PETROLEUM IMPORTS
FOR INTERNAL DEMAND
DEMAND POLICY
VERSUS
BASE CASE
(million barrels)
54.7
46.4
15.5
REFINED
OIL
REFINED
OIL
CRUDE
OIL
CRUDE
OIL
CRUDE
OIL
BASE
CASE
BASE
CASE
DEMAND
POLICY
1980
2000

Figure 15

WOOD DEMAND AND SUPPLY

BASE VS POLICY DEMAND



Demands and Supplies are in Millions of Metric Tons.

Figure 16

WOOD SUPPLY AND DEMAND
BASE DEMAND - BASE RESOURCE
CENTRAL/NAIROBI REGION

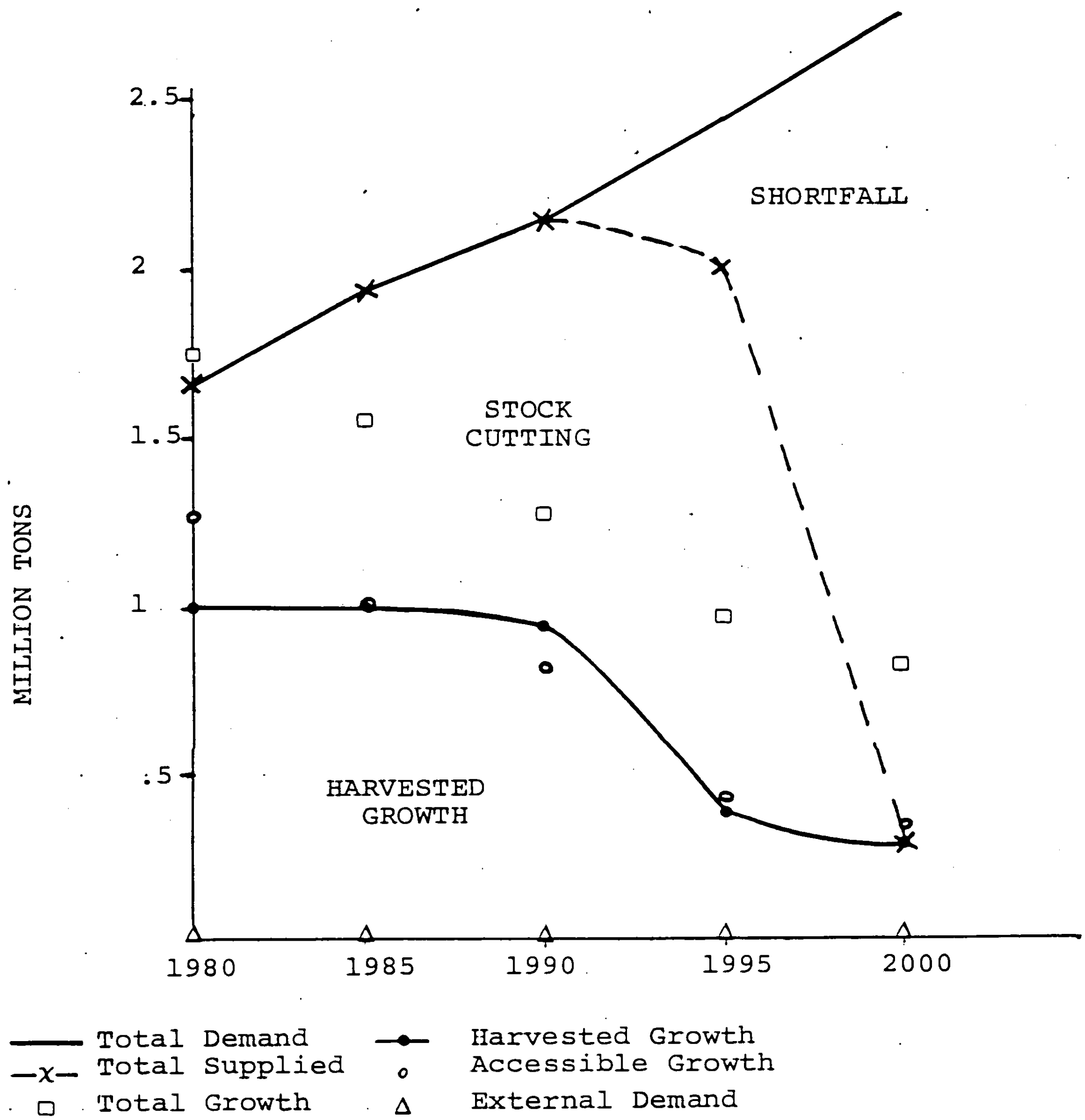
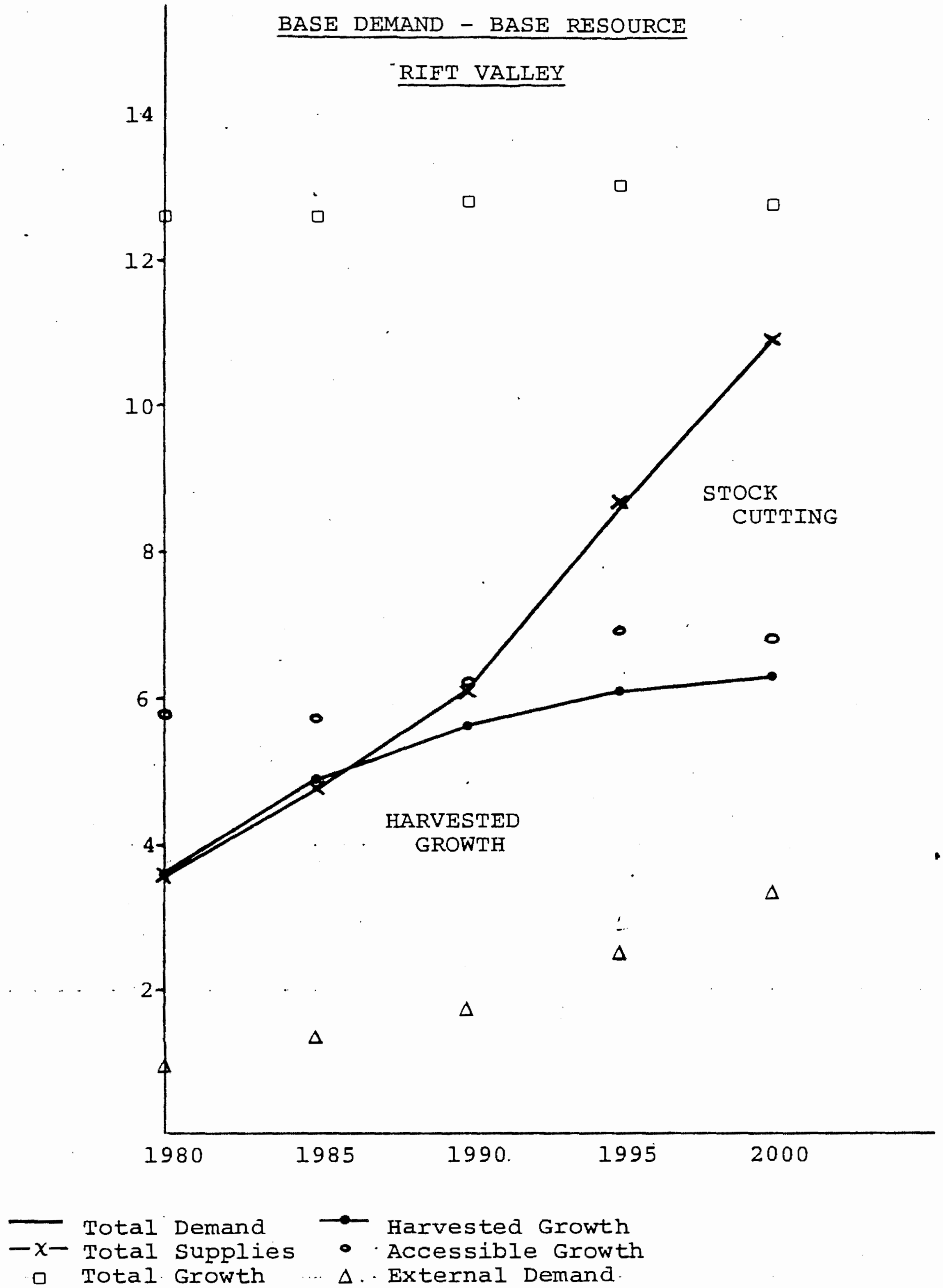


Figure 17

WOOD SUPPLY AND DEMAND

BASE DEMAND - BASE RESOURCE

RIFT VALLEY

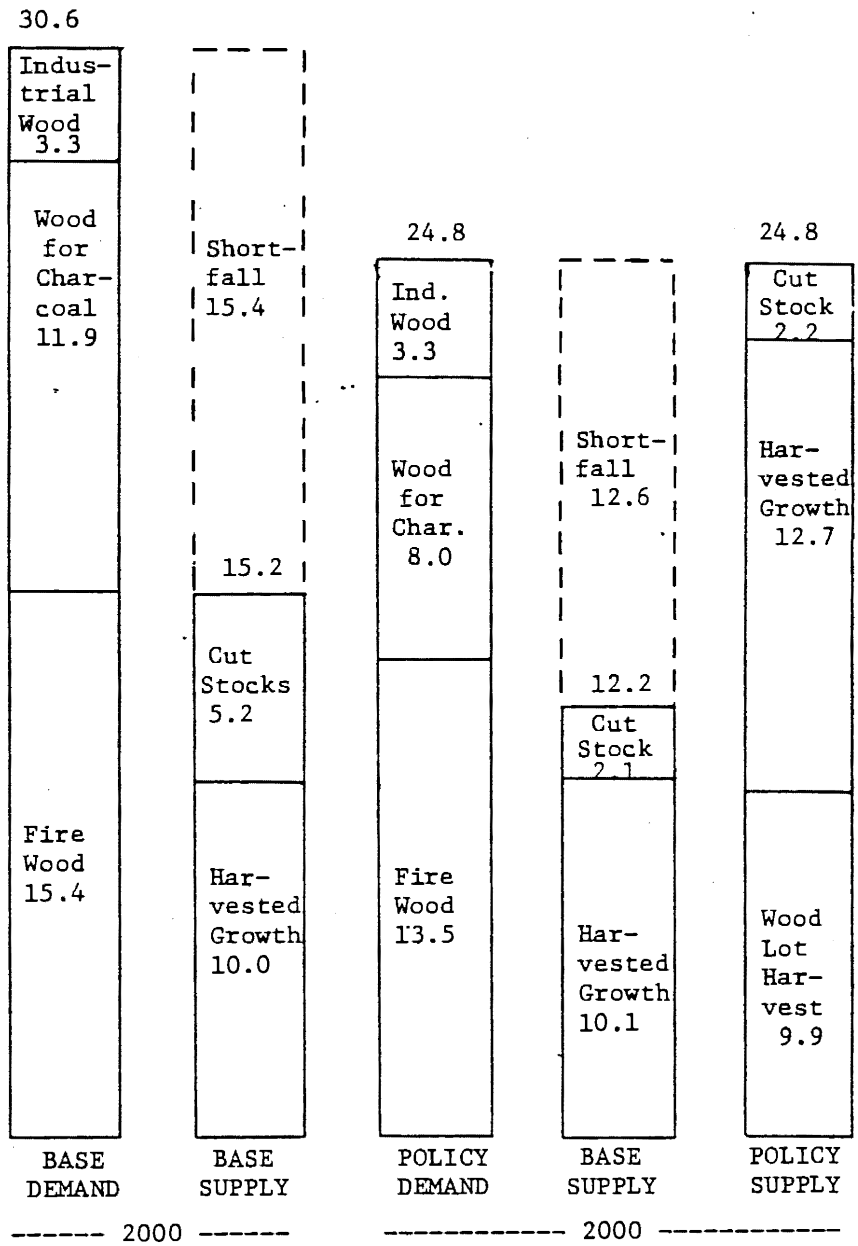


It is clear that one region is in much greater need for enhanced wood production. The next step is in determining what kinds of projects to implement and at what magnitudes. From foresters and development experts one can decide which schemes are appropriate for the particular country and ecological regime. One then needs to look at the landuse patterns within a particular region and decide which wood projects are feasible within that context. One then combines these land conversions to create a scenario, and returns the resource model to evaluate the consequences.

The results of some illustrative enhanced wood supply policies are shown in Figures 18 for national supply/demand balances, and Figures 19 and 20 for our two selected regions. The latter figures indicate that we have eliminated the shortfall in the first region and have even produced a small, but declining, surplus in the later years. In the second region we have entirely eliminated the stock cutting although the annual growth barely exceeds demand by 2000. Since there is a surplus in all previous years, the wood schemes for this region could probably be delayed with few ill effects. Because of the complex relationship between stocks and yields relating to wood resources, the creation and fine tuning of resource scenarios is not as straightforward as for the demand side. By further analyzing the results, policy scenario iterations can be performed to arrive at desired supply/demand balances over time. The scope and timing of real world policy efforts required to achieve these targets can then be examined.

Figure 18

WOOD DEMAND AND SUPPLY



Supplies and Demands are in Millions of Metric Tons

Figure 19

WOOD SUPPLY AND DEMAND

POLICY DEMAND - POLICY RESOURCE

CENTRAL/NAIROBI

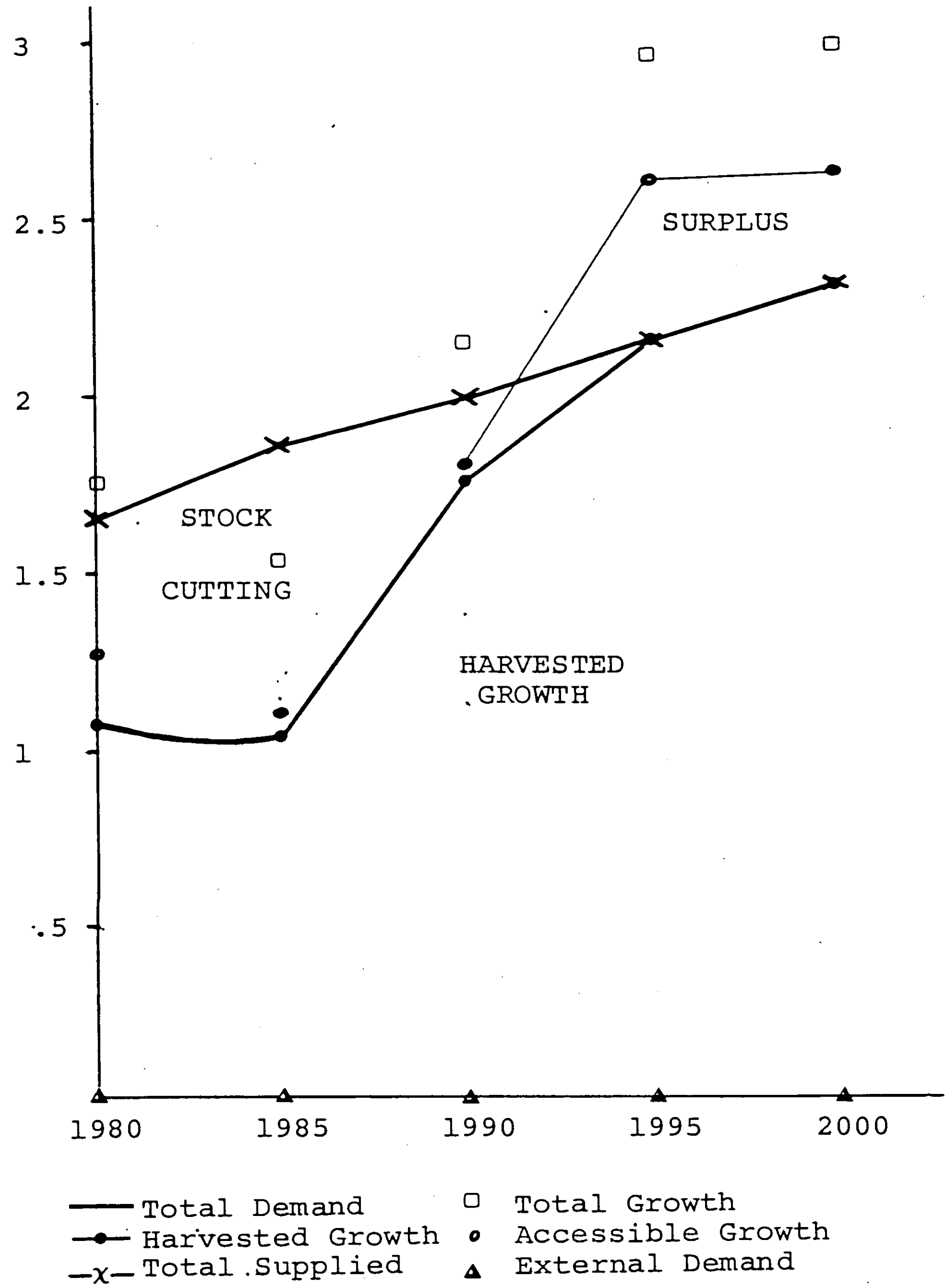
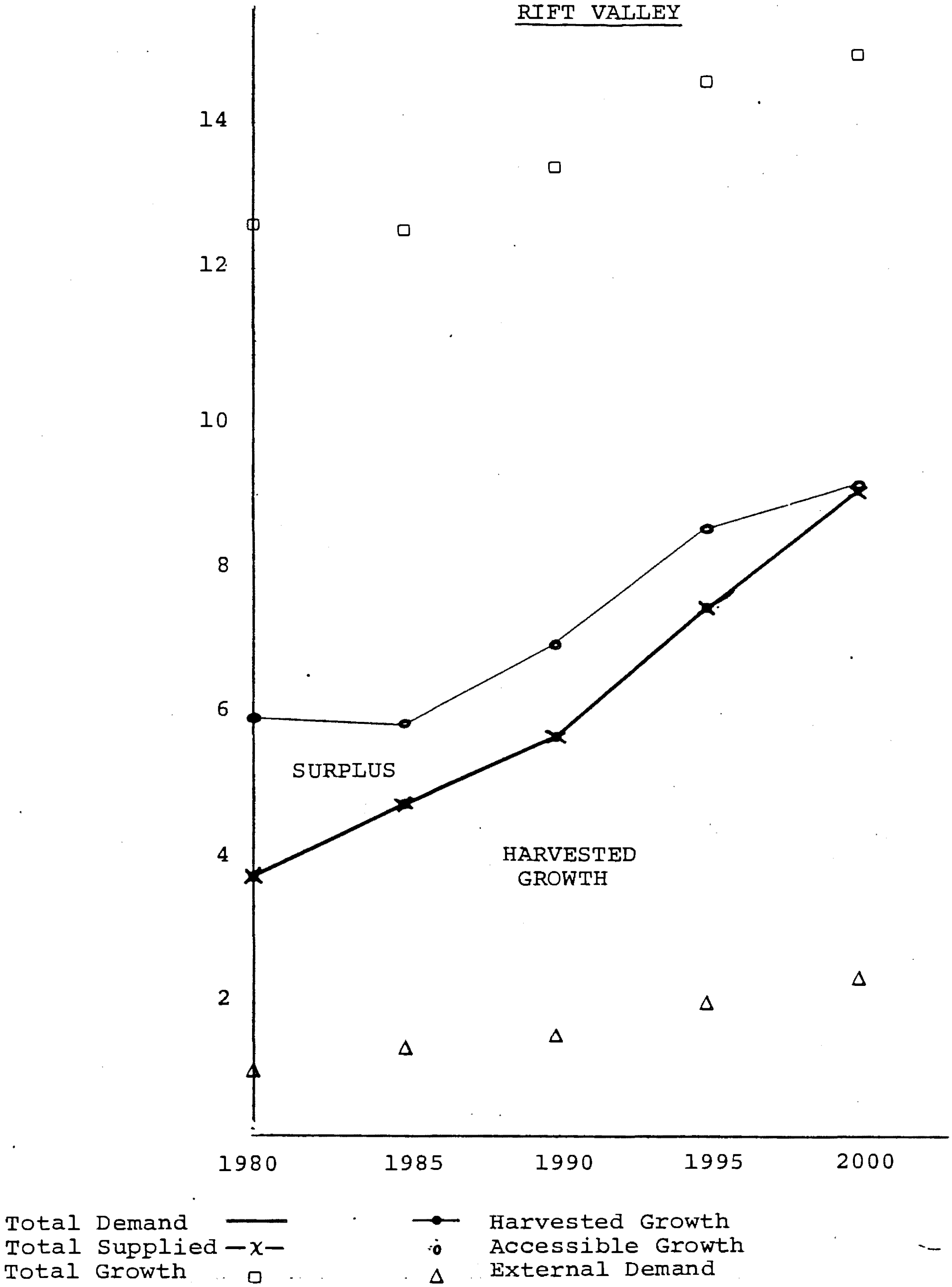


Figure 20

WOOD SUPPLY AND DEMAND

POLICY DEMAND - POLICY RESOURCE

RIFT VALLEY



5. STRUCTURE OF COMPUTER CODE

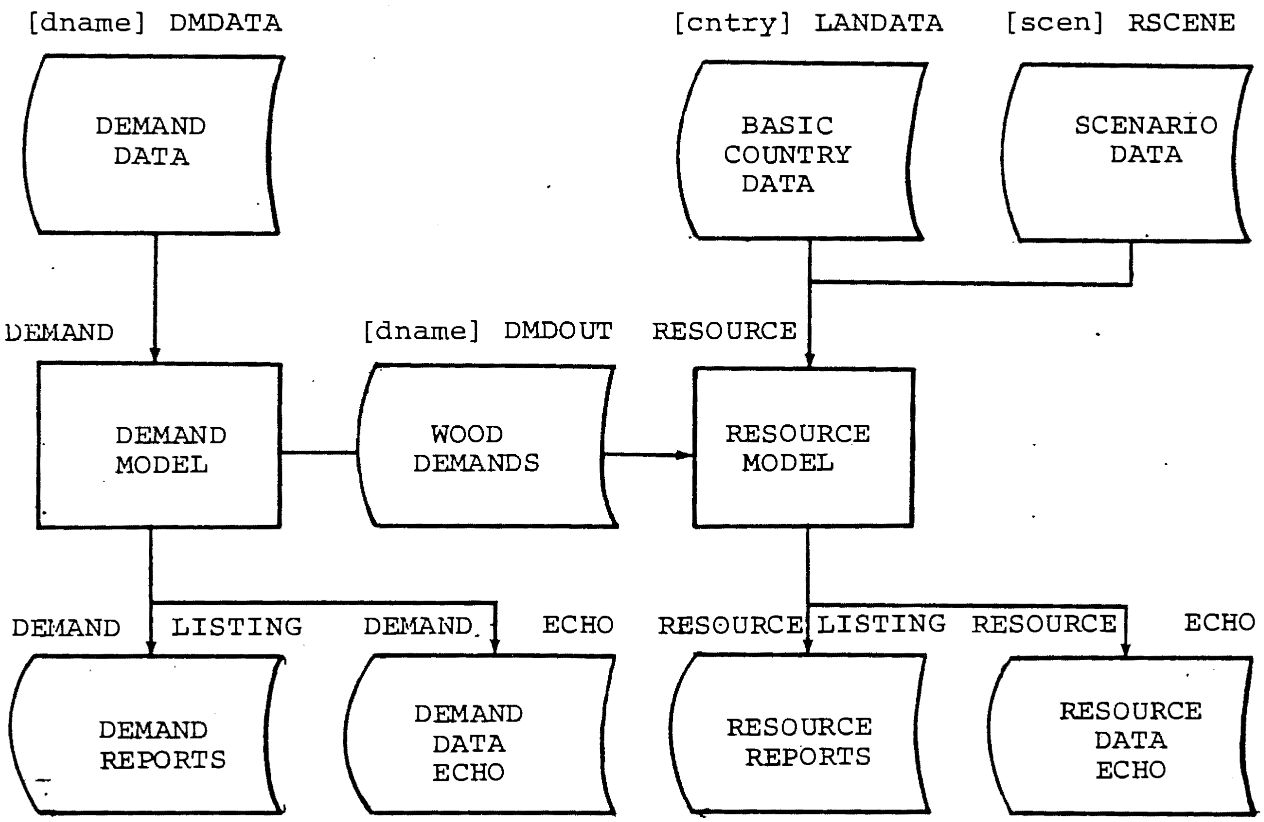
The following figures and tables describe the technical structure and data file formats of the computer code for the LEAP model. In addition, an illustrative example of the computer terminal session is provided, showing the input and report options available.

5.1 Structure

Figure 21 shows the basic structure of the LEAP computer modeling system, including the linkages between the Supply and Resource models and the input and output files. The relationship between the models is apparent from this figure. On the Demand model side the fortran coded DEMAND MODEL program performs the basic calculations. The input DEMAND DATA file for this model is specified by the generic name DMDATA, along with a scenario specific name [dname] so that the program can distinguish each scenario data file. There are three types of outputs produced by the Demand model. The first is the DEMAND DATA ECHO report designated by the name DEMAND ECHO, which provides a convenient way of examining the scenario input data for accuracy of entries and to allow subsequent modification of data inputs. The second type of output produced are the DEMAND reports, some examples of which have been shown in Section 2. These reports provide the basic results of the demand scenario analyses of the LEAP model. Finally the model also writes some of the scenario specific results onto a WOOD DEMANDS file which can be accessed by the Resource model. In particular, national fuelwood, charcoal, and construction wood demands estimated for each of the forecast years are provided in this file.

Figure 21

LEAP Energy Demand and Resource Model



The RESOURCE MODEL uses data from three files: (1) WOOD DEMANDS from the Demand Model, (2) BASIC COUNTRY DATA defining landtypes, wood and agricultural production, etc. and (3) SCENARIO DATA which includes various policy options and defines major landuse changes over time. Each of these files is tagged with the scenario specific names (i.e., dname, cntry, scen, respectively) characterizing the data set embodied therein.

The outputs of the Resource model include a RESOURCE DATA ECHO and RESOURCE REPORTS presenting the results of the landuse, agricultural, and wood resource projections. Samples of these various tables were given in Sec. 3.

5.2 Terminal Interaction

Table 23 below is a copy of a typical interactive session using the LEAP system. The discussion below will refer to this table. Characters in upper case are the system responses and queries. Lines in lower case letters are the user responses. The scenario combinations and output report options are chosen at the user's discretion.

The final command, "leap," activates the model. Then the first question posed is whether to run the Demand model. An answer of "yes" starts the Demand model and lists the currently available demand data files; by entering the scenario name of one of these files ("base") that file is selected and the program begins. The next query is for the level of detail required for the annual profile reports (discussed in Sec. 2); an entry of "0" (zero) suppresses completely these reports. When the demand calculations are completed, one is asked whether one wishes to see the summary results on the computer terminal: an answer of "no" bypasses that output. The next query inquires about printing the results. An answer of "yes" prints the Report and Echo files on the highspeed printer at the computer center. This then completes the Demand model sequence.

The next question is whether to run the Resource model or not. An answer of "yes" will start the process. The user then selects the three files needed for this model and the program execution begins. After the calculations are completed, the user has the option of examining a variety of the output reports (Landuse, Agricultural, Wood) at the national and regional level. In the example shown, the user selected the wood report for one region. After looking at individual reports, the user has the option of printing the entire Resource Report and Echo files as before. This completes the Resource model.

The Demand and Resource models can be run separately or in tandem. In addition, scenarios can be constructed by selecting among data files to interactively produce a variety of combinations of demand and resource scenarios.

TABLE 23

LEAP TERMINAL SESSION

```
leap

******************************************
*****  LEAP ENERGY MODELING SYSTEM   *****
******************************************

DO YOU WISH TO RUN THE DEMAND MODEL ( YES/NO ) ?
.yes

*** LEAP DEMAND MODEL ***

DEMAND SCENARIO FILES ARE.
KBASE     DMDATA    A1
KENES9    DMDATA    A1
KENIE1    DMDATA    A1
KENOA11   DMDATA    A1
KENOB91   DMDATA    A1
KENOI11   DMDATA    A1
KENSW1    DMDATA    A1
KENTE1    DMDATA    A1
KENTF1    DMDATA    A1
KENWA11   DMDATA    A1
KENWA21   DMDATA    A1
KENWA31   DMDATA    A1
KENWA91   DMDATA    A1
KP1       DMDATA    A1
ENTER SCENARIO NAME ?
.kbase
DMSLI07401 EXECUTION BEGINS...

SELECT ANNUAL PROFILE OUTPUT LEVEL
         ( 0=NONE, 1=SECTOR, 2=SUBSECTOR, 3=ENDUSE, 4=DEVICE).
?
.0
OUTPUT FILE IS: DEMAND LISTING
DO YOU WISH TO TYPE THE SUMMARY RESULTS ( YES/NO ) ?
.no
DO YOU WISH TO PRINT OUT THE RESULTS ( YES/NO ) ?
.yes

DO YOU WISH TO RUN THE RESOURCE MODEL ( YES/NO ) ?
.yes

****  LEAP RESOURCE MODEL  ****


COUNTRY FILES ARE:
KENYA    LANDATA  A1
ENTER COUNTRY NAME ?
.kenya
```

TABLE 23
(Continued)

```
SCENARIO FILES ARE:
BASE       RSCENE    A1
BAUO       RSCENE    A1
RF1        RSCENE    A1
LS1A       RSCENE    A1
LS1B       RSCENE    A1
LS2A       RSCENE    A1
LS2B       RSCENE    A1
LS3A       RSCENE    A1

LS3B       RSCENE    A1
LS4A       RSCENE    A1
LS4B       RSCENE    A1
ENTER SCENARIO NAME ?
.base

DEMAND OUTPUT FILES ARE:
KENES9     DMDOUT    A1
KENIE1     DMDOUT    A1
KENIN1     DMDOUT    A1
KENOA11    DMDOUT    A1
KENOB91    DMDOUT    A1
KENOI11    DMDOUT    A1
KENSW1     DMDOUT    A1
KENSW1R    DMDOUT    A1
KENSW1U    DMDOUT    A1
KENSW2     DMDOUT    A1
KENTE1     DMDOUT    A1
KENTE2     DMDOUT    A1
KENTF1     DMDOUT    A1
KENWA11    DMDOUT    A1
KENWA21    DMDOUT    A1
KENWA31    DMDOUT    A1
KENWA91    DMDOUT    A1
KF1        DMDOUT    A1
KBASE      DMDOUT    A1
ENTER DEMAND FILE NAME ?
.kbase
DMSLIO740I EXECUTION BEGINS...

 REGIONS:  7    ZONES:  4    LAND TYPES: 24


OUTPUT FILE IS: RESOURCE LISTING
DO YOU WISH TO EXAMINE THE OUTPUT REPORTS ( YES/NO ) ?
.yes
DMSLIO740I EXECUTION BEGINS...
```

TABLE 23
(Continued)

```
THE FOLLOWING REPORTS ARE AVAILABLE:
  1. LANDUSE AREA REPORTS
  2. NATIONAL AGRICULTURAL REPORT
  3. WOOD PRODUCTION REPORTS

** ENTER YOUR SELECTION (1-3) ?
?
.3
SELECT: 1=ONE REGION, 2=ALL REGIONS, 3=NATIONAL ?
?
.1
SELECT ONE OF THE FOLLOWING REGIONS:
   1 WESTERN PROVINCE
   2 NYANZA PROVINCE
   3 RIFT VALLEY PROV
   4 CENTRAL/NAIROBI
   5 EASTERN PROVINCE
   6 NORTHEAST PROV.
   7 COAST PROVINCE

?

.4


THE FOLLOWING REPORTS ARE AVAILABLE:
  1. LANDUSE AREA REPORTS
  2. NATIONAL AGRICULTURAL REPORT
  3. WOOD PRODUCTION REPORTS

** ENTER YOUR SELECTION (1-3) ?
?
.
DO YOU WISH TO PRINT THE RESULTS ( YES/NO ) ?
.no
R; T=9.26/12.23 11:48:33
```