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Basics of Wood Energy Planning

- A Manual -

DRAFT

FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS
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For copies write to: Regional Wood Energy Development Programme in Asia
c/o FAO Regional Office for Asia and the Pacific
Maliwan Mansion, Phra Atit Road,
Bangkok, Thailand.
Tel: 66-2-280 2760
Fax: 66-2-280 0760
E-mail: RWEDP@fao.org
Or visit our website: http://www.rwedp.org

FOREWORD

Why undertake wood energy planning? There are some very good reasons. The current situation in most countries is that a variety of interventions affect wood energy. These interventions include policies, laws, improved resource management, resource development, restrictions on cutting trees and transporting wood products, imposition of stampage fees, incentives, and other efforts. Probably the main common factor in all these interventions is that they are largely ineffective. No doubt, the interventions are well-intended, but they are based on inadequate knowledge of local and national situation. Quite a few interventions even have adverse impacts on the livelihoods of people on the economy at large. It is definitely possible to do better than that. Planning provides the tools to provide information and improve the quality of decision making, in wood energy as much as in other sectors.

Is wood energy planning worthwhile? Undoubtedly. Wood energy represents a total economic value of 30 billion US$ annually in the 16 RWEDP member countries. Moreover, wood energy is an essential commodity for some 2 billion people in Asia, its supply provides an income for up to 40% of the rural population, and many linkages exist with the rural society and economy. In the future the importance of wood energy will increase further, as is already being observed in western countries.

Is wood energy planning possible? Again, the answer is yes. The present document on the Basics of Wood Energy Planning is based on RWEDP's experiences over the past five years. It is well structured and can guide professionals in a number of different planning applications, as well as assist in the task of integrating of wood energy into energy planning. At the same time the Basics may serve as a general textbook on several important wood energy subjects.

The document was compiled by Joost Siteur and draws on RWEDP training courses conducted under the guidance of Conrado Heruela. Analytical concepts from APDC training manuals have contributed to these courses and therefore material from the manuals has been incorporated into the present document. Further inputs were provided by the RWEDP team.

Willem Hulscher,
Chief Technical Adviser,
FAO/RWEDP

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1. WOOD ENERGY POLICIES AND PLANNING

Despite being a major fuel in most Asian countries, wood energy[1] is often not recognised as such by energy and forestry planners, and wood energy is often not incorporated into their planning activities. When there are policies and programs for wood energy they are often based on misconceptions, and are supported by proper planning, i.e. analysis of the current situation, forecasting of both demand and supply, analysis of economic, environmental and social impacts, and identification of intervention options. At present, many forestry and energy agencies in the region lack the capacities to incorporate wood energy into their planning activities.

This manual provides an overview of the main aspects of wood energy planning[2]. Its aim is to provide planners from forestry, energy, and other relevant agencies with the basic concepts of wood energy planning. Many of these concepts are similar to the concepts used in other fields of planning, like energy or forestry planning, for which extensive literature is available. This manual provides an overview of the main aspects of wood energy planning in one volume. Therefore, these aspects are not covered in-depth, and the focus is on their practical application. The list of references contains several publications that can be consulted for more extensive coverage.

This chapter gives an overview of policies and planning for wood energy, and the following chapters discuss approaches and techniques for wood energy planning in more detail. Section 1.1 contains an overview of wood energy consumption and supply patterns. Section 1.2 reviews common policies related to wood energy, and Section 1.3 provides an introduction to wood energy planning, focussing on the need for planning, its elements and current approaches.

1.1. Characterisation of Wood Energy

Wood energy is, and will remain for many decades to come, an important source of energy in most parts of Asia. In most countries, between 20% and 80% of energy demand is met by wood (see Table 1.1). Contrary to common thinking, the use of woodfuels has been increasing considerably and will continue to increase in the future. But because wood energy consumption is not increasing as fast as the use of fossil fuels, its share in total energy consumption has been decreasing. The following sections give a short overview of the main patterns of wood energy consumption and supply.

1.1.1. Wood Energy Consumption

Wood energy is used by households, industries, commercial enterprises and institutions, mostly in rural areas but also in urban areas. With increasing rural populations and the limited incidence of large net shifts to conventional fuels, such as kerosene and LPG, wood energy consumption will continue to increase.

(a) Households

In many countries, the household sector is the main energy consumer and in all RWEDP-member countries it is the largest consumer of wood energy. The share of woodfuels in total household energy ranges from around 20% to over 90% for the 16 countries. When other biomass fuels are included the figures are considerably higher. The main end uses are cooking, water heating and space heating. The share of wood energy in total energy used for cooking is generally high, with percentages of over 90% in some countries.

[1] Wood energy refers to all forms of energy derived from wood, i.e. woodfuels. For Asia this mainly means fuelwood and charcoal, often used traditionally but it can also refer to modern applications such as dendro-power.

[2] Although not explicitly mentioned, many of the discussions apply to other biomass energy as well. For the sake of readability, usually the term 'wood energy' is used, but often it can be read as 'wood and other biomass energy'.

Table 1.1 Wood and biomass energy consumption in RWEDP countries (1995/96)

Unit: TJ	Wood Energy	Biomass Energy	Total Energy	Share of Wood in Total Energy	Share of Biomass in Total Energy
Bangladesh	143,700	563,600	845,100	17%	67%
Bhutan	13,225	13,225	16,145	82%	82%
Cambodia	78,818	80,460	94,591	83%	85%
China	2,911,362	6,716,663	34,690,295	8%	19%
India	3,832,597	6,060,327	12,826,698	30%	47%
Indonesia	837,222	891,948	2,921,332	29%	31%
Laos	35,368	35,368	40,763	87%	87%
Malaysia	82,689	154,073	1,082,036	8%	14%
Maldives	1,355	1,355	4,133	33%	33%
Myanmar	286,380	289,275	335,237	85%	86%
Nepal	236,386	264,605	297,765	79%	89%
Pakistan	491,907	882,828	1,960,134	25%	45%
Philippines	287,160	451,080	1,397,340	21%	32%
Sri Lanka	159,279	164,332	250,013	64%	66%
Thailand	369,903	521,591	2,212,598	17%	24%
Vietnam	429,000	604,000	891,600	48%	68%

Source: RWEDP Wood Energy Database (http://www.RWEDP.org)

The devices used by households, such as cookstoves and ovens, are generally simple. They are made from locally available materials, and are of poor quality (smoky and inconvenient). Efficiencies are low, because a lot of the heat is lost to the environment and due to incomplete combustion. This means there is a large scope for improving these technologies and for fuel conservation.

Although fuel substitution takes places at household level, total woodfuels consumption by households continues to increase in all RWEDP-member countries, mainly due to population growth. This trend is likely to continue in the coming years.

(b) Industries and Services

Fuelwood, charcoal and other biomass fuels are used by industries (e.g. brick making, lime production, textile processing, food industries), and by the services sector (e.g. restaurants, hotels, hospitals, schools and roadside/ambulant food vendors). When compared with the domestic sector, woodfuels use by industries and services appears small but nonetheless significant. On average, these sectors account for about 10-15% of the total amount of energy consumed and about 10-30% of the total amount of wood and other biomass energy consumed. Most of them operate informally, i.e. without registration and they mostly purchase their woodfuels.

Woodfuels-using industries contribute significantly to income generation and socio-economic development in rural areas. However, the processing technology and the energy conversion devices are generally poor and inefficient, which means that there is a large scope for energy conservation. In recent years woodfuels are increasingly used for modern technologies too.

The use of woodfuels and other biomass fuels by industries and services depends on the price and supply reliability of these fuels relative to conventional fuels, as well as other considerations. Many industries and services will continue to use wood and biomass fuels as long as these fuels are competitive and their supply is secure.

1.1.2. Wood Energy Supply

(a) Resources

The sources of woodfuels include both forests and non-forest lands. Forests include natural forests, plantation forests, other woodlands including shrub lands. Non-forest lands here include village woodlots and small tree farms, agroforestry systems, home gardens, crop lands, and scattered and line trees on roads, rivers, canals and areas considered as wastelands.

The share of woodfuels coming from non-forest areas is substantial. The ratio between woodfuels originating from forests and non-forest lands is generally not known, but data from eight RWEDP member countries indicate that about 1/3 of the woodfuels originates from forest lands, and about 2/3 from non-forest lands. Typically, non-commercial sources of woodfuels are located within a 20-km radius from the end-users, and commercial sources within a 100-km radius from the market.

Non-industrial tree plantations and private and community woodlots, including scattered or linear tree plantations on privately owned or community managed lands, have contributed significantly to the supply of wood in recent years. In many RWEDP member countries massive tree planting programs under social or community forestry development and non-industrial tree plantations of commercial importance have played a great role.

Secondary sources of woodfuels are residues from logging and wood processing industries, but also recycled wood from construction activities, packing crates, pallets, driftwood, discarded furniture, etc. In some areas recycled wood supplies as much as 20% of total woodfuels.

(b) Conversion

Generally, woodfuels are consumed by direct combustion in their primary form after drying and resizing, or in the form of charcoal. Today, wood energy conversion consists mainly of resizing, drying and charcoal production. Wood and other biomass can be converted also to other secondary forms of energy, such as a gaseous fuel or electricity.

Charcoal Production **-** Most charcoal is produced from wood, but other sources may be coconut shells and crop residues. Charcoal is produced through process called carbonisation or pyrolysis. Wood is heated without air inside kilns, breaking it down into gaseous, liquid, and solid products. The solid product is the charcoal. In Asia, types of charcoal kilns vary from simple earth mound kilns to more complex, controlled kilns. During the process, the water is driven off first from the wood (drying). Some of the wood is burned to drive off the water. Dry wood produces better charcoal at a higher efficiency. When the temperature in the kiln is high enough pyrolysis starts. When the pyrolysis is complete, the kiln gradually cools down, after which the charcoal can be removed from the kiln. Typically, around two-thirds of the energy is lost in the process, but charcoal has advantages over fuelwood, because charcoal can be used more efficiently and greater convenience, and can be transported more easily than fuelwood.

Modern Energy Conversion Technologies – There is now an increasing number of research, development and commercial venture activities on modern conversion technologies. New conversion technologies, such as gasification, have been developed to convert woodfuels into gaseous fuels and allow its use in modern end-use devices. However, these technologies are still not widely used. On the other hand, in recent years, there has been increasing use of wood and other biomass for energy electricity generation highly efficient electricity generation technologies such as dendro-power plants and co-generation systems, particularly in developed countries. As a result, there is also increasing number of literature now devoted to these subjects and knowledge on these are increasing.

(c) Trade and Marketing

Most woodfuels are collected for free and are a by-product of forest and tree-based agricultural production systems and wood-processing industries. Nevertheless, a substantial amount is converted and traded through an extensive network of producers, middlemen and traders, so-called woodfuels flow systems. Buyers of woodfuels are urban households and rural households of almost all income levels, commercial enterprises such as restaurants, food vendors and industries, e.g. food- and agro-processing industries.

Because of concern for forest resources, the commercial woodfuels trade is discouraged and even restricted in most Asian countries. Woodfuels traders need to obtain permits for tree harvesting and woodfuels transportation, which can be cumbersome and sometimes costly. During transport, woodfuels loads are inspected at checkpoints along the road.

Woodfuels trade provides an indigenous energy source to users and a substantial amount of employment. A significant portion of the rural population is employed in this trade, and for some of them it is the only means to earn cash income. For many others, it is an additional source of income during the off-farming season, or it works as a safety net in times of hardship. It is estimated that the labour employed in the woodfuels business per unit of energy consumed is around 20 times greater than that for kerosene, which is its closest substitute among the commercial fuels (ESMAP, 1991).

1.2. Review of Wood Energy Policies

Policies related to wood energy in Asian countries generally aim to ensure a sustainable and affordable supply of wood energy, mainly for subsistence use. In fact, wood energy relates to many policy areas, e.g. energy, forestry, agriculture, economy, environment, health and gender, but this is not yet fully acknowledged.

In the seventies, the belief in the ‘fuelwood gap theory’ led to serious concerns about the demand and supply situation of fuelwood, the so-called fuelwood crisis. The gap theory assumed that all woodfuels were supplied only from forests and that woodfuels use would increase at the same rate as the population. It was thought that this would result in overexploitation of forest resources leading to severe shortage of woodfuels. Policies to overcome the ‘gap’ between demand and supply, either aimed to reduce demand or to increase supply. On the demand side, energy agencies promoted fuel-efficient stoves and charcoal kilns and substitution by modern fuels (kerosene, LPG, electricity) to reduce fuelwood demand. On the supply side, forestry agencies aimed to increase fuelwood supplies with dedicated plantations and community woodlots (Leach and Mearns, 1988). Both approaches were essentially technology-oriented, without properly acknowledging local conditions and economic, social and other aspects.

The following is a brief review of supply-and demand-side policy approaches, which have been used, and are still being used for wood energy.

1.2.1. Supply-Side Policies

Supply-side woodfuels policies and programs have concentrated on managing natural forests, planting trees, manipulating fuelwood prices or restricting the flow of wood products. They either aim to increase the supply by planting trees or adapted management of resources, or aim to discourage and decrease the use of woodfuels by pricing and restrictions. However, many have had little success, and some even had adverse affects. Failures were due to the simplistic analysis of the actual situation (e.g. woodfuels gap theory), and insufficient evaluation of the feasibility of tree planting for woodfuels production considering the local conditions, e.g. fuelwood prices, land tenure and property rights, consumption patterns and causes of deforestation.

(a) Tree-Planting Strategies

The most common solution to fuelwood shortages is planting trees complemented with natural forest management. With proper planning that takes into account the opportunity cost of the land, land tenure constraints, availability and accessibility of markets, this can be an appropriate response. Several approaches exist:

Large-scale plantations: Large-scale woodfuels plantations have been established since the seventies. The majority used exotic, fast-growing species in state- or privately managed block plantations. Plantations were viewed as discrete, highly visible activities for which inputs and yields were easily quantified, and therefore amenable to standard economic analysis. Other indirect benefits include employment generation, environmental protection, reduction of pressure on forest lands, and demonstrations that governments were actively solving an important problem (Soussan and Mercer, 1991). Because of the high investment required for these plantations and competing uses that can pay higher prices than fuel users, in practice, most of the wood from these plantations ended up being used for other purposes, such as pulp and paper production. In most cases only the residues become available as fuel.

Community forestry: woodfuels production has been part of the many community forestry programs that have been implemented in the last few decades, many of which are successful. In areas where woodfuels is not a traded good, this may be the most feasible option for supply enhancement. Besides supplying woodfuels and other forest products to local communities, community forestry can contribute to protection of local ecosystems. Two types of community forestry programs can be distinguished: (1) those which involve the participation of communities in the management of existing natural forest, and (2) those which consist of village woodlots planted and managed by communities. The former requires lower investment, but can of course only be used for communities living in or near natural forests.

Natural forest management: The fundamental goal of natural forest management, whether under government, private or community management, is to produce a sustained yield of forest products while maintaining the balance of the ecosystem. Benefits include protection of bio-diversity, watershed protection, reduced soil erosion, and provision of basic needs to local people. With respect to woodfuels supply, the advantages of natural forest management compared to other approaches, include lower investment costs (e.g. no land clearing, seedling or planting costs) and greater adaptation to local conditions.

Tree production on non-forest lands: These already form a major source of woodfuels, both for own use and trade. Encouraging farmers, villagers and landowners to plant more trees could increase the supply of woodfuels and other wood products considerably. Unfortunately, this lies outside the responsibility of forest departments, and as of yet, no other agency is looking after this. Partly the promotion of scattered trees is incorporated into community- and agro-forestry programs, but no systematic efforts are made to encourage planting. Other existing barriers relate to land ownership and the right to use products from the land, and the restrictions on cutting trees and transporting wood, which act as a disincentive to private tree planting.

In conclusion it can be said that, in cases where woodfuels production is the main objective, one should go for programs that require low investments, and are based on existing management practices and patterns of woodfuels supply. Woodfuels is usually a by-product of other activities, and has a low value compared to other wood products, so high investments are not feasible.

(b) Fuelwood Pricing Policies

In many countries, 'free' open-access wood resources, forest and non-forest, account for 80-90% of the supply both for charcoal-making and for direct fuelwood use. The stumpage price at those sites is zero so market prices for woodfuels will not reflect the full scarcity value (i.e. the full social value) of the wood. Undervalued woodfuels resources may result in a number of impacts, the most important of which are waste and inefficiency in production and consumption and disincentives for tree growing. Implementing stumpage fees for harvesting fuelwood on government land would bring the price of wood at-the-forest-gate at least to its replacement cost (Openshaw and Feinstein, 1989). This is implemented in some countries, where forestry agencies sell logging residues as fuelwood.

(c) Transport Restrictions

In the name of protecting public forests, forest departments in many Asian countries have imposed restrictions on the felling of trees and the transport of wood products, including woodfuels. To cut trees on private land, often a permit has to be obtained in advance. Also charcoal making often requires a permit. Transport of wood, whether from public or private land, for self-use or trade, is subject to permits and limitations. These restrictions act as a disincentive for planting trees on private land and they hamper the free flow of woodfuels, which means that many people face difficulties in earning an income from the woodfuels business, and many may not even try because of the obstacles. Removing, or at least differentiating the restrictions on the woodfuels trade would allow for the development of a healthy market for privately produced woodfuels. It would also provide better opportunities for rural people, especially women, to earn an extra income.

(d) Improving Conversions Systems

Charcoal-Making Efficiency: Traditional charcoal making methods generally have low efficiencies. There have been numerous projects promoted by development agencies to introduce new or improved techniques to reduce the amount of wood required. Usually the objective of these efforts is to reduce the pressures on forest resources. However, in the majority of cases, these attempts have had little, if any, lasting impact on traditional charcoal making practices. The focus of many past programs has often been on technical matters, i.e., yield, quality, and consistency of charcoal making without considering local needs and priorities. Improvements often require higher investment for the charcoal makers that they may not be willing or able to make. In the case of traded charcoal, consumers may be more concerned about the price than the quality.

Briquettes: A considerable amount of crop residues and sawdust is generated from agriculture and forestry activities but these are usually not preferred as fuel because of problems in collecting, transporting and using them. Residues are small and loose, so they are difficult to collect and expensive to transport. When burned as loose material they have low efficiencies and they emit a lot of smoke. Briquetting technology has been developed to make the use of residues more economic, efficient and convenient, and it is promoted as an alternative to woodfuels. Briquetting has yet to gain a strong foothold in many developing countries because of technical constraints, lack of knowledge to adapt the technology to local conditions, and economic factors.

1.2.2. Demand-Side Policies

The primary objective of demand-side policies or programs is to reduce the consumption of woodfuels, either by improving the efficiency of woodfuels devices or by promoting inter-fuel substitution.

(a) End-use Efficiency Improvement

Improved cookstoves have higher efficiencies than traditional stoves, so they require less fuel for the same amount of cooking. In the early seventies, as a reaction to the oil crisis and concern for forest resources, improved cookstove programs were seen as a possible solution to the fuelwood crisis and a means to reduce the fuelwood demand. However, many programs failed because they focussed strongly on stove efficiency and fuelwood saving, ignoring the requirements of the users. There is no evidence that improved cookstoves have led to reduced wood energy demand, let alone reduced deforestation, but improved cookstoves can bring several social benefits, like cooking comfort, smoke free kitchens, convenience, health and safety.

(b) Fuel Subsidies

Increased reliance on modern fossil fuels and electricity in addition to woodfuels usually accompanies economic development. As national income rises, more and more people are able to pay for the increased cleanliness, convenience, and efficiency associated with modern fuels. As urbanisation proceeds there is a tendency for household energy use to increase and diversify and for households to switch fuels from fuelwood to charcoal to modern fuels. A hierarchy of fuel preference appears to exist, with animal dung and crop residues at the bottom, going up via wood, charcoal, kerosene and LPG to electricity.

Some countries have initiated policies to encourage a more rapid transition. In most cases these policies have consisted of price subsidies for conventional fuels such as kerosene or butane gas. Stated goals of inter-fuel substitution policies include reducing high fuel costs for the poor, increasing consumer welfare, saving woodfuels, and protecting the environment. However, it is now generally understood that poverty alleviation cannot be achieved by energy subsidies. The same applies to environmental protection.

1.3. Introduction to Wood Energy Planning

1.3.1. Why Wood Energy Planning

With a few notable exceptions, most of the discussed policy approaches above have failed to have lasting impacts on fuelwood scarcity, whether real or predicted, or on forest depletion. Wood energy policies and programs often did not achieve full success, mainly because they were based on inadequate information and misconceptions (see box below). They mostly ignored the complex interactions between woodfuels demand and supply, local conditions and social factors. Furthermore, they were often conceptualised and implemented top-down, without properly involving local participation and investigating local needs and problems.

Policy analysis needs to be supported by proper planning. Unfortunately, the need for planning for wood energy is often not recognised by decision-makers from the energy, forestry and other sectors. National energy planning concentrates on conventional fuels like electricity and oil products, and forestry planning focuses on the supply of commercial wood and the conservation of protected areas.

Woodfuels are an important energy source, particularly for the rural poor, and woodfuels use relates to public sector interests such as environment, public health, rural development, employment and even foreign exchange. Therefore, governments should be concerned with wood energy planning and developed and adapt appropriate policies. The direct effects of neglecting wood energy in energy and forestry planning can be scarcities for weaker groups, over-exploitation of natural resources and ineffective government interventions because of insufficient understanding of mechanisms and trends.

1.3.2. Approach and Elements of Wood Energy Planning

The approach to wood energy planning used in this manual involved the integration of wood energy in an *integrated energy planning process* – a planning process that involves matching energy demand and supply, with consideration of technical, economic, social and environmental factors. This planning process is not a one-time exercise, but rather a continuous and iterative process. The results are continuously reviewed and new information leads to new analyses. The steps involve include data base development, demand analysis, supply analysis, supply-demand balancing, identification of interventions (i.e., policies, strategies and programs) and the assessment and analysis of the economic, social and environmental impacts of the interventions. Interventions can be demand oriented, supply oriented or a combination of both.

This planning process is different from energy project planning (which involves technical evaluation, financial analysis, economic assessment and design of implementation of schemes of a project or a particular intervention). The integrated energy planning process involves the analysis of all related issues within a unified policy framework to arrive at a set of nationally optimal energy solutions including that for wood energy, over a long term period (say, from five to ten years or more). The solutions are in the form of policies, strategies, and programs. *In this manual, integrated energy planning is also referred to as perspective or indicative planning (see discussions in Chapter 2).*

Wood energy planning should however be part not only of national integrated energy planning process but also of other macro-level sectoral planning exercises such as those for forestry and agriculture. Government interventions in these sectors, as in energy – like resource management, investments, prices and subsidies - directly impact the supply and use of wood energy.

Wood energy situations vary within countries as the factors affecting its supply and use vary across areas of a country. Thus, the nature of wood energy demand and supply is site-specific. This means that wood energy planning need a decentralised approach. This provides impetus for integrating wood energy with other decentralised planning activities such as those for rural and agricultural development.

Chapter 2 discusses the concepts of energy planning and the integration of wood energy at different levels of energy planning in more detail.

(a) Data

Wood energy planning requires data on wood energy consumption, e.g. patterns of household and industrial/commercial energy use, and wood supply, i.e. wood resources, their productivity and accessibility, and patterns of woodfuels distribution. The lack of data on wood energy is often mentioned as a constraint to effective wood energy planning. In most countries, data on wood energy consumption and production are not collected systematically, and other relevant data (e.g. socio-economic data) are scattered over various agencies. In the case of wood energy, generally, only data on total wood energy consumption are available, and supply data are mostly lacking. As long as information on present and future woodfuels supplies is unavailable, obtaining more detailed consumption data to fine-tune demand forecasts remains largely an academic exercise.

However, for an indicative wood energy planning exercises, particularly, for initial attempts to conduct such exercises, data do not need to be very detailed. Since this is a cyclical planning exercise involving energy data collection, then energy assessment, then planning/policy formulation, then program implementation, and finally back to data collection – a comprehensive wood energy database can be developed over time, together with the evolution and institutionalisation of the wood energy planning process.

Note that for conventional fuels (i.e., electricity and petroleum fuels), detailed data are available only with regards to supply, and only the total volume is known for consumption, without much detail about what it is used for and by whom. Still, planning for these fuels is conducted, based on projections for total consumption that are based on past trends.

Chapter 3 discusses in greater detail the concepts of energy measurement, the data needed for wood energy planning, and techniques for obtaining the data.

(b) Institutions

Aside from energy, wood energy is linked to several other socio-economic sectors such as forestry, agriculture, rural development and environment. Therefore, wood energy requires cooperation among these agencies and the development of their capabilities for such. In Asian countries at present, capabilities of these agencies are limited and cooperation not adequate. Furthermore, at higher policy-making levels, decision-makers often lack understanding of wood energy situations. At the technical levels, approaches commonly applied in conventional energy planning (such as relating energy consumption to macro-economic factors like GDP and population) which are inappropriate for wood energy planning, are still widely used, leading to the formulation of inappropriate and ineffective policies and interventions. Further institutional constraints relate to lack of clear responsibilities or mandates of agencies, conflicting rules and regulations pertaining to production, supply and use of woodfuels, and lack of coordination amongst those who should be involved in wood energy.

1.3.3. Current Practices of Wood Energy Planning

Interventions related to wood energy mainly occur at project level, such as in community forestry and improved cookstoves programs. In most Asian countries, macro-level or indicative wood energy analysis and planning is not conducted to formulate national policies. In many countries, there is no appreciation in having national wood energy policies. Wood energy interventions are generally implemented on an ad-hoc basis. They are largely based on misconceptions, such as; woodfuels use is phasing out, all woodfuels come from forests, woodfuels use leads to deforestation, and wood energy problems can be generalised and so are the solutions - they are the same everywhere.

The following paragraphs gives some observations on the approaches followed by Asian countries with respect to data collection and analysis for wood energy planning.

(a) Consumption Data

i. Wood energy consumption data are generally limited to household data. Only a few countries have collected data for other sectors such as industries, institutions, and services, These data show that wood energy is also an important fuel in non-household sectors. This means that for many countries the available data may underestimate the total wood energy consumption.
ii. Few countries are conducting regular surveys on energy consumption that include wood energy. Thus, very few countries have actual historical data on wood energy consumption.
iii. For some countries, data is extrapolated from historical data assuming a linear relationship between total wood energy consumption and total population. The basis for extrapolation is a fixed figure for consumption per capita, based on earlier surveys, project-level studies or even estimates. This approach ignores fuel substitution due to changes in the economic structure (e.g. urbanisation, industrialisation), increased availability of other fuels (e.g. wider distribution of kerosene and LPG) better technologies (e.g. improved cookstoves) and responses to scarcities. In some cases, extrapolated data are updated after obtaining new survey data.
iv. Project-level data are sometimes extrapolated to national level. In some cases, these national-level data are used subsequently as bases to extrapolate historical data (see previous item). This appears to be a widely used approach, not only for energy planning, but also for other fields of planning. Wood energy consumption patterns vary from place to place, depending on local conditions (e.g. resource availability, socio-economic situation) so this approach can lead to both under- and over-estimates of wood energy consumption.
v. Data collection techniques have potential sources of inaccuracies. Some surveys obtain data from interviews only, without taking physical measurements. Woodfuels measurement standards such as bundles and bags may vary among areas and users, so they need to be measured in physical units. Also the density and moisture content of wood, and consequently the energy content, can vary significantly. Furthermore, users do not exactly recall the amount they use, so ideally consumption should be measured over a time period. However, due to budgetary and time constraints, data are usually obtained only by interviews.

(b) Supply Data

i. Data on wood resources generally refer to forest areas, and only include the stems of trees. Other significant resources such as branches and twigs, trees on non-forest land, residues from wood processing, and scrap wood (e.g. from construction sites, furniture, pallets) are usually not considered. This leads to an underestimation of the woodfuels supply potential. Combined with item iii above, this is known as the ‘fuelwood gap theory’.
ii. On the other hand, factors that restrict availability of resources such as land ownership, terrain conditions and social aspects are generally not considered. This may lead to the overestimation of wood energy supply.

iii. In contrast to consumption surveys, there are no commonly accepted methods for collecting wood energy supply data. Surveys for (wood) energy consumption follow approaches commonly applied by statistical agencies, such as sampling and questionnaires. The few studies that have investigated woodfuels resources used different kinds of approaches.

iv. The concept of wood energy flows, i.e., the production, transport and marketing of traded woodfuels, is not widely understood. Studies of wood energy flows provide crucial site-specific information on the socio-economic aspects of wood energy supply and use. These, including consumption and supply studies, are the basis of decentralised area-based wood energy planning. However, only limited information is available. For several countries area-based studies have been conducted, but at national level hardly any data are available.

v. Data on wood energy technologies are limited. A lot of data on energy conversion and end-use technologies are available from projects, laboratory studies and manufacturers. However, these are mostly of a technical nature (e.g. capacity, efficiency), and are often obtained under ideal circumstances. Data on scale of use, social factors and actual performance are rarely available. Furthermore, data are often specific to local circumstances, so care must be taken in using local data for other areas or at national level.

(c) Planning

i. *Fuelwood Gap Theory Approach*: This was the most common approach used widely during the seventies and eighties that led to the thinking that there was a severe fuelwood crisis. The gap theory assumed that fuelwood consumption increases in proportion to population and that all fuelwood comes from forests. Later on it was realised that woodfuels supply and demand systems are more complex. This has contributed to a decline in interest in wood energy.

ii. *Project-Level Planning*: Past wood energy interventions have been mainly at the project level. In some countries, several wood energy projects have been combined into a program. Approaches for wood energy project and program planning have been continuously developed, disseminated, implemented, evaluated and reformulated, particularly for woodfuels production in community forestry and agro-forestry systems, tree farming, dissemination of improved cook stoves and lately, modern wood energy applications.

iii. *Macro-Level Planning:* Wood energy analysis is not part of macro-level sectoral planning in many countries. Macro-level planning is important because it is the basis for formulating national policies and strategies, the most important of which are allocation of government resources, and prioritisation of development objectives and targets. Wood energy analysis should be a part of overall energy and forestry planning.

iv. *Decentralised Area-Based Planning*: Wood energy situations and problems are site-specific. They vary from country to country, from province to province, and from area to area. Therefore, it is improper to generalise patterns, problems and solutions. A decentralised area-based approach to planning is essential to properly understand wood energy situations and to formulate proper site-specific plans, policies and strategies. However, this is not yet systematically implemented in most Asian countries, except for China and India.

Misconceptions about Wood Energy

The importance of wood as a sustainable energy supply option and the problems associated with it are largely undervalued by planners and policy makers. Various widespread misconceptions hamper the development of wood energy and the integration of wood energy into energy planning, some of these are given below (see RWEDP, 1997 for more common misconceptions). Wood energy planning can help to correct these misconceptions.

"*Woodfuels use is phasing out*"
In fact, in all RWEDP countries woodfuels consumption has been increasing over the last decade, and will continue to increase in the foreseeable future, even when the share in total energy consumption is decreasing.

"*Woodfuels is a traditional fuel only*"
Wood energy is increasingly being used for modern technologies such as dendro-power, co-generation and combined heat and power generation (CHP). Many industrialised countries are deliberately increasing wood energy use, for environmental and socio-economic reasons

"*Woodfuels use causes deforestation*"
This assumption is based on the "fuelwood gap theory" from the 1970s, which assumed that woodfuels came from forests only. By now it is clear that woodfuels use is not the major cause of deforestation.

"*Woodfuels are being substituted by modern fuels*"
Modern fuels are largely used for modern applications (e.g. transport, new industries, and electric appliances) which complement woodfuels rather than substitute for them.

2. INTEGRATING WOOD ENERGY INTO ENERGY PLANNING

Energy planning should cover all energy sources, including wood and other biomass. Wood energy planning should be incorporated into energy planning, but this is not the case in many countries even if wood energy provides significant contribution to the total energy supply. This chapter discusses the forms and concepts of energy planning and the various approaches and constraints to integrating wood energy in energy planning.

2.1. Energy Planning

2.1.1. Emergence and Evolution

Serious and widespread interest in energy planning in Asia emerged after the first oil crisis in 1973. Before that, energy planning was mainly supply-oriented. The energy sector consisted of largely independent sub-sectors for oil, coal, gas and electricity, each of which concentrated on increasing the supply to meet the ever-increasing demand. Governments focused on electricity, whereas oil was mainly the domain of the private sector.

Energy (supply) planning had been mostly a technical issue, and consequently it was the domain of engineers. Due to the sudden price increases (as a result of the oil crisis), energy conservation became an important issue. Demand-oriented energy planning approaches started to evolve. The increasing prices of energy made economic and social issues more important. Governments tried to play a greater role in the whole energy scene by establishing energy ministries and departments, and units dealing with non-conventional energy sources were established and became important in the search for alternatives to imported oil.

Many developing countries started studying the whole energy scene, and many of these studies showed that wood and other biomass were major energy sources, and generally, they had a larger share of total consumption than conventional energy. This led to widespread concern over the availability of resources. Many assumed that all woodfuels came from forests and that consumption would increase at the same rate as the population. The response was to reduce woodfuels demand by promoting improved cookstoves and by subsidising conventional fuels, and to increase the supply by tree planting. In many countries, the authorities tried to control woodfuels demand by banning the cutting and transportation of woodfuels (see also **section 1.2** for a review of policies).

In the late 1980's, oil prices decreased to earlier levels. Consequently, energy planning largely returned to the sectoral supply-approach, and interest in renewables, including wood and other biomass, faded somewhat. However, in the last decade, renewable energy is regaining interest mainly because of environmental concerns, primarily on climate change.

Up until mid 1990's, governments in many countries attempted to control the energy sector by developing periodical energy master plans that set specific targets and guidelines to be implemented by sectoral agencies. These plans generally were set for a relatively short time-span, typically five years, and often coincided with national development plans. More recently, many countries in the region have begun the transition to a more liberal and market-oriented economy. For energy, this also means a shift to a less dominant role for government agencies, as shown by trends to privatise electricity utilities and the greater involvement of the private sector and NGOs. Consequently, the task of energy planners is changing as well, moving towards more of a monitoring and guiding role. This has resulted in a shift from short-term master plans to longer-term perspective energy plans in several countries. This new approach has made it more conducive to incorporate such considerations as commercialisation of alternative energy resources and technologies and, increasingly, the environmental costs and benefits of energy interventions, and also, even social aspects.

2.1.2. Levels of Energy Planning

We can distinguish between perspective (or development, or indicative) planning, and project or program planning. Perspective planning covers several end-using sectors and supposedly the whole energy supply processes (but as mentioned earlier, they usually leave out wood and other biomass sources) and considers a longer time span. It is a tool for policy analysis and provides a framework for project identification and program formulation (Hulscher, 1995a). Project or program planning involves analysis and assessment of the identified projects and programs, and the formulation of their implementation. It focuses on only one type of energy source, usually supplying one end-using sector.

Perspective energy planning can be done at various levels. Macro-level planning or national planning is planning for the whole country (although macro-level planning is also done for very large regions of a country). Decentralized planning is an approach that takes down planning at sub-national or local (e.g., regions, provinces, counties, districts) levels. Project planning can be considered as another level of planning too. A strong integration and interaction between the different levels are desirable.

(a) National Energy Planning

National energy planning also called macro-level planning, deals with planning for supposedly all energy needs of the whole country (however, as previously mentioned, current practices excludes wood and other biomass energy). It basically makes a projection of the energy demand for the future and then identifies which energy supply systems should be established. Demand is usually specified per sector and supply is specified per fuel source. Most countries summarised the anticipated demand for and supply of energy in an energy balance table, similar to a commodity national accounting table that provides data for production, processing, distribution, utilisation and inventory. The planning can be for a long-termed period, like up to 25 years in some countries, which can be made more detailed and operational-oriented by coming out with progress reports and updated implementation plans and targets, say annually. As such, the perspective plan becomes a program plan.

Inputs into national energy planning are the current energy balance, historical data to build energy consumption trends, supply assessment of various energy sources considered and, projections of population growth and economic development. All these will lead to quantification of future energy demand, which should be a key input in planning energy supply. The methods for forecasting energy demand can be as simple as extrapolating historical data of energy consumption by each sector. It can be more advanced (like input-output analysis or the use of econometric models) to assess the impacts of external variables such as economic growth, development and demographics on energy demand.

Planning for energy supply is based not only on the projected energy demand, but also on usual policy criteria such as technical feasibility, minimum cost, fuel security and foreign exchange savings. Availability of local resources is key factor in these criteria. Other policy criteria that are now increasingly taken into consideration are environmental concerns, at both global and local levels, and socio-economic aspects such as community acceptance, employment and equity issues. Planning energy supply must have a long-term perspective because of the long lead times needed for the implementation of most energy supply systems like power plants and oil refineries.

Below, some examples of policy options that characterise national energy planning are given (Codoni et al, 1985):

- reduce dependence on imported oil (e.g. curtail imports, change to non-oil technologies, restrict demand for oil, modern biomass applications, etc)
- research and development for non-conventional energy technology (e.g. direct solar, wind, mini-hydro, biomass)
- intensify energy conservation efforts: (e.g. improve conversion efficiency of end-use devices like cooking stoves, public awareness campaigns)
- widen the use of biomass energy resources (e.g. re-substitute commercial fuels like kerosene with firewood and biomass; research on modern applications of biomass, e.g. dendro-thermal power generation, co-generation)

Computer models are often needed for national energy planning exercises. Early models are supply-oriented and focus only at one sub-sector, such as power generation and transmission, petroleum supply, and rural electrification. The models allow optimisation analysis of supply, mainly minimising cost. In the 1990's, use of demand-oriented models that analyse the impact of energy efficiency programs and socio-economic variables on energy demand has become widespread. Now, with more powerful personal computers, there are models that allow an integrated analysis of supply and demand and the variables affecting them such as financial, economic and environmental factors.

As mentioned before, national energy planning can be a long-term indicative planning exercise that can be made detailed by follow-up implementation plans. The implementation plans consider recent socio-economic developments and new technological developments that affect the plan, and adjust the plan accordingly. The implementation plans are program plans that provide more details of projects and activities to be undertaken during a shorter-term period. Some countries have 10-, 20- or 25-year indicative plans and publish annual or bi-annual implementation plans.

Previously, when national energy planning was synonymous with electricity planning, engineers dominated it. Gradually, national energy planning activities included economists. Today, energy planning usually involved a multi-disciplinary team of specialists. (There are people now who are called as energy engineers or energy economists.) High-level policy makers, who form some kind of inter-ministerial coordinating body, sometimes guide their work. This is because of the strong linkages of energy with all sectors of the economy. It is an input to the growth of the various productive sectors, and because of its large investment needs, it has significant impacts on fiscal and budgetary policies.

(b) Sectoral Energy Planning

Sectoral energy planning can be part of national energy planning, or can be undertaken as a separate, complementary activity. In fact, early national planning exercises were sectoral energy exercises. A sectoral energy plan evaluates the energy demand of a particular energy-using sector, e.g. industry, transport, and commercial services (rarely agriculture and rural areas). Usually, each one of these sectors is under the responsibility of a particular ministry or department. A special energy sub-sector is the power (electricity) sector. It is considered crucial, as such, it is most subjected to strategic government decisions on pricing, subsidies, regional development priorities, and sometimes, environmental considerations.

Generally, sectoral planning is located at the national (central) level. Most of the characteristics of national energy planning equally apply to sectoral energy planning. Both national and sectoral energy planning have several limitations, especially with regard to planning for rural areas and wood energy (see Section 2.2). Several sectoral plans are sometimes combined to form the national energy plan.

(c) Decentralized Energy Planning

Decentralized planning takes down energy planning to sub-national or regional areas. Sub-national areas can be *political subdivisions* such as administrative regions, provinces or districts. The areas can also be based on distinct *geographical features* such as islands, valleys, plains or coastal areas, or by *agro-ecological zones* such as arid areas, savannahs, tropical forests, or wetlands. The area categories may coincide with each other, but it need not be. Decentralized energy planning is a planning approach that recognises the variation of energy situations in the different sub-national areas. Planning has to be area-based to recognise these variations and the local-specificity of the energy situation. Decentralized energy planning is synonymous with area-based planning, local energy planning, and rural energy planning.

Decentralized planning provides a more detailed analysis of the linkages between energy and the socio-economic aspects of the area being considered. It allows the incorporation of local inputs into the energy plan, and a closer feedback from the experiences in the implementation of the plan. Energy planning cannot be just the usual top-down approach, as is the case now with national energy planning.

Decentralized planning allows for a bottom-up approach. With a proper institutional set-up, local-level decentralized energy planning can be synchronised with national macro-level energy planning – "feeding into each other". Energy planning is a process rather than a blueprint type. With these approaches, national policies and programs may be made more responsive to local needs.

Decentralized energy planning is not yet common, but it is proper to make it a part of an overall local development plan. Decentralized energy planning can be an indicative plan (a master plan for the area) or a more detailed plan that formulate programs and projects, and define how these will be implemented. Also, like national planning, decentralized planning needs to be multi-sectoral.

Decentralized planning is most proper for rural energy planning. The rural energy situation varies from one rural area to another rural area. Rural energy is often not explicitly included in the national energy plan. With decentralized planning, the specific and unique character of the demand and supply of energy in particular rural areas is considered. It allows a need-based approach to energy planning. Planning is conducted by analysing first energy demand, where energy is analysed not as commodity to be supplied itself, but rather as an input in providing services such as heat for cooking and crop drying, and motive power to run irrigation pumps and mills. Thus, this approach allows analysis of the inter-linkages between energy and the local economic and socio-cultural structures in rural areas.

Decentralized energy planning for rural areas should looks into all types of energy supply - renewables, fossil fuels and electricity supplied from the national grid. The last two can generally be considered as "imported fuels" into the area being analysed. However, analyses and planning activities should focus first on local energy resources available for on-site applications, which are mostly renewables like wood, agricultural residues, streams for micro-hydropower, solar and wind energy.

Planning for wood energy in rural areas of developing countries is a good example for using decentralized energy planning. These countries are predominantly rural and wood energy is usually the dominant fuel in their rural areas making wood energy an important component of their energy supply. The wood energy situation varies from places to places – wood energy varies from being a problem to a possible opportunity for development. But whichever is the overall predominant situation, there are usually no national wood energy programs in most developing countries. As such, decentralized energy planning is needed for wood energy planning – to formulate and plan programs to solve wood energy problems or exploit the potentials of sustainable wood energy or both. Decentralized energy planning allows a closer analysis of the link between wood energy consumption of rural households, agro-processing activities and rural industries with that of tree/wood production and forestry activities. This should lead to the formulation of national policies and programs reflective of local needs.

Decentralized planning is also a very useful approach for environmental analysis, as it provides close analyses of the links between wood energy use and tree/wood production, a prime environmental concern in many regions. Furthermore, it can also allow appropriate analyses of the linkages with agricultural development, both in commercial and subsistence farming systems, as these are both consumer and producer of wood for fuel use.

Section 2.2 discusses the need for decentralized energy planning and its various aspects in more detail.

(d) Energy Project Planning

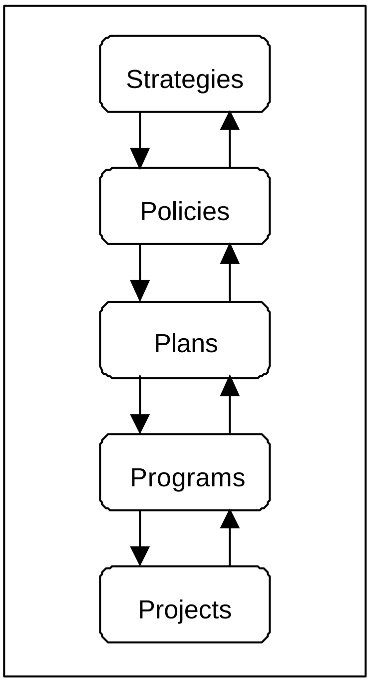
Energy projects vary depending on the objective; develop and manage energy resources, develop energy supply systems, promote energy conservation and efficiency, and promote support activities (like research, training, feasibility studies, technology dissemination, and evaluations). A number of related projects can be strung up together to form a programme. Most energy projects are, so far, directed at the supply side (and mostly conventional energy supply) rather than the demand side. Energy projects are often sponsored by donor agencies, both bilateral and multilateral.

Some energy projects, particularly rural energy projects, have multiple objectives, like with rural electrification, biogas, improved stoves, and social and agro-forestry projects. Apart from developing and managing energy supply (and several cases, also promoting energy conservation and efficiency), related objectives like sanitation, health, income generation, employment, environmental management, or overall rural development are usually integrated.

Ideally, identification of energy projects should be the outcome of a perspective planning process, i.e. the assessment of the current and future situation and the identification of alternative interventions, preferably at area-based level. However, in practice this may not always be feasible, and as such, not always followed.

(e) Integrating Levels of Energy Development

For energy planning to be successful – that is, it would lead to the formulation of appropriate policies and the identification of projects - a strong interaction should exist between different levels of energy development. The figure on the right outlines the main linkages between these levels (adapted from Ramani et al., 1995). This framework applies to all types of energy planning, e.g., for conventional energy, rural energy, and wood energy.



At the top, strategies set the overall vision for energy development in line with national development objectives. Policies translate this vision into objectives and directions for specific sectors and policy concerns. Plans for different sectors and geographical levels provide assessments of the situation and trends, and identify concrete actions, which are implemented as programs and projects. In return, projects and programs provide feedback on the implementation aspects of policies and plans. This feedback is to be incorporated into new and adjusted strategies and policies. In many cases, the flow occurs mostly from top to bottom (top-down), but the *interaction* between the implementation of programs and projects and the formulation of plans and policies is important to ensure that the latter set feasible and realistic targets and guidelines.

Naturally, a complete integration of all levels according to this framework is very hard to achieve and in fact, it represents an ideal picture. It is not always feasible to follow this path due to constraints and conflicting interests. In practice many programs and projects are formulated and implemented ad-hoc, without following all the linkages. In same cases, urgent action is needed, or a limited budget is available so it is not possible to do a proper assessment of problems and needs. In other cases, projects may result from some vested interests (e.g. politicians, government agencies, powerful industries, pressure groups, public opinion and international donors), and these interests may not be in line with national policies and plans. This is may be unavoidable and to some extent creates more problems, such as poor performance, failures, and even adverse affects to the intended beneficiaries.

2.2. Decentralized Energy Planning

At present, the most common approach to energy planning in Asian developing countries is national level planning with a strong focus on developing the supply of fossil fuels (such as petroleum fuels, coal and lately, natural gas) and electricity to meet their ever-increasing demand of urban areas and industries. Rural energy planning, if ever looked into, consist mainly of planning rural electrification by grid extension to the more physically accessible rural areas. This approach has several limitations for planning for energy needs in rural areas, because it particularly fails to address wood and other biomass energy issues.

Moreover:

- It severely ignores the energy needs and problems of lower-income households that in most countries form the majority of the population and are mostly in rural areas. These larger share of the population - the lower income and mostly rural based households - depend mostly on wood and other biomass fuels for the *heating requirements* of their domestic and livelihood activities. Thus their energy needs for heating forms a large segment of the country's energy needs, which makes wood and other biomass energy an enormous and important source for energy supply. However, no particular agency is taking care of the energy needs of this larger share of the population dependent on wood and other biomass energy sources.
- As the formulation and implementation of energy plans occur top-down from the ministry to local authorities, targets of these programs are imposed from the top and so, in most cases, local circumstances are hardly taken into account. This disconnects planning and implementation, which lead to a neglect of essential locally sensitive aspects in the implementation of plans and policies, and also, the necessary feedback from implementation to planning are hardly achieved.
- In spite having a national energy plan, it is mostly a compilation of sectoral plans. Sectoral approach to energy planning leads to the lack of co-ordination among the different energy sub-sectors so different energy programs do not have a relationship with each other, and may even overlap and conflict. Also little co-ordination exists between programs for energy demand on the one hand, if ever there is one, and energy supply on the other hand.
- The strong focus on conventional fuels means that sectoral planning neglects the major energy needs in rural sectors. For agriculture, sectoral planning focuses on conventional fuel needs for fertiliser production, irrigation and transport, and on removing constraints to increase agricultural output. This approach largely ignores the importance of animate power for agriculture and the use of crop residues as an energy source, and it may conflict with the interests of small-scale farmers. For the industrial sector, small-scale rural industries, which are major biomass energy users and provide substantial rural employment, often receive little attention. In the transport sector, the importance of animate power for rural transport is rarely recognised.
- Energy programs like rural electrification, improved cookstoves, fuelwood plantations and decentralised energy systems (both conventional and renewables), implemented by government agencies and NGOs, are often set up on an ad-hoc basis since adequate data on energy requirements and supplies are not available. This has led to many failures and adverse affects.
- Energy planning considers energy largely as a commodity in the form of fuels rather than as providing a service needed by users, e.g. in the form of heat for cooking and industrial processing, or motive power for machines and vehicles. Planning concentrates on increasing and spreading the conventional fuel supply, and in rural areas, this leaves little room for alternative approaches like decentralised renewable energy systems. It also hardly matches with the multiple functions of natural resources and the substitutability of energy sources.
- The production, distribution and consumption of wood and other biomass fuels occur at small-scale level, and like any rural energy systems are site-specific. Patterns of consumption and production may vary from region to region due to different agro-ecological, economic and social conditions.

This shows that planning at national level particularly if using a sectoral planning approach, makes it difficult to address the energy needs of the rural population who is the majority in developing countries. What is appropriate is a decentralized energy planning approach, i.e. area-based assessment and forecasting of energy demand and supply, and local formulation and implementation of energy programs and projects for distinct sub-national areas. *Decentralized energy planning is particularly applicable and needed in wood energy planning.*

2.2.1. Objectives and Outputs

The overall objectives of decentralized energy planning, among others, are to:

- meet the location-specific energy needs of small-scale energy consumers in rural and urban areas that don't have access to centralised energy supplies

- identify location-specific, decentralised energy resources and technology options and match them with local energy needs, with special attention to the basic needs of the poor, through the promotion of modern, clean and efficient applications
- improve the technical and market efficiency and social acceptability of decentralised energy systems that are based on local resources, such as woodfuels and other biomass and other renewables, through technological interventions, appropriate regulations, improved resource management, and targeted subsidies, and
- promote decentralised energy development as an integral part of overall national energy development, socio-economic development and natural resource management

The results of area-based decentralised energy planning will lead to realistic options for resource management and technologies to sustain future energy demand in the form of energy projects and programs. More specifically, the outputs of this planning exercise are:

- assessments of site-specific needs, resources, socio-economic and environmental aspects, and market potential for energy sources and technologies, particularly for wood and other renewables
- perspective and detailed plans that provide realistic and feasible targets and options that meet site-specific needs and conditions
- tailor-made programs and projects that incorporate site specific aspects in the implementation of interventions, and that provide feedback to planning and program/project formulation
- Integration of area-based energy development with national level energy development and other local development efforts

2.2.2. Approaches and Mechanisms

Decentralized energy planning should complement other sectoral energy planning exercises (e.g., petroleum, gas and power) and the sectoral plans should be integrated into a national energy plan. This national plan should provide the framework for identifying energy projects, both at the national and local levels.

However, most local projects have been developed at the national level. Many have failed because of the insufficient attention given to the needs and priorities of the local population. Such attention can only be assured through people's participation in planning and decision-making (e.g., policy/program formulation and project identification), and it can be most effectively achieved through decentralized energy planning. In this approach, energy planning should include analysis of all sources of energy and be integrated with other general development objectives for the area. It should include analysis of economic, social and even cultural factors.

Decentralized planning also allows for immediate feedback and interaction between the processes of identification and implementation of programs, projects and other forms of interventions (e.g., the performance of energy resources and technologies vis-à-vis the responses/reactions of the groups targeted). This is an important input in fine-tuning current programs and projects and formulating new ones.

The role of national agencies in decentralized energy planning is seen to be limited to developing an enabling environment for local agencies, NGOs, the private sector and local energy stakeholders to assess and manage energy supply and demand. This includes providing means and instruments like, planning tools (software and hardware), expertise, training and extension, financing and subsidies, and support for research and development.

The following list covers the main elements in developing a country's capacity to conduct decentralised energy planning (Ramani, 1996):

1. developing a policy framework
2. defining the geographical boundaries for area-based planning
3. arranging institutional responsibilities
4. outlining the integration of different levels of planning
5. performing the planning exercise

The first four elements or steps are needed to establish the scope of the plan and a proper planning framework before actual area-based planning can take place. They are closely interrelated and need to be done concurrently. Although adjustments will be needed at later stages, these four steps need to be performed in advance. The actual planning exercise is a continuous activity with strong interaction between the different elements. Each element is discussed in more detail below.

(a) Developing a Policy Framework

Decentralized energy planning requires a set of appropriate policies. For many countries this will a mean a reorientation from the centralised, sectoral approach dominated by central agencies towards policies allowing a larger involvement of the local population, decentralised agencies, NGOs and the private sector. Energy policies are usually set at national level, so these need to be reviewed to address decentralisation. Fuel subsidies and rural electrification programs are generally set indiscriminately at national level, without assessing local needs. Rather than imposing these interventions top-down, policies should enable and support the development of decentralised planning and intervention.

For wood energy in particular this applies, for example, to nation-wide restrictions on tree felling and woodfuels transport that may constrain the development of private mechanisms for woodfuels production and trade. In some areas these restrictions may be needed to protect natural resources, but in others they may discourage people from growing trees on private land. Therefore, policies should allow for differentiated regulations to be set by decentralised bodies.

(b) Defining Geographical Boundaries for Decentralized Planning

Units of area-based decentralized planning have to be decided considering the broad economic and administrative set-up of a country. The appropriate unit depends on several factors and may vary from country to country. It may be defined either by administrative boundaries or by factors such as agro-ecology, economy, demography, and social and cultural characteristics. The size of the planning unit should be large enough to allow for the integration with national and/or sub-national planning objectives, to incorporate energy requirements for subsistence and production and to justify the building up of a decentralised database for the whole country. On the other hand, the unit should be small enough to allow for the participation of the local population and the incorporation of their needs and priorities.

The unit of area-based planning may coincide with an administrative unit such as a province or district but it does not need to. Likewise, if area-based planning is conducted throughout the whole country or in several areas, the different units do not need to be defined in similar terms. For example, one area may be a province, another a district - and another may be defined by a nature reserve, crossing administrative boundaries. The presence of local agencies that can be involved in different planning stages is preferable. Defining areas as planning units does not need to be a one-time exercise. Boundaries may be redrawn over time when changes in natural resources, economic development and social and administrative structures take place.

(c) Arranging Institutional Responsibilities

Capable institutions that have sufficient means and authority are needed for decentralized planning. Considering the institutional set-up of decentralized energy planning, one may distinguish between two approaches: (1) planning for sub-national areas conducted by centralised agencies and (2) decentralising the planning process to lower administrative levels, with decentralised agencies having the responsibility, authority and means to conduct planning and implement interventions. The latter is the more desirable approach because it allows for close interaction among different stages of the planning process like data collection and analysis, and identification and implementation of interventions. It also allows more for the participation of the local population and the inclusion of social and cultural factors due to the local presence of planners familiar with the area.

At present in many countries decentralised (energy) agencies may be lacking or too weak, so area-based energy planning could initially take the form of “centralised” area-based planning, that is dis-aggregated decentralised plans done by a centralised top-level body. This can be implemented during the transition towards developing and strengthening decentralised agencies. Increasingly, the responsibilities and tasks are handed over to local-based decentralized bodies that are developing their capabilities for such.

(d) Outlining the Integration of Different Levels of Planning

Energy planning for a distinct area is never independent from other development processes within or outside the area, so there should be proper integration between several levels and fields of development planning. First of all, decentralized planning should be vertically linked with policies, plans and programs at national level. These linkages should occur in both directions, which means that a) national planning builds on specific features of the local plans formulated for the various areas and, b) the national planning framework provides the basis for local policies and programs for the areas. Secondly, energy is interrelated with many other sectors and policy fields, such as rural development, forestry, agriculture, environment, so there should be proper horizontal integration with other efforts in the area, in order to avoid duplication of efforts and conflicting activities. Thirdly, energy patterns within an area are inevitably influenced by processes in surrounding areas, for example through woodfuels trading, supply of conventional fuels, and inflow of technologies. Proper guidelines and mechanisms need to be developed to facilitate the different types of integration.

(e) Performing the Planning Exercise

With the above arrangements in place, the responsible agencies can conduct planning. This is not a one-time exercise leading to a specific “master” plan, but should be an ongoing process with proper interaction between the different planning activities. The activities in the planning process include, a) the identification of data requirements, b) data collection and assessment, c) analysis of energy demand and supply, d) demand-supply scenario analysis and the identification of interventions, e) the implementation of interventions through policies, programs and projects, and f) monitoring and evaluation. New developments and new information lead to the updating and fine-tuning of the energy plan, which may lead to new interventions.

The different activities of the planning process are discussed in more detail in the next section and in the following chapters. Although these discussions focus on wood energy planning, they apply to other forms of energy planning as well.

2.3. Wood Energy Planning

2.3.1. Objectives

Before embarking on data collection and analysis for wood energy planning, the planning objectives have to be defined. Planning is not a goal in itself but its serves a purpose, e.g. to provide basic information, to give input to policy making, or to identify projects. Once the objectives have been defined, they should be clearly kept in mind during the planning process, because many choices that have to be made (e.g. on data requirements or analysis techniques) are largely determined by the planning objectives.

Planning objectives should be defined as specifically and clearly as possible, in order to be able to match the analysis with the objectives and to avoid over complication of the analysis. Possible objectives of wood energy planning could be to:

- provide base-line information to support policy-making sustainable wood energy development (or validate existing policies and programs, if there are any);
- assess whether woodfuels use is causing deforestation;

analyse whether current wood energy trends and strategies are sustainable in the long run;
evaluate whether wood energy use could be increased, developing it as an indigenous modern, clean and convenient energy source;
evaluate the potential of wood energy as a strategy for the mitigation of CO_2 emissions (an increasingly important concern).

2.3.2. The Planning Process

Planning for wood energy (and other biomass energy sources that have been traditionally used) should be an integral part of energy planning. Also, planning for wood energy links energy planning directly with forestry, agriculture and land use planning. Figure 2.1 shows the basic framework for wood energy planning. The framework closely follows the planning process done for other energy sources and the planning process for wood (and other biomass) should be an integral part of such larger planning process.

Planning is a continuous process, and there should be close interaction between the different steps in the process. Results need to be reviewed continuously and new data and information are captured through regular monitoring of the implementation of policies/programs. These lead to new analyses and projections that in turn leads to possible changes in implementations of existing policies/programs or of the formulation of newer ones. The elements of wood energy planning are discussed in more detail in the following chapters, but a brief presentation follows below.

Generally, the *first step* is the assessment of needs, resources, technology and woodfuels flows. This refers to both the assessment of the current situation and developing forecasts, and it includes the identification, collection and assembling of information, as discussed in Chapter 3. The assessment of needs is also called demand analysis, which is further discussed in Chapter 4. The assessment of resources, technology and distribution refers to supply analysis, further discussed in Chapter 5.

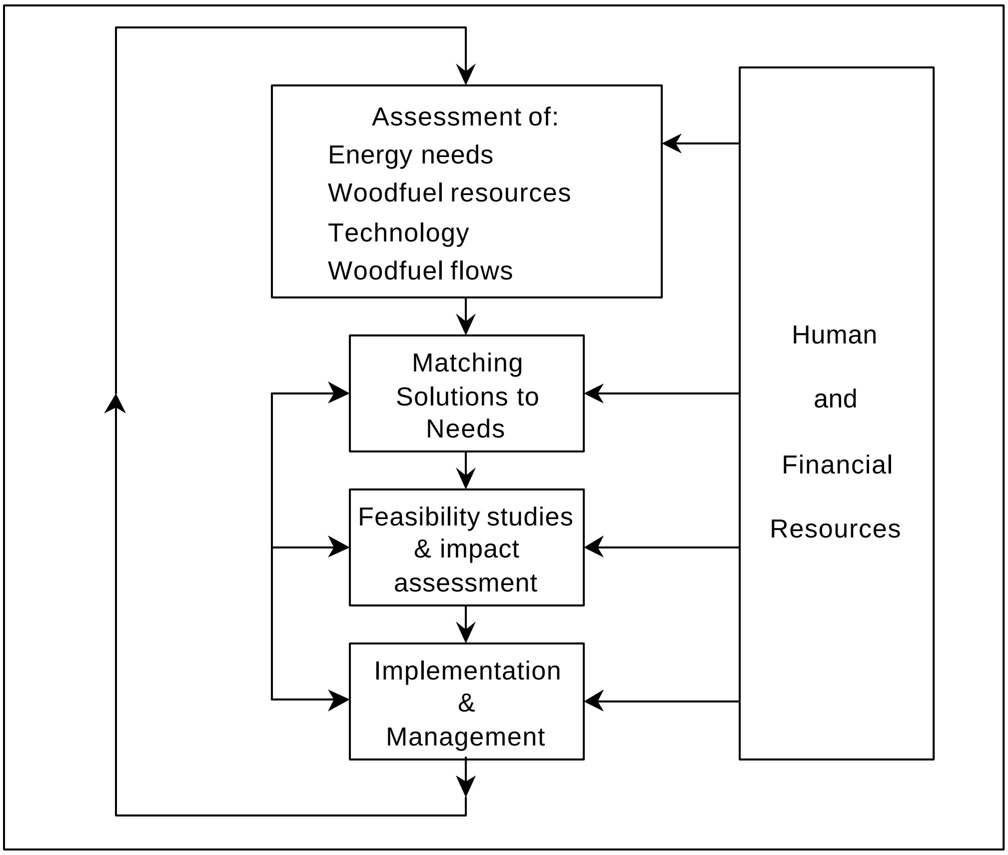


Figure 2.1 Framework for wood energy planning

Depending on specific needs, the availability of resources and technology, and distribution patterns, feasible solutions or interventions need to be identified, also known as supply-demand balancing. These solutions are to be implemented through policies, programs and projects. Interventions can be demand-oriented (e.g. conservation), supply-oriented (e.g. aiming at increasing or redistributing supply, introducing new technologies) or mixtures of supply- and demand-oriented solutions. Preferably, planners should provide a range of options or scenarios, specifying costs and benefits for each, so decision-makers can choose according to certain priorities.

Feasibility studies and impacts assessment are needed to address the feasibility of managing woodfuels demand and supply interventions in economic and technical terms, and to assess the possible impacts of the interventions on environment, economy, employment, gender relations, etc. For example, technologies may be too expensive or the required expertise may be lacking. Likewise, interventions may benefit some people but may have negative impacts on others. Usually, an intervention will have both negative and positive impacts, so then the choice depends on priorities at policy level (i.e., a political decision).

The interventions identified need to be translated into policies, programs and projects. Its implementation needs to be monitored and assessed because new constraints may arise that require changes in the interventions. Positive factors may also come about and they should be enhanced. That is why, assessment of needs, resources and technologies should be a recurring process, since the implementation of interventions result to changes in them, which in turn can lead to fine-tuning or changes in the interventions, and which in turn influences again those factors.

During all stages of the planning process, the input of human and financial resources is crucial, and at the same time it constrains the options. The availability of budget and expertise will influence the choice of methods of data collection and analysis, and the coverage and detail that can be achieved. It will also influence the feasibility of interventions, in the sense that they may just be too expensive, or human resources (expertise) required to implement and manage certain interventions may be unavailable. At present, in most countries, resources available for wood energy planning are limited and a substantial increase will be needed.

2.3.3. Constraints to Integrating Wood in Energy Planning

Planning for wood (and other biomass) energy should be part of energy planning, whether at national or decentralised level. However, several factors, of which the major ones are listed below, constrain such proper integration, as follows:

1. Energy planning generally follows supply-oriented and sectoral approaches for conventional fuels, which have several limitations for planning of rural energy, as discussed in section 2.2. Most of these constraints apply to wood energy as well.
2. The common approaches of energy planning rely heavily on data for conventional fuel supply and macro-economic factors. These are easily available from planning agencies and fuel suppliers. Wood energy data are more difficult to obtain, and consequently difficult to integrate with data for conventional fuels (see also section 3.2.6).
3. Patterns of wood energy demand and supply are considerably more complex than for conventional fuels. Wood energy relates to many sectors and non-energy aspects, like forestry, land use, gender, small-scale industries, rural employment and other informal sector activities. Furthermore, woodfuels supply systems are widely distributed, small-scale and largely informal, while the supply of conventional fuels is highly centralised and easy to control. This requires special approaches and considerable input of resources for data collection.
4. Many planners and policy makers consider wood energy as traditional, dirty and damaging to the environment (causing deforestation), and assume that its use is phasing out through substitution by so-called “modern fuels” such kerosene, LPG and electricity. This often results in policies and programs that aim to control woodfuels use and production (e.g. transport restrictions) and to

promote the use of alternatives (e.g. subsidised kerosene, LPG or electricity). These measures are often implemented without a proper assessment of the situation and the underlying mechanisms.

5. Commercial wood energy supply systems or businesses exist in thousands of cities and urban centers in the developing world. Although the people involved can be substantial, they are not a powerful stakeholders group who can advocate its development and attract investments. Commercial woodfuels supply systems are manned/operated by poor rural households linked with local middlemen/traders, contrary to powerful business interest in the conventional fuels supply systems (e.g., the oil, coal, gas and the power sector industries). “Woodfuels business” activities are largely in the informal sector (and sometimes, considered illegal), and most of their “customers” are lower-income households and small-scale industries and enterprises, also a group that has not much political clout.
6. Because of the view of decision-makers and the absence of powerful stakeholders and political advocates (points 4 and 5), limited human and financial resources are invested into to wood energy development. This severely constrains the development of proper policies, approaches, tools and institutions that are needed to deal with the complex nature of wood energy issues.
7. Energy planning is often approached from a technical perspective, focusing on reducing demand and increasing supply, without sufficient consideration of the underlying social and economic processes pushing the consumption of energy. Wood energy relates to many aspects, and approaching it from a largely technical viewpoint is insufficient. For example, early cookstove programs focused on decreasing demand without incorporating aspects like timesaving, convenience and health.
8. Techniques for energy modelling are largely based on technical and macro-economic factors, like total population and economic production (e.g., GDP), and on assumptions about the linear relationships between the different factors. This approach is too simplistic for wood energy (and for energy planning in general) as it does not allow for the incorporation of many aspects such as economic transformation, increases in household income, availability and accessibility of substitutes, and even health concerns and social practices – particularly gender roles. These all have very significant impact on wood energy use.
9. Energy planning focuses to a large extent on monetary instruments like subsidies, taxes, pricing policies and financing for large-scale investments. The impact of such instruments on wood energy problems may be limited, because a lot of woodfuels are still produced and used non-commercially, and the commercial woodfuels trade occurs largely through informal channels. The macro-approach and the strictly financial criteria used in defining these instruments disadvantages modern and small-scale wood energy applications. Modern and efficient but small-scale wood energy systems are often more expensive in financial terms under existing project evaluation paradigms. Mechanisms for alternative financing and incorporating benefits in terms of environment and health are rarely in place in many developing countries.

The list may appear to be overwhelming, as it points out several major obstacles that need to be overcome to integrate wood energy into energy planning. Nevertheless, governments in developing countries should make considerable efforts for this integration, since wood energy is and will remain a major energy source for their population, and a large-scale shift to other fuels is not feasible for many of them in the foreseeable future. In fact, even if a country were to aim to completely replace woodfuels with other fuels, it would need to embark on a considerable planning exercise, in order to know how to implement this.

2.3.4. Tools for Wood Energy Planning

The complex nature of wood energy, and the attendant constraints in efforts towards understanding such complexity makes wood energy planning, and the analysis involve in it, a daunting task. Fortunately, several tools are now available to assist planners in this task, of which (computerised) energy models are the most used. Models for energy planning are used to (a) perform demand and supply analysis, (b) develop forecasts, (c) conduct energy supply-demand balancing and develop future scenarios, and (d) perform impact assessment. They are mostly used at national level. Different types of models exist, depending on the approach and objectives. They can broadly be distinguished into econometric and techno-economic models (Desai, 1990).

(a) Econometric Models

These are mainly demand models and are based on the assumption that energy demand is driven by macro-economic indicators such as Gross Domestic Product (GDP), income, fuel prices. Demand is forecasted by establishing relationships that describe the energy consumption as a function of a number of variables, mainly income (or GDP) and prices. The main limitation is the difficulty to find these relationships, even if sufficient data are available, and the fact that these factors are not the only ones influencing demand. After the oil crisis it was found that these models were not able to deal with rapid changes of energy prices and national economic structures. Other approaches were needed, which led to the development of techno-economic models. Attempts to improve econometric models have had limited success. However, they are still used at macro-level, mainly because they are easy to implement and they require few data. They are hardly applicable for wood energy planning and planning at area-based level.

When the demand is estimated using econometric models, the results are often used in combination with supply models. Usually these supply models are optimisation models, which means that they try to find the optimum solution for a given set of objectives (supplying sufficient energy), decisions to be made (e.g. coal or oil power plant) under certain conditions that restrict the possible outcome. The main condition is usually to find the cheapest solution. Other conditions may be limiting energy imports and environmental considerations. Like econometric models, these models are hardly applicable for wood and area-based planning, because they cannot easily incorporate social aspects and woodfuels supply is small-scale, highly scattered and generally non-monetized.

(b) Techno-Economic Models

Techno-economic or energy accounting models were first developed after the first oil crisis. For energy demand they use the following approach:

- detailed representation of types of energy end-uses (e.g. cooking, heating, lighting);
- calculation, for each end-use, of the demand for useful and final energy on the basis of technical, economic and social indicators; and
- use of scenarios to account for the development of all factors closely related to energy or economic policy (simulation approach);

Some models cover energy supply as well, through the simulation of energy conversion processes, e.g. power plants, oil refineries and charcoal kilns. Factors that are considered are efficiencies, inputs, outputs, costs and in some cases environmental impacts, like emissions.

The simulation approach means that the model imitates the real world in a quantitative manner, by using scenarios to describe future trends and define options. Several forecasting scenarios can be developed to compare the results under different conditions and assumptions. By developing a range of alternative scenarios, several options for interventions can be identified and evaluated, both for demand and supply.

These models are more applicable to wood energy planning than econometric models because they can account of the factors affecting woodfuels supply and use, and consequently can handle more complex situations. They can also easily be applied at decentralized area-based level. However, they may require large amounts of economic and technical data, and still, they have limited capability to incorporate social aspects. Users need to have sufficient knowledge of the social, economic and technical aspects to be able to develop realistic scenarios and interventions.

(c) Considerations for Energy Modelling

Several energy models are available and the choice of one will largely depend on the objectives and scope of planning. Some countries have adopted existing models, while others have developed their own model. The following list highlights aspects that need to be considered:

The model should match the level of planning, e.g. macro-level planning or decentralized planning, and the scope and objectives of the planning exercise, e.g. national indicative planning for a 25-year period, or detailed planning for project identification and formulation.

Operating a model requires data and skills. Sufficient human and financial resources should be made available to collect and analyse the data. If data and resources are unavailable, complex and data intensive models will be ineffective.

Energy modelling should be seen as a tool to assist in planning, not as a goal. Every model has its limitations to represent the real world and planners should be aware of these. Energy models focus on demand and supply in quantitative and economic terms, and social aspects are hard to incorporate. Generally, for wood energy social and qualitative aspects are just as relevant as quantifiable aspects, and in many cases for wood energy planning, they really need to get considerable attention.

Data needs will to a large extent depend on the model used, so when identifying data requirements (see section 3.3.1) the data structure of the model should be used as a guideline.

Since the purpose of planning is to match demand and supply, supply analysis should balance demand analysis. For wood energy, analysis and modelling exercises generally focus on demand, largely ignoring resources and supply. However, there is no point in carrying out a detailed demand analysis and trying to refine demand model, if it is not matched with a compatible analysis of supply.

For most cases, complex models are not needed. Spreadsheet programs are often good enough for analytical tasks, and may even provide a higher level of transparency.

LEAP Model for Wood Energy Planning

The Long-range Energy Alternatives Planning model (LEAP) combines characteristics of econometric and techno-economic models. LEAP is appropriate for wood energy planning because it covers the whole flow of energy, including wood and biomass resources, it is applicable at different levels of planning, and it is relatively easy to operate. It contains a biomass module that can be used to investigate resources of wood and other biomass, and balance these with demand scenarios.

RWEDP conducted as case of area-based energy planning case study using LEAP in Phrao district, Thailand. The case study documents the planning process from the identification of data requirements to the impact analysis of future trends and intervention options (RWEDP, 1997a).

LEAP was developed by the Stockholm Environment Institute – Boston (SEI-B). See SEI-B (1997) or http://www.seib.org/leap/ for more information on LEAP.

3. WOOD ENERGY DATA

This chapter discusses the types of data needed for wood energy planning and the various approaches to data collection. Section 3.1 discusses some basic energy and measurement concepts. Section 3.2 discusses in detail the types of data required for wood energy planning, and section 3.3 discusses methods of data collection. Finally, section 3.4 discusses presentation and assembling of wood energy data.

3.1. Energy and Measurement Concepts

This section discusses basic concepts of energy and measurement. For a more elaborate discussion of these, see Wood Energy Basics (RWEDP, 2000).

3.1.1. Energy and Fuels

Energy is defined as the ability or capacity to do work. In this manual, energy refers to energy in the form of heat, mechanical energy or electrical energy needed for domestic and economic activities like cooking and industrial processes. *Energy carriers* or *fuels* are needed to provide this energy. Energy carriers can be divided into combustibles (i.e. they can be burned, e.g. gasoline, fuelwood) and non-combustible (e.g. electricity, running water). The rate at which energy is consumed, produced or transmitted is called power.

(a) Energy Content

Energy carriers have an energy content, also called heating value or calorific value, expressed as the amount of energy per physical unit, e.g. joule per kilogram, or ton of oil equivalent (toe) per litre. For combustible fuels (including biomass fuels), this is the amount of energy that is released as heat when the fuel is burned completely. The energy content of a fuel can be recorded using two different methods: gross and net. The Gross Heating Value (GHV), also called higher heating value, refers to the total energy that would be released through combustion divided by the weight of the fuel. The Net Heating Value (NHV), or lower heating value, refers to the energy that is actually available from combustion after accounting for energy losses from water evaporation. The NHV is the amount of energy actually available, and it is always less than the GHV.

For completely dry wood (oven-dry), the amount of energy per unit of weight is more or less the same for all wood species, with an average value for GHV of 20 MJ/kg for stem wood. Values may vary slightly because of the ash content of wood, i.e. components that are non-combustible (other than water). For small branches and twigs, heating values tend to be lower and more variable. However, in case no local measurements are available, it is reasonable to use the value of 20 MJ/kg oven dry for all tree species and parts. In practice, the moisture content of wood is the most crucial factor determining the energy content of wood (Leach and Gowen, 1987).

(b) Moisture Content

The moisture content of a fuel is defined as the quantity of water in the fuel, expressed as a percentage of the weight of the fuel. For wood and other biomass, moisture content is the most critical factor determining the amount of heat that can be obtained through combustion. When burning the fuel, the water needs to be evaporated first, before heat becomes available. Therefore, the higher the moisture content, the lower the energy content.

All combustible fuels contain some amount of water, but for biomass the levels can be high, seriously affecting the energy content and combustion properties. The moisture content varies between types of biomass, the length of time between cutting and using and the atmospheric humidity. After the biomass is cut it will gradually lose moisture until it reaches equilibrium with its environment (a piece of wood from the same species would have a different moisture content in a monsoon climate than in a desert).

Therefore, when recording levels of energy consumption and comparing different fuels, it is important to account for the moisture content.

To indicate moisture content in broad terms, three terms are commonly used:

fresh wood - wood that has been freshly cut, so its moisture content is still high;
air dried wood - wood that has dried naturally over time, so its moisture content is in equilibrium with the humidity in the atmosphere;
oven dried wood - wood that has been dried completely, so its moisture content is zero.

Values for moisture content can be given on a 'wet' basis or a 'dry' basis. Moisture content on a dry basis is defined as the ratio of the water weight in the fuel to the weight of dry material, expressed as a percentage. Thus,

$$MC_{dry\ basis} \quad \frac{Water\ weight}{Dry\ weight} \quad 100\,\%$$

Moisture content on wet basis is defined as the ratio of the water weight in the fuel to the total weight of the material, expressed as a percentage. In formula:

$$MC_{wet\ basis} \quad \frac{Water\ weight}{Total\ weight} \quad 100\,\%$$

$$or \quad \frac{Water\ weight}{Water\ weight \quad Dry\ weight} \quad 100\,\%$$

The value for the wet basis is always lower than for the dry basis, so it is essential to report the basis type with the value.

Figure 3.2 shows the variation of energy content for different values for moisture content. It shows that the energy content is seriously affected by the amount of water in the wood (source: Leach and Gowen, 1987).

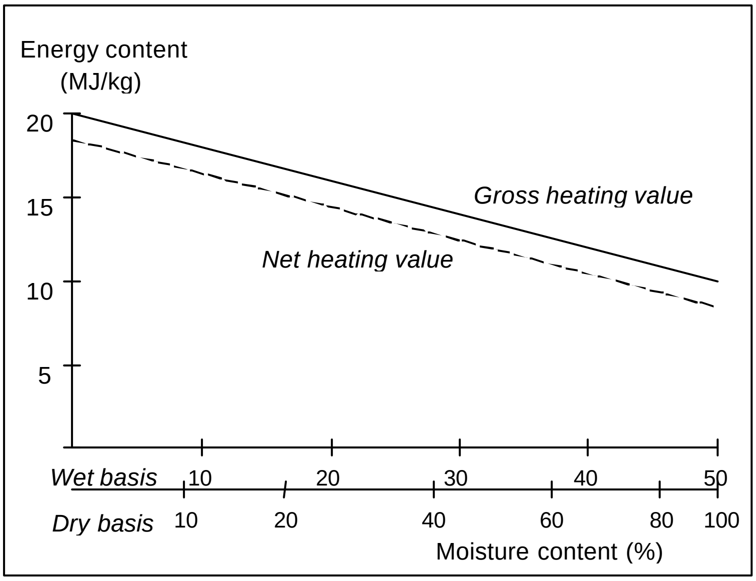


Figure 3.2 Energy content as function of moisture content

(c) Units

When accounting for energy consumption and production, several units for energy and power can be used. The most common one for energy is the *joule* (J), and power is almost always measured in *watt* (W), where 1 watt is equivalent to 1 joule per second. Both the joule and watt are often used with prefixes to indicate multiples of 10 (e.g. 1 kJ = 1 kilojoule = 10^3 J = 1,000 J and 1 MW = 1 megawatt = 10^6 W = 1,000,000 watt). Other common energy units are *ton of oil equivalent* (toe), *ton of coal equivalent* (tce), *calorie* and *British Thermal Unit* (BTU). These units can be easily converted into other units. See Annex 1 for conversion values between common energy and power units.

Since wood is not only used for energy purposes, units other than energy units are used to indicate quantities of wood. Conversion from one type of unit into another is not always straightforward, because it depends on wood species, density and moisture content. Basically, the three types of units that are used are volume, mass and energy units.

- Volume (e.g. cubic meter): Most commonly used way to report forestry and wood processing statistics. It is important to distinguish between volume of stacked wood and solid wood. One cubic meter of stacked wood is the amount of wood that would fit in a space of 1 m^3. Because wood has irregular shapes, this leaves a lot of air space. One cubic meter of solid wood refers to 1 m^3 actual volume of wood, regardless of its shape. Naturally, 1 m^3 of stacked wood contains less wood than 1 m^3 of solid wood.
- Weight (e.g. kg, ton): Used for forestry and energy statistics. Conversion between volume and weight units is not straightforward, because the density depends on wood species and moisture content. For energy assessment, weight units are more appropriate than volume units, because energy content varies widely per unit of volume depending on the density.
- Energy (e.g. joule, BTU, ton of oil equivalents): Conversion between energy units can be done using standard conversion values. Conversion from weight to energy is less easy because large variations may exist in moisture content, and consequently in the energy content.

(d) Levels of Energy

Before energy is ready to be used for a particular purpose, it has to go through a number of conversion processes to produce a final product from natural sources. In the stages of energy production, conversion and consumption, we can distinguish four levels of energy:

- Primary energy: the raw form in which it is available in nature, before any processing, e.g. wood from trees, oil reserves, running water;
- Secondary energy: energy after a conversion process in a form in which it can be transported or transmitted to the market place, e.g. charcoal, diesel, electricity;
- Final energy: the form in which it is available to consumers in the market place, e.g. charcoal for sale on the market, diesel at the gas station, electricity from the grid or batteries;
- Useful energy: the actual energy required for the end-use, almost always in the form of heat, mechanical shaft power or electrical power. Useful energy is only the part actually used for the end-use, the rest is called loss.

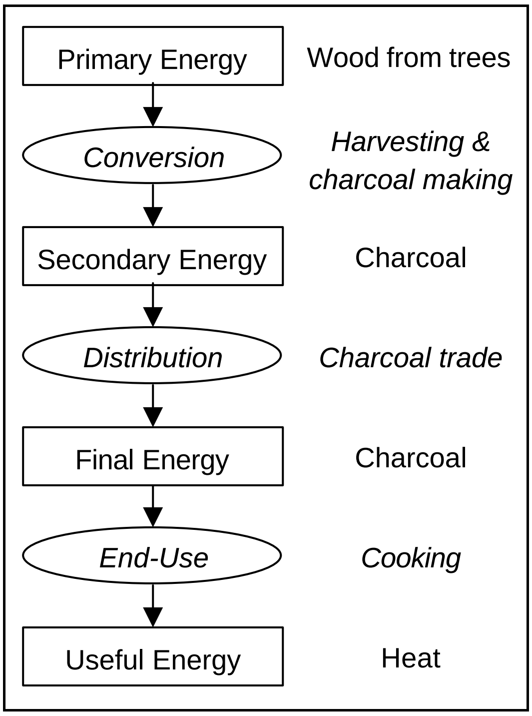


Figure 3.1 Wood energy system example

Taking charcoal for cooking as an example, the primary energy is wood in the form of trees. The secondary energy is charcoal after conversion in a kiln, and the final energy is charcoal for sale at the market. The useful energy is the heat for cooking generated by burning the charcoal, but only that part of the heat that is directly used for the preparation of the food. The rest is lost, due to the warming up of the stove and heat losses to the environment. Note that there can be short cuts to these stages. For example, when branches are collected and directly burned as fuel, the primary energy serves directly as final energy.

Energy devices or technologies are used to convert one form of energy into another, either for conversion or end-use. Conversion (or transformation) devices are used to produce fuels from raw material, e.g. charcoal kiln, power plant, oil refinery. End-use devices are used to obtain the useful energy needed for a particular application, e.g. cookstoves, motorcycles, radios.

3.1.2. Wood Energy Conversion Technologies

As already stated, raw (primary) energy is converted to forms that are convenient for transport and end-use consumption. Conversion technology varies from complicated units with multiple inputs and outputs to simple, single input-output processes. Biomass conversion technologies usually are simple, single-output processes, e.g. charcoal kilns. The main conversion processes (or transformation) for wood and other biomass are listed below:

Drying is the process of removing moisture or water from the fuel, most common process used is just by air drying.

Densification is a process used to overcome the bulky nature, low thermal efficiency and the smoke emission from loose biomass fuels such of wood wastes and agriculture residues. These fuels can be processed to produce smokeless briquettes. Some processes involve the carbonisation (see following) of the residue first and then briquetted with or without binders.

Carbonisation is a pyrolytic process, the process of heating wood or biomass in the absence of air. The process breaks down wood and other biomass into liquids (tar), gases and a solid product, commonly called *charcoal*.

Gasification is also a pyrolytic process but the main product is a combustible gas, known as *producer gas*. This gas consists of carbon monoxide and hydrogen gases. There is also a liquid by-product, known as tar, which can be processed to a fuel similar to diesel.

Biogas production or anaerobic digestion is a biochemical process, a process involving the actions of microorganisms in the decay of organic matter (especially human, animal and plant wastes) in the absence of air. The process produces a combustible gas called *biogas*. The remaining slurry can be used as organic fertiliser.

Fermentation or ethanol production is also a biochemical process, the process of producing alcohol from agriculture crops such as sugarcane, cassava and sugarbeet through the action of microorganisms. The crops are sources of starch and sugar that are converted into ethanol, which can be used as liquid fuel.

Combustion for power generation: biomass fuels can also be converted for electricity, in its raw form or after one or more of the above mentioned transformation processes. Several technology options are now commercially available to achieve such conversion.

(a) Efficiency

During energy conversion and end-use, not all of the energy ends up where it is needed, and part of the energy is wasted or lost in the process. This loss is usually in the form of heat. In energy conversion part of the energy is used during the process, e.g. in charcoal production part of the wood is burned to start the carbonisation process. In end-use not all of the energy is directed to the end-use because the device and surroundings are warmed up. For example, the cookstove and air also become hot during cooking, and an electric light bulb emits both light and heat. Furthermore, combustion may be incomplete, which means that not all fuel is burned and not all energy is used.

The ratio of the useful energy output to the energy input is the efficiency of the process. In other words, the higher the efficiency, the less energy is “lost”. Efficiency is usually expressed as a percentage, i.e.

the percentage of the energy input that is directed to the end-use or available as fuel after conversion. Any energy conversion process implies losses, and the efficiency of a conversion process is never 100%. It can be as high as 90% (for example, in a well-run water turbine) or much less than this (for example, around 15% in a traditional woodstove).

Improved operation practices and good equipment design can reduce energy losses significantly. For example, properly drying the fuel before use reduces the amount of energy lost to water evaporation. For industrial processes (e.g. brick-making), using small pieces of fuelwood and continuously attending the fire by adding small amounts will lead to a more complete combustion, and consequently to higher efficiencies. Devices like kilns and stoves can be improved by regulating the air inlet to achieve a more complete combustion, and by improving the isolation to reduce heat losses.

(b) Combustion and Emissions

Wood consists mainly of carbon, hydrogen and oxygen. It also contains small amounts of nitrogen, sulphur, inert materials (which forms the ash), and often some amount of water (depending on the moisture content). Agricultural products have higher sulphur content than wood.

When wood is burned, a chemical reaction takes place that combines carbon with oxygen in the atmosphere to form carbon dioxide (CO_2), and hydrogen with oxygen to form water vapour. When the combustion is complete, i.e., the wood is burned completely, all carbon will be transformed into carbon dioxide. Growing trees capture carbon dioxide from the atmosphere, so if woodfuels are used sustainably, no net amounts of CO_2 are added.

However, when combustion is incomplete, carbon monoxide (CO) and hydrocarbons (HCs, e.g. methane) are also formed. These can have serious health impacts on users and they are major greenhouse gases, so their emission should be minimised. Combustion can be incomplete for two reasons. First, the air inlet may not be adequate, so there isn't enough oxygen to convert all carbon to CO_2. This can be due to poor equipment design, lack of ventilation or overloading of the fuel. Second, when the wood has a high moisture content, the combustion temperature isn't high enough to complete the chemical reactions.

3.2. Data for Wood Energy Planning

Wood energy data can be grouped into five categories, i.e. resources, consumption, technology, woodfuels flows and socio-economic aspects. The following sections identify and discuss types of data for each category (see Tables 3.1 to 3.4). *This does not mean that all the data items listed always need to be collected.* In practice, data requirements depend on several factors, so for a certain application less data may suffice. For example, indicative planning at macro-level generally requires less detail than a project level study. The lists of data items for each category should be seen, as guidelines to identify which data may be needed for a particular study. One should avoid collecting more data than is actually needed.

It should be noted that data not only refers to quantifiable information, e.g. the amount of fuelwood consumption by households, or the area of natural forest. Qualitative or descriptive information is important too. This includes for example social aspects of woodfuels use, qualitative assessment of success and failure of previous programs, and analyses of government structure. These types of information are as important for planning as quantitative information. For all five data categories both quantitative and qualitative information is needed.

3.2.1. Resources

Assessment of wood energy or woodfuels resources needs wood resources data and data for assessing how much of wood resources are available for energy use. In recognition that woodfuels resources do not only come from forests, FAO Forestry Department has recommended a terminology system for woodfuels under its proposed “Unified Biofuels Classification Scheme” (see Appendix A). Under this system, woodfuels is defined as follows:

(a) Definition and Classification of Woodfuels

Woodfuels include all types of (woody) biofuels derived directly and indirectly from trees and shrubs grown in forest and non-forest lands Woodfuels include biomass derived from silvicultural activities (thinning, pruning, etc.), as well as industrial by-products derived from primary and secondary forest industries, which are used as fuel. They also include woodfuels derived from *ad hoc* forest plantations. Taking account the available database, woodfuels can be classified into four groups, as follows:

Direct Woodfuels: consist of wood directly removed from *forests, other wooded lands* and *other lands* (i.e., agricultural lands, meadows and pastures, built-on areas, barren lands, etc.) to supply energy demands and includes both inventoried (recorded in official statistics) and non-inventoried woodfuels. (This woody biofuels comprise of stem, bark, branches, and twigs of trees, alive and dead, shrubs and bushes, including stumps and roots, but excludes, foliage, flowers and seeds.) Direct woodfuels can be divided into *primary* and *secondary fuels*, depending on whether they are directly burned or converted into another fuel such as charcoal, pyrolysis (or producer) gases, pellets, ethanol, methanol, etc.

Indirect Woodfuels: consist of industrial by-products, derived from primary (sawmills, particle boards, pulp and paper mills) and secondary (joinery, carpentry) wood industries, such as: sawmill rejects, slabs, edging and trimmings, sawdust, shavings and chip barks, etc. They preserve essentially the original structure of the wood and can be used either directly (i.e., as primary fuel) or after some conversion to another biofuel (i.e., as secondary fuel).

Recovered Woodfuels: refer to woody biomass derived from all economic and social activities outside the forest sector, usually wastes from construction sites, demolition of buildings, pallets, wooden containers and boxes, etc. burned as they are or transformed into chips, pellets, briquettes, powder, etc.

Wood-derived fuels: refer to woodfuels produced (as a by-product in wood processing), that do not preserve the original (rigid and solid) physical structure of wood, such as black liquor (a by-product in pulp and paper processing).

(b) Direct Woodfuels – Area, Stock and Yield Data

As discussed previously, direct woodfuels consist of wood directly removed from *forests, other wooded lands* and *other lands* (i.e., agricultural lands, meadows and pastures, built-on areas, barren lands, etc.) *Forests*[1] consist of natural forests and plantations, lands with tree crown cover of more than 10% and area of more than 0.5 hectares. *Other wooded lands* consist of lands either with a tree crown cover of 5-10% of trees able to reach a height of at least 5 m at maturity *in situ.* It also include lands with crown cover of more than 10% of trees not able to reach at height of 5 m at maturity *in situ*, shrub or bush cover. (It excludes areas having tree, shrub or bush cover specified previously but of less than 0.5 ha and width of 20 m, which are classed under “other land”). *Other lands*, which consist of agricultural lands, meadows and pastures, and barren lands, also include agroforestry, home gardens, grasslands, and lands along rivers, canals and roads.

The parameters needed in assessing direct woodfuels resources are *land area*, *stock* and *yield.* Some of these data and information, as previously mentioned before, are available as part of official statistics. Data on land areas by types of land are readily available from basic country statistics. Forestry statistics provide data on changes in forest areas and the growing stock in them. Such information are even divided by types of forests in terms of natural or plantation forests, by types forest formation (closed/open forests), by degree of human disturbance or modification, by forest composition by species group, by ecological zones, etc. However, such data cannot be used readily for assessing direct woodfuels resources as discussed as follows:

[1] See Appendix - “FRA 2000 Terms and Definitions

Table 3.1: Wood Energy Resources Data

Data Items
❖ **Direct wood resources:**
Topography and agro-ecological zonation;
Land use (e.g. forest, crops lands), which may include:
- Land area, including land use change, e.g. deforestation, increase of agricultural land and urban areas;
- Land ownership and user rights: e.g. public, private, leasing;
- Management systems, e.g. agencies, companies, NGOs, communities;
- Wood production systems, e.g. natural, plantation, agro-forestry;
- Wood productivity: standing stock and average annual yield;
- Accessibility constraints, e.g. protected areas, share of landless population;
Qualitative information, for example:
- Government agencies and NGOs dealing with land and forestry;
- Past and ongoing programs, e.g. on reforestation, land reform, tree planting;
- Regulations and policies affecting tree resources, e.g. logging ban, access rights to public resources;
❖ **Indirect wood resources:**
Production per type of industry;
Residue-to-Product Ratio (RPR): this is the average amount of residue generated per type of product. This may be available from literature, but actual values may be different because of local conditions like wood species and practices.
End-uses for residues, e.g. recycling, energy source for the factory.
Qualitative information, for example:
- Government agencies and NGOs dealing with wood industries;
- Regulations and policies, e.g. with regards to waste disposal, wood species, etc.
- Status of processing technologies and prospects for introducing improved technologies;
❖ **Recovered wood:**
Share of recovered wood in total woodfuels consumption;
Scale of activities that generate considerable amounts of wood waste, e.g. housing construction.
❖ **Agrofuels:**
Crop production per type of crop;
Residue-to-Product Ratio (RPR): average amount of residue generated per type of crop.
End-uses for residues and dung, e.g. fertiliser, raw production material.
Qualitative information, for example:
- Government agencies and NGOs dealing with agriculture;
- Use of fertilisers, e.g. animal dung, crop residues, chemical fertilisers
- Regulations and policies, e.g. open burning of crop waste;
- Acceptance of using animal dung as energy source;

Land Area and Accessibility: Not all of wood resources in forests will be available for energy purposes. Total forest areas have to be modified to *accessible forest areas* for harvesting and collection of woodfuels. Availability and accessibility of resources for energy end-uses are constrained by:

- Other end-uses: Wood is used for a variety of other purposes than energy (e.g. construction, furniture, and fodder), limiting their availability as fuel. Often residues from these other activities are used as fuelwood.
- Land ownership and legal aspects: resources may be inaccessible to certain user groups because of ownership and user rights of land, e.g. protected forests, trees on private land.
- Physical factors (e.g. infrastructure, slope, lack of transport means): Some resources may simply be too far, given the distance, infrastructure, time, money and transport means, or inaccessible due to large natural obstacles (e.g. wide rivers, mountains) and the lack of proper tools for harvesting and processing.
- Social and cultural factors (e.g. religion, taboos): trees that are considered sacred are usually not accessible to woodfuels users, e.g. certain tree species, trees around temples.
- Economic aspects: This applies mainly to the commercial trade of woodfuels. The economic accessibility of resources depends on the market price of fuelwood compared to other fuels and costs of extraction and transport

Accessibility of wood resources is very site-specific, depending on many local factors, e.g. proximity to forest areas, tenurial systems, tree management practices and road network. Accessibility also may be different for different user groups within a certain area, e.g. landless people versus landowners.

Stock and Yield Data: Stock and yield data are the parameters used for estimating the volume and biomass of trees in forests. Stock (or *standing stock*) refers to the amount of standing wood per unit of area, expressed in weight or volume (e.g. ton or m^3 per hectare). Yield (or *annual average yield*) refers to the increment of the stock per year. In principle, this is the amount that can be extracted annually, without decreasing the stock. These data can be found in most national forestry statistics. Data for all forest types may not be available, but it is important to distinguish between broadleaf and coniferous forests, because their wood productivity usually is substantially different. However, there are some countries where data are collected and published by ecological zones, which is an important determinant of the biomass productivity of forests.

Information on the volume and biomass of trees is an important indicator not only of the economic potential of forests, but also role of forests in carbon storage. However, by definition, growing stock refers only to "stem volume of all living trees more than 10 cm diameter at breast height (or above buttresses if these are higher), over bark measured from stump to top of bole. It excludes all branches." Furthermore, since the main objective of collection of these data is to tapped the economic potential of forests for timber production, stock and yield data are usually available only for tree species considered as actually or potentially commercial under current local and international market conditions.

Such data do not include significant volume or biomass of tree parts (i.e. smaller stem, branches and twigs), shrubs and bushes, and "non-commercial" species, which are substantial sources of woodfuels. As such, using such data grossly undervalues the amount of direct woodfuels resources available from forests. Unfortunately, there have very few studies done to provide the type of yield and stock data required for assessing direct woodfuels resources.

Direct woodfuels are also harvested from other wooded lands and other lands and their contribution is significant. Unfortunately, probably only data on land areas for these types of land are available. Data on stock and yield are not available as woody biomass from these types of land, viewed from a timber or commercial crop point-of-view, are not considered of economic importance as previously mentioned. (This is not actually the case, the amount of direct woodfuels used – from forests, other wooded lands and other lands – is of major economic importance both as a forestry/agriculture product or indigenous energy source.)

As such, there are very few published data on stock and yield of woody biomass that will allow a near-accurate assessment of direct woodfuels resources, particularly those from non-forest areas. One needs to be careful in using those data (in extrapolating them over wide areas or as bases for resources assessment studies in other localities), as these data are site-specific.

(c) Indirect Woodfuels Resources

As mentioned above, this consists of industrial by-products (or wood wastes), derived from primary (sawmills, particle boards, pulp and paper mills) and secondary (joinery, carpentry) wood industries, such as: sawmill rejects, slabs, edging and trimmings, sawdust, shavings and chip barks, etc. They preserve essentially the original structure of the wood and can be used either directly (i.e., as primary fuel) or after some conversion to another biofuel (i.e., as secondary fuel). It is estimated that from a standing tree, only 20 to 30% of the wood may end up in the final product.

The are two basic parameters needed to assess indirect woodfuels resources. The first is the *average amount* of woodfuels by-product (in the form of wood residues) produced per unit amount of the main product (e.g. tons of wood residues per ton of wood product). This is usually an industry norm and as such can be obtained from records. But even if data is not available, it can be readily obtained from wood balance studies in concerned industries. The second parameter is the projected *amount of production* (e.g. annual production) of the main wood product, which can easily be obtained from industry records. As in assessment of direct woodfuels resources, there might also be need to look at *accessibility factors (e.g. location, transportation, alternative uses, etc)* that may limit the potential woodfuels supply from these indirect woodfuels resources.

(d) Recovered Woodfuels

Recovered woodfuels, as mentioned above, refer to woody biomass derived from all economic and social activities outside the forest sector, usually wastes from construction sites, demolition of buildings, pallets, wooden containers and boxes, etc. burned as they are or transformed into chips, pellets, briquettes, powder, etc.

This is the most difficult type of woodfuels resources to estimate, as it is also difficult to determine the level of production/operation of the primary economic or social activities generating the wood wastes. But these woodfuels resources can be important for many urban poor families of developing countries both as their energy source and income source (for selling them). Site-specific studies are the only option available to obtain the needed data.

(e) Other Biomass Energy Resources - Agrofuels

Agrofuels are other forms of biomass energy resources obtained a product of agricultural biomass and by-products. It covers mainly biomass materials derived directly from fuel crops and agricultural, agro-industrial and animal by-products. These biofuels are also important energy sources in several countries, substituting woodfuels use. The types of agrofuels are:

Agricultural by-products (or crop field residues) are mainly vegetal materials and by-products derived from the production, harvesting, transportation and processing in (on-site) farming areas. Field residues are residues that are left in the field after harvesting. They are scattered over a wide area (making it difficult to collect for fuel use), and are generally used as fertiliser. It includes among others, maize cobs and stalks, wheat stalks and husks, groundnut husks, cotton stalks, etc.

Agro-industrial by-products refer to residues produced in the processing (e.g. milling) of crops such as sugar-cane bagasse; rice/paddy husks and hulls; coconut shells, husks, fibre and pith; ground nut shells; olive pressing wastes; etc. They are available at a central location. Some agro-industries use their own process residues as an energy source for generating heat and electricity.

Besides being used as energy source, both field and process residues are used for several other purposes, such as fodder and raw manufacturing material, so an assessment of how much is available as fuel needs to be made. In some cases they are just burned as waste.

Animal by-products refer to dung and other excreta from cattle, horses, pigs, poultry and, in principle, humans. It can be dried and used directly as fuel (which is the more popular application today), or converted to *biogas* by anaerobic fermentation.

Similar to indirect woodfuels, The are two basic parameters needed to assess biofuels resources. The first is the *average amount* of biofuels by-product (in the form of residues) produced per unit amount of the main product (e.g. tons of residues per ton of agricultural product). There is usually an established norm for this that can be obtained from records. But even if data is not available, it can be simply obtained from actual field measurements. The second parameter is the projected *amount of production* (e.g. annual production) of the agricultural product that can easily be obtained from agricultural statistics. As in assessment of woodfuels resources, there might also be need to look at *accessibility factors (e.g. location, transportation, alternative uses, etc)* that may limit their potential as energy source.

3.2.2. Consumption

Wood energy is used by different groups of users, and for different types of end-uses. In many countries, household cooking is the largest end-use, but other sectors like industries and services are major users as well, and they need to be considered. At present, usually, data can be found for the households sector but are unavailable for other sectors, probably because more studies have focused on the household sector. It can be assumed that this lack of data (see Table 3.2) on wood energy consumption by industries and services has led planners to underestimate consumption.

Woodfuels can be used for different types of energy end-uses, but today are used mainly for applications that require heat, like cooking, space heating, drying and firing. Modern wood energy technologies are available to generate steam and electricity, but at present their use is not widespread and limited to specific industries.

In collecting energy consumption data, data for other fuels that can substitute woodfuels are also needed to assess incidences and options for fuel switching.

Consumption Patterns - Data on both woodfuels and that of alternative fuels (e.g. agrofuels, kerosene, LPG, etc) consumption patterns are needed. Data on energy consumption patterns are needed to allow energy planners to identify the factors influencing energy consumption, analyse how the future demand of wood and alternative energy sources are affected these factors, and project future demand for wood and other energy sources.

The first factor affecting energy consumption is the type of end use. For households, woodfuels are mainly used for cooking, but also for space heating, water heating and drying. The choice for fuel and the pattern of consumption depend also on availability and prices of fuels and energy devices, household income, household size, climate, preferences and cultural factors (e.g. diet, cooking habits, rituals). Where woodfuels are collected for free, consumption levels depend also on the available time and labour to collect woodfuels. Consumption pattern data means gathering energy consumption data vis-à-vis these factors mentioned. The effects of these factors on consumption may differ by area (e.g. country by country, region by region, rural vs. urban, dry vs. wet area, hills vs. plains), so *data disaggregation* into sub-areas is preferable. Consumption patterns change over time, so *historical data* are needed to develop projections for future consumption patterns.

Industries using woodfuels can be divided into wood-based industries (i.e. primary and secondary wood industries – see Section _), agro-processing industries (e.g. sugar processing, food canning, tobacco, etc), and others (e.g. mostly rural-based industries such brick-making, lime burning, etc). Many agro- and wood-processing industries use their own residues as an energy source, either to generate process heat or electricity, or both. (The simultaneous generation of heat and electricity is known as co-generation or combined heat and power generation or CHP). Data on energy consumption by industries have to be provided by types of industry and end-use.

Table 3.2: Wood-Energy Consumption Data

Data Items
❖ **Households:**
availability and prices of fuels and devices;
use of devices (e.g. improved stove, LPG stove);
population (total and distribution), number of households, average household size;
average energy consumption per household or per capita, possibly divided into:
- rural or urban area;
- income group (e.g. low, middle, high);
- household size;
- end-use (e.g. cooking, space heating);
- device (e.g. traditional or improved stove);
- fuel (e.g. fuelwood, charcoal, crop residues, LPG, kerosene);
sources of woodfuels (e.g. purchased, collected) and time and money spent;
qualitative information, for example:
- Government agencies and NGOs dealing with household energy;
- Programs and policies, e.g. fuel subsidies, improved cookstoves;
- Status of devices, prospects for introducing improved devices.
❖ **Industries:**
For each type of industry (e.g. brick-making, tobacco, pottery, food processing):
availability and prices of fuels and devices;
economic factors, e.g. investment and operation costs;
production: current and past levels;
specific energy consumption per unit of production, possibly divided into:
- rural or urban area;
- process and types of equipment;
- fuel (e.g. fuelwood, charcoal, LPG, kerosene);
sources of woodfuels (e.g. purchased, collected) and time and money spent;
qualitative information, for example:
- Government agencies and NGOs dealing with industries and energy;
- Regulations and policies, e.g. fuel subsidies, support to certain industries, privatisation efforts;
- Status of technologies; prospects for introducing improved technologies.
❖ **Services:**
For each type of establishment (e.g. restaurant, hotel, hospital):
availability and prices of fuels and devices;
number of establishments;
specific energy consumption per establishment, possibly distinguished by:
- rural or urban area;
- end-use type (cooking, space heating);
- device (e.g. traditional or improved stove);
- fuel (fuelwood, charcoal, LPG, kerosene)
sources of woodfuels (e.g. purchased, collected) and time and money spent;
qualitative information, for example:
- Government agencies and NGOs dealing with services and commerce;
- Regulations and policies, e.g. fuel subsidies, licences for starting a business;
- Status of devices, prospects for introducing improved devices

The service sector consists of commercial establishments (e.g. restaurants, hotels, shops, food vendors) and institutions (e.g. hospitals, schools, offices, army camps). Many of the commercial establishments are part of the so-called informal sector, i.e. unregistered activities (e.g. road-side food vendors) that are generally not included in any statistics, but that may be major woodfuels users. The service sector uses woodfuels for similar end-uses as households, like cooking and space heating, but generally in larger quantities using larger devices, and similar factors determine consumption patterns. Data on energy consumption have to be provided by types of establishments and end-use. Like in the household sector, disaggregation by area may also be necessary.

3.2.3. Technology

Technology data refers to information on the technologies (i.e. equipment and/or process) used for producing and consuming energy. Energy technologies can be distinguished between conversion (or transformation) technologies and end-use technologies. Conversion technologies are used to transform primary energy resources such as wood into more convenient energy forms, e.g. charcoal or electricity. End-use technologies are used by consumers for end-use activities, e.g. for cooking, space heating, or process heating for post-harvest, agro-industrial and manufacturing activities.

Traditional wood energy technologies for both conversion and end-use that are now widely used are usually inefficient and of low quality. Combustion of woodfuels is often incomplete in traditional end-use devices, leading to emissions of pollutants. Often, users make the devices themselves from locally available materials. Designs vary from area to area. Data on traditional technologies, mainly on traditional stoves, are therefore not generally available. The type of data needed include technical specifications, like fuel properties, design characteristics, material of construction, and efficiency. Health aspect data, such as emissions, are also important. In cookstove design for example, other information such as “indoor impacts” of emissions, and “cooking positions” are also important.

Increasingly, wood energy is used with modern technologies, like co-generation or combined heat and power generation (CHP), and dendro-thermal power systems (integrated woodfuels plantation – wood-based power generation system). Both are process combining conversion and end-use technologies. Modern wood stove technologies that allow more convenient, clean and efficient use are increasingly available too. Data on these technologies are generally available from laboratories and/or manufacturers, and are sometimes published on journals and other forms of technical literature.

3.2.4. Woodfuels Flows

A lot of woodfuels are collected for free by users, but a large share is produced and distributed commercially through an extensive network of producers, transporters and traders, a so-called woodfuels flow system. Woodfuels trade occurs often at small-scale and outside the official economy, but in total it may be substantial. It is an important source of income and employment, especially for the rural poor, and in times of hardships, for example when crop harvests are low. Data on woodfuels flow systems are needed to characterise the trade and actors involved, and to identify the main woodfuels sources, e.g. farmland, forest.

In many Asian countries the forest authorities restrict the distribution and marketing of woodfuels. The amount that can be transported freely is limited and for larger amounts the trader needs to obtain a permit in advance that is often checked during transportation. In this way, forest departments aim to control the illegal extraction of wood from forests, but in fact many woodfuels come from non-forest sources. Therefore, the restrictions may have a contra-productive impact, because they act as a disincentive for planting trees on private land and they hamper the free flow of woodfuels. Data on sources and distribution of woodfuels can help to develop better policies and regulations that allow for a healthy market for privately produced woodfuels.

Table 3.3: Wood Energy Technology Data

Data Items
For each type of device in use, both for conversion and end-use, the following data are useful. For devices that are not used (yet), these data are relevant as well, in order to evaluate options for introducing new technologies:
Number of devices in use by type of user and conversion process;
Technical specifications, like
- material
- fuels that can be used
- characteristics (e.g. with or without chimney, fixed or movable)
- origin (e.g. local, imported, share of local components)
- efficiency
- emissions of pollutants (e.g. CO_2, CO)
Operation characteristics (e.g. require small pieces of wood, continuous feeding, used in sitting or standing position);
Costs of investment and operation (e.g. fuel, maintenance);
Stage of commercial feasibility (e.g. still under research, too expensive, feasible);
Production process
- Number of producers/factories;
- Number of devices produced annually or monthly;
- Cost of production
Qualitative information, for example
- Government agencies and NGOs dealing with energy technology
- Regulations and policies, e.g. import restrictions on foreign technology
- Past and ongoing programs, e.g. on cookstoves, charcoal kilns, brick kilns
Status of devices; prospects for introducing improved ones

Table 3.4: Woodfuels Flow Data

Data Items
Production:
- sources (e.g. forest, farmland, sawmills);
- producers, including the role of women in production (e.g. land-owners, middlemen);
- production system (e.g. dedicated plantations, residues, collected from public land);
- production costs (e.g. tree planting, stumpage fees);
Transport:
- modes of transport (e.g. carried, pushcarts, trucks);
- restrictions and regulations (e.g. permits, taxes);
- average distances;
- quantities;
- transportation costs (e.g. labour, truck rental, gasoline);
Charcoal production:
- types of charcoal kilns;
- quantities produced;
- costs (e.g. purchase of wood, labour);
Pricing and costs: prices and cost build-up at different stages:
- costs of production and transport;
- taxes and fees;
- cost margins for producers, transporters, wholesalers and retailers;
Social aspects:
- income and employment from woodfuels production and trade;
- gender: involvement of women;
- health: hazards of felling, carrying, and charcoal production (e.g. emissions, burns);
Environment (e.g. over-exploitation of resources).

3.2.5. Socio-Economic Aspects

Data on several socio-economic aspects are needed to get a better understanding of the area under study, and to develop projections for wood energy demand and supply. Most of these data generally can be obtained from existing sources like the national statistical office or planning agency, and miscellaneous studies.

Data Items - The main types of socio-economic data are discussed below. It is not meant as a checklist for what data need to be collected, but it only suggests items that may be relevant. Before and during data collection it is important to consider what information on these aspects is really needed, depending on the objectives and limitations of the study. The collection of information that may be interesting but is not relevant for the study should be avoided (FAO, 1983).

Demography: basic parameters are number of population, number of households, population density and population growth rate. Also the distribution of gender and age groups are relevant, for example for patterns of fuelwood collection. Rates of births and deaths, compared to the national figures, can be indicators for health and poverty. Also patterns of migration, and whether these are seasonal or permanent are relevant.

Economy: economic activities have a clear relationship with energy use, and economic statistics can serve as indicators for present and future levels of energy consumption. Basic parameters are Gross Domestic Product (GDP) for the area under consideration, and sectoral production data for different types of industry and enterprise sectors. Also general patterns of technology, agricultural production, markets, credit, communications, occupations are relevant.

Income: this is a major factor in fuel choices and quantities consumed. However, income is often difficult to measure. First, people may be unwilling or unable to give precise figures of income, and income can be in other forms than money, e.g. food or services. In that case other indicators can be used to estimate wealth, like land ownership, livestock, trees owned, type of housing and household possessions (e.g. motorcycles, radios, clothing). Secondly, there is no such thing as a household income. Individual household members may not share all earnings and spending decisions. In particular, gender roles can have a major influence here.

Gender: different roles of men and women may have a major influence on patterns of wood energy consumption and production. For example, in general women are responsible for cooking and woodfuels collection, but they don't always have a saying in spending decisions, so even if a household could afford to buy woodfuels it might still rely on collected fuels. This relates also to opportunities for women to earn income. If a woman can earn more income from labour by saving time (e.g. buying fuels instead of collecting or using an improved cookstove), the decision-maker, usually a man, may consider it worth to spend money on this. Other gender specific information includes health impacts of cooking and fuelwood collection, and access to resources like land and trees.

Environment: Additional environmental data includes physical characteristics of the area (e.g. climate, slopes), the availability of resources (e.g. land, soil, forest, water), and impacts of human activities. Examples are the rate of deforestation, land quality and loss of top soil, quality of water and air, and condition of wildlife.

Social: income and access to resources also relates to social divisions in a society, for example ethnic and religious divisions, and landless versus landowners. Other aspects are illiteracy rates and the shares of population in absolute poverty and with access to health services, clean water and sanitation.

History: some events in the past may have impacts on wood energy, e.g. wars, road construction, population movements, so it is good to be aware of these.

Political-Administrative: examples are: the government structure, the existence of agencies at central and local level, the level of people's participation in decision-making, the role of NGOs, and the impact of laws and regulations on woodfuels. This information is relevant for data collection itself, for example government agencies can be sources of data and can be involved in data collection. It also relevant for implementation of follow-up activities, e.g. special projects that are the outcome the planning study.

3.2.6. Complications in Wood Energy Data

Several factors can complicate the accounting of wood energy, basically stemming from the nature of wood energy use and production. Some are listed below:

- Patterns of energy consumption and production are very site-specific depending for example on the type of area (e.g. rural or urban), agro-ecological conditions, availability of local resources and alternative fuels, climate and local practices. These patterns can even vary per season. It should be noted that this applies to all fuels, not only woodfuels. For conventional fuels, accurate and regular data on production and consumption are available, but this is only at aggregated, mostly national level. Detailed information on end-users and applications and corresponding consumption patterns are generally not available from suppliers (such as oil and electricity companies), and this can only be obtained from surveys.
- Significant volumes of woodfuels, like most biomass fuels, are by-products of other activities. Woodfuels are produced from forestry (logging, timber harvesting) and wood processing industries. Woodfuels also produced from trees cut down during conversion of forests to other land use such as farming. These other sources of supply have to be accounted for also.
- Wood resources can be used for several end-uses other than energy use (e.g. construction material, electric poles) which makes it difficult to distinguish energy products from these other activities. An understanding of the interactions among different end-uses and biomass products is required for energy evaluation.
- Many rural households collect and produce their own fuels from biomass resources on private or public land, and they keep no records of the quantity.
- Woodfuels are often collected and measured in non-standard units (such as bundles, bags, head loads, and baskets) which can vary from person to person, season to season, and area to area.
- The density and moisture content, and consequently the energy content, of woodfuels can vary per wood species, area, climate and season.
- Available information on agriculture, forestry, household expenditure is generally inadequate for the purpose of wood energy planning. For example, forestry data on standing stock and average annual yield of forest types usually refer to the stem volume of commercial tree species only and ignore the crowns including the branches and twigs these species. Such forestry data also do not include non-commercial tree species and other woody biomass such as shrubs and bushes. Furthermore, both forestry and agriculture statistics do not provide data on wood resources from non-forest lands.

These factors require surveys to be complemented with physical measurements to obtain data on consumption and production. The list may make it seem nearly impossible to obtain good wood energy data. However, for most applications of wood energy planning, the level of detail and accuracy doesn’t need to be high. In most cases it will be sufficient to have an indication of the main trends of demand and supply and an overview of technical, economic and social aspects. These difficulties with data also highlight the need for a decentralized area-based approach to energy planning.

3.3. Data Collection

In the following sections several aspects of wood energy data collection are discussed. Many of these aspects are not only relevant to wood energy: they can be applied in other fields as well.

3.3.1. Data Requirements

Before choosing data collection methods and starting data collection, level of the data requirements have to be defined clearly, i.e. which type of information is required, and at what level of detail. In some cases, only a few of the data discussed in section 2.2 will be needed. The requirements depend on several factors:

- Objectives: What are the data needed for (e.g. overviews, project planning), and what is the level of implementation? For example, an indicative overview of woodfuels demand and supply at national level will require different data than for a project that aims to increase employment and income opportunities from wood energy production at village level. In the former case, data does not need to be very specific, while in the latter case detailed data on the current income and employment situation and opportunities are needed. In general, data requirements for policy analysis will be less detailed than for implementation programs.
- Level of planning: What is the area under consideration, e.g. the whole country, a province or a few villages? For national planning, less detail may be needed, and the size of area will also determine the level of detail and which data collection methods can be used.
- Type of area: Areas with different characteristics will have different data requirements, e.g. rural versus urban areas. For example, in urban areas most woodfuels are traded commercially, so data on prices of woodfuels and other fuels are needed. In rural areas, people may have more ways to obtain woodfuels, so data are needed on different woodfuels sources, e.g. crop fields, home gardens, forests.
- Time, personnel and budget: Apart from technical considerations, the available time, qualified staff and budget will limit the amount and level of detail of data that can be collected.

3.3.2. Secondary Data Collection

Secondary data refer to data from existing publications, statistics, databases and studies. These are very important sources of information, and a review of existing publications and statistics should be the first step in data collection, since they may contain a lot of useful information and they can save a lot of time and money. Nevertheless, secondary data can vary considerably in reliability, quantity, scale and frequency, so they should be carefully reviewed and checked.

Secondary data may be available from a variety of official, historical and other sources. Many basic socio-economic data (e.g. population, income), both at national and sub-national level, will be available from statistical reports. Historical data on various topics need to be reviewed to identify past trends and to be able to develop forecasts. Social studies on related topics can provide useful background information.

For wood energy, useful secondary data are statistics on population, economic growth, agriculture and industrial production. If available, methods and results of past energy consumption surveys should be reviewed before conducting a new one. Forestry statistics on wood resources may be available, but these often refer only to stem volume of commercial trees in forest areas. Studies of social aspects and energy technologies may be available from universities and research institutes. Private businesses may also be able to supply data on technologies. In some cases, even data from foreign publications can be used, particularly on technologies and resources. Policies, laws, regulations and programs should also be reviewed.

3.3.3. Primary Data Collection

Primary data collection means the collection of data from surveys. These surveys are carried out to collect data that are missing or to update earlier data. Several survey methods exist, ranging from structured surveys to rapid collection methods. No single method is the best, and the choice will largely depend on the data requirements. In general, a combination of different methods is preferable. An overview of common methods is given below. For more elaborate discussions see FAO (1983).

(a) Sample Surveys

Sample surveys are a widely used method of collecting all kinds of data. It is the generally accepted method for collecting household energy consumption data. A sample survey is based on the principle of random selection, which limits the influence of subjective judgement of the data collectors. Sampling techniques range from pure random sampling, which selects samples from the total population, to multistage, stratified random sampling, which divides the sampling procedure into several stages, starting with the selection of large units (e.g. districts, villages), followed by the selection of smaller units (e.g. households) within selected large units. Sample surveys are needed to obtain data at national level, but they may be applied at sub-national and local level as well.

Most countries have a statistical office that collects basic socio-economic information through sample surveys. When doing a wood energy survey it is recommended to do this in cooperation with the statistical office, e.g. for the selection of samples and the development of questionnaires.

Sample surveys are generally used for interviewing people, possibly in combination with physical measurements. For wood energy surveys interviewees could be, for instance, household members, woodfuels traders, charcoal producers or managers of industries. For wood resources assessment they can also be applied, by randomly selecting sites (e.g. from a satellite image) and doing actual measurements of tree volumes and densities on each site. Sites can be in forest and non-forest areas (see ESMAP, 1993 for an elaborate wood resources assessment study in Pakistan).

Sample surveys can provide a wealth of information, but they are time consuming and expensive. Another drawback is the difficulty to account for non-quantifiable, social aspects when doing sample surveys, because these cannot be easily incorporated into standard questionnaires, interviews and measurements. Therefore, additional methods are often needed in order to prepare for a sample survey and to collect additional information.

(b) Measurement Techniques for Sample Surveys

After selecting samples, data need to be obtained from each sample. The main instruments for this are questionnaires, interviews and physical measurements. Often, a combination is advisable. For example, in energy consumption surveys, questionnaires can be used, supported by physical measurements to actually measure the consumption reported by interviewees.

Questionnaires - A questionnaire is composed of structured questions prepared in advance. Sample surveys usually make use of questionnaires, which offers several advantages. First, data on specific items can be collected quickly by cheap and inexperienced staff after a short period of training. Second, questionnaires provide structure and comparability, and survey results can easily be transferred into standard forms for analysis. Questionnaires are most effective when supported and tested by an experienced person with personal observations, insights and knowledge. The design and preparation stage of questionnaires is extremely important. First, a basic knowledge of the community is required to know which questions to ask or not to ask. Second, a brief pre-testing is required for refining and clarifying the questions.

For household energy consumption surveys, it is important to identify the right person to interview. For example, women usually do the cooking and often the fuelwood collection, so they can provide more accurate information than men can. However, it may not be easy to directly contact the woman in a household, especially for a male surveyor. Also the location of the interview is important, preferably it should be held at the site of the activities, e.g. in the kitchen, near a charcoal-making kiln, so questions and answers can be directed by visual aspects.

The design of a questionnaire will differ for each application. Annex 2 contains some examples of questionnaires that can be used for household surveys on wood energy.

Interviews - Instead of questionnaires, open-ended or semi-structured interviews can be used for sample surveys, to allow for more flexibility during the interview. Of course this is only feasible with more experienced interviewers and a small number of samples.

Interviews with selected individuals or households are also useful for obtaining additional information during surveys. For example, to identify questions for a questionnaire some households can be interviewed first. Interviews can also help to crosscheck and clarify results, and to obtain non-quantifiable information. An open-ended type of interview allows the conversation to be directed by the respondent. A minimum set of pre-selected questions gives the interview structure and comparability. Similar to questionnaires, the selection of the person to be interviewed and the location of the interview are important.

Physical Measurements - During interviews, respondents are not always able to precisely indicate amounts of woodfuels in physical terms, or they use local standards, such as bags and baskets. Therefore, physical measurements are needed to get more accurate data. For consumption surveys, interviewers can make use of a portable scale to weigh the amount indicated by a respondent. Physical measurements are also needed to obtain conversion values for local standards, e.g. by weighing a number of bags in the market. Also the density of the main woodfuels species and the moisture content of air-dried wood need to be measured, in order to establish local standards and conversion values.

For wood resources assessment, field measurements are required to determine dimensions, forms, volume, density, age, stand density and increments of trees, in both forest and non-forest areas. The main parameters are tree diameter, height, and crown width. For several tree species relationships between different parameters are established (e.g. between crown width and tree diameter), which can be used to estimate the total biomass from measured parameters. For sample surveys, maps or satellite images can be used to select sample sites, after which measurements at these sites are to be conducted.

Satellite Images and Aerial Photography - Satellite images are available at regular intervals and relatively low cost, so they are useful when no recent or adequate land use maps are available. They can also be used to obtain samples for assessment of wood resources. However, their use requires technical expertise and equipment. Aerial photographs are expensive and generally not available at regular time intervals. Nevertheless, when available they can provide a wealth of information for a trained user.

(c) Other Survey Methods

Besides sample surveys, several other survey methods exist. These are mostly applicable for local level studies and project formulation, but they are also useful for preparing sample surveys.

Interviews with Key Informants - A key informant is a person who is knowledgeable, who has contacts and who is willing to talk, such as a village headman, a large farmer or the headmaster of the local school. Other important key informants are people with valuable experiences and insights from outside the community and specialists in certain fields, e.g. a social scientist or a charcoal producer. Two problems of using key informants are bias and representation. People differ in wealth, occupation and age and no individual can represent all the perceptions of a community. However, when cost and time are limited key informants can be a useful and rapid source of information. Furthermore, key informants can be useful in the preparation of sample surveys, for example to check initial survey results and to clarify unclear relationships. At the preliminary stage of a study, key informants can help the survey team to become familiar with the area and local aspects.

Group Interviews - A group interview is a short-cut method of rapidly gathering data. A group of people can be highly informative, by modifying, supplementing and contradicting individual statements. Often interviews with individuals in public places evolve into group interviews because other people will join in the conversation, out of curiosity, suspicion or willingness to help. Guidance of group interviews requires a flexible balance between sticking to the main topic and allowing people to wander from the main topic when they provide useful information. Like key informants a group cannot represent a whole community. Also social relationships can prevent people, particularly women, to speak or disagree openly. To overcome this, groups of men and women should be interviewed separately.

Observations - By simply observing people and the environment, a lot of information can be obtained. This can be used to obtain background information during a study, to prepare for a large survey and to validate information obtained in other ways. Even a small 'windscreen survey', i.e. driving around in an area can quickly provide valuable information, for example on what crops are grown, types of housing and quality of infrastructure. When observing people's activities, three modes can be distinguished, i.e. participant, non-participant and time-allocation observation:

In non-participant observation the observer remains separate from the population's activities and attempts not to interfere. He or she must be careful not to impose preconceived notions, and must remain flexible and open to new interpretations.

In participant observation the investigator directly participates in the activities of the community, to become an 'insider', for example by helping to collect fuelwood. It improves the understanding of the community and it allows for checking the difference between what people say and what they do. However, the researcher must be careful not to influence their activities.

The time that people spend on tasks is often an important aspect of a study. Because there can be differences in the perception of time and individual daily and seasonal variations in the time spent on activities, it is difficult to get precise information from interviews. To determine a meaningful average one can make random spot observations on what people are doing at particular times, over a long enough period to generalise.

Rural Appraisal Techniques - Some development projects have failed due to the difficulty of obtaining adequate and accurate information about an area. Complex and inflexible research methods that attempted to achieve unrealistic and unnecessary levels of precision suffered from a number of biases. These include primarily visiting locations that are easily accessible, talking only to selective groups of people, visiting only during dry seasons and the assumption that local people posses little information or knowledge. These considerations leaded to the emergence of Rapid Rural Appraisal (RRA), and more recently Participatory Rural Appraisal (PRA).

Rapid Rural Appraisal is essentially a process of learning about rural conditions in an intensive, iterative and expeditious manner. It relies on small interdisciplinary teams that employ a range of methods, tools and techniques to enhance understanding of rural conditions, by combining the knowledge of local inhabitants with modern scientific expertise. Acquired knowledge and information is continuously checked and revised through observations, semi-structured interviews, field measurements and other methods (KKU, 1987). Although it is called 'rural', RRA could be applied for urban areas as well, e.g. for studying woodfuels flows.

Participatory Rural Appraisal evolved from RRA and is similar in that it aims to obtain information in a flexible way by a multi-disciplinary team. However, in PRA, local people undertake data collection and analysis, with outsiders facilitating rather than controlling. PRA techniques are equally applicable in urban settings and are not limited to assessment only. The same approach can be employed at every stage of the project cycle (World Bank, 1996).

3.3.4. Considerations in Survey Design and Implementation

The following paragraphs summarise the previous discussions into a list of steps and considerations that can be followed when carrying out data collection for wood energy planning.

Steps in survey design and implementation:

1. Definition of objectives: What are the data needed for? For national planning? Policy analysis? Or project formulation? The level of implementation is also important.
2. Identification of data requirements: Which data are needed? In addition to the objectives and level of planning study, data requirements are also determined by type of targeted area, and time and budget. Data needs have to be considered carefully before starting any data collection. Data

collection is time consuming and expensive, so it should be avoided collecting more data than needed should be avoided. On the other hand, once a survey is implemented additional data are difficult to obtain.

3. Review of existing data and studies (secondary data collection): Which data are available from previous studies and surveys? Some data may already be available, so no new surveys are needed. Wood energy relates to many fields, like energy, forestry, agriculture, economy, so the types of data needed vary widely. Consequently, data may have to be obtained from a large variety of agencies, e.g. ministries, specialised departments, local administration offices, NGOs and universities. Also, survey methods for existing data should be studied, in order to assess their reliability and usefulness. In case a new survey is needed, methods and results of similar surveys should be reviewed first. In many cases it is desirable to follow comparable methods, in order to be able to analyse past trends and to develop forecasts, rather than aiming for higher accuracy or a wider coverage. Other surveys need to be reviewed too. In particular, surveys from the national statistical office may be useful. For example, data on household income may be available from expenditure surveys, so an energy consumption survey preferably should be made compatible to these, by adopting the same sampling approach. Furthermore, past and ongoing programs have to be reviewed, to evaluate the reasons for successes and failures.
4. Choice of survey methods: How will data be collected? This depends on data requirements and available time and budget. For example, for certain data a sample survey would be the ideal method, but if results are needed quickly, another method is needed. Preferably, a combination of methods should be used. No single method is the best, and each method will supplement the others. In this way results can be compared and cross-checked as well.
5. In case a sample survey with a questionnaire is implemented, the following steps are needed:
   - Selection of sampling method: this should preferably be done in consultation with the national statistical office, which might have several sampling frames to choose from. This will make the survey compatible with other surveys.
   - Questionnaire design: This is extremely important, and it requires sufficient knowledge of the area to know what to ask. Questions should be unambiguous and phrased in such a way that they are understandable for interviewers and respondents. Avoid asking too many questions, the questionnaire shouldn’t be too long, since people can spend only a limited amount of time to answer questions. Each question should be evaluated to determine whether it contributes to the objectives of the study.
   - Pre-testing of questionnaire: This allows questions to be refined, to avoid ambiguity, embarrassment and resentment, so that they really can provide the information needed.
   - Hiring and training of survey staff: Preferably, interviewers should be locals, who know the area and the people, which will facilitate access to households and communication. However, they should have adequate skills in reading, writing and record-keeping as well. High school students and graduates can be good sources of recruits. The interviewers have to be trained in advance. They should be aware of the objectives and methods of the survey, and should have some basic knowledge on wood energy.
6. Survey implementation: When implementing surveys, one should be aware of potential biases that can distort the results. For example, it is generally easier to conduct surveys in rural areas during the dry season, because sites are more accessible and households have more time. However, patterns of wood energy may vary throughout the year, so only a dry-season survey can’t provide the whole picture. Preferably, data collection should be repeated a number times over a year. Other major biases that should be avoided are only talking to men, the elite, households near roads and people who ‘offer’ themselves as information sources.

7. Data validation and processing: During surveys cross-checking of results with interviews and observations is necessary to spot inconsistencies and inaccuracies. Final results have to be validated with results from other studies to assess their reliability. After data collection, results have to be processed and presented in comprehensible formats (e.g. tables, graphs, overviews) to be used for further analysis.

Finally, it should be noted that the local knowledge, expertise and perception are important and should be included. Preferably, there should be local participation in all stages of data collection.

3.4. Data Assembling and Presentation

After data collection, data needs to be assembled and presented in comprehensive formats, like tables and graphs. These are useful for general information purposes and as input for policy making. Periodical publication of comprehensive sets of data is useful for analysing trends.

At national level, data related to wood energy could be compiled into a wood energy database, for easy reference and comparison. This would also facilitate the integration of wood energy into national energy planning. For each country, such a database could look different in terms of level of detail and computerisation, depending on available data and database expertise. It could range from a file cabinet with copies of publications and analysis results, to a database system that stores all data and background information in a computer. Ideally it should cover all the five data categories as discussed in section 3.2.

3.4.1. Wood Energy in Energy Balances

For energy data, the energy balance is the most commonly used presentation format. An energy balance table gives an overview of consumption, conversion and production for each energy source in a certain period, usually a year. All values are given in one energy unit, e.g. petajoule (PJ) or kiloton oil equivalent (ktoe). An energy balance is usually given for a country as a whole, but it could be used for any other area as well, e.g. a village or province. An energy balance table can represent the current situation, but also the future as the outcome of a scenario.

Most Asian countries publish an energy balance every year. Unfortunately many of them do not include wood and other biomass energy sources, even though these are often major energy sources. Table 2.1 shows an example of an energy balance table specifically for wood and other biomass energy sources and products. It is similar to general energy balances, so it could be integrated into energy balances that are already used by countries.
The columns represent the different energy sources and products. These can be primary resources, like fuelwood, or secondary products like charcoal. Electricity is included here because it can (and already is in some countries) generated from wood and other biomass. Fuelwood can include any form of wood like stems, branches, finished wood products, off-cuts and sawdust, coming from different sources, e.g. from trees, processing residues and wood waste. Charcoal refers to carbonised biomass, either from wood or other biomass. Crop residues can include several types, e.g. rice husk, bagasse. Electricity is only taken into account if generated from biomass. This is generally not supplied to the grid and therefore not accounted for in electricity consumption in national energy balances. Where appropriate and relevant for a country, columns can be further disaggregated, for instance to separate bagasse or briquettes.

The rows represent different processes, distinguished in three parts: production (rows 1 to 13), conversion (rows 14 to 21) and consumption (rows 23 to 32).

In the production part, rows 1 to 10 give the primary production per source, with row 1 showing the sum. This includes only primary resources like fuelwood, crop residues and animal dung. Charcoal and electricity can only enter in the primary supply as imports and exports. Production is distinguished per type of source, in order to facilitate the formulation of policies and programs targeting specific resources. Additional categories can be added as appropriate. Imports and exports relate to the area under consideration, which need not be a country. For example, a provincial balance would show fuelwood and charcoal from other provinces as imports.

Table 3.5 - Example of a detailed energy balance for wood and biomass energy

	Energy Sources and Products	Fuelwood	Charcoal	Crop Residues	Animal Dung	Electricity	Total
1	**Primary Energy Production**						
2	Direct Resources:						
3	- Forests						
4	- Agriculture lands						
5	- Other lands						
6	Indirect Resources:						
7	- Logging residues						
8	- Processing residues						
9	Recovered Wood:						
10	- Discarded wood						
11	Imports						
12	Exports						
13	**Primary Supply**						
14	Energy Conversion:						
15	- Charcoal production						
16	- Electricity generation						
17	- Co-generation						
18	Consumption by energy sector						
19	Losses in transport & distribution						
20	Non-energy use						
21	**Final Supply**						
22	*Statistical differences*						
23	**Final Consumption**						
24	Households:						
25	- Rural						
26	- Urban						
27	Industries:						
28	- Large scale						
29	- Small scale						
30	Services:						
31	- Institutional						
32	- Commercial						

The second part (rows 13 to 21) shows all conversion processes between primary production and consumption. The final supply (row 21) presents the supply of final energy as the output of primary supply and conversion. For all conversion processes, energy inputs should be indicated as negative values, and energy outputs as positive values. Since any conversion process has losses, outputs will be smaller than inputs. Electricity generation here only includes electricity from biomass sources. When included in an overall energy balance, it would include electricity generation from other sources as well. Non-energy use refers to the use of energy products for non-energy purposes, e.g. charcoal for chemical processes. This doesn't include non-energy products like timber or furniture, which should be left out of the balance table.

The third section (rows 23 to 32) shows final energy consumption by different sectors. Rows can be added as appropriate. Row 23 gives the total final consumption for each energy source. Ideally, final supply should be equal to final demand, but in practice this may not be the case, because of gaps or errors in data. These can be included under statistical differences (row 22).

3.4.2. Formats for Resources Data

Besides the energy balance, other formats are needed for assembling and presenting wood energy data, particularly for wood resources. Unlike the energy balance, no standards exist, but the tables below are possible formats for wood resources data.

Table 3.6 - Direct Wood Resources

Land use type	Area (ha)	Stock (ton/ha)	Yield (ton/ha/yr.)	Accessibility (%)
Forest land: - natural forest (broadleaf) - natural forest (coniferous) - forest plantations - …				
Non-forest land: - crop fields - homegardens - …				

Table 3.7 - Indirect Wood Resources

Process	Production (ton/yr.)	Residue generation per unit of production (ton or %)	Availability of residues as fuel (%)
Forestry-based: - logging - saw-milling - …			
Agro-based: - rubber - coconut - …			

4. WOOD ENERGY DEMAND ANALYSIS

The aim of energy demand analysis is to provide a set of projections, forecasts or scenarios on future values and/or likely paths of energy consumption. This is needed in order to identify the possible energy trends and problems well in advance, so adequate measures can be taken and opportunities can be pursued. Measures and opportunities could be on the demand side, e.g. reducing demand or encouraging the use of alternatives, and on the supply side, e.g. increasing supply, developing new energy sources.

4.1. Conceptual Preliminaries

Before discussing the methodological aspects of energy demand analysis, such as for wood energy, the issues of consumption versus demand, the notion of useful energy, and the character of energy needs have to be clarified. (APDC)

In energy demand analysis we have to distinguish between need, demand, and consumption:

- Energy needs: the need for energy is derived from applications and services (so called end-uses), e.g. heat for cooking and space heating, motive power for transport, electrical energy for lighting, radios. Needs are site-specific depending for instance on climate and local cooking practices, and they may vary for users groups, e.g. poor and rich households, industries. Different forms of energy can meet a certain need, and at the same time not all needs may be fulfilled because some people cannot afford certain fuels and there may be scarcities in supply. Needs can be expressed as useful energy (see section 3.1.1, *Levels of Energy*);
- Energy demand: this is the need for energy sources that are used to deliver useful energy. Like needs, energy demands may not always be met due to costs and supply of fuels and devices. For analysis and forecasting, demand is expressed as a function of influencing parameters, such as population, income, technologies and economic growth. Demand is expressed in terms of final energy. Because of differences in efficiencies, demands levels for different fuels for the same end-use may vary.
- Energy consumption: this is the actual use of energy sources, sometimes also called expressed demand. Surveys usually aim to estimate current patterns of consumption, and try to link these with factors that can be used to estimate future demand.

These differences should be clearly kept in mind when doing demand analysis. What users actually need is useful energy, for which they buy or collect energy sources. Different fuels and equipment may be used for a certain end-use, each with its own characteristics, advantages and limitations, and some needs may not be fulfilled by energy carriers and technologies but by other sources, like animate power and direct sunlight. Demand analysis should go beyond the demand for final energy, and should also include useful energy needs and technologies. It should acknowledge that energy sources are not commodities, but that they provide a service to satisfy needs for useful energy.

4.2. Macro and Sectoral Analysis

Two major approaches to energy demand analysis are macro and sectoral demand analysis.

4.2.1. Macro Analysis

Macro analysis largely follows an economics approach. It considers energy demand as a function of macro-economic factors, like prices, GDP and population. It studies demand for total energy and for different fuels for the economy as a whole. Total energy demand is considered as a function of population, the level of economic activity (in terms of GDP), and national income (in terms of GNP). When analysing demand per fuel, the influence of changes in and differences among price levels are considered. Sometimes macro analysis distinguishes demand for major sectors, like households, industries, agriculture and transport, but only in broad terms.

Energy balances and reference energy systems provide the main data needed for macro analysis. It is desirable that these should cover a certain number of years. Other data needed, like economic and demographic data, are usually available from statistical offices, planning agencies and ministries. Demand forecasts should be in line with forecasts for macro factors as available from national plans. Based on available data, relationships that model energy demand can be established (see section 4.4).

Macro analysis provides a relatively simple approach to studying energy demand, and it requires few data. It can be used for defining broad policy measures and further planning activities. However, for detailed studies and area-based analysis its applicability is limited. It doesn't distinguish different user groups and it doesn't account for several important factors (e.g. income distribution, access to fuel, technology, location and social aspects) and trends (e.g. fuel substitution, technology development). For wood energy, macro analysis is hardly suitable, because economic factors are less dominant, while social and technical aspects play a greater role. Nevertheless, wood energy should be included in macro analysis, in order to study its importance in the overall energy scene.

In some simple approaches of macro analysis, the shares of energy carriers in total energy consumption are used for forecasting energy demand. This approach is too simple and often misleading since it hides actual trends. For most countries, the share of wood energy in total energy has been decreasing, but actual consumption has been increasing. Often this is not realised and acknowledged because it is erroneously assumed that a decreasing share means decreasing consumption. This misunderstanding is caused by the fact that the consumption of other energy forms, like oil and electricity, has been increasing faster than wood energy. One should realise that fuel shares only show a derived trend, and represent no actual processes. Therefore, demand analysis should consider energy consumption in absolute terms.

Similarly, it is commonly assumed that woodfuels consumption per capita will decrease with increasing income per capita. However, there is no evidence that consumption for such. (Hulscher, 1997).

4.2.2. Sectoral Analysis

Sectoral demand analysis looks at energy demand in detail per sector and sub-sector. It basically starts where macro demand analysis leaves off by looking into the detailed structure of different sectors, including technical and social aspects. Because sectoral analysis considers more aspects and goes into more detail than macro analysis, it also requires more data. Sectoral analysis can easily cover structural changes and technology development.

Sectoral analysis is implemented according to the following stages:

- analysis of current consumption patterns per sector and sub-sector;
- assessment of technologies and options for efficiency improvement and fuel substitution;
- development of several forecasts under various assumptions. These forecasts are inputs for the evaluation of trends and options for supply-demand balancing.

The first two stages are discussed in more detail in section 4.3. For forecasting, several techniques can be used (see section 4.4).

4.2.3. Considerations

For energy planning in general, it can not be said that one approach is better than the other, or one should be done before another, because the approach to be selected largely depends on the planning objectives. For most applications, and certainly at national level, both approaches are needed. Macro analysis can be used for studying broad trends and providing inputs for further studies and national policies, for instance on energy import and conservation. Sectoral analysis is needed for more detailed studies on how to implement certain policies and programs, and for analysing specific (sub-) sectors, fuels and aspects. In practice, the distinction between macro and sectoral analysis isn't even that sharp, and it is largely a question of the level of detail in the analysis. They need not be two separate studies, since macro analysis can easily evolve into sectoral analysis if more aspects are taken into account.

For wood energy and overall area-based planning, demand analysis requires a careful assessment of social, technical and economic parameters, so sectoral analysis is the more appropriate approach. Since these parameters are different per sector, each sector needs to be studied in detail. Nevertheless, certain macro-level factors and national-level policies need to be incorporated into the demand analysis.

4.3. Sectoral Analysis of Wood Energy Demand

As stated above, in most cases sectoral demand analysis is the most appropriate method for wood energy. A general analysis of the main woodfuels-using sectors follows below. Naturally, variations occur among countries and areas, so these discussions only serve as a guideline.

4.3.1. Households

Patterns of household wood energy consumption are site-specific, i.e. they vary from country to country, and from area to area within countries. They are dependent on the type of area - the agro-ecological situation, the socio-economic conditions, the availability of local energy resources and alternative fuels. Some parameters can still change because of seasonal variations. Nevertheless, some general observations can be made.

1. Most of the woodfuels are used for cooking, while space heating and water heating for bathing are important in colder areas. In some cases there is multiple use of devices and fuels, for instance when the heat from cooking is used for warming the house and drying goods, and the fire provides light.
2. Most woodfuels are used in rural areas and are collected for free. They are usually by-products of forests, tree-based agricultural production systems and wood-processing industries. These types of woodfuels may be in the form of stems, twigs and branches of standing trees, dead wood, residues from commercial logging, industrial residues, and discarded waste wood from different sources (e.g. old furniture, crates, pallets, recovered wood from old construction activities, driftwood).
3. Because in rural areas, woodfuels are collected for free, consumption patterns are hardly affected by income levels. They are affected by the availability of woodfuels, other biomass fuels, and the labour and time to collect fuelwood. Mostly women and children collect woodfuels. So as long as women's labour is not valued, fuelwood will remain cheaper than fossil fuels.
4. Households may switch to other biomass fuels such as crop residues and animal dung when woodfuels or labour to collect wood are in short supply. Fuel switching from woodfuels to fossil fuels occurs in areas where these fuels are available, accessible and affordable, such as in urban areas. In these areas, rising incomes can lead to increasing woodfuels consumption, but higher-income households may switch to the use of fossil fuels.
5. In urban areas, woodfuels are often purchased and they compete with other traded energy sources. Household cooking is still the main end-use, but a considerable amount of woodfuels is used by the enterprises. It includes restaurants, roadside food vendors and many small informal sector service enterprises. It also includes large industrial enterprises. Fuel prices play a role in the choice of fuel by these users, but so do the price of devices, convenience of use, stability of supply and cultural preferences. Since urban users purchase woodfuels, they are sensitive to relative fuel prices so inter-fuel substitution can occur as their income status changes.
6. Rural users generally use stoves of poorer quality than urban users. Rural stoves are mostly self-made from local material, and do not require financial expenditure. There are opportunities for woodfuels conservation by introducing more efficient stoves, but when fuelwood and devices are free goods, fuelwood saving is not always a concern for rural households. Besides their inefficiency, the use of traditional stoves can have serious health impacts, due to the smoke.

Cookstoves

For cooking, several types of stoves are used. The simplest and oldest is the three-stone stove, built by arranging three stones in a triangle around a fire, so the cooking pot can be put on the stones. A variation is the tripod, a metal ring with three legs, which is widely used in Asia. Major drawbacks are dispersion of flames and heat because of the wind, poor control over the fire, exposure to heat and smoke, and fire hazard. Over time other stoves have been developed to overcome these problems. These are either fixed in the kitchen or portable, and come with or without a chimney. They are either self-made from local materials by households, installed by local stove builders or mass-produced and purchased from the market. Locally available material that is used for building stoves differs from area to area. While in some areas only mud is available, in other areas even wheel rims are used to make stoves. Still many of these stoves are of poor quality and have shortcomings. People try to improve their stoves gradually but generally they lack the technical-know how and financial means to achieve major improvements.

Cooking with poorly or improperly designed stoves emits several serious pollutants such as carbon monoxide (CO), methane (CH_4), particulates and other products of incomplete combustion (PIC). These can cause direct health problems, such as headaches, respiratory diseases, adverse pregnancy outcomes (e.g. stillbirth, low birth weight), cancer and eye problems. Women are generally the ones responsible for cooking, so they and their young children can be exposed to smoke for many hours. Generally, women are not sufficiently aware of the hazards and the need for ventilation, and do not relate smoke with health problems they or their children may have. Other major health hazards related to cooking are fires in kitchens, and the poor ergonomics of cookstoves, which cause women to spend hours in uncomfortable positions.

Analysing Demand by Households

In analysing household wood energy demand, several factors need to be considered:

1. <u>Average consumption</u>: Together with data on population and the number of households, this is the basic parameter for assessing total household demand. Average consumption can be expressed on a per capita basis per household. Preferably, it should distinguish different end-uses and user groups, e.g. by the agro-ecological condition of their location (wet tropical forests or arid croplands) and their socio-economic situation (e.g., rural or urban, income levels).
2. <u>End-uses</u>: Consumption should preferably be distinguished by end-use, such as cooking and space heating. In practice, this may be complex because of the multiple use of devices. Also energy use for household businesses should be distinguished, because it is driven by other factors than domestic use.
3. <u>Income</u>: With changes in income, consumption patterns may change. Despite the difficulties in measuring income (see also section 3.2.5), income is a major factor affecting energy consumption, and as such should be measured. However, one should avoid assuming automatically that with an increasing number of household having higher income, total woodfuels consumption will decrease, because this may not always be the case.
4. <u>Fuels and stoves</u>: Their characteristics determine the demand for final energy, the important aspects are efficiencies, prices and operation characteristics.
5. <u>Household size</u>: A relationship exists between household size and the level of woodfuels consumption. Because of economy of scale, the consumption per capita for large households is lower than for small households. Large households tend to have higher income and more labour available for fuelwood collection.
6. <u>Woodfuels sources</u>: Woodfuels may be collected or purchased. If collected they may come from own land (e.g. home gardens, crop fields) or public land (e.g. forests, wastelands, village plantations). The way people obtain their fuels has an impact on levels of consumption and possibilities for fuel switching and conservation efforts.

7. Gender: Generally women are the woodfuels users, and men control most of the household cash flows. Their perceptions and interests will differ, which may affect the choice of fuels and devices, and the effectiveness of interventions.
8. Preferences and practices: Depending on food habits, households may have preferences for certain stoves and fuels, e.g. for grilling meat. Also cooking practices play a role. For instance, cooks may be engaged in other activities during cooking so they need to be able to leave the fire unattended safely.

4.3.2. Industries

Industries, mainly in rural areas, are also substantial consumers of wood energy. These are mainly small and medium scale industries, and many operate informally, i.e. without registration, bookkeeping and tax payments. Many are family or village businesses, using traditional methods and serving traditional markets. They also tend to have low start-up costs, few assets, low profit margins and high labour intensity. In addition, usually owners and labourers have no formal training in management, marketing or technology, and have no means to obtain this knowledge. These industries provide substantial employment in rural areas.

Woodfuels using industries can be grouped in seven categories:
1. Agro-processing industries like tobacco and tealeaf processing, rice-milling, sugar production, rubber sheet smoking, and processing of coffee, cocoa and spices. Fuelwood and other biomass are used to dry or boil the products and to produce steam and electricity for mechanical power. Some processes use their own residues, like rice-husks, bagasse, and coconut shells, to generate steam and electricity.
2. Food processing industries like bakeries, dairy products, distilleries and fish smoking. Fuelwood is used to fire ovens, boil products and generate steam and smoke.
3. Metal processing industries, like blacksmiths, foundries and brass and bronze casting, which mostly use charcoal.
4. Mineral-based industries like brick making, lime burning and ceramics, which use fuelwood and other biomass in kilns.
5. Wood products, like timber drying, paper, particleboard, plywood and saw milling. Wood residues of the processes are often used to produce heat for drying the wood and boiling wood pulp.
6. Textile-based industries like fabric dyeing and silk yarn processing, which use woodfuels for boiling and to produce steam.
7. Miscellaneous activities like ceremonies, cremations, road tarring and soap manufacturing.

Analysing Demand by Industries

In analysing industrial wood energy demand, several factors may need to be considered:
1. Specific energy consumption: this refers to the energy requirements per unit of production, e.g. kg fuelwood per kg of dried tobacco. Together with production figures, this is needed to estimate total energy consumption per type of industry. It should be noted that large variations in specific energy consumption could occur, depending on the scale of production, technology, fuels, operation practices, and product quality. Therefore, one should be careful in using data from other countries or areas. Preferably, different classes of industries need to be distinguished and local measurements or interviews have to be undertaken.
2. Production: reliable and complete data on production per type of industries may be difficult to obtain, due to the informal nature of many industries. Formal statistics only cover larger industries, which are not the main woodfuels users. Production figures may need to be estimated or derived from other factors. For instance, in areas where houses are mainly made of bricks, their production could be estimated from population growth.
3. Seasonal variation: production may vary per season, usually related to agricultural activities. For instance, some industries are active during the agricultural high season because of the availability of input products (e.g. tobacco curing, sugar industries), others may only operate in the off-season due to the availability of labour (e.g. brick-making).

4. Technology: woodfuels-using industries generally use technologies of poor quality, which are inefficient, dirty, and may be even hazardous to workers. Consequently, products are often of low quality. Many improvements could be made, but industries often lack the technical knowledge and financial means.
5. Costs: fuel costs can make up a large part of total production costs. In that case, industries and enterprises will be interested in implementing improvements that will save fuel.
6. Substitution: most industries could use different fuel types for the same purpose, so there is scope for substitution. In practice, this doesn't occur that often, mainly because it involves major changes in equipment which require considerable investments. Factory owners might not be able to afford this or may be unable to obtain credit. They also may not see the possible long-term benefits, or these may be uncertain due to business instabilities. Furthermore, the supply of conventional fuels may be unreliable in rural areas, which makes fuel switching a risky operation.
7. Employment: woodfuels-using industries generally are labour intensive and provide substantial employment. Introducing improvements could mean loss of jobs.

4.3.3. Services

The services sector is the third largest wood energy consumer, and uses woodfuels for similar purposes as households, i.e. cooking, space heating and water heating. It can be assumed that woodfuels consumption by the services sector is considerably larger than estimated at present, because data are hardly available. In services we can distinguish between two categories:

Commercial establishments: these are private enterprises such as hotels, restaurants, shops and food vendors. It also includes the so-called informal sector, which comprises unregistered, small entrepreneurs such as roadside and itinerant food vendors, and small eateries. Generally, no information is available about the scale and characteristics of these informal activities. For larger establishments, statistics on their number and earnings may be available, but information on energy use is limited to conventional fuels.

Institutions: these are mainly government and community organisations such as hospitals, schools, offices, army barracks. As for commercial establishments, data on energy consumption patterns is limited.

In comparison with households, services use wood energy for similar purposes but at larger scale and with larger devices. The analysis of demand is somewhat similar but far less complex than for households, because the level of consumption and choice for fuels and devices is mainly driven by economic factors such as prices and availability of fuels. Since consumption is relatively small, the analysis need not be very detailed, unless the services sector is the specific target of programs.

4.4. Forecasting Approaches

Several approaches exist for developing energy demand forecasts. No single method is the best, and the choice will depend on the planning objectives and available data. This section discusses two methods that are applicable to wood energy. Other approaches exist (e.g. input-output analysis) but these are considered less suitable. A major distinction can be made between the econometric approach and process analysis, which closely corresponds with macro and sectoral analysis and classes of energy models (see section 2.3.4). Broadly speaking, the econometric approach look at energy demand in total, possibly distinguishing energy carriers and sectors, whereas process analysis considers sectors, fuels, end-uses and technologies in detail. Both are discussed in more detail below.

4.4.1. Econometric Approach

Econometrics is a standard and widely used tool for economic analysis. It applies statistics and mathematics to economic data to build models of an economy. Based on past data, relationships are established, that describes a dependent variable (e.g. consumption) as a function of a number of so-called independent variables (e.g. prices, income). In other words, it is assumed that the dependent variable is influenced by the independent variables. Once the relationships have been established, they can be used to develop forecasts for the dependent variable based on predictions or expectations for the independent variables. The results can be used to assess the possible impact of policies and to control the course of the economy. By establishing several interdependent relationships, a model can be built.

Applying econometrics to energy planning is similar. For example, in many applications total future demand for a certain energy carrier is considered as a function of current consumption and changes in relative price (compared to other energy sources) and income (often in terms of GDP or GNP per capita). Instead of total demand, demand per capita can be used.

Relationships are mainly established by a technique called regression analysis, which determines equations from past data on the different variables. The equations approximate the relationship between the factors, often in the form of elasticities that are a measure of responsiveness of the dependent variable to changes in the independent variable. Two types of data can be used, time series and cross-sectional data. Time series data refers to a set of data available for periodic intervals, e.g. annual data for population and energy consumption. Cross-sectional data are data on several factors collected at the same point in time, e.g. energy consumption and income as may be available from a household energy survey. Also combinations of time series and cross-sectional data can be used for regression analysis, if cross-sectional data are available at periodic intervals (Gujarati, 1995).

The econometric approach has the advantage that it can easily assist in analysing energy-economy interactions and the influences of absolute and relative prices. With relatively few data it can cover energy demand for the whole economy, and assumptions made about which factors determine energy demand are explicit.

The disadvantages are that ideally experienced econometricians, of whom there are not many in developing countries, are the only one able to do it. Also, the available data may not be sufficient or reliable enough in some countries. Furthermore, for time series analysis, there should be a reasonable stability and only gradual change over time without big changes, in order to be able to establish sensible relationships. The oil price hikes of the seventies brought out this limitation clearly. Finally, the econometric approach cannot capture changes in technologies, i.e. the introduction of new technologies and the improvement of existing ones, and it doesn't consider useful energy.

4.4.2. Process Analysis

Contrary to the econometric approach, process analysis looks at types of users (sectors and sub-sectors), applications, technologies and the need for useful and final energy in detail. The planner draws up an energy demand structure, which represents the current energy consumption. For each sector and sub-sector, all end-uses that require energy, devices used for these applications, and energy needs are studied. As an example, consider energy consumption for cooking by different types of households in an area. One could draw up a structure consisting of the number of households, the types and percentages of households performing cooking, the types of devices and fuels and user share, and the average consumption per household for each fuel (see Figure 4.1). In this example, households are distinguished into rural and urban, as percentages of the total number of households. For both types, all households do cooking, but they use different types of stoves, with different user shares and average consumption. Note that some households may use both types of stoves so percentages for devices sum up to more than 100%. Other sectors like services can be included in the structure in a similar manner. Combining all elements in the structure would give the total current energy consumption.

Energy intensity represents the typical, average energy consumption for a type of user, end-use and device during a certain period, usually per year. This could be average consumption per household (or per capita), per unit of production, per restaurant, etc, depending on available data and objectives. One should take care that the units at sector/sub-sector level match with the ones for energy intensity, for example the number of *households* and average consumption per *household*. Instead of using final energy as in this example, one could also use useful energy needs and efficiencies of devices, if data are available and device efficiencies are the focus of the analysis.

In developing a demand structure, the planning objectives should be clearly kept in mind, so that the level of disaggregation matches the objectives. If the objective is to get a general indication of woodfuels consumption and trends, it is not be necessary to distinguish sectors in detail, e.g. per end-use, and device. If on the other hand the objective is to analyse fuel shifting, then a more detailed disaggregation would be needed, e.g. by distinguishing households per income group. Also data availability is a major consideration in the level of detail that is desirable and can be achieved. In some cases it may not be possible to distinguish in a certain way, simply because data are lacking. Estimates could be used to overcome this, but it might actually reduce the reliability of the results.

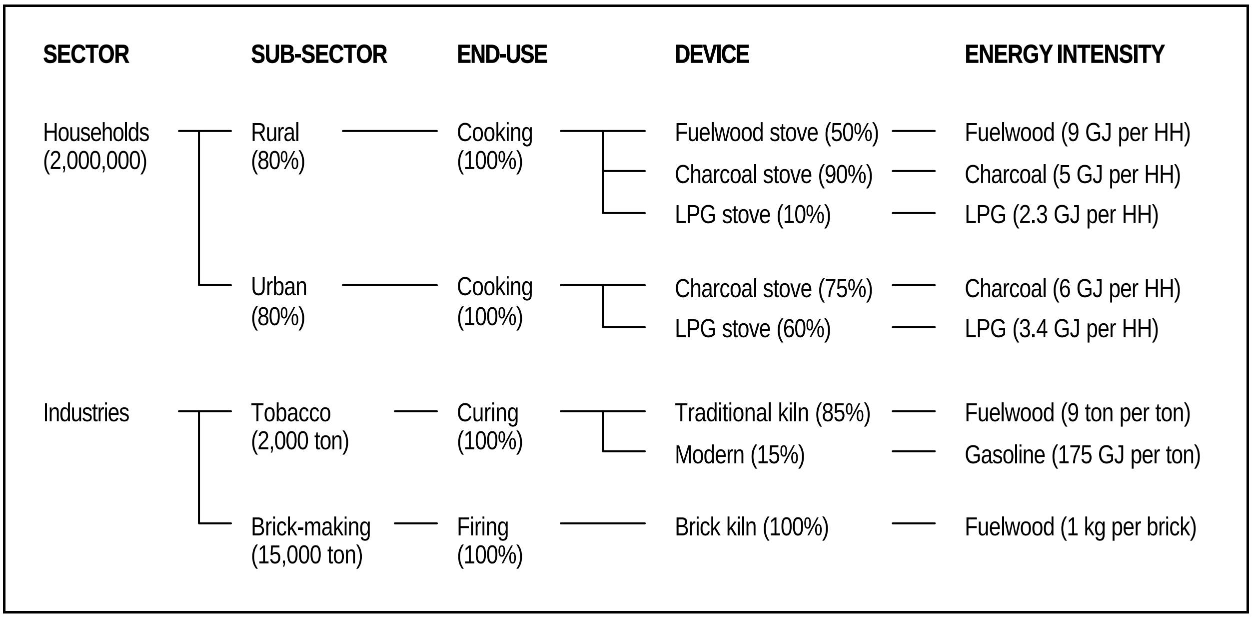


Figure 4.1 Example of process analysis of energy demand

The demand structure represents the current situation. To develop projections, elements of the structure that may change are identified, and individual projections for these elements can be developed. A combination of such projections builds up an overall scenario of energy demand of the whole society. By using different individual projections, several alternative scenarios can be developed. Demand scenario need be to be developed concurrently with supply scenarios, which is part of supply-demand balancing (see chapter 6).

4.4.3. Projection Techniques

For process analysis, several techniques can be used to build projections for single elements in the demand structure, and within one scenario a combination of techniques can be applied easily. The basic techniques are discussed below.

(a) Trend Analysis

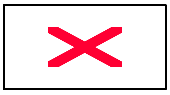
The basic idea of trend or time series analysis is to analyse past trends and to simply extrapolate these trends to the future, much like drawing a line beyond the current moment in a graph. This can be done with varying levels of complexity. For example with only few data points, one could extrapolate linearly (i.e. draw a straight line), or calculate the average annual growth rate over a certain period and apply it to the future. Note that a constant growth rate implies exponential growth, because the annual increase will be larger and larger. This may not be realistic for many cases. A more complex form of trend analysis is curve-fitting, which means following the past shape of the curve into the future. This can be done either mathematically or graphically.

Trend analysis is a simple method that is often applied, but it has severe limitations. First of all, past trends may not be continued in the future, for instance because of rapid developments or structural changes, like the use of new technologies. Second, insufficient data may be available to identify a trend. Finally, trend analysis does not explain what determines changes so projections lack a fundamental basis. Nevertheless, without studying past trends it is impossible to make realistic projections, so trend analysis is needed in combination with other techniques.

For wood energy, trend analysis is often used to forecast woodfuels use at national level. First, a value of wood energy consumption per capita is obtained for the base year. Then, this value is multiplied with the forecasted figures of total population for future years to obtain future total wood energy consumption. This can be used for basic forecasts over a medium time period (e.g. 5 to 10 years), or when few data are available. However, for more detailed analysis and longer time coverage this is too simplistic. People's consumption behaviour is influenced by many factors, like supply constraints, technology development, income and prices, so the average consumption per capita is not constant.

(b) Elasticities

Elasticities are widely used in econometric modelling. They can also be used within process analysis they can be used to develop individual projections. As mentioned above, elasticity is a measure of the responsiveness of one variable to changes in one or more other variables. In other words, if an independent variable increases with a certain percentage, what will be the increase or decrease of the dependent variable. In basic formula:



Where:	*D*	dependent variable
	D	change in the dependent variable
	I	independent variable
	I	change in the independent variable
		elasticity

A positive value means *D* increases parallel with *I*, while a negative value means *D* changes in opposite direction of the change of *I*. A zero value means *D* doesn't respond to a change in *I*. Although this simple formula can be used to calculate an elasticity value when two measurements for both variables are available, this is too simplistic and unrealistic, and preferably more sophisticated techniques for regression analysis should be used. As mentioned for the econometric approach above, sufficient and reliable data for such an analysis may not be available. In any case, elasticities should be used with care.

4.4.4. User Typologies

In many cases, detailed historical data on wood energy consumption by different users groups will not be available, so it is hardly possible to develop forecasts of consumption patterns. In that case, one could distinguish typical groups of users that have similar energy consumption behaviour and consequently develop forecasts for the size of each user group. Examples of possible user groups are types of households, by locations in terms of agro-ecological conditions and/or socio-economic situation (e.g. rural and urban), possibly further distinguished according to occupation (e.g. farmers, factory workers) or income (e.g. low, middle, high as in the example above). For industries, user groups could be types of industries, e.g. brick-making or tobacco drying, or a typical figure for energy consumption per unit of production can be used, e.g. tonne of tobacco produced. Assuming that the characteristics of user groups are constant, one can develop forecasts for their energy demand by forecasting the size of each group, e.g. the number of low-income rural households, the number of brick-making industries, or the amount of tobacco produced.

5. WOOD ENERGY SUPPLY ANALYSIS

Wood energy supply analysis refers to the analysis of the current and potential flow of woodfuels from natural resources to end users, i.e. from primary energy to final energy (see section 3.1.1). For energy planning in general, supply analysis should include resource assessment and evaluation of conversion, transformation, and distribution systems. Thus for wood energy it also includes the analysis of woodfuels flow systems, i.e. the distribution of traded woodfuels by a commercial network of producers, transporters and traders.

5.1. Resource Assessment

Resource assessment includes the assessment of existing resources, the evaluation of their availability as an energy source, and the development of projections for sustainable woodfuels supply. Section 3.2.1 lists the main types of data needed for resources assessment. Besides wood resources, other biomass resources such as crop residues and animal dung need to be considered.

5.1.1. Wood Resources

In wood resources we can distinguish between (1) wood coming directly from trees on land (direct resources) (2) residues from wood processing (indirect resources) and (3) wood waste from construction, demolition and discarded items (recovered wood). Naturally, all wood originates from land, but supply mechanisms for the three types are substantially different, so the distinction is important.

(a) Direct Resources

For direct resources the main factors to consider are types of land use, wood productivity per land use type, size of areas, and locations of areas.

1. Land Use

   Land use data are generally available from departments of land development, although they may be out of date and they do not always fit with the scale and scope of planning, e.g. land use categories may be too broad or the map scale too large. In the case of area-based planning, data may be improved and updated by using aerial photographs, satellite images, or the knowledge of local land use administrators and foresters. Land ownership, tenure, management and production systems, and cost aspects should also be considered because they have an impact on the accessibility of resources.

   Land use change is a crucial factor in determining the future existence of resources. Past land use changes and mechanisms that drive these changes need to be studied to assess whether these processes will continue in the future for example forest clearing for agricultural land or infrastructure development, expansion of settlement areas, or the increase in production of a certain crop type. When forest areas are cleared for other land uses (e.g. crops), this will provide a woodfuels source, even when it is not the purpose of forest clearing.

2. Wood Productivity

   For wood productivity, the basic factors are standing stock and average annual yield per unit of area. Standing stock refers to the amount of standing wood per unit of area, expressed in weight or volume (e.g. ton or m per hectare). The annual average yield refers to the average increment of the stock per year due to natural growth that can be extracted sustainably, without decreasing the overall level of standing stock.

For each land use type data on stock and yield are needed. In most countries some data on wood productivity from forest resources will be available, distinguishing different types of forests and tree species. However, in most cases these refer only to the stem volume of larger trees above a certain diameter, excluding the crown and smaller branches and twigs. The smaller tree parts are often used as fuelwood so it is important to obtain estimates for the whole tree volume to assess the production potential of wood resources. In case these are unavailable, estimates for the ratio of stem and crown need to be made by experts. Also smaller trees and bushes in forests are not included in forestry statistics, but they may be important woodfuels sources. Over time, special woodfuels stock and yield tables need to be developed.

When doing field measurements to assess standing resources, important parameters are tree height, diameter, age and crown density. In addition, the shape and size of tree stems determine the commercial value of the resources. The volume of a single tree can be calculated from the tree's height and diameter, by using volume tables that give the relationship between these parameters for a certain tree species. Preferably local volume tables should be used, because the relationships depend on local conditions. Note that these volume tables do not always include the crown and smaller branches, and may need expansion to cover these parts. To assess the standing resources per unit of area, the volume for different diameter classes of trees and their number is needed. Besides biomass volume, the density and moisture content of the wood need to be measured, in order to calculate the amount of energy available.

Weight units are more suitable than volume units for the assessment of woodfuels resources. The amount of energy that can be obtained from a kilogram of wood mostly depends on the moisture content, and not so much on the species. But the amount of energy from a cubic metre can vary widely depending on tree species as well as moisture content. Forestry statistics are usually given in volumes, so these need to be converted to weight, using figures on densities per tree species.

It should be noted that the distinction between stock and yield is not necessarily equivalent to distinguishing stems and branches. For example, in some forest plantations, trees are harvested in rows, felling and replanting one row every year. In this way the annual yield includes stems, while the average level of standing stock remains the same. Similarly, in undisturbed natural forests, dead trees can be considered as sustainable yield because the standing stock is constant due to natural re-growth. This means that whether yield can be considered sustainable depends on management and the purposes of wood production.

Depending on planning objectives, data on stock and yield don't have to be very detailed. For instance, for macro-level studies or indicative planning it would not be necessary to distinguish all occurring forest types in detail, using different stock and yield figures for each. However, it is very useful to distinguish between broadleaf and coniferous forests, as their wood productivity may be very different.

3. <u>Woodfuels Supply from Non-Forest Land</u>

It is crucial to consider resources on both forest and non-forest land. In Asian developing countries the supply from non-forest land is substantial and for most countries even greater than supply from forest areas. Many people grow trees on their own farmland or around the house as source of fruits and wood and as shelter from wind, sun and rain. They use the wood for their own needs and they may sell the surplus to other users or traders. Also small trees and bushes on public land are often used as woodfuels sources. Neglecting these sources would severely underestimate the available supply and eventually could lead to ineffective and adverse interventions. Most woodfuels supply studies of the past considered only the forest resources, which were unable to meet the projected consumption. Consequently, programs for wood energy tried to increase supply by planting fast-growing trees for fuel and to reduce demand by discouraging woodfuels use and by introducing more efficient cookstoves, even in cases where there may not have been a woodfuels scarcity. Unfortunately, even today, some woodfuels supply studies continue to ignore non-forest resources.

Regretfully, few data on woodfuels resources on non-forest land are available. Actual measurements and assessments have been done only in a few countries, and these were elaborate and expensive studies. Cost-effective methods for assessing non-forest wood supply are still under development. Initially, estimates on standing stock and yield can be used, based on experts' judgements and international data, and possibly checked with supply information from consumption surveys. While these estimates may be rough they provide a more accurate assessment than completely neglecting non-forest supply. Over time, more accurate data should be obtained through surveys and actual measurements.

(b) Indirect Resources

Indirect resources refer to residues from processing activities, like logging, saw-milling and furniture making. These may be considerable additional sources of woodfuels, particularly as an in-house energy source for wood industries and for landless people that have no access to wood from land resources.

For processing residues, we can distinguish between forestry-based activities (e.g. logging, saw-milling) and agro-based activities (e.g. coconut, rubber and palm plantations). Basic factors to consider are scale of production of the final product, residue generation per unit of production and availability of residues as fuel.

For forestry-based activities, the rate of residue generation refers to the amount of incoming wood that doesn't end up in the final product. This depends on several factors, like operation practices, equipment and type of product. Residues can be in the form of solid residues or sawdust, or in the form of black liquor in paper and pulp factories. For agro-based wood residues, the rate of residue generation refers to the amount of pruning residues that are generated per unit of area at certain time intervals, e.g. per year. This depends mainly on tree species, plantation density and pruning practices.

Like for direct resources, not all wood residues will be available as fuel. For example, it might be used as raw material for other products, it might be too far from potential users, or it might already be used as an energy source by the production plant itself, so it isn't available for other users. When promoting the use of residues for electricity generation at processing plants the current use of residues should be considered as well, because it might deprive some user groups from their fuel source.

(c) Recovered Wood

This refers to discarded wood, e.g. from construction material, demolished houses, old furniture, pallets, crates and driftwood. These may be important woodfuels sources, particularly in urban areas, and they could account for up to 20% of total woodfuels supply in some areas. It is very difficult to assess resources of recovered wood since it is not linked directly to production and there can be an interval of years before the wood becomes available as fuel. Its use and availability may be related to factors such as population growth, economic growth, (distribution of) income, prices of woodfuels and other wood products, and local resources. For example, with a high population growth discarded products may be recycled at a high rate, rather than being burned as fuel.

Since it is hard to assess resources of recovered wood for fuel, it may be more feasible to assess the importance of recovered wood from the consumption side, by analysing sources of consumed woodfuels in detail. This requires the inclusion of woodfuels supply in consumption surveys. For example, questionnaires for sample surveys could include detailed questions on how users obtain their woodfuels, e.g. collected or purchased, and if collected, whether it is from own land, public land, wood waste, etc. This would lead to an estimate for the share of recovered wood in total consumption, which consequently can be excluded from resource analysis, because its supply is met by recovered wood. In case the share is considerable, further analysis of its sources may be needed to assess whether this will continue to be the case in the future. For example, a boom in construction of houses and roads may generate a large amount of woodfuels for a while, but this may not be a continuous source. So far, recovered wood is hardly ever accounted for in resource assessment studies.

5.1.2. Non-Wood Biomass Resources

Other important biomass energy sources are crop residues and animal dung, both products of agricultural activities. Considerable amounts of crop residues are generated during crop production, and these are often under-utilised. However, because of their characteristics, such as their bulky and smoky nature, they are not preferred as fuel. Improved technologies for conversion and use are needed before they are widely used as fuel. Both crop residues and animal dung are often used as fertiliser or other end-uses, so they cannot simply be diverted to energy use.

The use of crop residues and animal dung varies from place to place. In some areas it is a major fuel, in others it is hardly used. In case they are of minor importance, the assessment of their resources can be limited to general estimates on residue availability per crop and animal type. When they are major fuels or intended to be used for supply projects, a more detailed assessment is required, preferably with local measurements on the amount of residue generation and their availability as fuel.

For the assessment of crop residues, it is important to note that not all crop residues are suitable or preferred as fuel. Furthermore, for a certain crop type the amount of residue may vary strongly among varieties, e.g. high yield varieties generally produce few residues. Separate measurements may be needed for each. It is also important to distinguish between field and process residues, since their availability can be very different. Field residues are generally left in the field, often used as fertiliser and soil conditioner, while process residues are available at a central site and can be a nuisance.

5.1.3. Accessibility of Resources

For all resource types, accessibility and availability of resources are crucial factors and should be part of any resources assessment. Not all existing resources can be used as fuel, due to other end-uses and physical, social and economic barriers (see also section 3.2.1). Accessibility constraints can significantly limit the availability of fuelwood in a certain area, even where abundant wood resources exist in the neighbourhood. For example, people living in areas close to protected natural forests (e.g. designated national parks or wildlife reserves), sometimes have no access or only limited right of access to these resources. Natural physical barriers (due to difficult terrain, steep topography, cliff and big river crossings, etc.) also limit the access to local resources. Also note that accessibility may differ for different user groups, i.e. what is accessible to one group may not be accessible to another.

Neglecting accessibility can have strong impact on the effectiveness of interventions. For instance, in a certain area more than enough resources may be available to meet the consumption, but some users, e.g. people without land, may not have access to the wood. In that case building a mechanism for the redistribution of fuelwood to different user groups could be more effective than planting trees, since the problem is access to land, rather than insufficient resources. Another example is the case of some fuelwood plantations that aim to provide fuelwood to local communities, but the wood may end up being sold as commercial wood because it can fetch a higher price.

Analysing accessibility and availability of resources can be a complicated task, because constraints are site-specific and complex. At national level it is generally not feasible to do a detailed analysis, and only rough estimates for different land use types can be made. At area-based level a more detailed analysis may be feasible, when sufficient data are available and specific interventions are planned. No standard methods exist. The main inputs to accessibility analysis are maps (e.g. land use, land tenure, infrastructure, population density), supply information from user surveys, production and use of other wood products, and local expert knowledge. With sufficient information and expertise a GIS could be used to spatially analyse accessibility. The main factors to consider are:

Physical barriers: major physical barriers to consider are distance, large rivers, high mountains and steep slopes. Of course accessibility also depends on the existence of infrastructure (bridges, roads) and the availability of transport means and tools.

Production and management system: The production system affects the availability of resources in the form of logs and residues. For example, in the case of plantations of fast growing trees for the paper and pulp industry, no residues may be available. Fruit trees are generally planted for a number of years, so some pruning residues may be available. Timber plantations generally generate harvesting residues in the form of branches and twigs. Whether these residues are available to other users may depend on who owns the land and the type of management, e.g. private, government or community.

Other end-uses: resources may be used for other purposes, such as construction material for houses and fences. In the case of processing residues, these may be used as energy source in the processing plant, making them inaccessible to other users. Whether wood is used for energy or other purposes also depends on the scarcity of woodfuels and the availability of other energy sources and materials.

Legal barriers:

Social and cultural factors: trees of certain species or at certain locations may not be harvested because they are considered sacred.

Costs: even if resources are accessible in terms of the above factors, the costs in terms of time and money needed for collection and transport may be too high. This relates to income, prices of wood and other fuels, demand and prices for other wood products, and the overall availability of biomass resources. Also the social value assigned to women's time and their opportunities to earn income from other activities is important.

5.2. Resources Analysis and Scenario Development

As with demand analysis, a form of process analysis can be used to analyse the various resources. Figure 5.1 shows an example of this for different types of supply sources.

First the current situation should be assessed. For scenario development, one should identify those factors that are likely to change in the future and develop projections for those factors. By developing several projections and combining these, alternative scenarios for resources can be developed. Techniques to develop projections are the same as discussed for demand analysis (see section 4.4 under *Process Analysis*). Scenarios for supply and demand need to be developed in parallel, which is further discussed under supply-demand balancing (see chapter 6).

Source	Type	Productivity	Accessibility
Direct Resources	‣ Forest Land		
	- Natural forest	- Stock 80 ton/ha; Yield 1 ton/ha/yr.	- 20%
	- Plantation	- Stock 40 ton/ha; Yield 2 ton/ha/yr.	- 40%
	‣ Non-Forest Land		
	- Homegardens	- Stock 15 ton/ha; Yield 0.5 ton/ha/yr.	- 80%
	- Crop fields	- Stock 5 ton/ha; Yield 0.2 ton/ha/yr.	- 80%
Indirect Resources	‣ Forestry-Based		
	- Logging	- 0.4 ton / ton logs (40%)	- 80%
	- Saw-milling (solid)	- 0.35 ton / ton sawn wood (35%)	- 60%
	- Saw-milling (dust)	- 0.12 ton /ton sawn wood (12%)	- 40%
	‣ Agro-Based		
	- Coconut	- 2 ton/ha (pruning residues)	- 30%
	- Rubber	- 2.5 ton/ha (pruning residues)	- 10%
Crop Residues	‣ Field Residues		
	- Rice straw	- 1.75 kg straw / kg rice	- 20%
	- Maize stalks	- 2.0 kg stalks / kg maize	- 20%
	‣ Process Residues		
	- Rice husks	- 0.27 kg husks / kg rice	- 50%
	- Bagasse	- 0.29 kg bagasse / sugar cane	- 60%

Figure 5.1 Example of process analysis for resources assessment

5.2.1.Technology Evaluation

As discussed in section 0, several types of conversion processes exist for wood energy. Technology evaluation refers to the analysis of conversion processes and technologies currently used for (wood) energy supply and the identification of options for improvements and interventions. These solutions may be of a technical nature, but they may also relate to operation and management practices.

It should be noted that technology evaluation does not refer to pieces of equipment only. It also includes the evaluation of natural and human resources, financing mechanisms and institutions, such as government agencies and supply companies. In technology evaluation several non-technical issues play an important role and need to be assessed properly.

(a) Wood Energy Technologies

Most biomass energy is used through direct combustion in its primary form, possibly after some form of physical processing. In some countries, charcoal is a popular fuel. Traditional conversion and consumption technologies for woodfuels are often basic and inefficient, and this makes their use inconvenient and dirty compared to conventional fuels.

Other conversion technologies such as gasification and anaerobic digestion have been developed to provide alternatives and to match biomass resources with modern end-use devices. However, these technologies are still not widely used, because they are often expensive and therefore considered economically unviable. However, if evaluated on a life-cycle basis, i.e. including costs and benefits for the environment, health, employment and foreign exchange they are not necessarily more expensive than traditional methods of woodfuels use, or any other fuel for that matter. With the development of financial mechanisms that incorporate these benefits, these modern technologies will become more important in Asian developing countries as in the developed countries..

Technologies for wood and other biomass can broadly be distinguished into three categories:

- Direct combustion
- Thermo-chemical
- Bio-chemical

Each category is briefly discussed below. Since charcoal is widely used in some countries, and it is promoted in others, it is discussed in more detail.

(b) Direct Combustion Processes

Direct combustion systems are designed to produce heat that can be used directly (e.g. for drying), or transferred to fluids for industrial processes (e.g. steam), or used to generate power (Hall and Overend, 1987). Technologies range from simple systems like cookstoves, furnaces and boilers to more advanced systems like fluidised bed combustion technology. These are largely demand-side technologies.

Different types of applications include:

- Domestic use: Most woodfuels are used by households for cooking and heating. Generally, very simple cookstoves are used, often not more than a three-stone stove or tripod. These are inefficient, inconvenient and they can emit a considerable amount of pollutants, which have an impact on health. Improved technologies have been developed that are considerably more efficient and convenient, but as of yet these are not widely used.
- Commercial and institutional use: the service sector uses woodfuels for applications similar to households use, although generally at a larger scale. Equipment such as stoves and ovens generally are of slightly better quality, but considerable improvements can be made here too.
- Industrial use:

- Heat generation: many (rural) industries use woodfuels to produce heat needed for drying (e.g. tobacco curing), boiling and frying (e.g. food processing) etc. Equipment comes in various sizes and capacities. It is commercially available or self-made. Due to poor quality and poor maintenance and operation, these technologies are rather inefficient.
- Co-generation: co-generation systems generate both heat and electricity, which can save considerable amounts of energy compared to two separate systems. Co-generation is generally applied by industries that need both heat and power and generate a considerable amount of biomass residues, which can be used as an energy source. In Asia it is commonly applied by sugar, rice and palm oil industries. The type of system depends strongly on whether heat or power is the main product. The heat and electricity are used by the plant, and sometimes the surplus is sold to other users or to the grid.

Power generation: In several, mainly industrialised countries wood is used for thermal power generation for the grid or decentralised supply systems, generally through direct combustion (dendro-power). At present this normally occurs at a modest scale, with capacities in the range of 2 to 3 MW. In some cases, combined heat and power (CHP) systems are applied. These use the waste heat for other purposes, e.g. district heating in northern European countries. Also co-firing of wood (or other biomass) with conventional fuels occurs.

With direct combustion, usually some form of physical pre-processing is done. This consists of drying, resizing and densification. For households and rural industries, drying is unfortunately not always properly done. Resizing the wood consists of splitting and cutting to make it easier to transport and use. For some more advanced technologies it is necessary to chip the wood into small particles.

Briquetting

Densification (or briquetting) refers to compacting the loose material to make the use, storage and transport more convenient. The resulting briquettes are used by households, services and industries. Raw materials can be sawdust, crop residues, and charcoal fines. The material is compacted under pressure and, depending on the material, the pressure, and the speed of densification, additional binders may be needed to bind the material. The main types of briquetting technologies are:

- Direct briquetting with binders: these are low-pressure machines, in which the biomass is mixed with 4-8% binders such as starch, clay, molasses.
- Direct briquetting without binders: these are high pressure machines, with two types:
  - reciprocating ram or piston type: the material is punched into a die by a ram with a high pressure.
  - revolving screw type: the material is compacted continuously by a screw. This generally produces briquettes of higher quality than with the piston type.
- Bio-coal: this is compacted charcoal made from wood residues or low ash agricultural residues. Two systems exist:
  - briquetting (without binders) followed by carbonisation: the briquettes are more dense than wood-charcoal.
  - carbonisation followed by briquetting with binders (starch, molasses, clay).

(c) Thermo-Chemical Processes

These convert biomass into higher-value products, which have higher density and energy content and are more convenient into use and transport. The basic thermo-chemical process is called pyrolysis or carbonisation, which breaks down the material and releases a gas, an oil-like liquid and a char. Depending on the technology and operations, one of these is the final product. The main applications are:

- Charcoal production: this is the most common form of thermo-chemical conversion. The biomass material is partially combusted with a restricted amount of air. Charcoal production is a medium temperature form of pyrolysis. It is further discussed below.
- Gasification: this is a high-temperature form of pyrolysis with a complete thermal breakdown of the biomass into a combustible gas (called producer gas), volatile matter and ash. The gas can be used for the generation of heat and power, and can be used in existing end-use equipment. The

composition and heating value of the gas vary depending on the raw material used, e.g. wood, rice husks, coconut shells. The heating value is in the range of 4 to 6 MJ/m^3, which is low compared to natural gas. Different types of gasification processes exist, such as moving bed and fluidised bed gasifiers. Their application depends among others on the raw material used and the scale of production.

(d) Bio-Chemical Processes

These make use of the biochemistry of biomass and the metabolic action of microbial organism to produce gaseous and liquid fuels. For the conversion of wet biomass they are more appropriate than thermo-chemical conversion. The main processes are:

Anaerobic digestion: digestion of wet biomass by bacteria in an oxygen-free (anaerobic) environment produces a combustible gas, called biogas. The biomass (usually animal dung but also plant material can be used) is put in a closed container (the digester) and left to ferment. After some days (depending on the atmospheric temperature), a gas will have formed. The gas is mixture of methane and carbon dioxide, it has an energy content in the range of 16 to 20 MJ/m^3 and can be used for several purposes such as cooking, heating, power generation. The remaining slurry from the digester makes a good organic fertiliser. Biogas digesters are introduced at village level in several countries (e.g. China, India, Nepal), as an alternative to fuelwood. Waste water from animal farms and industries can also be used to produce biogas, at the same time cleaning the water before release.

Alcohol fuels: ethanol and methanol are liquid alcohol fuels. Ethanol is produced by fermenting sugars, and methanol is produced by the destructive distillation of woody biomass. The technology has been used for centuries by liquor producers, but more recently it is being used to find substitutes for fossil fuels in transport, notably in Brazil. In developing countries, sugarcane is the most used raw material to produce ethanol. Other possible feedstocks include sugarbeet, potato, wheat and maize (Flood, 1986). Alcohol fuels can be used as transport fuel in its pure form or blended with gasoline.

Landfill gas: this combustible gas is obtained from the fermentation of Municipal Solid Waste (MSW). The waste is spread out and covered to let it ferment, recovering the gas by pipes inserted at regular spacing. The gas consists of methane and carbon dioxide and has an energy content of about 18 MJ/m^3. Extraction and use of the gas reduces pollution and the risk of explosions at disposal sites and can help to reduce methane emissions (Woods and Hall, 1994).

(e) Charcoal Production

As already stated, charcoal production is a form of thermo-chemical conversion process. Most charcoal is produced from wood, but other sources may be coconut shells and crop residues. Charcoal is cleaner, easier and less smoky and smelly than direct combustion of biomass fuels, so very appropriate for household use.

Charcoal is produced by breaking down the chemical structure of wood under high temperature in the absence of air. Traditionally it is produced in kilns. During the process, the water is driven from the wood (drying), and then the pyrolysis starts followed by carbonisation when the temperature in the kiln is high enough. When the carbonisation is complete, the kiln is closed and left to cool down, after which the charcoal can be removed from the kiln. Because some of the wood is burned to drive off the water, dry wood produces better charcoal at a higher efficiency. Typically, around two-third of the energy is lost in the process, but charcoal has advantages over fuelwood like higher burning efficiency, greater convenience and easier distribution, which compensate for this loss.

The oldest and probably still the most widely used method for charcoal production is the earth kiln. Two varieties exist, the earth pit kiln and the earth mound kiln. An earth pit kiln is constructed by 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 first covered with green leaves or metal sheets and then with earth to prevent complete burning of the wood. The earth mound kiln is built by covering a mound or pile of wood on the ground with earth. The earth mound kiln is preferred over the pit kiln where the soil is rocky, hard or shallow, or the water table is close to the surface. Mounds can also be built over a long period, by stacking gathered wood in position and allowing it to dry before covering and burning.

Earth kilns can be made at minimal cost, and are often used near wood resources, since they can be made entirely from local materials. Earth kilns can be made in any size, with the duration of the process ranging from three days to two months. Considerable variations in the quality of the charcoal can occur, because in one batch some of the wood is burned and some of the wood is only partly carbonised. Efficiencies are generally low, around 10-20% by weight and 20-40% in energy terms. The efficiency and the quality varies depending on the construction of the kiln (e.g. walls can be lined with rocks or bricks and external chimneys can be used), and the monitoring of the carbonisation process.

Several other types of charcoal kilns have been developed, which generally have higher efficiencies but also require higher investments than the earth kiln. Two often-used types are fixed kilns made of mud, clay, bricks, and portable steel kilns. Fixed kilns usually have a beehive shape. Smaller beehives are usually made of mud and are not very durable. Larger beehives are made of bricks and have external chimneys. Beehive kilns have an opening for loading the wood and unloading the charcoal, which is closed after loading. Portable steel kilns can be made from oil drums, and can be used both in horizontal and vertical position. They generally have a short lifetime. When used in the horizontal position, an opening is made in the side, through which the wood is loaded. For the vertical kiln the top is cut out and used as a lid.

More advanced processes of charcoal production use so-called charcoal retorts. Instead of combusting part of the wood, the wood is placed in a closed container and heated externally. Retorts operate at relatively large scale and require considerable investments. They are more efficient, cleaner and produce better quality charcoal than kilns. They are not very common in Asia, since charcoal production is small-scale and is discouraged in several countries.

5.2.2. Considerations in Technology Evaluation

In the evaluation of supply technologies and intervention options, several considerations are important. These are discussed below, focusing on (decentralised) supply systems for wood and biomass energy. Each set of considerations is equally important. Naturally, many of them apply to other energy sources as well. It should be stressed that these considerations can be very site-specific. What has proven to work in one country or area may not work at all in another.

(a) User Needs

User needs and consumption patterns are of course crucial in determining which supply options are the best. Results from demand analysis should be incorporated into technology evaluation. The main issues to consider are:

- Useful energy needs: users require useful energy e.g. heat, light, motive power, so supply options should be able to satisfy these needs. For example, the multiple function of a household stove for cooking, drying, heating and lighting is important, and it sometimes is a reason for households to reject a new stove design.
- Rate of use: this is the amount of energy needed during a certain period, e.g. per day or year. This will determine the capacity needed for consumption and conversion devices.
- Fluctuation: energy use may not be constant during a certain period. For example, the need for space heating will be higher in winter, and agro-based production may peak during certain months. Moreover, also there may fluctuations in energy needs on a daily basis, which is particularly important for electricity supply.
- End-use devices: users are currently using certain devices for their needs, which have to be evaluated. Improving existing end-use devices may in some cases be more feasible and effective than introducing new technologies. Implementing a new supply system may require users to adopt new end-use devices. They may not be willing or able to do this, because of the costs, trouble and the change of habits involved.

(b) Resource Availability

Any supply system needs the input of sufficient natural resources. Besides the total quantities available, other issues to consider are:

- Local availability: insufficient resources may be available locally, so they may need to be (partly) brought in from outside the area (imported). At national level, the import of biomass resources isn't common and hardly feasible due to transport costs, so this issue is more important at area-based level. Usually, biomass resources will be available, but resources may cross area boundaries, which will involve costs for transport and storage, and may even cause user conflicts and resistance.
- Seasonal availability: Some biomass resources, notably crop residues, will be available only at certain times of the year, e.g. directly after the harvest.
- Range of alternatives: One type of biomass may not be able to provide sufficient resources, so the option of using several types may be considered, e.g. using wood to complement for crop residues during off-season.
- Sustainability: Supply options are generally designed to work for a number of years, so an evaluation of whether the use of resources is sustainable in the long term should be carried out.
- Concentration: Some resources are available at concentrated sites, for example wood and crop residues at processing plants. Others are spread over a large area (e.g. residues on crop fields), so their collection may be complicated, time-consuming and costly.
- Other uses: resources may already be used, both for energy and non-energy purposes, so a supply project should avoid depriving current users of their resources. On the other hand, a supply project may fail because resources are already claimed for other purposes.
- Labour: large-scale production of biomass for energy will require sufficient workers. These may not be available, or not for the whole year round, depending on agricultural activities.
- Costs: refers to costs of production processes, i.e. harvesting, collecting, transporting and storing. In case of dedicated tree plantations, opportunity costs of land, comparing wood production with other land use options, should also be assessed.

(c) Technical Characteristics

The main technical aspects to consider are (Ramani et al., 1995):

- Efficiency: this is the ratio of energy input and delivered output. The higher the efficiency, the less energy input is needed for the same output (or in other words, the less energy is wasted). Most traditional end-use and conversion devices are highly inefficient. Large improvements can be made in existing technologies, even simple improvements in operation practices can raise efficiency..
- Capacity: refers to the quantity of energy output per unit of time (e.g. day, week, year). For conversion devices this is in terms of final energy, for end-use devices in terms of useful energy. This should match with user needs. Some technologies are more economically viable and perform better in technical terms at small scale, others at medium or large scale.
- Input requirements: supply technologies require input of energy and human resources. Depending on the technology, energy input often needs to be in a specific form, e.g. size and moisture content, which may require additional processing, and consequently extra costs. The operation and maintenance of supply systems requires skilled workers, who may not always be available locally.
- Technology status: this is particularly relevant to technologies that are new in a country or area. The reliability of a technology, even if proven in another area or context, depends on site-specific conditions, such as climate, local practices and human resources. Furthermore, technologies need to be flexible enough to allow for adapting to local conditions.
- Dimension: the physical size of a supply system is important in cases where space is limited or land is valuable.
- Emissions: certain technologies emit air pollutants, which have health impacts and contribute to global warming. Water and soil pollution is also an important consideration.

(d) Social Aspects

Technologies that are considered technically feasible may not be feasible in social and cultural terms. Ignoring these aspects may lead to resistance and failures. Some issues to consider are:

Employment: certain supply options will provide more local employment than others, which may contribute to the acceptance of the system at local level. In other cases, some people might loose income because of new supply systems.
Gender relationships: supply options may benefit men and woman differently, and consequently their preference for certain options may be different. Since it is mainly the women who do the cooking, they will be interested in options that will save time and bring higher convenience, while men will look more at costs. Likewise, men and women will have different perspectives in the case of tree planting, redistribution of resources, provision of employment, etc.
Acceptability: local communities may object to a certain option and this will hamper its implementation, indeed one might need to drop the option. For example, the use of animal dung may not be considered appropriate by some communities. In general, introducing change always causes reservations and sometimes even resistance, especially if people are not properly informed. Furthermore, the perspective of users may be different from planners. For instance, national concerns such as environmental benefits in terms of global warming or saving foreign exchange may not be a concern to local communities.
Current supply patterns: introducing new supply systems will have an impact on current supply patterns. For instance, kerosene and woodfuels traders may loose business, and may even try to obstruct the introduction of a new supply system.

(e) Economic Feasibility

Naturally, the feasibility of supply options in economic terms needs to be considered. Two types of cost-benefit analysis should be distinguished:

Financial feasibility: this considers the profitability of a supply option from the perspective of an investor, accounting for financial costs and benefits, i.e. the outflow and inflow of cash money. Advanced wood energy technologies are still relatively expensive, so they are often not feasible in pure financial terms.
Economic feasibility: some costs and benefits may not be incurred in cash flows, but they are very relevant for justifying certain options, e.g. health, environment, employment. These aspects are external in the financial analysis, i.e. not explicitly accounted for. Economic analysis aims to 'internalise' these aspects by assigning economic value to them. In this manner, options that may be unfeasible in financial terms can be economically feasible. This could justify for extra support, e.g. subsidies, incentives for investors. In recent years, more and more financing schemes are being developed for this purpose, e.g. the UNDP/World Bank Global Environment Fund (GEF). The main problem with this type of economic analysis, is the difficulty to estimate the economic value of certain aspects.

5.3. Woodfuels Flows

Woodfuels are often gathered freely for own use, but in many places, particularly in urban areas, fuelwood and charcoal have become traded goods. Woodfuels are bought by urban and rural households of almost all income levels. Industries and services generally also buy wood for their energy needs. Compared to the amount of non-commercial woodfuels, quantities of commercially traded woodfuels may be small, but nevertheless significant enough to affect developments of energy, forestry, agriculture, environment and economy. At the same time, policies for these sectors may affect the development of resources as well as the woodfuels trade, e.g. fuel subsidies, restrictions on tree felling and woodfuels transport. Therefore, the analysis of woodfuels flows, particularly to urban areas, should be part of wood energy supply analysis.

The analysis of woodfuels flow systems covers the commercial channels of production, conversion, transport and trade. It closely links with the analysis of resources, technologies and consumption patterns, and it is an input for supply-demand balancing.

Several woodfuels flow studies have been conducted for selected urban centres (see for instance RWEDP (1997b) for an overview of four studies). In Pakistan, a woodfuels study was conducted at national level, as part of the household energy study (ESMAP, 1991). However, flow studies are not very common, and generally not included in wood energy supply analysis.

5.3.1. Aspects of Woodfuels Flow Systems

Woodfuels supply patterns can be complex and are site-specific. They may depend on resources, users, prices of woodfuels and alternatives, and restrictions on tree felling and woodfuels transportation. Woodfuels trade occurs mostly at small-scale and in the informal sector, so no comprehensive statistics of its scale and the number of people employed exist. Nevertheless, the studies that have been conducted in recent years can give a general picture of woodfuels flows.

(a) Supply Sources

Sources of traded woodfuels are both forest and non-forest areas. Regarding formal supplies from forests, a country's forest department may sell woodfuels itself or it may issue permits to contractors to remove wood from certain areas. Besides formal removals, woodfuels may be removed from forests without permits by people living near or in the forests. In some countries people are allowed to collect dead wood for own use as head- or backload, but a substantial amount is sold.

For traded wood from non-forest land, the situation varies per country. In some cases, a permit is required to cut trees on private land. In other cases, only a transport permit is required. It is difficult to estimate the scale of trade of non-forest woodfuels, because a large amount may be used for free or traded locally, and no records exists for this supply.

The major share of collected woodfuels is for own use. However, where sources of collected wood are near large woodfuels markets in town and cities, a large share of the gathered wood may be sold, while the woodfuels gatherers will use other fuels for own use, such as small twigs, leaves, crop residues and animal dung.

(b) Processing and Conversion

After cutting, the woodfuels are converted and processed and this may involve several stages. At the resource site, wood is cut, split, bundled, and sometimes converted into charcoal. Bundle sizes can vary greatly depending on the area and the end-user. Bundles can also be re-packed at intermediate stages of the trade. Small industries usually prefer larger pieces of wood and buy in larger quantities than households. Larger industries purchase woodfuels in bulk by weight or volume measures.

Kilns used for charcoal making vary in size and type. They are often of the temporary type such as earth pit kilns and earth mound kilns, because wood supplies at one location are often temporary and small. In some cases, charcoal is made near the home of charcoal producers where it is easier to control the carbonisation process. Wood used for charcoal making is generally of larger size than fuelwood, and may consist of all types of wood such as tree trunks, stumps and roots. After production, charcoal is packed in bags or baskets for transport.

(c) Distribution and Trade

In the woodfuels trade we can distinguish between small woodfuels gatherers and occasional traders, and the larger contractors and full-time traders.

Woodfuels gatherers carry the woodfuels to local markets by head or back load or bicycle and sell it directly to consumers and shopkeepers. Some truck and bus drivers act as occasional traders by buying woodfuels along the road and selling it to the market. In some countries trucks may carry a load of woodfuels back after delivering other goods. Transport of small quantities is normally considered to be for own use, so it circumvents the regulated trade channels and restrictions.

Woodfuels trade by professional traders has various forms. The transport to the market in a town can be done by a rural trader, who sells it directly to an urban trader or end-users. In other cases several intermediaries can be involved both in rural and in urban areas. Some traders buy woodfuels from small producers and sell it to transporters. Other traders buy from local sellers along roads. In larger cities there may be a network of wholesalers and retailers.

Usually a permit will be needed for the transport. The permit has to be obtained in advance. It is usually issued by local forestry authorities after inspection of the source, the species and the amount of the wood. During transport the woodfuels load can be checked at checkpoints, to see whether the load corresponds with the permit.

(d) Prices

Prices and conditions vary per country and area within a country. Nevertheless, the price structures in different countries show a common pattern. In the case of fuelwood, in general owners of trees account for about 20% of the final sales price, while the wood cutters/collectors account for about 30%. Where the land/tree owner is the same as the cutter/collector, his or her share amounts to about 50-60%. Transport accounts for about 20-30%, while the share of traders is around 20-25%. In the case of charcoal, the owners of the trees together with the charcoal producers receive around 50%, transport accounts for 10-15%, while the share for the traders is around 30-40%.

(e) Employment

The woodfuels trade provides a significant source of employment and income in rural areas. For some rural people it is their only means to earn cash income, for others, it may be an additional source of income during the off-farming season. It is estimated that the labour employed in the woodfuels business per unit of energy consumed is at least 20 times greater than that for kerosene (ESMAP, 1991). Unfortunately, this positive aspect is rarely acknowledged by statistics and policy-makers.

(f) Policies

In the name of forest and environment protection, the commercial woodfuels trade is subject to restrictions on tree felling and woodfuels transport in most Asian countries. Generally, it is the forestry department that gives out permits and implements control. Often a permit is required to fell trees, even when they grow on private land. Permits are also needed, sometimes with inspections taking placebefore loading and after unloading the kiln. For transporting small amounts of woodfuels generally no permits are needed. For large-scale transport, permits need to be obtained in advance, and loads may be inspected at checkpoints along the road. The process of obtaining permits can be cumbersome and sometimes costly.

5.3.2. Analysis of Woodfuels Flows

As stated, woodfuels flow studies are not very common and have been conducted only in selected areas. Hence, methods for the analysis of woodfuels flow systems are not standardised and still under development. Nevertheless, some characteristics of woodfuels flow studies can be defined.

Flow studies are generally conducted for urban centres, in order to assess the 'flow' of woodfuels from rural areas to an urban centre, such as a city or town. In some rural areas woodfuels are largely traded commercially, so woodfuels flow studies can also be done in these cases.

(a) Objectives

The main objectives of woodfuels flow studies are to:

- Characterise the commercial woodfuels production and trade in quantitative and qualitative terms, including patterns of distribution, marketing aspects, actors involved, and environmental and social aspects.

Identify the main sources of commercial woodfuels (e.g. forests, farmland) and user groups (e.g. types of industries, household groups, commercial enterprises).
Analyse the impact of policies and regulations, and identify options for removing or differentiating restrictions.

(b) Elements

In analysing woodfuels flows, the key elements to consider are:

Quantities: volumes of the production and trade need to be estimated, in order to asses the importance of commercial woodfuels, in comparison to non-commercial woodfuels for the area. If possible, quantities should be crosschecked against data from the consumption side, i.e. how many users purchase their woodfuels and how much do they consume.

Actors: different types of actors are involved in the woodfuels business, e.g. producers, transporters, wholesalers and retailers. Woodfuels traders may not always be easily identifiable, because their business is largely informal. They could be traced by interviewing key informants, such as forestry officials and large consumers. Also a systematic analysis could be applied starting from consumers, tracing each stage of the flow backwards, although this could be time-consuming and expensive. Separate studies could be initiated for different types of actors. Often, the distinction between the different types isn't that clear, e.g. wholesalers can also act as retailers, and producers may deliver directly to retailers.

Retailers: aspects to study include acquisition of woodfuels, sales prices and profit margin, volume and patterns of sales (e.g. seasonal variation, delivery) and types of customers. Some retailers may only trade woodfuels, others might sell other items, so the relevance of the woodfuels trade is important as well. Methods for data collection could be interviews with key informants, RRA and sampling surveys. Since it may be difficult to select samples for retailers, alternative sample units could be roads, markets and shops.

Wholesalers: these act as middlemen between retailers and transporters, but, especially at larger scale, they often fulfil these other roles as well. Aspects to study are quantities of buying and selling, prices and profit margins, types and quality of woodfuels, labour employed and storage. In general there will be fewer wholesalers than retailers, so they are easier to identify, through key informants and retailers. In some places they may even advertise or appear in business directories. If there are few wholesalers, a complete census could be conducted. Otherwise sampling surveys or interviews with selected wholesalers could be used.

Transporters: major aspects are modes of transport (e.g. headloads, pushcarts, boats, trucks), costs (e.g. fuel cost, fees for permits), distances, trips per months, load per trip, and profit margin. Also information about where and from whom they buy, and where and to whom they sell is needed. Information could be obtained by interviewing transporters at major entry points, such as main roads, harbours and railway stations.

Producers: main aspects are sources (e.g. private land, forests, processing residues), costs (e.g. planting, harvesting, permits), tree species, selling price and profit margin. Conversion aspects are important too, such as equipment (e.g. charcoal kilns), labour and costs. Producers could be identified from interviewing transporters and wholesalers or from forestry agencies that give out permits.

Sources: these need to be identified from producers. Amounts extracted need to be quantified and compared with productivity data. Supply sources could be defined as a 'woodfuels catchment area', i.e. the area around an urban centre that supplies its woodfuels. Naturally, it may be difficult to define boundaries for such a catchment, but it could be identified from information from transporters and producers. Supply in small quantities from remote areas could be left out from the catchment area and considered as 'import'. All resources within the catchment area should be assessed, in order to evaluate the sustainability of the commercial supply. The analysis of sources is also important in the review of regulations and restrictions.

Users: information needed on users that buy woodfuels includes quantities, end-uses, and relative prices of woodfuels and other fuels. It may be available from consumption studies and demand analysis, otherwise it should be covered in the flow study, by conducting a survey for household and other major buyers. Also projections are needed to identify possible trends and prospects of commercial woodfuels supply.

Prices: information on prices and profit margins for different actors can provide insight into profitability and market efficiency. Also information on fluctuations in prices is needed, because these may be an indication of scarcities or oversupply, and they may lead to fuel switching.

Employment: woodfuels businesses provide a substantial amount of employment, which may be strongly affected by certain policies and interventions. Therefore, information is needed on the number of people involved, income from woodfuels business, and whether it is a full-time occupation or a part-time or seasonal activity. In the latter cases, the share of income from woodfuels trade and reasons for partly doing this are important aspects.

Regulations: regulations can exist in several forms, e.g. permits for tree felling and transport, checkpoints on the road, taxes for traders. The impact of regulations and restrictions should be evaluated, for example the effect on prices and income, the scale of illegal or informal trade to avoid regulations, and the extent to which these regulations discourage tree planting and woodfuels trade.

(c) Conducting Surveys

Since hardly any secondary information will be available as inputs for woodfuels flow studies, surveys are essential. Often, pilot studies are needed to collect preliminary information, after which larger surveys can be implemented, e.g. sample surveys. Because flow studies are relatively new, it is difficult to anticipate responses from people interviewed. Therefore, survey methods need to be flexible, in order to easily respond to incoming information. Thus, open-ended or semi-structured interviews will allow for more flexibility than formal structured questionnaires.

In designing and conducting woodfuels flow surveys, some guidelines can be kept in mind (Remedio, 1993):

- Study experiences and methods from previous studies in other areas.
- Clearly define overall objectives, in terms of what output is expected, what kind of information will be generated.
- Develop a list of possible methods and instruments to achieve these objectives.
- Make use of secondary data
- Crosscheck results from different sources, e.g. check responses from transporters with secondary data and information obtained from producers and wholesalers.
- Carefully select and apply survey methods considering:
    - type of data to be collected.
    - availability and skills of interviewers.
    - perception of respondents and their ability to provide specific information.
    - local conditions.
    - budget and time limitations.

6. Supply-Demand Balancing and Impact Assessment

The results of demand and supply analysis are input for supply-demand balancing, which refers to the development of alternative scenarios for demand and supply, in order to identify future developments and possible interventions. In addition, the impacts of these developments and interventions need to be assessed, in economic, environmental, and social terms. Impact assessment could lead to the development of additional scenarios, for example for interventions that aim to mitigate certain impacts. As such, supply-demand balancing and impact assessment are to a large extent parallel activities.

6.1. Supply-Demand Balancing

Supply-demand balancing is a crucial element in wood energy planning. It is the basis for identifying inconsistencies in data and imbalances in demand and supply. Data errors have to be resolved by reviewing the analyses for demand and supply, while imbalances should lead to the identification and evaluation of interventions. The outputs of supply-demand balancing would be a number of alternative strategies, which need to be evaluated in terms of investments and economic, environmental and social impacts. In short, the objectives of supply-demand balancing are to:

- evaluate the consistency of the data;
- identify scarcities and distribution problems;
- identify and evaluate options for demand and supply interventions.

Inputs for supply-demand balancing are the results of demand and supply analysis. During supply-demand balancing, it may appear that refinements of these analyses are needed, so the balancing of supply and demand overlaps with these tasks to a large extent.

Supply-demand balancing can be done at several levels, e.g. macro, sectoral, national and area-based level. Basically the same approaches can be used for all levels. It should be noted that balancing at aggregate level cannot reveal imbalances at more detailed level. For example, at national level resources may be sufficient to meet the total requirements, but in certain areas scarcities or pressure on resources may occur. Likewise, scarcities may exist for certain users groups, e.g. poor households, because accessibility of resources may differ for different user groups. Therefore, supply-demand balancing should be done for several levels of disaggregation.

6.1.1. Scenario Development

In scenario development we can distinguish several steps. Each is discussed in the following.

1. Identify base year and planning horizon;
2. develop wood energy balance for the base year;
3. develop base case scenario;
4. identify options for interventions and develop corresponding scenarios.

The initial step in scenario development is to identify the planning horizon, i.e. for which period scenarios will be developed. This can be short-term, say 5 years, or long-term, up to 25 or even 50 years. The period will largely depend on the planning objectives. For indicative planning, i.e. to assess demand and supply in broad terms, the period typically spans 10 to 20 years. For more detailed and project level planning, the planning period usually is shorter. Related to the definition of the planning horizon is the choice of the base year, which is the first year of the planning horizon and consequently the starting point for analysis and scenario development. The base year should be a recent year for which sufficient data are available for demand and supply.

Based on the results from demand and supply analysis, first a wood energy balance has to be developed for the base year, with the basic objective to check data consistency. The underlying reasoning is that what has been consumed must have been produced. Therefore, if total woodfuels demand appears to be considerably higher than potential supply, it probably means that demand estimates are too high or supply estimates are too low (or both), because if resources don't exist they can't be used either. Of course, shortages may occur, but this would mean that consumption is lower than it would be if more supply was available, and consumption would be close to potential supply. A major issue here is the supply from non-forest resources, which is considerably in most countries, usually larger than supply from forest resources. Omitting non-forest resources from the analysis would mean a severe underestimation of potential supply. Therefore, the base year balance may lead to revision of demand and supply data and analysis. The final base year balance will be the basis for scenario development.

In scenario development, we can distinguish between:

- Base case scenario: this is the scenario that is most likely to occur in the absence of any specific wood energy interventions. It should cover both demand and supply.
- Intervention scenarios: these simulate specific interventions, e.g. conservation efforts, price measures, tree planting, redistribution of supply. These interventions should be based on the base case scenario. By developing several alternative scenarios, different intervention options can be evaluated in terms of costs and benefits.

The results of the base case scenario will determine the type of interventions that may be needed or feasible. Therefore, it is important to develop a sound and realistic base case scenario, covering demand and supply. The base case scenario for demand needs to be balanced with the base case scenario for supply, before thinking of any interventions. For example, it would not be realistic to think of interventions that aim to reduce woodfuels consumption, if there is sufficient supply in the long run. In that case one could even think of options to encourage the use of woodfuels. Therefore, intervention scenarios for demand need to be developed concurrently with supply scenarios.

(a) Base Case Scenario

The base case scenario is sometimes also called the business-as-usual scenario, which doesn't mean that things stay the same. Both on the demand and supply side, changes may occur, without any government interventions driving these changes. This includes non-energy parameters, e.g. population growth, industrial production, economic growth, land use change, and energy parameters, e.g. average fuel consumption per household and per unit of production, use of fuels and devices for certain applications, development of end-use and conversion devices. Some aspects to consider in the development of a base case scenario are discussed below.

(b) Demand Scenarios

- Projections for sectors and sub-sectors like households and industries generally are available from planning agencies and economic units. Many countries have development plans for short- and long-term periods that may include these factors. Therefore, it may not be necessary to develop projections for them. However, existing projections may be based on targets of certain policies and programs, so then it may be necessary to assess whether these can be achieved. If projections are not available, they need to be developed in close consultation with sector experts and agencies concerned.
- When analysing energy intensity for a certain device and fuel, this can be in terms of final energy or useful energy (see section 3.1.1, *Levels of Energy*). When using final energy, it combines both the need for energy and the efficiency of the device in one parameter. Both factors can have an impact on future energy intensity, and this can occur independently and in opposite direction. For example, over time, households may use more efficient devices, which would lead to a reduction consumption, but they may earn more income, which could lead to an increase in consumption. Then the stronger effect would determine whether overall consumption increases or decreases.

(c) Supply Scenarios

- The main factor influencing scenarios for resources is the change in land use. For example, forests might be cleared due to expansion of agricultural land, an increase in population would lead to expansion of settlement area, and road construction could lead to loss of agriculture and forest lands.

These changes are likely to the potential resources. But, land use conversion may also generate a considerable amount of wood waste, which may become available as woodfuels.

Apart from changes in land use, changes in land management may occur and these could have an impact on the accessibility of resources. For instance, forest areas may become protected, or may be designated as logging concession areas, which would reduce accessibility for woodfuels gathering. Establishment of community forests could increase resources and their accessibility. Accessibility can also change due to a number of other factors. For example, road construction will make some areas more accessible. In case woodfuels become scarce, resources that were previously inaccessible may become accessible, e.g. increasing woodfuels prices could make resources accessible in economic terms.

Technologies used for woodfuels conversion may change over time. Existing equipment may be improved and there may a shift to better equipment. This could make woodfuels conversion more efficient, which in turn could lead to a reduction in requirements of primary resources. Changes in conversion technologies may be driven by several factors, like technological developments, woodfuels prices, and costs of woodfuels conversion.

In balancing base case scenarios for demand and supply, it may appear that future demand exceeds available supply. One should realise that this doesn't have to represent reality. First of all, the base scenario is the outcome of data and assumptions, which may be incomplete and inconsistent. Secondly, If shortages happen in the future, this doesn't mean that consumption will proceed as projected, leading to a gap. Consumers may respond to scarcities in several ways. For example, when they need to spend more time or money on woodfuels, users will try to use less, e.g. by minimising losses, using better devices, changing habits and operation practices, or switching to other fuels. On the production side, scarcities may induce people to plant more trees on their own land and may stimulate commercial woodfuels trade (Heaps et al., 1993). These responses need to be incorporated into the base case scenario, in order to develop a realistic scenario. Interpreting and presenting scarcities as "gaps", which would damage wood resources. Based on these considerations, the initial base case scenario may need to be revised to develop a final base case scenario. Nevertheless, even though physical gaps do not exist, people may still be suffering from woodfuels scarcities, which require interventions.

6.1.2. Interventions

The output of the base case scenario can reveal problems or undesirable trends in the future, such as shortages, unequal distribution of woodfuels or sub-optimal use of existing resources that require interventions, either on the demand side, the supply side, or a combination of both. Interventions can be implemented either by policies, such as pricing, subsidies, promotion of conservation or technologies, or by projects such as improved cook-stoves, community forestry, tree planting.

For each intervention under consideration, a scenario has to be developed. This should incorporate targets and costs of the intervention. The following section discusses common and other possible interventions for wood energy.

(a) Demand-Side Interventions

Historically, interventions on the demand side aim to reduce wood energy consumption, either through improved technologies or the manipulation of prices of alternative fuels such as LPG and kerosene. Because most woodfuels come from non-forest land in Asian countries, shortages may not be as severe as often thought, although local scarcities may occur. In some areas there may be a large over supply, which could be an opportunity for stimulating wood energy use by developing and applying modern technologies, e.g. dendro-power. Besides consumption in quantitative terms, interventions should also cover qualitative aspects like health and environmental benefits.

Households

1. Improved Cookstoves - The main objective of cookstove programs usually is to reduce total energy consumption by increasing the thermal efficiency. However, there is no evidence that more efficient cookstoves reduce total woodfuels demand. Unfortunately, with the realisation that improved cookstoves cannot save forests, interest in these programs has diminished. Apart from fuel saving, improved cookstoves can bring about several other benefits, like cooking comfort, smoke-free kitchens, time saving, convenience, health and safety. Present cookstoves, including the improved ones, emit large amounts of pollutants which contribute to global warming and seriously affect the health of users. In fact, many so-called improved cookstoves cause more emissions than a three-stone or tripod, because they reduce air-inlet, which reduces heat losses but also makes combustion incomplete. Therefore, cleaner and emission-free cookstoves are needed. Cookstoves programs should focus on this rather than on reducing consumption, and can be initiated in areas without a woodfuels scarcity.

2. Fuel Subsidies: By subsidising alternative fuels such as LPG and kerosene, many countries have attempted to reduce woodfuels demand, among other goals. In practice, this has hardly had any impact on woodfuels demand, mainly because the largest share of wood energy is collected and used without any money transfering involved. Furthermore, subsidies aim to make conventional energy affordable to the poor but they actually tend to benefit the more affluent households. Due to the low price these are not stimulated to use energy efficiently. Low prices also inhibit the development and use of new technologies that are more efficient and environmentally beneficial. Therefore, subsidies should be used sparingly and preferably phased out, in order to reflect the true economical costs of fuels. Since this may have severe social and economic impacts this should be done gradually, possibly compensated by subsidies to promote appropriate alternatives, such as improved wood and biomass energy technologies.

3. Other Interventions: Besides conservation measures, other interventions can be implemented. Although they focus on other aspects, they can lead to reduction in wood energy consumption at the same time. Some examples are:
   - Improved use: households often use woodfuels improperly manners, leading to energy losses and smoke. For example, the wood is not always fully dried, because users may not have time, or they believe that wet wood burns longer, requiring less attention. However, using wet wood significantly reduces the thermal efficiency and increases the amount of smoke. Overloading the fire and using large pieces of wood is also common, and the ash from a previous fire is not always removed, all leading to similar effects. These can cause severe health problems. Households are not always aware of this, so improvements can be achieved, even without improved technologies, e.g. by public awareness campaigns. In practice, this hardly occurs and it is hard to implement, because it is difficult to reach millions of households. Substantial efforts are required to make an impact.
   - Clean cookstoves: In recent years, a renewed interest in improved biomass technologies has emerged due to environmental concerns. Woodfuels use doesn't necessarily contribute to net CO_2 emissions, as long as its use is sustainable and combustion is complete (see section 0). Combustion in presently used cookstoves, even in the so-called improve stoves, is generally incomplete, causing emissions of major greenhouse gases. Therefore, clean combustion technologies are needed to reduce emissions. Such technologies are already available for household end-uses, but they need to be further developed, made cheaper and promoted on a wider scale. Carefully targeted subsidies and support programs are needed to achieve this. At the same time this would be beneficial from a health perspective, and it would provide considerable employment from woodfuels production. For countries that need to import fossil fuels, it would save on foreign exchange.

Industries

There is a large scope for improvements for woodfuels using industries. All types of interventions concentrate on the improvements of the production process, but objectives may vary. Energy conservation is the most obvious objective, but there may be many other reasons. For instance, reducing production costs could make industries more stable, which could lead to more and long-term employment. Cleaner production could be another objective, by reducing air emissions and local pollution of water and soil. Any intervention could have multiple benefits, such as reduced costs, safer working environment, less pollution and better products, as well as negative impacts. The targets for an intervention may vary, and will also depend on the interest of industries, because energy conservation may not always be their concern.

There are four types of interventions to improve production processes, i.e. housekeeping measures, process improvements, major equipment changes and fuel substitution.

- Housekeeping measures are generally cheap and easy to implement, and can be introduced by factory owners themselves without external technical assistance. Examples are drying and proper sizing of fuel, consistent fuel feeding, maintenance of equipment, and proper control of secondary and primary air in kilns. What is often needed is to create awareness of the possibilities through publicity campaigns, promotion and demonstrations.
- Process improvements are generally also easy to introduce, but besides raising awareness they require some technical assistance from outside, because small-scale rural industries often do not have the capabilities to implement these improvements. Examples are changes to the equipment to reduce heat losses and to improve air inlet. Changes in some stages of the production process can be implemented too, e.g. leaving bricks to dry in the sunlight before they go into the kiln.
- Major equipment changes will require technical and managerial assistance and back-up service. In some cases financial assistance may be needed, e.g. the provision of loans. Modern examples of major equipment changes are combined heat and power generation and co-generation.
- Fuel substitution is a feasible option for industries, and in fact this occurs without government interventions. But not all industry managers are able or willing to invest in fuel substitution, so substantial support may be needed. Of course this also involves major equipment changes, requiring technical assistance.

Services

End-uses and devices for the service sector are similar to households, and consequently interventions could be similar, focusing on technologies and operation practices. Because consumption patterns are largely determined by economic factors, interventions may be relatively easy to implement.

(b) Supply-Side Interventions

Interventions for supply can be divided into resources, technology and woodfuels flows.

Resources

Interventions for resources aim to enhance the sustainable supply of woodfuels. Several approaches can be followed:

- Improved management of natural forests: natural forests are important sources for woodfuels collection by nearby villagers and landless people in many areas. Enhancement of supply from natural forests could be achieved by involving the local population in the management of (degraded) forests, e.g. by community forestry programs as already initiated in many countries (joint forest management). This may be an appropriate strategy in areas where woodfuels are largely non-commercialised. Besides providing fuel, this can help governments to protect forest areas (RWEDP, 1997c).

- Woodfuels from non-forest resources: a large share of woodfuels is supplied by non-forest areas, such as homegardens and crop fields. This could be further increased by encouraging tree planting on private land, (further) promoting agro-forestry and the establishment of community woodlots on wastelands. This closely relates with the issue of land ownership and user rights, since people will not be inclined to plant trees on public or rented land if access rights are unresolved.
- Improved use of residues: forest logging, wood processing and agricultural production generate considerable amounts of residues. These could be used as an energy source but are often left unused, because of distribution problems and lack of proper technologies to convert them into convenient fuels. Efforts could be made to develop mechanisms for gathering, processing (e.g. briquetting) and distribution. Of course economic factors play an important role here, and financial support may be needed to make this economically feasible.

In supply enhancement strategies, one should avoid investing in large-scale dedicated woodfuels plantations. These are sometimes pushed by policy-makers and donors as quick and highly perceptive solutions, but past experiences have shown that these are largely economically unviable, since woodfuels is a low-value product. Other options such as community forestry and agro-forestry programs are generally much cheaper and more successful in providing sustainable sources of woodfuels supply.

Technology

- Improved charcoal kilns: commonly used charcoal kilns have low efficiencies and produce low quality charcoal. Several programs have aimed to improve production methods, with limited success. Improvements may require considerable investments, which users may not be able or willing to make, especially if sufficient wood supply is available. This also relates to commercial woodfuels trade, which is restricted in many countries, and therefore insecure. Attempts to improve charcoal production methods should be linked with proper regulations for the commercial woodfuels trading system.
- Modern technologies: several modern technologies exist for clean and efficient conversion of wood into more convenient energy forms, such as gaseous and liquid fuels, and electricity. These are increasingly being used both in developed and developing countries, and can support environmental objectives like increasing the use of renewable energy. At present some technologies may be too expensive and the may not fit with local practices and needs. Policies supporting research and development and the adoption of technologies could help to overcome this.

Woodfuels Flows

The commercial production and trade of woodfuels is subject to a number of restrictions, such as permits needed for tree harvesting and woodfuels transport. These restrictions act as a disincentive for the development of an efficient system for commercial woodfuels production and trade, and it is not proven that they help to protect the forests. People may be discouraged from planting trees on private land because of the regulations. For many people woodfuels trade is the main source of income but these regulations create severe obstacles. Some traders may therefore engage in illegal operations.

Woodfuels production and trade is rarely acknowledged as a legitimate economic activity that contributes significantly to the energy sector and provides substantial employment. Promoting sustainable production and trade, in combination with improved technologies, could be a viable strategy for most developing countries. This can have several benefits, such as increased employment, indigenous energy production, and environmental protection. To achieve this, regulations and restrictions need to be reviewed and removed, or at least applied only when carefully targeted, instead of enforcing them indiscriminately.

6.2. Impact Assessment

The output of supply-demand balancing could be a number of alternative intervention options. Each of these options may have several impacts on society as a whole, which have to be analysed, in order to identify major bottlenecks and adverse impacts (Ramani et al., 1995). The outcome of impact assessment may lead to the modification of existing scenarios or development of new ones. The alternative intervention options can then be presented with their positive and negative sides, as input for the formulation of policies and programs.

Types of impacts to analyse are:

- economic impacts;
- environmental impacts;
- social impacts.

6.2.1. Economic Impacts

The analysis of economic impacts is crucial in wood energy supply-demand balancing and scenario development. Economic impacts of trends and interventions can be direct and indirect. For example, government policies targeting a certain sector may induce secondary changes with additional impacts. Major economic impacts for wood energy are briefly discussed below. For more elaborate discussions on economic impact analysis see Codoni et al (1985) and Ramani et al (1995).

(a) Energy Imports

At present, many countries rely heavily on wood energy. With economic development, more users might tend to adopt other, mainly fossil-based fuels, leading to a substantial increase in their consumption. For countries that import these fuels, this would mean a greater dependence on energy imports, which affects the trade balance and makes the economy more susceptible to changes in international energy prices.

(b) Energy Prices

Energy prices are closely related with prices of products and services that require energy inputs. An increase in energy prices will generally lead to price increases for many products and services, particularly those that have energy requirements. The extent of this effect depends on the price elasticity of demand, the availability of cheaper energy substitutes, and government control on prices. Woodfuels scarcities may lead to higher prices, affecting households and industries.

(c) Fuelwood Collection and Time Allocation

Particularly in rural areas, many people collect and produce their own woodfuels. They may need to spend a considerable amount of time for this, which means they lose the opportunity to engage in other activities, such as jobs and education. This mostly affects women and children who are generally responsible for woodfuels collection. On a macro level, this may affect the productive capacity of the population.

(d) Costs and Investments

Governments avail of several policy instruments for implementing wood energy interventions (see also section 7.2). The main instruments and their possible economic impacts are discussed below (Ramani et. al 1995). In assessing the economic impacts, the direct costs as well as the indirect benefits, based on the expected effectiveness of interventions have to be investigated.

- <u>Pricing, taxes and subsidies</u>: these are commonly applied instruments to influence energy consumption, although for wood energy their impact is limited because it is largely non-commercial and, if commercialised, informal. Nevertheless, pricing and subsidising direct alternatives (e.g. LPG, kerosene), may affect woodfuels consumption patterns as well. Fuel subsidies could reduce consumption of woodfuels, but at the same time they add to the import bill or require large-scale investments in energy production, and they may hamper the development and adoption of modern wood energy technologies.

<u>Technology development</u>: current wood energy technologies are of poor quality, with low efficiencies and high risk of health impacts. Supporting the development of better technologies and their adoption, requires government policies that provide incentives for research institutes and private enterprises, e.g. by direct support or tax exemptions. The impact analysis should not only look at the development of the technologies, but also at the adoption of these new technologies by manufacturers and users.

<u>Investments</u>: Interventions may also require investments in energy production (e.g. for tree planting or dendro-power generation), either by the government or the private sector. These investments may induce investments by users and as such support other interventions and developments. For example, tree-planting programs may support the adoption of convenient energy technologies, providing a modern alternative to kerosene and LPG. In general, private investments induced by government policies are preferable to government investments, since the former are more likely to be self-sustaining. Nevertheless, in some cases private investors may not be able or willing to invest (e.g. when the scale is too large or the risk is too high). In these cases direct investment by the government might be necessary.

Energy conservation: In order to induce producers and users to conserve energy, governments can make use of information campaigns, training programs, demonstration projects, as well as the provision of incentives through taxes and subsidies. Assessing the impacts of these interventions is often problematic because it may be difficult to separate them from other phenomena that lead to similar changes.

(e) Environmental Impacts

The environmental aspects of wood energy use are diverse. They range from local land use to global climate change, and from applications in smoky kitchens to electricity generation in large-scale dendro-power stations. Consequently, environmental impacts of wood energy use and production can be both positive and negative. These can be studied by a process called Environmental Impact Assessment (EIA), defined as the process of identifying, predicting, evaluating and mitigating the biophysical and social effects of interventions, before they are implemented. The objectives of EIA are to (IAIA, 1999):

- ensure that environmental considerations are explicitly addressed and incorporated into the decision-making process;
- anticipate and avoid, minimise or offset adverse significant adverse biophysical and social effects;
- protect ecological processes and the productivity and capacity of natural systems;
- promote development that is sustainable and optimises use and management of resources.

When studying environmental impacts of wood energy, it is necessary to account for both for supply and consumption practices. The major aspects to consider are discussed below.

Deforestation

When talking about wood energy and environment, many people think of deforestation. Cutting wood for fuelwood and charcoal has often been cited as a major cause of deforestation, largely based on the ‘fuelwood gap theory’ (see section 1.2). Now it is widely accepted that the major cause of deforestation is the conversion of forest land into agricultural land and urban areas, due to the growing population and growing demand for food.

Nevertheless in some areas woodfuels use may contribute to localised deforestation and forest degradation, and this would require interventions. Forest clearing has an impact on soil quality, which may lead to erosion. Excessive use of forest resources through pruning may reduce the regenerating capacity of the forest, making it more vulnerable to wind and fire and affecting wildlife. Excessive use of fallen branches, twigs and leaves may deprive the forest of a vital nutrient source (Codoni et al., 1985).

Emissions

Combustion with devices that are commonly used is generally incomplete, leading to the emission of several harmful gases (see section 0). These contribute to global warming, and can have serious health impacts. So far, measurements of emissions from woodfuels devices have been done at a limited scale. More studies are needed to assess emissions from different types of devices, such as traditional and improved cookstoves, in order to account fully for their impacts.

It should be noted that natural decomposition (rotting) of wood and other biomass also emits CO_2 and small amounts of methane (CH_4). This should be included in the impact assessment, since it could be environmentally beneficial to use wood residues as fuel instead of letting them decompose.

Forest Plantations

Establishing large-scale (woodfuels) plantations can have serious impacts on soil, biodiversity, air and water, depending on management practices and past land use. These can be both negative and positive. For example, developing a plantation on previously barren land would obviously mean an improvement, whereas the clearance of natural forest for monoculture tree plantation could mean a loss of soil quality, biodiversity, and carbon storage. The use of chemical fertilisers will have an impact on water, which may jeopardise the health of people and animals.

Charcoal Making

Charcoal making using traditional ways affects the local environment, as well as the global environment. At a local level the process of charcoal making destroys all nearby vegetation and affects the soil. Charcoal making also emits pollutants such as CO_2, CO, CH_4, NMHCs and particulates, contributing to global warming and affecting the health of workers and nearby residents.

Social Impacts

Social aspects of wood energy are diverse and are particularly important for formulating and implementing programs and projects at local level.

Employment

Wood energy is strongly related to employment, particularly in rural areas. Firstly, commercial woodfuels production and trade is a major source of full-time employment. It also provides an opportunity to earn extra income during the off-season or hard times. Secondly, many rural industries, which provide substantial employment opportunities, use woodfuels as an energy source. Interventions may have impacts on both aspects. For example, policies that aim to reduce woodfuels consumption could lead to a loss of jobs for woodfuels traders, whereas promotion of modern woodfuels technologies might also provide employment in the woodfuels production sector. Similarly, impacts on industrial employment can be both negative and positive. Employment in the wood energy sector, whether direct or indirect, also relates to rural development and poverty alleviation.

Health

Most woodfuels in Asia are used by households mostly using traditional stoves. These stoves have low efficiencies and often burn wood incompletely, leading to the emission of pollutants such as carbon monoxide, methane and nitrogen oxides. Besides contributing to greenhouse gas emissions, these pollutants can have serious health impacts, e.g. headaches, respiratory diseases, adverse pregnancy outcomes (e.g. stillbirth, low birth weight), cancer and eye problems. Studies on the health aspects of cookstoves show that these impacts are severe (see Smith, 1987; Pandey, 1997). This also has an economic side, since health impacts can affect the level of economic output.

Gender

Households are not homogeneous entities, but consist of men (though not always), women and children who have different responsibilities, opportunities and needs. Generally, women are responsible for in-house activities such as raising the children and preparing food, which includes fuelwood gathering, and men hold control over resources such as land and money. Women also work more hours per day than men do. However, gender roles can be different per country, area and ethnic group. Consequently, men's wishes for improvements related to wood energy do not always correspond with the needs of women, who are the actual woodfuels users. Therefore, the roles and needs of men and women should be properly acknowledged.

Gender analysis refers to tools, or procedures, to help planners consciously and systematically take gender differences into account. Ideally, they should be applied to all projects, not just projects specially intended to benefit women, in order to avoid failures and adverse affects. Gender analysis starts with the recognition that households consist of individuals, and each of them has different roles, needs and interests. Gender analysis distinguishes (RWEDP, 1996b):

- The type of work done by men, women and children, and how the work is organised. Three categories of work are productive work, reproductive work and community work.
- access to and control over resources. Resources include money, land, equipment, political influence, time and education;
- macro-economic, social and political factors, that influence gender relations, e.g. male migration, religion, women's organisations;
- practical needs and strategic interests. Practical needs relate to food and water, education and health of children, and income. Strategic interests are long-term and less obvious, and they relate to improving the position of women, e.g. political participation, job opportunities, reducing violence and abuse.

7. FORMULATING WOOD ENERGY POLICIES

The interventions identified have to be translated into appropriate strategies and policies and implemented as programs and projects. This chapter discusses issues relevant to policy-making for wood energy[1].

7.1. Issues in Policy Formulation

One major difficulty in developing coherent wood energy policies is the fact that wood energy relates to so many policy areas. Obviously, these include government policies on supply and demand of energy at large, and policies on forestry, reforestation and land use. But they also include agriculture policies, as agricultural practices not only consume energy but also produce fuels in the form of wood and crop residues. Furthermore, industrial policies are relevant, particularly those which aim to support small-scale enterprises, many of which are in rural areas and use woodfuels. Further policy areas relevant to wood energy are labour and employment, rural development, gender issues, public health, technology transfer, international cooperation and trade. Last but not least, environmental policies of the government can have major implications for woodfuels issues. In all these areas national governments formulate policies. Some of these policies may support efforts to solve wood energy problems, others may not. Some government polices may even conflict and have adverse effects on wood energy, although these are generally unwanted and unforeseen. Resolving conflicts and harmonising the various policy areas is not an easy task, and there is no general solution to achieve this. How wood energy can best be addressed, will depend very much on the political structures and mechanisms in a particular country.

When considering policies relevant for wood energy, several levels of disaggregation should be distinguished, particularly with respect to rural areas. Some polices, like on pricing, imports and macro-economics, can only be formulated and implemented at central level. Other policies and interventions may require a detailed knowledge of local, site-specific conditions. Examples are local land use, woodfuels flows, local end-use and conversion technologies, consumption patterns and local management of resources. The corresponding interventions should preferably be prepared at a decentralised level of government authority, e.g. provincial, district or even village. This requires close interactions between the various levels of policy development and implementation.

7.2. Policy Instruments

The following policy instruments are relevant for wood energy development.

7.2.1. Legal Frameworks

These include laws and bylaws, acts, regulations, licences, titles, permits, etc. A lack of firm land titles for rural people is often dissuades people from growing trees for fuelwood and other purposes. Also, non-specific logging bans can be counter-productive or can unnecessarily affect villagers. Many regulations and permits are prevalent in the transport of woodfuels, but they are not always effective, or apt misuse. On the other hand, a differentiated legal system that incorporates protection areas with buffer zones allowing for controlled use of forest products, could simultaneously support environmental protection, rural development and income generation. Regulations on liabilities against government credits can have far-reaching implications for people's abilities to invest in improved woodfuels practices, e.g. improved technologies. Furthermore, environmental laws can be relevant for wood energy, provided these laws are being enforced.

[1] This chapter is based on Hulscher (1995b).

7.2.2. Pricing

This is considered one of the major policy instruments for governments. However, for woodfuels pricing policies are of limited effect as these are only partly commercialised. Still, the stumpage fee or royalty as practised by forestry departments is a factor in the price of fuelwood and, the sustainability of forest resources. Also, the pricing of alternative fuels such as kerosene and LPG and related goods and services are obvious instruments for a national government. Price controls have an economic impact by affecting the attractiveness of investments, and a social impact by affecting the distribution of benefits between producers, traders and consumers. For wood energy the impacts of price controls are not yet fully understood.

7.2.3. Taxation and Duties

These are further obvious instruments. Governments have to struggle constantly with conflicts of public costs and private benefits. It is very hard, though not impossible, to develop a tax regime which prevents individuals from earning their profits at the expense of public resources. This applies to the management of woodfuels resources as much as other natural resources. Taxes and tax exemptions for wood-based productive activities can further be applied to direct development.

7.2.4. Incentives

Incentives for wood energy development can be given in many ways, and they provide major instruments to stimulate or support a particular policy. Credits, subsidies, and free use of facilities and services are amongst the possible incentives. Straightforward product subsidise should be applied with great care, as a subsidy is not always effective for achieving the stated policy objectives. For instance, subsidising kerosene for combating deforestation by supporting an alternative for woodfuels has shown to be of very little effect, or can even adversely affect initiatives to grow fuelwood. On the other hand, a small subsidy for the acquisition of improved woodfuels stoves can be very effective. Also credits for small-scale industries to introduce woodfuels saving technologies can provide an adequate incentive. However, such credits should not exclude the informal sector, and this often implies a major administrative bottleneck to be straightened out by local authorities. Free use of facilities and services can be applied for testing technologies and for quality control in relevant productive activities. Other major incentives are extension and dissemination of information, advisory services, and further administrative supports.

7.2.5. Education, Training, Information and Demonstration

These can be grouped together as major instruments to implement wood energy policies. Usually, many other ministries incorporate these activities in addition to the ministry of education. Information campaigns and demonstrations should be prepared carefully, based on adequate understanding of local conditions and constraints. Too often policy makers think in terms of awareness creation only, as if that were sufficient to introduce change. Admittedly, awareness is usually the first phase in adopting new woodfuels options or new attitudes. However, it is not always acknowledged that many people, whether in urban or rural areas, are already very much aware, of the issues, especially those that affect their own interests. Sometimes they are right in being aware that an innovation that is being promoted will not necessarily respond to their needs. It is only by follow-up interventions like training and supporting measures, for instance credits or even subsidies, that a certain awareness can develop into real change.

Education at various levels is a long-term intervention and a most important factor for future wood energy development. Relevant educational programs are partly vocational, i.e. addressing the specific areas of expertise required for wood energy development. Other educational activities are general, i.e. incorporated as part of the country's general education system at primary, secondary and tertiary level, or built in as elements of specialised curricula in related fields, e.g. forestry, energy.

7.2.6. Infrastructure Development

This is amongst the major policy instruments in so many sectors, including the sub-sector of woodfuels development. It is up to central and local government authorities to create favourable conditions for the introduction and promotion of improved woodfuels consumption practices. Amongst the relevant infrastructural conditions are means for communication and transport for e.g. extensionalists and others. Relevant services refer to technical support for maintenance, spare parts and repairs of wood energy conversion devices. Even the local production of some capital goods that are essential for improved woodfuels use may have to be initiated by government interventions. It is acknowledged that major infrastructural facilities can not be developed for the sake of woodfuels alone, but some new infrastructures could incorporate the requirements of the woodfuels sub-sector.

7.2.7. Coordination

This is part of institutional development (discussed in section 7.3), and a necessary condition for the development of wood energy policies. As is obvious from the policy instruments listed above, woodfuels policies link to a wide range of issues and government interventions. It is up to a central coordinating body to overview the issues, analyse their implications, coordinate, and prepare decision-making by the government.

Some policy instruments will be effective only if applied in a package. For instance, taxation, pricing and legal frameworks go together where an industry is entitled to have tax exemptions when adopting a woodfuels saving technology, provided that industry qualifies in a certain category set by government regulations. Moreover, such an intervention will work only when the relevant industries are informed and, may be, advised how to proceed with the new technology and the supporting incentives.

7.3. Institutional Development

A country's institutional set-up for wood energy development encompasses norms, values and attitudes of the population, via legal frameworks, government structures and organisations, down to institutes, infrastructure and competence. It is this set-up which enables to prepare deal with wood energy in a proper way. What actually should be considered as 'proper', depends on the country's policy. Institutional development constitutes a major challenge to governments of developing countries as well as other countries in a changing world. This very much applies to institutional development for a complex issue like wood energy.

For instance, when woodfuels are an under-priced commodity largely ignored by policy makers, the result will be that people tend to use woodfuels in a wasteful way without even knowing they do so. The sub-sector will suffer from under-investment as is the case in many countries. Moreover, the technologies and infrastructure for more efficient conversion devices will not be available, and little competence will exist in the country to anticipate any depletion of woodfuels in particular areas. Obviously, it would not be sufficient to hire one or two consultants for a few months to redress the situation. Once the government has decided that woodfuels, indeed, is a precious commodity, it will take the country a long time to build up the proper institutions for change. What would at least be required is developing relevant expertise via education and training, establishing responsibilities within the government organisation for analysis and policy development, addressing the public, developing legal frameworks, infrastructures, and extension networks, and then prepare adequate interventions, including new pricing systems, the introduction of new technologies, etc. Such a programme may take several years before becoming effective.

Popular norms, values and attitudes are part of institutional development, as stated above. Also within the government sector itself, attitudes of civil servants often represent an under-valuation of wood energy. Sometimes, officers in the ministry of energy perceive rural energy as rural electricity only. These officers will be excited by devoting their attention to the preparation of some modern hydro-electric scheme, for which firm data are available or can be acquired, rather than engaging in the cumbersome work on wood energy. It is up to the policy makers to increase the overall appreciation and status of the so-called traditional energies.

If wood energy planning is to be taken up at all, it requires institutional development, which can be outlined in a number of initial steps as follows.

1. The central government acknowledges that wood energy is an important policy area, which is to be addressed. For such acknowledgement, a number of good reasons have been mentioned in section 1.3.1.
2. The government identifies or establishes a unit that is responsible for wood energy planning within the government. Related to this is the political question of which ministry will be responsible for wood energy planning, what will be the relation with the national planning commission, and what decision-making procedures will be instituted.
3. The unit develops relevant planning expertise by training or other, and analyses the wood energy problems to be addressed. The linkages with relevant policy areas are identified, and the respective policies are documented.
4. The unit identifies which type of information will be required for wood energy planning. The information needs will encompass both the demand side and the supply side in a very disaggregated way, corresponding to different regions within the country and other relevant parameters (see also chapter 3).
5. The unit considers which levels of local government should be involved in the process of wood energy planning, and how. Decision-makers are advised accordingly. Next, priorities are set, and suitable methodologies for data collection, interpretation, appraisal and planning are selected.
6. The unit identifies which relevant centres of expertise exist in the country (on economic development, wood resources, socio-economic surveys, gender, technologies, etc). Amongst the centres may be academic institutes, specialised units within other ministries, non-government organisations, consultancies and other private sector companies, international agencies and institutes, etc.
7. Working relations are established with the planning commission, decentralised government authorities and relevant centres of expertise, including (national) statistical offices. At the same time, the responsible unit for wood energy planning identifies which relevant types of information, competence and infrastructure are lacking in the country, and decides how to deal with these gaps. For instance, statistical officers and enumerators may need additional training to deal with various aspects of wood energy.

So far, the steps as indicated are all part of institutional development, and no real output on wood energy planning is yet achieved. The planning activities are still to start. However, the institutional development is a pre-requisite for wood energy planning.

Where in the steps as listed above, reference is made to a 'unit' within a ministry, this could also be taken as a 'committee', for instance a national advisory committee on wood energy development. However, for such committee to be effective, a firm link with the national government needs to be established. The link should specify the decision-making procedures following the committee's work, as well as budgets allocated by the national government to the activities of the committee. Also, it is noted that some countries do not have a ministry of energy under that name. In these countries energy is under the responsibility of another government department.

It should be emphasised that some elements in the steps listed above have a wider implication than wood energy planning. Amongst these elements are the scope for inter-ministerial coordination and the roles to be played by decentralised government levels. Sometimes it looks as if inter-ministerial cooperation is either just impossible or, alternatively, good enough to proclaim any decision-making postponed forever. There is no simple solution for this but there must be better alternatives to coordinate such multi-facetted problems as wood energy. Finding solutions for inter-sectoral or inter-ministerial coordination is probably one of the most crucial institutional developments for wood energy development.

It will depend on the country's general political and administrative culture, which authority in planning, decision-making and implementation can be allocated to decentralised levels. However, common experience in wood energy planning and related issues shows that state/province, regional/district, and even village levels have important roles to play. One of the reasons is that the planning and management of an issue like wood energy have to be closely connected, while the management of the implementation of wood energy interventions must largely be at the local level.

The final more general issue is the role of the private and non-government sector. For sure, in most countries, wood energy policies can hardly be implemented without contributions from the private sector. This being true, it may be effective for policy makers to interact with the private sector already in the stage of planning and policy formulation. This would reduce the chances that plans are being made and policies are being formulated which, in practice, can never be implemented. These days it is well recognised that public-private partnerships are indispensable for sound economic and social development. Similarly, non-government organisations have an essential role to play. These organisations are usually strong in expressing the people's needs and can give valuable advice to the government on the relevance of its policies. Furthermore, NGOs have proven to be instrumental in the implementation of improved wood energy practices.

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ENERGY AND POWER UNITS

Units for energy and power can easily be converted from one to another using conversion values, as given in the tables. The values give the conversion from the units at the left to the units at the top (e.g. 1 MJ = 239 kcal and 1 kcal = 4.2×10^{-3} MJ).

Energy

unit	*kilocalorie*	*megajoule*	*kilowatt hour*	*tonne of oil equivalent*	*tonne of coal equivalent*
abbreviation	*kcal*	*MJ*	*kWh*	*toe**	*tce**
kcal	1	4.2×10^{-3}	1.2×10^{-3}	100.3×10^{-9}	144.3×10^{-9}
MJ	239	1	0.2887	23.88×10^{-6}	31.42×10^{-6}
kWh	860.4	3.6	1	85.98×10^{-6}	122.8×10^{-6}
*toe**	9.969×10^{6}	41,868	11,630	1	1.428
*tce**	6.979×10^{6}	29,310	8,142	0.7001	1

* Note: the calorific values of both oil and coal may vary significantly, so conversion values for *toe* and *tce* vary as well. The conversion ratios given here are based on the European Union norm.

Power

unit	*watt*	*kilowatt*	*metric horsepower*	*horsepower*
abbreviation	*W (or J/s)*	*kW*	*CV*	*hp*
W	1	0.001	1.4×10^{-3}	1.3×10^{-3}
kW	1,000	1	1.360	1.341
CV	735	0.735	1	1.014
hp	746	0.746	0.9860	1

EXAMPLES OF QUESTIONNAIRES

Two examples of questionnaires for household energy surveys are given below. The first one could be applied for household energy surveys focusing on wood energy. The second one could be used to obtain wood energy information from socio-economic household surveys, as regularly conducted by statistical offices in many countries. It should be noted that these two questionnaires are merely examples, and they should be adapted to local circumstances and practices when implemented. It is recommended to seek advice from the national statistical office in a country when designing the questionnaire and implementing the survey.

Example 1: Questionnaire for Household Woodfuels Survey

The questionnaire has 3 main sections: A. General; B. Energy consumption; C. Energy supply. Section A covers general information about the interviewee, the household and the village. For each section, more questions could be added, going in to more detail for certain aspects. However, asking too many questions should be avoided, since this will take too much time, and the information obtained should fit with the objectives of data collection.

Energy Consumption

Section B covers information about end-uses, fuels, devices and amount of consumption. The main use of woodfuels is for cooking, so the questionnaire focuses on this. For woodfuels and crop residues, interviewees are asked whether the fuel is used, and if so, how much. If people do not use woodfuels or crop residues, they may have done so in the past, so they it should be asked when and why they switched. Apart from cooking, woodfuels and crop residues may be used for other purposes, so some questions related to other purposes are included.

The interviewee will indicate an amount of consumption, e.g. a bundle or a bag. It is necessary to measure this physically, preferably weighing it with a little scale. Ideally, the species of the wood, density and moisture content should be measured too, but considering the objectives of the survey, this can usually be left out.

Another important piece of information is the type of cooking stoves households use. Before interviewing households in an area, the interviewers should familiarise themselves with the stoves used and available in that area so they will be able to recognise and classify the stoves when doing the interview. This can be done by going to the market to see what stoves are sold, and what prices.

Energy Supply

Apart from energy consumption, it is important to know how households obtain the fuels and how much they spend for them. Section C covers these issues, with questions on whether people collect or purchase wood and biomass fuels, and what problems they face in doing so. Before doing the interviews, the interviewers should find out which fuels are available in the area (both woodfuels and conventional fuels) and what are the prices. Then for conventional fuels the consumption can be calculated from the expenditure, and for woodfuels earlier answers can be cross-checked.

Questionnaire for Household Wood Energy Survey

A. GENERAL

1. Name: ....
2. Age: ....
3. Sex: ....
4. Occupation: ....
5. Main source of income for the household ....
6. Address (name of village, district, province): ....
7. Number of household members ....

B. ENERGY CONSUMPTION

1. Household Cooking

   1.1 What is the main fuel for cooking? ....

   1.2 Do you use fuelwood for cooking (yes/no)? ....

   If yes:

   - how often (1. daily 2. regularly 3. sometimes 4. rarely) ....
   - how much (e.g. per day, occasion, or month)? ....

   Measure weight or volume !!

   If no, did you use fuelwood before? How long ago? Why not anymore? ....

   ....

   1.3 Do you use charcoal for cooking (yes/no) ....

   If yes:

   - how often (1. daily 2. regularly 3. sometimes 4. rarely) ....
   - how much (e.g. per day, occasion, or month)? ....

   Measure weight or volume !!

   If no, did you use charcoal before? How long ago? Why not anymore? ....

   ....

   1.4 Do you use crop residues for cooking (yes/no) ....

   If yes:

   - what kind (e.g. rice husks, bagasse, straw)? ....
   - how often (1. daily 2. regularly 3. sometimes 4. rarely) ....
   - how much (e.g. per day, occasion, or month)? ....

   Measure weight or volume !!

If no, did you use crop residues before? How long ago? Why not anymore? ....

....

1.5 Stoves for Cooking:

How many stoves do you use for cooking? ....

....

How do you obtain the stoves (self-made, purchased, made-to-order)? ....

....

What are the costs/prices of the stoves? ....

....

How long do the stoves last? ....

....

Do you have any problems with the stoves? ....

....

2. Other End-uses

2.1 Do you use fuelwood for other purposes (yes/no)..

If yes:

- what for? ....
- how often (1. daily 2. regularly 3. sometimes 4. rarely) ....
- how much (e.g. per day, occasion, or month)? ....

Measure weight or volume !!

2.2 Do you use charcoal for other purposes (yes/no) ....

If yes:

- what for? ....
- how often (1. daily 2. regularly 3. sometimes 4. rarely) ....
- how much (e.g. per day, occasion, or month)? ....

Measure weight or volume !!

2.3 Do you use crop residues for other purposes (yes/no) ....

If yes:

- what for? ....
- how often (1. daily 2. regularly 3. sometimes 4. rarely) ....
- how much (e.g. per day, occasion, or month)? ....

Measure weight or volume !!

C. ENERGY SUPPLY

1. Fuelwood: do you collect or buy? ....

   1.1 If collected:

   Where do you collect? (indicate type of land, e.g. homegarden, village, forest) ....

   ....

   Do you face any problems in collecting fuelwood? (e.g. not enough wood, difficult to land, obstructions in transport) ....

   ....

   What costs do you incur for collecting wood? (e.g. transport, labor, tools)................

   ....

   1.2 If bought:

   Where do you buy? (e.g. in the market, in the village, delivered at home, outside the village)

   ....

   ....

   What is the price? (e.g. per bag, delivery, bundle, kilogram) ....

   Measure weight or volume !!

   How much do you spend? *(per day, week or month)* ....

   Do you face any problems in buying fuelwood? (e.g. high or rising prices, difficult to land, obstructions in transport, difficult to get) ....

   ....

2. Charcoal: do you produce yourself or buy?

   2.1 If self-produced:

   Where do you collect the wood? (indicate type of land, e.g. around the house, in the village, in the forest)...

   ....

   Do you face any problems in collecting wood? (e.g. not enough wood, difficult to land, obstructions in transport) ....

   ....

   What equipment you use for making the charcoal (e.g. earth pit kiln, earth mound kiln, mud kiln, brick kiln, metal kiln) ....

   ....

   What cost do you incur for producing charcoal? (e.g. transport cost, hired labour, equipment)..

   ....

   2.2 If bought:

   Where do you buy? (e.g. in the market, in the village, delivered at home, outside the village)

   ....

   ....

What is the price? (e.g. per bag, delivery, bundle, kilogram) ....

....

Measure weight or volume !!

How much do you spend? *(per day, week or month)* ....

....

Do you face any problems in buying fuelwood? (e.g. high or rising prices, access to land, obstructions in transport, difficult to get) ....

....

3. Do you buy modern fuels (e.g. LPG, kerosene)?

3.1 LPG (yes/no): ....

If yes, how much do you spend? *(per day, week or month)* ....

If no, why not? (e.g. not available, too expensive) ....

....

3.2 Kerosene (yes/no): ....

If yes, how much do you spend? *(per day, week or month)* ....

If no, why not? (e.g. not available, too expensive) ....

....

3.3 Electricity (yes/no): ....

If yes, how much do you spend? *(per day, week or month)* ....

If no, why not? (e.g. not available, too expensive) ....

....

3.4 Diesel (yes/no): ....

If yes, how much do you spend? *(per day, week or month)* ....

If no, why not? (e.g. not available, too expensive) ....

....

3.5 Gasoline (yes/no): ....

If yes, how much do you spend? *(per day, week or month)* ....

If no, why not? (e.g. not available, too expensive) ....

....

3.6 Other (yes/no): ....

Example 2: Energy Questionnaire for Socio-Economic Household Survey

Many countries conduct household surveys to obtain information about their socio-economic status. These cover aspects such as housing, income and expenditure for goods and services, sometimes including energy. Woodfuels are often non-traded goods so they are not covered by this type of survey. A small questionnaire as given below could be attached to questionnaires for regular household surveys, in order to get an indication of wood energy consumption by households in a certain area, in case no statistics are available. It should be kept short (one page), so as not to take up too much of a housholds' time.

Energy Consumption Pattern

Indicate the fuels being used for certain end-uses and frequency of use:
1. daily 2. regularly 3. sometimes 4. rarely 5. never

	Cooking	Water Heating	Lighting	Other (specify)
Fuelwood				
Charcoal				
Crop residue				
Animal dung				
Kerosene				
LPG				
Electricity				
Other (specify)				

Fuelwood

1. How much fuelwood do you use? (per day, week or month) ....
2. How do you obtain fuelwood? (collected or purchased) ....

   If collected:
   - From what sources? ....
   - What are the costs of collection? ....

   If purchased:
   - How much do you pay? ....
   - How often do you buy? ....

Charcoal

3. How much charcoal do you use? (per day, week or month) ....
4. How do you obtain charcoal? (self-produced or purchased) ....

   If self-produced:
   - From which sources do you get the wood? ....
   - What are the costs of production? ....

   If purchased:
   - How much do you pay? ....
   - How often do you buy? ....