The Long-range Energy Alternatives Planning model (LEAP) and Wood Energy Planning

Overview and Exercises

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This paper discusses the Long-range Energy Alternatives Planning model (LEAP), and provides exercises on data analysis for energy planning, focussing on wood energy. The exercises are used by RWEDP during LEAP tutorials for its member countries. The tutorials are usually held for small groups, which allows for lively discussions and interaction. Nevertheless, the exercises can be of use for individual users and trainers as well.

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PART I: THE LEAP MODEL

1. INTRODUCTION

Models for energy planning are used (a) to perform demand and supply analysis, (b) to develop forecasts, (c) to identify gaps in the demand and supply and options for intervention, and (d) to perform impact assessment. Several models have been developed and used in recent years for planning, mostly at national level. They vary from econometric models using linear programming to techno-economic models that analyse sectoral energy consumption at detailed level.

Of these models, the Long-range Energy Alternatives Planning model (LEAP) is probably the one best known and used in developing countries mainly because it includes the supply of biomass as an energy source and many countries are willing to adopt it for data storage and planning purposes. LEAP is appropriate for wood energy planning because it contains a land use module, which can be used to produce a land use inventory, based on a division of the area in sub-areas, zones and land types.

LEAP is a simulation model used to represent the current energy situation for a given area and to develop forecasts for the future under certain assumptions. First, an overview of the current situation should be created by specifying data for the starting year, and a basic scenario can be developed assuming a continuation of current trends. After this, interventions can be evaluated by using scenarios. Scenarios are developed by asking 'what if?' questions, e.g. what if the population growth slows down, what if improved cookstoves are introduced?

2. MODULES OF LEAP

Below a description is given of the five scenario modules of LEAP (demand, transformation, biomass, environment and evaluation).

Demand

LEAP follows an end-use, demand-driven approach, which means that the analysis starts from the end-use of energy. The demand program divides the society in a hierarchical tree structure of four levels: sectors, sub-sectors, end-uses and devices. An example of one branch of this structure could be households (sector), rural households (sub-sector), cooking (end-use) and charcoal stove (device). For each device, a fuel type (e.g. fuelwood, charcoal, LPG) and the average consumption (e.g. 20 MJ per household per year) should be specified.

An example of the tree structure is shown in figure 1. Of the 20 million households, 80% live in rural areas, and the remaining 20% in urban centres. The 100% for cooking and lighting means that all rural and urban households use energy for cooking and lighting. The percentages for the devices refer to the share of a particular device used for an end-use, e.g. 60% of the cooking by rural households is done by using fuelwood stoves. It can be seen that the sum of percentages for devices used for cooking by rural households is higher than 100%, which means that some of these households use more than one device for cooking.

Scenarios can be developed by changing the demand parameters for future with three different methods: specifying explicit values for certain years, specifying annual growth rates or using drivers (e.g. GDP) and elasticities. More than one scenario can be developed by using different assumptions for different scenarios.

The total consumption per fuel for each data year is calculated by summing up the consumption for all sub-sectors and sectors.

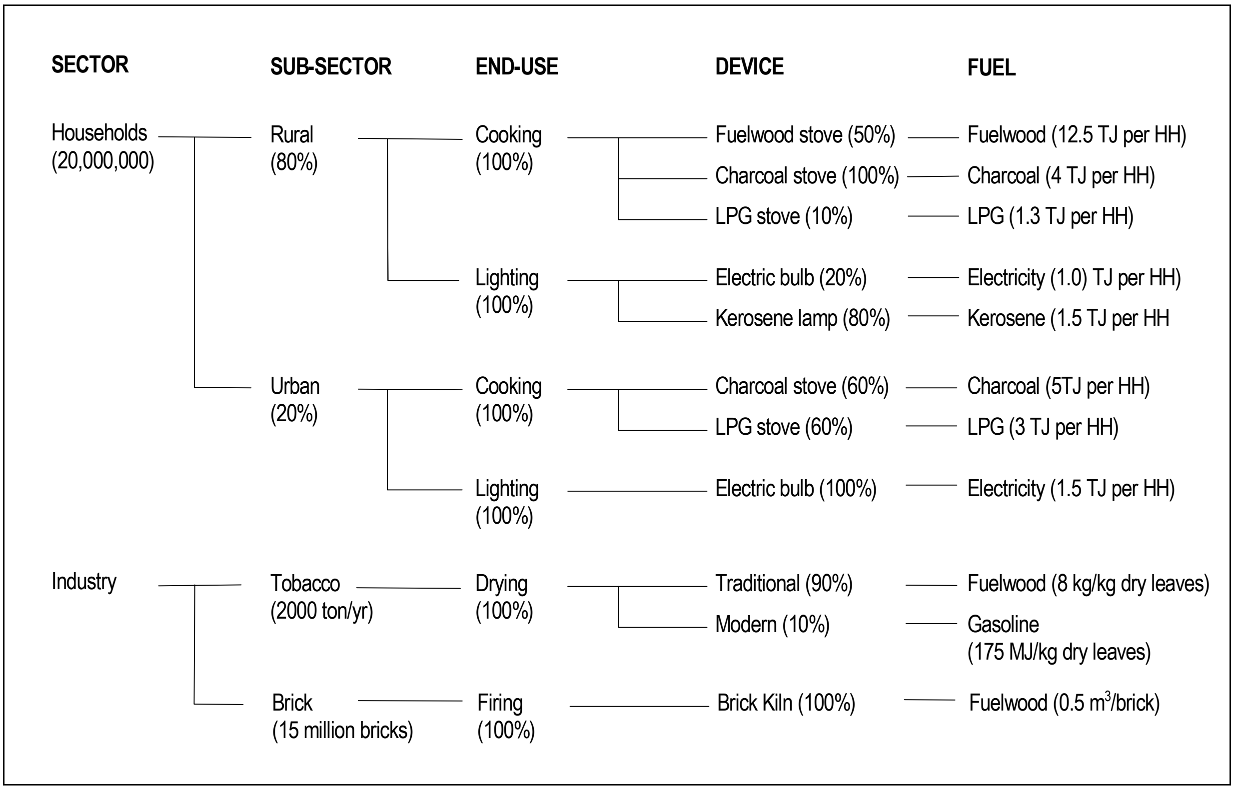

Figure 1 Example of Tree Structure in the Demand Module of LEAP

Transformation

Before being used by consumers, the primary energy has to be transformed through secondary energy into final energy. These transformation processes with their efficiencies and losses can be incorporated in the model, in order to calculate the total amount of primary energy that is required to produce the final energy demanded. Different levels of complexity of the transformation processes can be distinguished, from simple (i.e. single input and single output with only one efficiency factor, e.g. wood as input into a kiln and charcoal as the output), to more complex processes with multiple in- and outputs and efficiencies (e.g. power plants).

Similar to energy demand analysis, developments in the use of different conversion technologies can be simulated in scenarios. After specifying the conversion parameters for different fuels, the total fuel requirements can be calculated for different combinations of demand and transformation scenarios.

Biomass

The evaluation of the biomass resources is incorporated through land use evaluation. Similar to energy demand analysis, the study area is divided in a tree-structure of sub-areas, zones and land use types. For all land use types the acreage, the productivity (i.e. standing stock and average annual yield of woody biomass or crop productivity) and the access fraction is to be specified.

The access fraction represents the maximum fraction of annual yields and stock that can be used for energy purposes, in order to incorporate the accessibility of wood. This fraction can represent several limiting factors such as distance, land tenure and harvesting constraints. In this way all plots of one land use type in one zone have the same accessibility regardless the spatial distribution of the plots.

An example of the tree structure for biomass resources is given in figure 2. The area of study is divided in two regions, Northern and Central, and in both regions, two zones are considered (forest and non-forest), each with respective land use types. The percentage specified for each land use type refers to the share of the resources on that type of land use that is accessible and available for energy use.

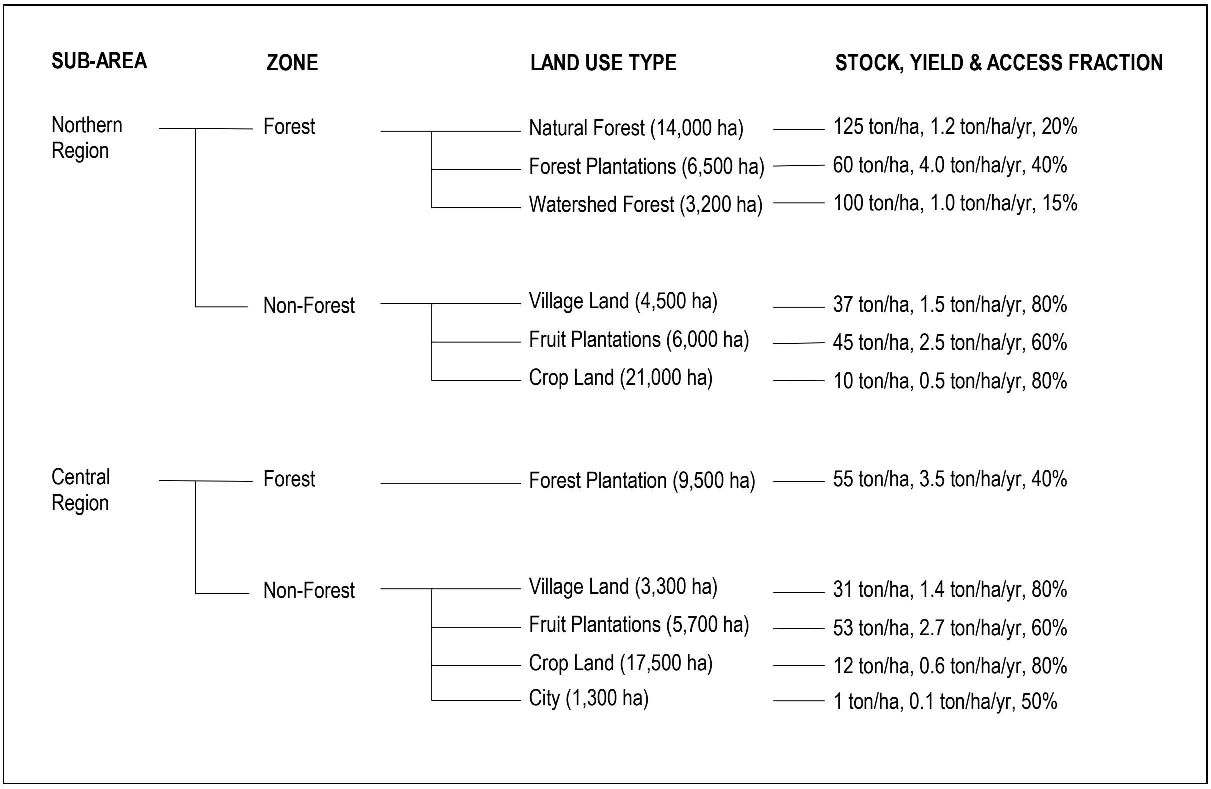

Figure 2 Example of a Wood Resources Structure in the Biomass Module of LEAP

Forecasts are based on land conversion by indicating how much area of one land use type is converted to another land use type. This can be specified by a constant size of area per year, an annual growth rate, or by using a macro-driver (e.g. population).

For crop residues and animal dung, productivity figures can be specified per sub-area, to allow for the evaluation of the supply of these biomass fuels.
The availability of biomass fuels can be evaluated for different combinations of demand, transformation and biomass scenarios. For wood, required supplies are assumed to come from sustainable yields, as far as these are sufficient, after which the wood is assumed to

come from standing stocks. In this way the sustainability of wood energy consumption and supply can be evaluated. Figure 3 gives the structure of the fuel flow as applied in LEAP.

Environment

The model contains an Environmental Data Base (EDB) which contains data on environmental effects on water, soil and air for several types of end-use and transformation devices. It can be used to evaluate the environmental impacts for the alternative demand and transformation scenarios.

Evaluation

For a given area different scenarios can be developed, assuming different conditions for future development of demand and supply of energy. The change of the values of variables over time can be specified according to several methods. This can be through entering future values, giving a growth percentage, linking it to a macro-driver (e.g. GDP or population) through elasticities, or a combination of these methods. With the evaluation module, the alternative scenarios can be compared to find the most satisfying solution to meet future goals. The evaluation can consider physical, energy, environmental and economic cost factors.

3. LEAP & WOOD ENERGY PLANNING

LEAP can be a useful tool for (wood) energy planning considering its flexible data structure and the incorporation of land use data for the evaluation of the biomass supply. It provides a comprehensive framework for the whole energy flow from biomass resources through conversion to end-use consumption. Forecasts for single factors can be made by using growth rates or macro-drivers and elasticities, or by explicitly specifying a value for each data year. In the latter way LEAP can easily incorporate the results of other models that focus on a specific part of the energy flow or that follow another method, e.g. econometric demand models or simulation of power plants.

References

SEI (1995), *LEAP User Guide*, Version 95.0, Stockholm Environment Institute, Boston.

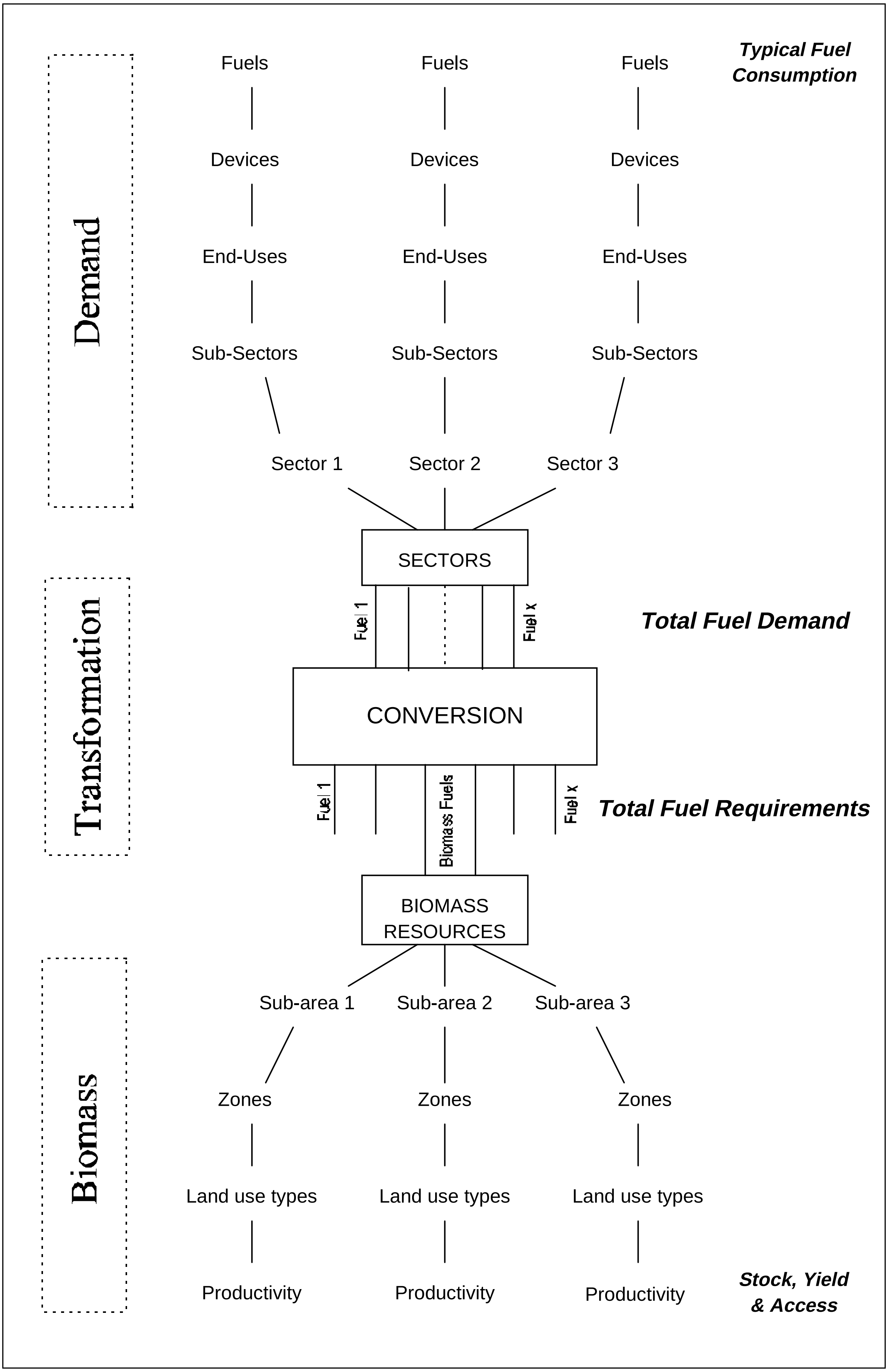

Figure 3 Overview of the Demand, Transformation and Biomass Modules of LEAP

PART II: EXERCISES ON DATA ANALYSIS WITH LEAP

1. INTRODUCTION

The following exercises aim to let you go through a process of data analysis required for LEAP. In this way you will reach a better understanding of problems with the availability and use of energy demand and supply data. The exercises focus particularly on wood energy, but they include other fuels as well. With the help of some guidelines, you have to analyse and organise data for a fictitious area, called Wood Hills district.

The exercises cover two types:

- 'Analysis' exercises in which you have to analyse and organise data that are provided, before using the LEAP model. These exercises aim to give you a better understanding of problems with the availability and use of energy demand and supply data. From the data provided, you will identify lacking data and learn how to make assumptions for lacking data and forecasting.
- 'Hands-on' exercises on the computer using LEAP, in which you will enter the organised data in the model and you will develop and evaluate alternative scenarios. These exercises aim to provide you practical experience in using the LEAP model for scenario development and evaluation.

Wood Hills district is a rural area in a tropical country. Its total area of 130,000 hectares comprises a floodplain (30,000 ha) surrounded by a mountain range (100,000 ha). The district contains a district centre and 100 villages, most of which are located in the floodplain. The main occupation is farming, with rice as the major crop. Industries include pottery and brick-making, and agro-processing activities such as tobacco drying and rice-milling.

The authorities in Wood Hills district recognise the role of energy for development in the district and they realise that biomass fuels, particularly fuelwood and charcoal are important sources of energy for the people in the district. At present there is little information available about energy consumption and supply. Woodfuels are mostly self-produced, but also produced and traded commercially by small entrepreneurs. For many of them it is a source of additional income, and there is no information on how many there are and how much they produce and trade. Conventional fuels, like electricity, kerosene and LPG are brought in from outside. Only for electricity there are some statistics on sales and number of users.

The district office is concerned about energy needs of households and industries on the one hand, and about the natural resources on the other hand. Therefore they request you, as a wood energy planning expert, to analyse the present situation, to make forecasts and to give recommendations for future activities, necessary interventions and development opportunities. To help you, they have already assembled all available data that are related to energy demand and supply. As a starting point, they have requested the energy department to do a small survey on household energy consumption. Its results are available to you as well.

2. DEMAND EXERCISES: WOOD ENERGY DEMAND

2.1 Analysis Exercise

In the four tables below (tables 1 to 4), you will find data related to energy consumption in Wood Hills district. You have to organise the available data in a tree structure of sectors, sub-sectors, end-uses, devices and average energy consumption. An example of such a structure is given in Figure 4. **Note that this figure is only given as an example, your structure may look entirely different!** If for a particular level no disaggregation can be made, use one reference for all (e.g. all sub-sectors under one sector). Note that not all data can be used, because some data are unavailable. Take care that the units throughout a branch of the structure match, e.g. number of households and fuel consumption per household.

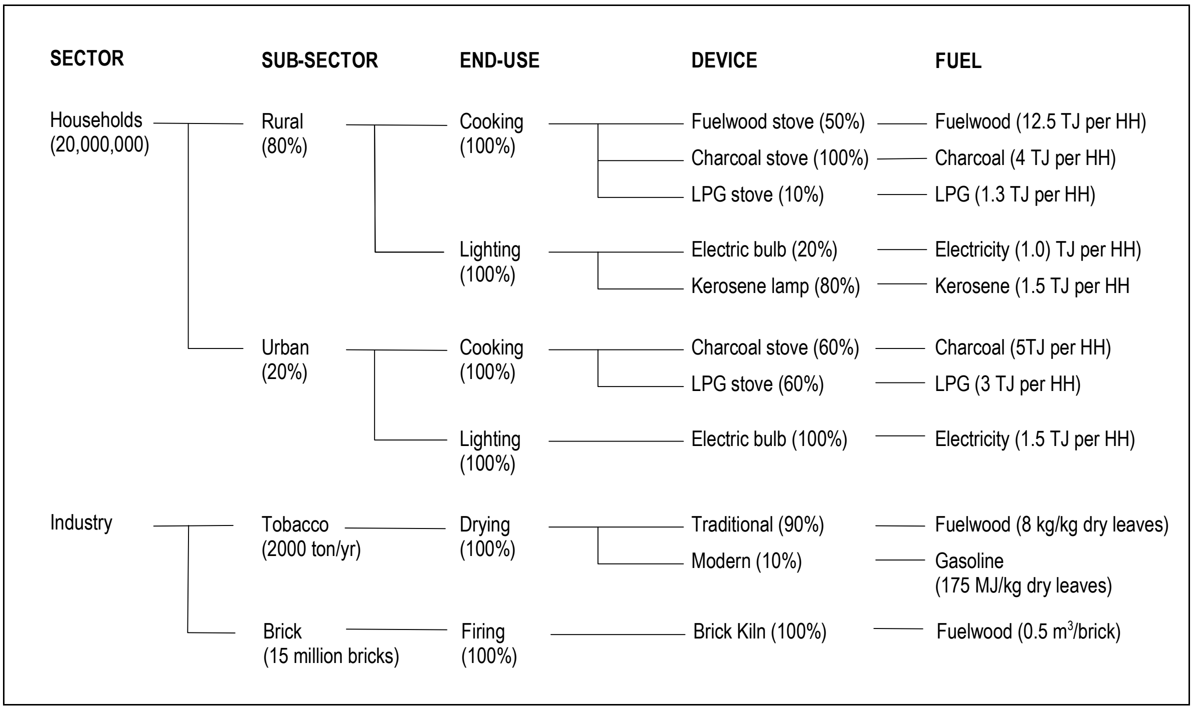

Figure 4 Example of Tree Structure for Energy Demand Analysis.

In the example of figure 4, there are 20 million households, of which 80% live in rural areas, and the remaining 20% in urban centres. The 100% for cooking and lighting means that all rural and urban households use energy for cooking and lighting. The percentages for the devices refer to the share of a particular device used for an end-use, e.g. 50% of rural households use a fuelwood stove for cooking. It can be seen that the sum of percentages for devices used for cooking by rural households is higher than 100%, which means that some of these households use more than one device for cooking.

Assignments:

1. Identify the base year for the data structure. This will be the starting year for your analysis.
2. Identify sectors, and identify for each sector its sub-sectors if existing. For each sub-sector, identify possible end-uses, from here identify devices, fuel and average consumption. **Do not make assumptions at this stage!**
3. Draw the tree structure on paper with the sectors, sub-sectors, end-uses, devices and fuels that you have identified in step 2. Add numerical values and units for each of these.
4. Identify and list data that are lacking and that would additionally be required to use all data provided.

5. The tree structure refers only to a base year. For planning it is necessary to make forecasts of the situation in future years. How can you develop scenarios from the available data? Which assumptions would you have to make?

Energy Demand Data for Wood Hills District

The tables 1 to 5 give data on several factors related to energy consumption. Table 1 gives data on population and households in the district, as compiled by the statistical office.

Table 1 Population and Households in Wood Hills District

	1985		**1990**		**1995**		**Average Annual Growth Rates**			
							1985 - 1990		**1990 - 1995**	
	Pop.	*HH*	*Pop.*	*HH*	*Pop.*	*HH*	*Pop.*	*HH*	*Pop.*	*HH*
Total	48,900	14,400	51,000	15,200	52,300	16,700	0.84	1.09	0.50	1.90
Villages	45,300	13,300	46,900	14,000	47,900	15,300	0.70	1.03	0.42	1.79
District centre	3,570	1120	4,170	1,220	4,580	1,430	3.16	1.73	1.89	3.23

Table 2 gives the results of the household energy consumption. It shows the consumption per income group and the average consumption for all households. Also the income range of the groups is given.

Table 2 Average Household Energy Consumption per Income Group in 1995

Income Groups	
Low	0 - 750 US $ per year
Middle	750 - 2000 US $ per year
High	over 2000 US $ per year

	Low	**Middle**	**High**	**Average**
Energy Consumption	*(MJ per HH per year)*	*(MJ per HH per year)*	*(MJ per HH per year)*	*(MJ per HH per year)*
<u>Cooking</u>				
Fuelwood	12,700	13,500	6,700	10,700
Charcoal	2,250	4,250	3,000	3,400
Animal Dung	500	-	-	120
Crop Residues	1000	-	-	250
LPG	830	1,250	4,300	1,800
<u>Other</u>				
Kerosene	130	-	-	30
Electricity	1,050	2,400	3,100	2,100

Table 3 gives some data on production by different industries, but there are no data for brick-making and pottery. These are generally small-scale businesses, and there is no information on the number of businesses and their production.

Table 3 Industrial Production in Wood Hills District in 1995

Tobacco Drying	350 ton dried tobacco
Rice-milling	14,000 ton rice
Pottery	?
Brick-making	?

Data on industrial energy consumption are available from several studies from the local university (see table 4). Tobacco industries generally use fuelwood. For rice milling, three types of mills are in use: electric mills, diesel mills or mills that use their own residues (rice husk) as fuel. Brick-making factories mainly use fuelwood. For pottery making there are no average consumption data, also because consumption depends very much on the size and type of pots produced.

Table 4 Energy Consumption by Industries

Tobacco Drying	11 kg fuelwood per kg dried tobacco
Rice-milling	0.13 kWh per kg rice (electric mills), or 0.2 litre per kg rice (diesel mills), or 350 kg rice husks/ton paddy
Brick-making	0.45 kg fuelwood per kg of bricks

Table 5 gives figures for the energy content for some fuels that are generally used in the district. It should be noted that the energy content can vary widely, especially for biomass fuels, because it depends a lot on the moisture content. For example, freshly cut wood has a much higher moisture content (and therefore a lower energy content) than wood that has been dried.

Table 5 Energy Content of Fuels

Fuel	**Energy Content**
Fuelwood	15 MJ/kg
Charcoal	25 MJ/kg
Crop residues	12.5 MJ/kg
Animal waste	8.4 MJ/kg
Electricity	3.6 MJ/kilowatt-hour
LPG	45 MJ/kg
Kerosene	43 MJ/kg

2.2 Hands-on Exercise

In this exercise you will enter the data in the tree structure from the analysis exercise in LEAP and develop some alternative demand scenarios.

General Data

First of all, you have to start LEAP. From the LEAP Main Menu, select *Energy Scenarios*. From the 'LEAP Energy Scenarios Menu', select the 'General' submenu, move the cursor to *Select Area* and press enter. You will see a list of LEAP areas available on your computer. Choose *<Create New Area>*, and give the new area the name 'Woodhill'. When LEAP asks whether you want to copy data from an existing area or use default data, select *use default data*. Press enter to confirm, then LEAP will create a new area and use that area. You should see the name of the area at the bottom right corner of the screen.

Note that at any point in the program, you can find information about the current location in LEAP and valid functions keys at the bottom of the screen. For example, at this point, you can see from the bottom of the screen that you are in the Energy Scenario Main Menu and you are using the area WOODHILL. Furthermore, you can use the <F1> key for help, and the *General* submenu (marked in red) to set-up parameters for the area you are working with.

Select *Years/Energy Unit* from the *General* submenu and fill in the following data:

Area Name:	Wood Hills District				
Default Data Years:	1995	2000	2005	2010	2015
Default Reporting Years:		2000	2005	2010	2015

Standard Energy Unit:	GIGAJOULES
Alternative Spelling:	GIGAJOULES
Abbreviation for Energy Unit:	GJ

When you are finished, press the <F10> key, then choose *save data*. LEAP will then return to the *General* menu.

Select *Fuels* from the *General* submenu. This will display a list of fuels and their characteristics. Use the <F6> and <F5> keys to check the information for the fuels fuelwood, charcoal, kerosene and electricity. If necessary, change the parameters according to the information that has been provided. When you are finished, return to the Energy Scenario Main Menu.

Demand Tree

Now you will create a LEAP Demand structure for Wood Hills District from the tree structure that you have developed in the first exercise. Select the *Demand* submenu, press enter on *Enter Data & View Results* and then select *Enter Data* from the *Demand Main Menu* that comes up next. Select *Branches* from the *Demand Data Menu*. You will find yourself at the Sector level of the default data set. The screen should look like this:

Activity Levels

Sector Name	1995	Scale	Driving Activity	Proj. Meth.	2000	2005	2010	2015
Sector name here	1.000			INT	.	.	.	.

Press the spacebar to edit the name of the default sector shown (*Sector name here*). Specify the value for the sector below *1995*. You can use *Scale* to change the multiplication factor. For example, when you want to enter a value 20,000 (twenty thousand), enter 20 below the year and choose *Thousand (1E+3)* as scaling factor. Note that the scaling factor applies to all years for the selected sector.

Below *Driving Activity* you can indicate the activity measure, to keep track of the driving activities for a demand branch. Normally, you will have an absolute driving activity in only one of the four levels in each branch, with relative driving activities for the other levels. For example, in figure 4, the branch Households-Rural-Cooking-Fuelwood Stove-Fuelwood has an absolute driving activity, i.e. 20,000 households at the sector level with percentages as driving activity for the other levels. Note that the absolute driving activity should match with the unit of the average energy consumption, which is terajoules per household in the example of figure 4.

Below *Proj. Meth.*, you can specify the projection method for future values, which determines how future values are calculated. There are three options: interpolation, growth rate, or a driver with an elasticity. At this point you can leave the projection method at the default INT (interpolation) and leave the future data years blank.

Press the <F2> key (choose *Add Branch at End*) to add a new sector. Create first all sectors according to your tree structure. When you have finished the sectors, you can start to create the sub-sectors. Highlight the first sector and press <F4> to go to the sub-sector level. Press enter to change the name of the default sub-sector, and change the other parameters for the sub-sector. Note that the name and parameters of the current sector are displayed at the top of the screen, so you can always see which sector you are working with. Press <F2> to add a sub-sector if there are more than one (choose *add branch at end*). Create all sub-sectors for the current sector.

To enter end-uses, highlight the first sub-sector and press <F4> to go the end-use level of the tree structure. Note that both the current sector and sub-sector are displayed at the top of the screen. Press enter to change the name of the default end-use, and specify also the other parameters. Press <F2> to add an end-use if necessary. Create all end-uses for the current sub-sector.

Highlight the first end-use and press <F4> again to go the device level. Press enter to change the name of the default device, and specify also the other parameters. Press <F2> to add an device for the current end-use if necessary. Enter the name for the new device and choose the fuel for this device from the list that is displayed. Create all devices for the current end-use.

Now press <F4> again. You will see the same devices you have just created but now the screen is titled *Energy Intensity Data*. Here you can enter data on average energy consumption. First you have to check the fuel that is specified behind the first device. This is the default fuel that is entered by LEAP (i.e. electricity). If it is necessary to change it, highlight *Electricity* and press enter to select the correct fuel from the list. Then, enter the values for the specific energy consumption for each device.

Press <F3> twice to go back to the end-use level. If there are more than one end-use for the current sub-sector, specify devices and consumption values for the other end-use(s) in the same way as you did before. Then, go back to the sub-sector level, and specify end-uses and devices for any existing sub-sector of the current sector. Finally, go back to the sector level and repeat the procedure of creating sub-sectors, end-uses and devices for other existing sectors. At any point in the tree you can press the <F9> key to view the tree structure and to move to another level or branch.

View Results

After entering all the demand data for the base year, you can view the results for the present demand scenario. Press <F10> to return to the Demand Data Menu. Choose *Exit* and *Save Data*, and select *View Results* and press enter. LEAP will calculate the total energy consumption based on the data that you have entered. At first, it will show the energy consumption per year and per fuel. Use the <F2> key to view the energy consumption per sector. Which is the most consumed fuel? What is the share of each fuel in total energy consumption?

Scenario Development

So far, you have only entered data for the base year, which means that the results are the same for all data years. Of course this is not realistic, so you will have to make projections for future energy consumption.

Have a look at your demand tree structure and try to identify factors that are likely to change. Try to estimate these changes from the available data or make assumptions. Incorporate the changes in the demand tree for the base case scenario and view the results again.

Do you have enough data to develop projections? If not, which data are lacking? What do you suggest to obtain these data?

3. TRANSFORMATION EXERCISES: CHARCOAL CONVERSION

In the following exercises you will analyse data on energy transformation (or conversion) and you will evaluate the primary energy requirements for the demand scenarios you have developed in the previous exercises.

3.1 Analysis Exercise

The information that is available about energy conversion in Wood Hills district is very limited. There are no power plants, oil refineries or other transformation plants for conventional fuels like oil, gas and electricity. This means that these fuels are brought in from outside the district (i.e. imported), and the only energy conversion process that takes places in the district is charcoal production.

There are no statistics available about charcoal production in the district. Charcoal is often a self-produced good so it is difficult to obtain information on the amount of produced charcoal and the technology used. From an energy consumption survey in the district it is known that 80% of the households buy charcoal. From the same survey it is also known that some villagers living in the forest produce charcoal using so-called earth-mound pits. They sell the charcoal to shop owners in the district centre. Some people in other villages produce their own charcoal using different types of kilns, such as the earth-mound pit, mud beehive kiln or brick beehive kiln.

A report from the national energy agency provides information on technologies for charcoal technologies that are commonly used in the country, including the three types used in Wood Hills district. An earth mound pit is constructed by first digging a small pit in the ground. Then the wood is placed in the pit and lit from the bottom, after which the pit is covered with rice husks, saw dust or earth. The process takes up to 3 days. A mud beehive kiln is a semi-spherical or parabolic shaped kiln made of mud or clay, above the ground or partially underground. Sizes vary from kilns with a 30 kg fuelwood capacity to large kilns with 6-10 ton output capacity, with varying production time. It produces better quality charcoal than the earth mound pit at a higher efficiency. The brick beehive kiln is similar to the mud beehive except that it is made of bricks. The average efficiencies for these kilns are given in table 6.

Table 6 Average Efficiencies of Charcoal Kilns

Kiln Type	Average Efficiency
Earth Mound Pit	35
Mud Beehive	45
Brick Beehive	50

Assignments

1. Identify the kind of data that are required to evaluate the primary wood requirements for the fuelwood and charcoal consumption in the demand scenarios. Are these data available? If not, which data are missing?
2. Can you develop scenarios for energy transformation from the available information? Do you think that there will be any changes? Which assumptions would you make?

3.2 Hands-on Exercise

In this exercise you will enter data in the transformation module in LEAP and evaluate results. From the *LEAP Energy Scenarios Menu*, move the highlight to *Transfor*, press enter and press enter again on *Enter Data & View Results*. Choose *Enter Data* from the Transformation Main Menu. You are now in the Transformation Data Menu, which displays a list of default Transformation modules. Here you have the opportunity to create new modules, or edit existing ones. The only conversion process in the district is charcoal production, so we are only interested in the module *Charcoal Production*.

Move the highlight to the module *Charcoal Production* and press enter. Press enter again on *Kiln Data*. In this screen you can specify data on charcoal kilns, like input fuel, efficiency and share. Enter the data available on the three types of charcoal kilns that are used in Wood Hills district. Press enter to change the name of the default kiln. Press <F10> to accept the default parameters for Feedstock Fuel and Energy Share. Feedstock Fuel refers to the input fuel, and Energy Share to the share of each feedstock fuel in the input in energy terms. Since in this case there is only one feedstock fuel (Wood for Charc.), the energy share is 100%.

Press <F2> to add the two other kiln types. Enter the data on efficiency and share for each kiln. The share refers to the percentage of the total charcoal production that is produced in each kiln type. The total for all kilns should be 100%.

View Results

After entering all data for charcoal production, you can view the results for the demand and transformation scenarios that you have developed so far. Press <F10> to return to the Transformation Data Menu and choose *Exit* and *Save Data*. From the Transformation Main Menu, select *View Results*. LEAP will calculate the total energy consumption and conversion according to the data you have entered. The results are presented in an energy balance. Which fuels have to be imported? Use the <F2> key to look at the results for the module *charcoal production*. How much wood is required for charcoal production? After viewing the results you can press <F10> to return to the LEAP Energy Scenarios Menu.

Scenario Development

Also for energy conversion, changes can occur. Review the transformation data and try to identify factors that are likely to change. Try to estimate these changes from the available data or make assumptions. Incorporate the changes in the base case scenario and view the results again.

Do you have enough data to develop forecasts? If not, which data are lacking? How could you obtain these data?

4. BIOMASS EXERCISES: RESOURCE ASSESSMENT & ACCESSIBILITY

After you have evaluated the biomass energy requirements for consumption and conversion, the next step is to see whether the existing resources can meet these requirements. The biomass resources to consider are wood from forest and non-forest land, agriculture residues and animal dung.

4.1 Analysis Exercise

Below you will find information about the biomass resources in Wood Hills district. You have to analyse and organise these before you can use them in LEAP. You have to organise the available data in a tree structure of sub-areas, zones, and land use types. An example of such a structure is given in Figure 2 on page 4. You will find that some data are missing. Try to make assumptions for these data.

When you identify sub-areas and zones, you have to consider the way LEAP uses sub-areas. When you use more than one sub-area, you have to specify the share of the total requirements in each sub-area. LEAP then assumes that each sub-area supplies its own requirements, but you have the option to specify transport of biomass fuels between sub-areas. If you don't have data about this, or you think this is not realistic, you should not use more than one sub-area.

Assignments:

1. Identify possible sub-areas, and identify for each sub-area its zones if existing. For each zone, identify the existing land use types. **Do not make assumptions at this stage!** Note that the use of sub-areas and zones is optional. You can create one sub-area and one zone with all land use types if you prefer.
2. Draw the tree structure with the sub-areas, zones and land use types that you have identified in step 1. Add numerical values and units for the area of the land use types.
3. For the wood resources, estimate figures for stock and yield from the provided information on standing stock of forest types. Add them to the tree structure.
4. Estimate the accessibility for each land use type, considering the information given below.
5. For crop residues, estimate their production per hectare for different land use types.
6. For animal residues, estimate the number of animals and the average amount of residue per animal.
7. Can you create scenarios from the available data? Which changes do you expect? Which assumptions would you make?

Biomass Resources in Wood Hills District

The district is formed by a plain area surrounded by mountains. The plain area mainly consists of settlements and agriculture land, and the mountains are covered by forest. All the villages and the town are located in the plain area. Figure 5 shows the location of the town, villages, main roads, and the plain and forest areas in the district. Land use data are available from a map of 1992 (see table 7). It was reported that the area of forest has decreased with 1.5% per year during the last ten years, due to expansion of agricultural land at the edge of the forest.

Available data on standing stock and average annual yield for the wood resources are very limited. The forest department has data on standing stock for some forest types, but these refer only to the stem of trees, so branches and twigs are not included. For trees on agricultural land and other non-forest land, no data are available.

Considering agricultural residues, rice is the major crop with a production of around 10,000 ton of paddy annually. One ton of paddy generally produces around 700 kilogram of rice. All the rice grown in the district is milled in the district. On an average, the processing of one ton of paddy generates 300 kg of rice husks. In the field, the harvest of one ton of paddy generates around one ton of residues in the form of rice straw. Rice straw is generally ploughed back in the field as fertiliser.

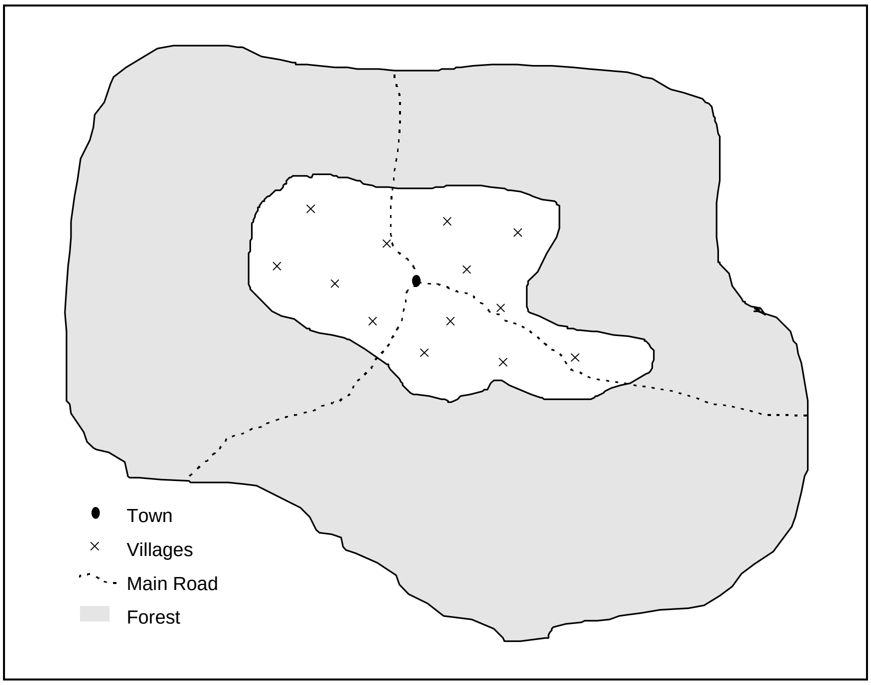

Figure 5 Map of Wood Hills District

Table 7 Land Use in Wood Hills District

Land Use Type	Area (ha)
Mixed field crops	11,000
Mixed Orchards	2,000
Mixed Orchards/Mixed field crops	3,000
Village/Mixed Orchards	500
Bushes and shrubs	500
Town	100
Village	1,900
Water	100
Tropical evergreen forest	9,000
Dry dipterocarp forest	7,000
Mixed deciduous forest	6,000
Tropical evergreen /Mixed deciduous forest	1,500
Mixed deciduous forest/Dry dipterocarp forest	2,500
Forest plantation	2,000
Degraded tropical evergreen forest	3,000
Degraded dry dipterocarp forest	500

There are no statistics on the number of cattle in the district, but generally each farming household has at least one buffalo for working in the rice field. Animal dung is often used as fertiliser for agriculture land.

Of course, not all resources will be available as fuel. They may be physically inaccessible because they are located in remote or inaccessible areas, or they are scattered over a large area so they are difficult to gather. They may also be used for other purposes than energy. For example, wood can be used for timber production, and crop residues and animal dung may be used as fertiliser. There is no information about these factors available for Wood Hills district. It is known from the energy consumption survey that 90% of the households collect their own fuelwood, and 80% buy the charcoal they use. People collect fuelwood in large quantities in the forest during the dry season when they are not fully engaged in agricultural activities.

Table 8 Standing Stock

Forest Type	**Average Standing Stock** *(ton/ha)*
Dry Dipterocarp	100
Mixed Deciduous	75
Mixed Deciduous with teak	90
Pine Forest	105
Tropical Evergreen Forest	130

4.2 Hands-on Exercise

In this exercise you will enter the data on biomass resources in the LEAP model and evaluate if the resources can meet the requirements from the demand and transformation scenarios.

From the *LEAP Energy Scenarios Menu*, move the highlight to *Biomass*, press enter and press enter again on *Enter Data & View Results*. Choose *Enter Data* from the *Biomass Main Menu*. In the *Biomass Data Menu* you can see three categories of menu options, *Land*, *Products* and *Resources*. Under *Land* you find the options to enter the tree land tree structure that you have created in the analysis exercise. Move to *Subarea Names* and press enter. Here you can specify the names of all sub-areas that you have identified. If you have no sub-areas, you can use *All Subareas* and press <F10> to return. Move to *Zone Names* and press enter. Here you can specify the names of all zones that you have identified. If there are no zones in your tree structure, you can use *All Zones* and press <F10> to return. Move to *Land-type Names* and press enter to enter the names of land use types that you have identified. After finishing, press <F10> to return. Until now you have only entered names of sub-areas, zones and land types without specifying values for land areas. Move to *Land Areas* to enter these values. On top of the screen you can see the current sub-area and zone. If necessary, use the <F6> key to change the current sub-area and zone. Use the <F2> to add land types for the current sub-area and zone, and specify the area for each land type. After finishing, press <F10> to return to the Biomass Data Menu.

Under *Products*, you find the options *Requirements*, *Transport* and *Milling*. Under *Requirements* you can specify the share of the total requirements per sub-area. Under *Transport* you can specify data on transport of biomass fuels from one sub-area to another. If you have identified only one sub-area, you can skip these menus. Under *Milling* you can specify data on wood residues recovered from saw mills. If you don't have data for wood milling, you can skip this.

Under *Resources* you will find options to specify data on resources of wood, crop residues and animal dung. Move the highlight to *Wood* and press enter. Press enter again on *Assign Products to Land-types*. In this menu you can specify for each land type the type of product that is coming from the wood resources. By default there are two product groups, *Woodfuel & Poles* and *Commercial Wood*. In this case there are no data for commercial wood so make sure that for all land types *Woodfuel & Poles* is selected. In the last column you can indicate what will happen with the wood stocks when part of a land type is converted to another land type. If you think that the wood will be available as fuelwood, indicate Y (yes), otherwise N (no).

After returning, choose *Inventory* press enter. Here you can specify values for the standing stock, average annual yield and accessibility for each land use type. In the last column you can specify the wood growth pattern. As default this is *Unmanaged Woodland*, which means that both yields and stocks can be cut when necessary. If you choose *Managed Woodland*, stocks can never be cut, no matter how much wood is required. This can be used for certain protected areas where woodfuel collection is allowed to a limited extent. If for a certain land use type woodfuel collection is not allowed at all, you should specify an accessibility factor of 0%. If you want to choose *Managed Woodland* for some land use types, accept all the defaults suggested by LEAP.
After entering data on wood resources, you can specify data on crop residues and animal dung. Leave the *Wood Resources Menu*, and choose *Dung* and *Crop & Crop Residues* respectively. Enter the data that you have estimated in the analysis exercise.

View Results
After entering all resources data, you can view the results to see whether the resources can meet the demand. From the *Biomass Main Menu* select *View Results* and press enter. LEAP will calculate the total available supplies and compare these with the total requirements. First, the *Wood Balance* is shown. The first row of the balance shows the wood requirements for all data years. Below *Supplies* you can see the supply from different sources, i.e. land clearance, yields, and stocks. LEAP assumes that first wood from land clearance will be used to meet demand, then wood from yields, and finally, if necessary wood from stocks. The last row of the wood balance, *Adjustments,* shows the shortage of supply.

Note that when the balance indicates a shortage, it doesn't necessarily mean that in reality there are shortages. The scenarios are based on data and assumptions which may not be entirely correct. The first thing to do when you find a shortage, is to check your data and assumptions. If you find a shortage already in the base year, there may be gaps in the data. What has been consumed must have been produced, so you may have overlooked some wood resources, e.g. non-forest land. At the same time, the consumption and transformation estimates may not be correct. If shortages appear for later years, you may wish to develop a new demand scenario. People will react to shortages, e.g. by consuming less fuel, by using other biomass fuels, or by using conventional fuels. You can develop a new demand scenario that shows these changes.

Can the resources meet the requirements according to your scenarios? If not, what could be the reason? Are the data reliable enough? Can you make recommendations for interventions or is additional data collection required?

After viewing the wood balance, you can use the <F2> key to view more detailed results and the results for the other biomass resources. For example, you can see the requirements for different wood products, the area for each land use type and data year, and the detailed results for supplies of crop residues.

Scenario Development

After viewing the results, again you have to develop forecasts for the biomass resources. Review the data and try to identify possible changes and estimate these changes from the available data or make assumptions. Incorporate the changes in the base case scenario and view the results again.

Do you have enough data to develop forecasts? Which data are lacking? How could you obtain these data?

5. EXERCISES ON ENVIRONMENTAL IMPACT ASSESSMENT

The use and production of energy can have impacts on the environment through emissions of materials in the air, water and soil. With the Environmental Data Base of LEAP you can estimate these emissions. Then, you can compare different scenarios to evaluate the most favourable ones in terms of environmental impacts.

The Environmental Data Base (EDB) contains data on emissions for several types of end-use and transformation devices. If you have data on emissions for devices used in your country or area, you can include these in the EDB and use them for the environmental evaluation. If not, you can use the data for similar devices in the EDB. You can make use of the EDB data by linking the devices in the demand and transformation scenarios with the EDB through so-called EDB links.

Assignments

Go to the demand module and from the *Demand Main Menu* select enter data. If you have created new scenarios, be sure that you are working with the Base Case scenario, because you can edit EDB links only in this scenario. Select *EDB Links* and press enter. LEAP will show the demand tree structure and ask you to select a device from the tree. Use the arrow keys to select a stove and press enter. LEAP will display a list of the devices for the current sector/sub-sector/end-use branch (see top of the screen). To link the first device, press enter and select the appropriate sector, sub-sector, end-use and device from the lists. Move to the next device and link it to the EDB in the same way. When you have finished for all devices on the current screen, you can move to the next screen by pressing <F6>.

You are not required to link all devices to the EDB, but unlinked devices will not be included in the environmental calculations. You can use the <F7> key to see the devives that haven't been linked yet. Devices that use electricity are usually not associated with environmental impacts, so you don't have to link these.

Leave the demand program, go to the transformation program and select *Enter Data*. Select the charcoal module and select *Kiln EDB Links* from the menu. Similar to the demand program, LEAP displays a list of transformation devices that are used in the transformation scenarios. Select *Charcoal Production/ Kilns - Firewood /Generic Kiln* for all of them.

After linking the demand and transformation scenarios, leave the transformation program and select *Environ* from the *Energy Scenario Main Menu*. Select *View Results* and select the demand and transformation scenarios for which you want to see the results. After you select *View Results*, LEAP will calculate the environmental effects of the scenarios. First, it will show the total emissions for all materials by year. Use the <F2> key to see more detailed reports.

6. EXERCISES ON SCENARIO DEVELOPMENT AND EVALUATION

In the previous exercises you have developed the data structure and base case scenarios for demand, transformation, biomass and environment. In the following exercises you will further review and refine the scenarios to come up with alternative scenarios.

Developing scenarios for energy is often difficult because of a lack of data. Still we need to develop forecasts so in some cases we have to make assumptions about future changes. In this exercise you will have to make several assumptions in energy scenarios for Wood Hills district. Because this is very difficult for a fictitious area, you can use experience, knowledge and data from your own country, province or district for this purpose.

Create New Scenarios

Go back to the demand module and try to develop scenarios that deviate from the base case scenario. To create a new demand scenario, go to the *Demand Main Menu*. Move the highlight to *Scenario: BA - Base Case*, press enter and select *<Create New Scenario>*. Give a label to the new scenario, for example S1. LEAP will ask whether you want to copy data from an existing scenario. By default, LEAP creates a copy of the base case scenario. If you want to create a new scenario based on an existing scenario other than the base case scenario, you can enter ‘Y’ (yes) and select that scenario from the given list. At this point, there is only the base case scenario so you can enter ‘N’. LEAP will create the new scenario and use it. Select *Enter Data* to specify changes in the demand structure for the new scenario.

Note that in new scenarios you cannot make changes to the base year data. Also you cannot change the data structure, e.g. delete or add branches. If you want to add a branch for a new scenario, you first have to create it in the base case scenario and use a zero value for the base year. Then, in the new scenario you can specify a value other than zero for the new branch. Branches that are different from the base case scenario are marked in red.

Methods for Scenario Development

To specify changes to parameters in the demand tree structure, you can choose three methods, i.e. *interpolation*, *growth rates*, and *drivers and elasticities*. *Interpolation* means that you explicitly specify values for future years, which you may have obtained from another model or assumed. Intermediate values for blank data years are derived by linear interpolation. When using an annual *growth rate,* future values will be calculated from the base year value. The projected values will be automatically displayed. You can also calculate future values as a function of a *driver and an elasticity*. This method assumes a constant relationship between the activity level and an independent driver variable. A driver can be a macro driver like GDP, population or income. A change in the driver will then result in a change of the demand parameter that depends on the value of the elasticity. The use of drivers and elasticities requires a lot of data, in order to be able to calculate a correlation between two factors. Even if these data are available, elasticities should be used with caution. If there appears to be a correlation between two factors, this does not necessarily mean that one factor <u>causes</u> the change of the other factor. If you are not sure how to use drivers and elasticities, or if you think data are insufficient, it is better not to make use of this method.

Demand Scenarios
Try to develop several demand scenarios. For example, you can develop a scenario with different assumptions than in the base case scenario. You can think of changes in population growth, and changes in patterns of household energy consumption. Consider also the results of the biomass module for scenario development. Is it possible that biomass fuel consumption will increase? In case there is a shortage of biomass resources, you could develop a scenario that considers energy conservation by households and industries. In case of an abundance of biomass resources, you could consider a continuing or even increasing use of biomass fuels by industries and households. View the results to compare the different scenarios.

Apart from scenarios that are based on past trends, you can develop scenarios that are based on interventions. These scenarios can be used to evaluate costs and benefits of specific programs and projects.

Try to develop a scenario for an improved cookstove program, i.e. the introduction of cookstoves that require less fuel than traditional ones. You can do this by estimating the average consumption for an improved stove. Assume that the efficiency is 15% for a traditional fuelwood stove and 20% for an improved stove. Also make estimates for the share of the improved stoves used for cooking. View the results. How much would consumption decrease compared to the base case scenario? Go to the biomass module and view the results using the new demand scenario. How much would the requirements go down?

Transformation Scenarios
After developing several demand scenarios, go to the transformation module, and try to develop several scenarios considering the overall biomass resource availability and the different demand scenarios. For example, people may switch to more efficient kilns. You can create new transformation scenarios in the same way as for demand scenarios. Note that in the transformation module you can only select existing demand scenarios, not create new ones. View the results for different combinations of demand and transformation scenarios.

Biomass Scenarios
After developing several demand and transformation scenarios, you can develop new biomass scenarios. Go to the biomass module, and create new scenarios in the same way as for demand and transformations scenarios. Note that you can only specify changes in land conversion, wood growth patterns and parameters for future years. If you want to use different values for base year data (e.g. land areas, wood stocks or accessibility), you have to create a new area under the *General* menu and copy the data from the present area. After developing new biomass scenarios, view the results for different combinations of demand, transformation and biomass scenarios.

Evaluation
After you have developed several demand, transformation and biomass scenarios, you can use the evaluation module to compare different combinations of these scenarios in terms of energy, costs and environmental effects. In the *LEAP Energy Scenarios Menu*, go to *Eval* and press enter. Select *View Results* and press enter. This will show the *Evaluation Main Menu*. Here you can select two cases of demand, transformation and biomass scenarios for comparison, the *reference case* and the *alternative case*. Initially you can use the base case

scenarios as reference case, later you can use other scenarios as reference case. For the alternative case, select at least one different scenario than the reference case. Next, you can select the combination for which you want to compare the results. After calculating the results, LEAP will show the differences between the two cases. By default, LEAP will display the value of the alternative case minus the reference case.

Differences can be calculated for total costs, foreign exchange costs, energy use and environmental effects. Note that the costs can be calculated only when costs of have been specified in the demand, transformation and biomass scenarios. Environmental effects can calculated only when devices in the demand and transformation devices have been linked to the Environmental Data Base, as discussed in section 5.

Conclusions

At this point, you should be able to draw some conclusions about the current wood energy situation and future trends. The authorities in Wood Hills district are eagerly waiting for your results, so what are you going to tell them? Do you need more data? Are there any interventions required? If so, which ones? Good luck!