6 Planning sustainable urban wood energy systems

6.1 STRATEGIC AND OPERATIONAL PLANNING LEVELS

The challenges of the booming energy demand in urban areas of countries in tropical Africa, Asia and Latin America, combined with the poverty conditions of many urban and peri-urban dwellers, require a renewed and strengthened commitment by policy-makers together with adequate planning tools.

Two main planning levels can be identified: a *strategic* planning level, aiming at the formulation of national-level policies and strategies, and an *operational* planning level, aiming at the implementation of these policies in a local context.

To support strategic planning, it is necessary to have a comprehensive spatial knowledge of woodfuel consumption levels and sustainable supply capacities, which may be called a "strategic knowledge base". This holistic view of the wood energy sector should cover the entire country and show the geographic variability of demand and supply patterns.

The aim of this strategic knowledge base is to integrate all available spatial and statistical information on (or related to) woodfuel consumption and production capacities of a country, or broad geographic region, in order to create a geographically discrete overview of woodfuel demand/supply patterns and to determine the potential sustainable supply zones of selected urban areas. The main objectives of this geostatistical database may be summarized as follows:

- identifying and outlining woodfuel surplus and deficit areas, i.e. areas with a positive or negative woodfuel supply/demand balance, for an entire country (or broad geographic region);
- identifying administrative units and populations affected by subsistence energy shortages (deficit areas) as well as those with high bioenergy potentials (surplus areas);
- outlining the potential sustainable supply zones of major, or selected, urban areas with regard to urban/peri-urban woodfuel consumption and suitable/accessible production capacities;
- supporting strategic planning and policy formulation aiming at the establishment of sustainable wood energy systems;
- defining objectively priority areas of intervention (e.g. vulnerable regions and/or communities, urban woodsheds) within which in-depth studies and operational planning should be given precedence.

To support operational planning and sustainable resource management within specific urban woodsheds, it is necessary to undertake local studies, such as in-depth woodfuel flow analyses, providing reliable parameters.

The objectives of in-depth studies on urban wood energy and its implications on urban forestry, on the urban/rural interface and on sustainable resource management may be outlined as follows:

- guiding policy- and decision-makers to address energy demand in urban and peri-urban environments as it relates to the sustainable management of landscapes, forests and other woody resources;
- supporting the sustainable management of urban and peri-urban tree cover and other woody biomass resources;
- supporting the sustainable management of forests and other wood resources beyond peri-urban areas in response to woodfuel demand.

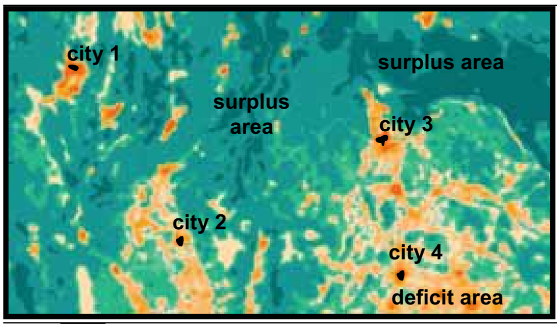
6.2 ADAPTATION OF THE WISDOM METHODOLOGY TO URBAN AND PERI-URBAN WOOD ENERGY

From a WISDOM methodological perspective, the creation of a strategic knowledge base implies comprehensive analysis of the WISDOM baseline and urban woodshed delineation for all major urban centres in a country.

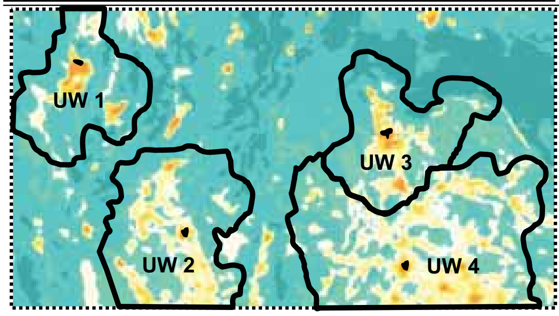
An in-depth analysis for operational planning represents a subsequent and more detailed level of investigation that may be limited to selected woodsheds. The main aims of these analytical steps are summarized in Figure 35.

FIGURE 35
Levels of analysis in support of urban wood energy planning (thematic maps are merely symbolic)

Strategic knowledge base

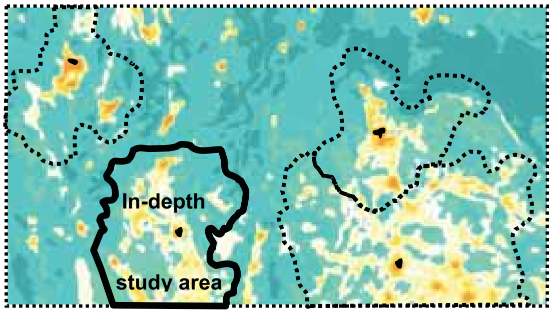


1. **WISDOM baseline**. An overview of the entire country (or broad geographic region) that, based on existing data and maps, provides a geographic representation of woodfuel supply/demand balance based on woody biomass supply potential and fuelwood/charcoal consumption patterns. This overview can be produced by using the standard WISDOM approach. The key features are wall-to-wall coverage; definition of deficit and surplus areas; categorization of administrative units; support to strategic planning and policy formulation, etc.



2. **Urban woodshed (UW) delineation**. A delineation of the supply zones of selected cities is undertaken using the WISDOM baseline data and additional parameters related to the commercial character of woodfuel sources and to accessibility factors. This analysis constitutes the additional urban woodshed module of the WISDOM methodology (see Sections 4.3.1 and 5.2), based mainly on existing data and maps. The aim of this module is to support strategic planning and to identify the priority areas of intervention, where additional investment in data collection and analysis is justified.

In-depth woodfuel flow analysis for operational planning



3. **In-depth study within priority urban woodsheds**. A detailed analysis of current and potential sustainable woodfuel flow with reference to a specific urban area and its urban woodshed, and with the aim of guiding policy decisions and operational action. This level of investigation requires accurate data since it seeks to support operational planning.

The WISDOM methodology, with the additional urban woodshed module that creates the strategic knowledge base, is described in detail in Section 4.3.1. The method was applied in the selected case studies described in Chapter 5. These analyses were based on relatively coarse thematic maps that were drawn for subregional analysis (FAO, 2006b; FAO, in press) but proved useful for the delineation and description of potential sustainable supply zones from different perspectives. The approach proposed is extremely flexible and can be adapted to the information already existing within countries or, as in the case of the East African and Southeast Asian studies, in regional and global data sets.

For operational woodshed planning the generic parameters of the overview are no longer sufficient. Consumption and supply data may need to be reviewed, except in the rare cases where recent surveys have produced reliable and location-specific information, and additional socio-economic parameters directly related to the woodfuel flow within the study area must be collected.

At this level of analysis a more detailed WISDOM is recommended, with additional parameters collected through woodfuel flow analysis methods, as described in woodfuel survey guidelines (FAO, 2002a; Zakia *et al.*, 1992) and applied in several case studies (FAO, 1997a; 1998b; 2000; 2001b). The parameters to be estimated in detailed woodfuel flow studies are summarized in the following paragraphs.

6.3 KEY PARAMETERS OF IN-DEPTH WOODFUEL FLOW ANALYSIS FOR OPERATIONAL URBAN WOODSHED PLANNING

The main parameters to be studied in order to allow local-level planning are briefly described here. Significant variables, their usefulness and practical survey methods may be found in *A guide for woodfuel surveys* (FAO, 2002a) to which the reader is referred for additional details.

6.3.1 Woodfuel demand

The determination and mapping of current woodfuel demand and the prediction of likely future scenarios are essential to understand people's needs and to define other thematic elements such as supply and provision. Table 16 gives a list of the main variables to be considered in the course of local woodfuel demand studies.

TABLE 16
Most significant variables to be analysed in detailed woodfuel demand surveys (FAO, 2002a)

General variables	**Breakdown and explanation**
End users Urban residential, rural residential, agricultural, industrial, trade and services, institutional sectors	By Size (number of users, households, establishments), geographic distribution (usually census subdivisions), form of provision
Specific variables	
Source of provision	Direct, indirect and recovered (see Section 6.3.2)
Saturation or penetration	Fraction of a given sector making use of woodfuels
Multiple fuel use	Families or establishments making alternative or contemporaneous use of two or more energy sources
Substitution	Amount of woodfuel replaced by a unit of alternative fuel
End uses	The needs that the user satisfies through the use of woodfuels
Activities	Major unitary operations that can characterize an end use
Fuel-burning means	Installations or appliances: stove, hearth, oven, boiler, lamp, etc. Simple fuelwood burning methods still in use in Bangui, Central African Republic, are shown in Figures 36 and 37
Consumption	Total consumption Specific consumption = amount of fuel consumed per consumer, unit of time, activity, unit of product obtained or unit of raw material processed

FIGURE 36
Simple improved stove in the market at Bangui, Central African Republic

FIGURE 37
Traditional three-stone system still common in households in Bangui, Central African Republic

Photos: Salbitano

6.3.2 Woodfuel supply

When considering woodfuel supply it is important to differentiate between *actual supply* (i.e. effectively available) and *potential supply*, which is what could be made available through sustainable management of wood resources and without compromising the normal production levels of other wood.

Since woodfuels are not normally stored for a long time, it may be assumed that *actual supply* is equal to *consumption* and consequently its estimated volume can be based on estimates of actual consumption.

On the other hand, *potential supply* requires the identification and measurement of all potential woodfuel sources, the estimation of legally and physically accessible productivity under sustainable management regimes and the deduction from such value of other wood products consumed under normal conditions.

Table 17 gives a list of the main variables related to woodfuel consumption to be considered in the course of local woodfuel supply studies.

TABLE 17
Most significant variables to be analysed in detailed woodfuel supply surveys (FAO, 2002a)

General variables	**Breakdown and explanation**
Woodfuel sources	Direct sources (trees and woody shrubs) Indirect sources (charcoal producers, sawmills, cellulose plants, furniture factories, tannin, resin and vegetal oil extraction plants) Sources of recovered woodfuels (residues of wood industries, discarded building or packaging material)
Specific variables	
Stocks	Total woodfuels from direct sources present in a unit area of a given resource at a given time. Not applied to indirect sources and recovered woodfuels
Productivity	Direct sources Total woodfuel productivity = net annual above-ground wood growth suitable for energy use, i.e. the increase of above-ground woody biomass in live trees and bushes, including stems and branches (excluding twigs and leaves) Accessible and available woodfuel productivity = total woodfuel productivity minus fraction of wood growth destined for other uses and not accessible because of legal and physical constraints
	Indirect sources Charcoal estimates are made from saturation and consumption studies For wood processing industries, it is possible to calculate supply by applying coefficients of by-product generation
	Recovered woodfuels Estimated on the basis of production statistics for wood derivatives, applying empirical or estimated recovery coefficients

The most common, and usually the only, sources of information on wood productivity are forest inventory reports and forest management documentation, but these are usually focused on timber assortments, rather than on woody biomass. They are limited to “productive” forest formations, while woodfuel sources are often open and degraded formations, trees and shrubs from farmlands, orchards, etc.

While woodfuel productivity values from inventory data of productive forests can be derived with reasonable approximation (FAO, 1997b; Brown and Lugo, 1984), acquiring data on the sustainable productivity of hybrid formations is far more complex and uncertain. Fully fledged surveys on sparse and heterogeneous landscapes are unlikely, but remote sensing data of adequate resolution and minimal field sampling can prove helpful and provide a first-level assessment of wood resources in non-forest landscapes, as was done in the framework of the Slovenia WISDOM study (FAO, 2006a).

Supply sources in the urban woodshed context

Woody biomass sources within the urban area. *Direct* sources are from pruning and thinning of green areas such as parks, gardens, road and shade trees (Figures 38 and 39).

Indirect and recovered woodfuel sources are by-products and residues of wood industries, and wood fractions of urban waste, discarded building material, etc.

FIGURE 38
Fuelwood from city park management in Bangui, Central African Republic

FIGURE 39
Twigs and leaves collected for fuel in Bangui, Central African Republic

Photos: Salbitano

Woody biomass sources in the immediate surroundings (urban development area). *Direct* sources are orchards, woodlots and farm trees, short rotation forestry and land conversion by-products related to urban expansion.

Indirect and recovered woodfuel sources are by-products and residues of wood industries.

Woody biomass sources within the actual supply area (current sources). The actual supply area can be outlined, with some approximation, on the basis of declarations by informed persons (fuelwood/charcoal retailers and traders, forestry officers, rural authorities, etc.).

It is important to distinguish between the sources of woody biomass suitable, and used, for woodfuel production destined for the urban market, which may be called “commercial” resources, and other sources that are suitable, and used, for local demand only. This distinction enables the theoretical area for the sustainable production of the necessary woodfuel to be mapped out.

Woody biomass sources within the potential supply area (potential supply sources under sustainable management). Once current and projected woodfuel consumption levels and the “commercial” productivity of main land use, land cover types and other sources have been determined, it is possible to revise the theoretical supply area, assuming a sustainable supply regime.

This new delineation based on detailed local information will help to update the urban woodshed zone determined during the first phase of the study. Enhanced productivity values collected in one location can thus improve the general overview and allow more reliable assessment of supply/demand balance analyses and more accurate delineation of other urban woodsheds.

6.3.3 Woodfuel provision (production, transport and marketing)

Woodfuel provision relates to the totality of processes and activities whereby woodfuels move from their place of origin to the end user. If the users themselves are responsible for production and transport, this is termed self-provision but if paid third parties are involved, the provision is referred to as commercial.

Table 18 gives a list of the main variables related to woodfuel production, transport and marketing to be considered in the course of local woodfuel flow studies. Several aspects of the fuelwood trade in and around Bangui, Central African Republic, are shown in Figure 40.

TABLE 18

Most significant variables to be analysed in detailed woodfuel flow studies (FAO, 2002a)

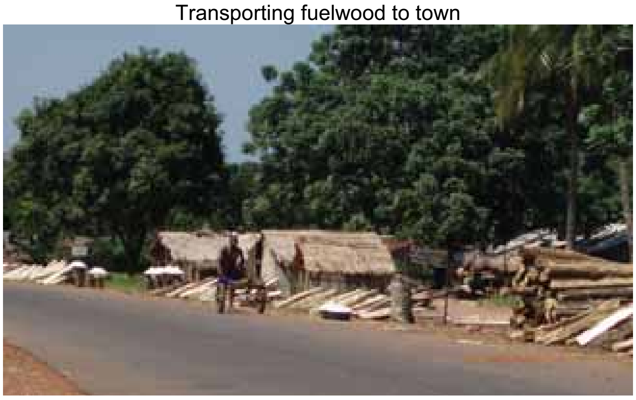
General variables	**Breakdown and explanation**
Woodfuel producers	Individuals or firms that harvest or recover woodfuel from their direct or indirect sources – loggers, farmers, charcoal burners, wood-based industries, wood recovery operators. These are subdivided by quantity, type (self-provision, commercial) and location
Transport operators	Individuals or firms that use any mode of transport (human, animal, mechanical) to take woodfuels from producers to traders and/or final consumers. These are subdivided by commercial transporters and self-providers
Commercial suppliers	Individuals or firms engaged partly or exclusively in buying and selling woodfuels. These are subdivided by quantity, size and location
Specific variables	
Type of provision	Self-provision Commercial provision
Periodicity of provision	
Cost of woodfuels	
Market network	Individuals and firms intervening in the commercial provision of woodfuels
Price setting for woodfuels	Price mark-ups during the passage from producer to end user via market supply chain or network
Woodfuel values	Exchange, use and existence values
Supplementary woodfuel variables	
Local units and their IS equivalents	
Specific weight	
Moisture content	
Heating value	

FIGURE 40

Transport and trade of fuelwood in Bangui, Central African Republic

Transporting fuelwood to town

Small-scale roadside fuelwood sales



Fuelwood and charcoal market in peri-urban area

Fuelwood log market

Photos: Salbitano

Accessibility zoning based on legal, physical and economic factors

The first two phases of analysis, the general overview and woodshed delineation, include a definition of the legal and physical accessibility of supply areas. This aspect is estimated tentatively on the basis of legal constraints (protected areas) and physical constraints (slope, distance from roads and settlements and distance from selected urban areas), as described in Section 5.2.1. See also Annexes 3 and 4.

During the implementation of in-depth studies, i.e. detailed investigation of woodfuel provision, additional elements and parameters should be collected to support the definition of real accessibility within the study area. These should include:

- elements of accessibility linked to land tenure and legal constraints;
- distance along roads and slopes within which woodfuel production is considered feasible and economical (under normal conditions);
- distance along roads, railways and rivers within which woodfuel transport costs are considered acceptable (under normal conditions).

Detailed accessibility parameters will help to revise further the urban woodshed delineated during the second phase of the study. Enhanced accessibility factors can thus improve the general overview and allow more accurate delineation of other urban woodsheds.

6.3.4 Analysis of the impact of urban woodfuel demand

The impact of urban wood energy has *n* dimensions, ranging from local and regional social, economic and environmental factors to global climate change in both negative and positive terms. The type of impact considered here is limited to the reduction in woody biomass productivity caused by excessive and non-sustainable fuelwood extraction and charcoal production for urban consumption.

Other types of impact will need to be considered when formulating long-term policies; however, they will be defined and discussed at a more detailed and circumscribed level of analysis.

Land cover monitoring

The perception of the relationship between woodfuel use and forest depletion has changed over time without achieving a stable and all-convincing position. The fears of the 1980s and 1990s of an epochal fuelwood crisis associated with forest destruction caused by excessive fuelwood exploitation have proved unrealistic (Arnold *et al.*, 2003) and there is now a more pragmatic understanding of supply sources, which are often non-forest, and of adaptive mechanisms in case of fuelwood shortages. However, the issue of booming charcoal demand linked to rapid urbanization is of great concern at present and deserves close attention.

Continued and excessive exploitation for charcoal production will cause degradation of forests and woodlands although permanent impacts generally result from the combination with other factors such as population pressure and demand for cropland. In the presence of a multiplicity of factors it is difficult or even impossible to point to a single cause or the contribution of a single factor. Nevertheless, it is important to identify and quantify unsustainable practices and land cover change rates in order to take remedial action and determine future resource scenarios. To this end it is recommended that land cover monitoring within the urban woodshed be undertaken by means of a methodology that guarantees the most reliable analysis of land cover changes and the best inference on the underlying cause-effect mechanisms.

The optimal approach to assess land cover changes should be based on permanent sample plots, which would allow assessing more subtle changes such as phases of degradation and change in species composition. In fact, rather than carrying out ad-hoc surveys for woodshed analyses it would be preferable to deduct the needed information from national-level inventory data periodically collected and designed to respond to the needs here discussed.

In general, however, continuous forest inventories are rare and woodshed-level change analyses must be based on present-day in-situ observations and remote sensing data for present-historical comparison. Several approaches exist nowadays to remote sensing-based land cover monitoring, thanks to the advances in sensors characteristics and image processing software.

The choice of the best approach depends on a range of specific factors that includes, of relevance, the accessible human and technological resources and experience on GIS, image processing and interpretation. If such capacities are high, a wider range of options is available, including the multi-temporal segmentation approach (Desclée et al., 2006), which appears rather promising, although the method is yet to be tested on varied contexts. In a lower technological context, a suitable alternative is the monitoring methodology based on the interdependent interpretation of multitemporal remote sensing data (FAO, 1996; Drigo, 1995), which aimed to ensure a reliable identification of land cover modifications based, mainly on visual analysis by fieldcompetent interpreters. Key recommended features of the monitoring methodology are described in Annex 5.

6.3.5 Social, economic and institutional context

Identification and mapping of stakeholders

A survey of woodfuel demand and provision enables the physical flow of woodfuels to be determined and the direct stakeholders of wood energy systems to be identified and located. These include not only woodfuel producers, traders, transporters, retailers and users but also institutional, legal and administrative stakeholders from the specific city and supply zones. These stakeholders must be clearly defined and be involved in the design of an operational project and in negotiations from the early stages.

In addition, after the delineation of the theoretical sustainable supply area, the forest and rural communities potentially involved in the expanded urban woodshed should be identified and included in the stakeholder map.

Analysis of stakeholders includes physical dimensions (volumes, numbers, distances) that are best analysed in a flow analysis, especially suitable for urban areas where consumption is concentrated (FAO, 2002a). Non-physical stakeholder dimensions, such as cultural and social, may be related to territorial competence, where this may be defined, or simply added as layers to the stakeholder map and as members of the decision-making process.

Analysis of social and economic dimensions

An analysis of the social and economic dimensions of woodfuel production, consumption, transport and trade (economic flows in and out of cities) includes the economic magnitude of commercial physical flows and can only be undertaken once these have been described and mapped.

Price chain analysis and the estimation of the contribution of each stage (producers, stockpilers, transporters, wholesalers and retailers) to final prices will help to formulate tax policies and social equity measures.

As stated in FAO's woodfuel survey guidelines, "An understanding of economic flows helps gauge and interpret the importance of woodfuels in the regional or national economy, their contribution to job creation and income generation, their potential for the creation of fiscal revenue and the impact of substitution of energy sources. This is very important for defining energy, social and natural resource management policy" (FAO, 2002a).

A socio-economic profile of users (income levels, elasticity) may be useful for projecting substitution rates according to economic growth trends and for defining likely demand scenarios also with regard to fluctuating oil prices.

In general, wood energy systems are characterized by a marked fragmentation of operators (producers, transporters, retailers) who tend to work in isolation on an individual or family basis. The sector is characterized by an almost complete absence of associations, such as those that group and strengthen farmers. Fragmentation leads to poor bargaining power and lack of job security especially for the weaker links in the chain – decentralized farmers and forest dwellers producing fuelwood and charcoal. In part, this is because fuelwood collection and charcoal production often take place out of formal legislative prescriptions and with the fear of illegality. Lack of formal rights to exploit communal areas, for instance, keeps the whole system extremely weak and damages the poorest operators and the environment. Compared with other rural and urban occupations, fuelwood collection and charcoal production are prerogatives of the poorest members of the community who, in general, have a low social profile.

As regards charcoal, traders and transporters' roles may dominate strongly over other operators (such as producers and retailers); they may often exert some kind of monopoly.

Formal recognition of customary rights over the exploitation of communal lands and contract agreements between producers and (urban) users of woodfuel would improve the equity of the system by enhancing and consolidating the role of decentralized communities and facilitating the sustainable management of forests and woodlands.

6.4 LAND MANAGEMENT OPTIONS AND BEST PRACTICES IN URBAN AND PERI-URBAN WOOD ENERGY PLANNING

The magnitude and complexity of the impact that recent urban booming has on landscape and land use require an understanding of the multiple spatiotemporal scales of urbanization versus land management (see Section 2.1.3). Moreover, city and regional, national and international policies demand more and more multifunctional benefits from the landscape in general and from forests in particular.

Matching multifunctional requirements with rapid urban development, preservation of landscape characteristics and environmental quality requires a great deal of prior planning with long-term perspectives and participatory approaches (FAO, 2005d). The importance of planning is illustrated by many case studies, such as that in Quito, Ecuador, which pointed out that many existing problems in the urban forest system could be easily resolved by a more universal commitment to planning at the strategic and negotiation level. The absence of sufficient prior planning often led to disastrous results. For example, planning efforts consistently underestimated the pace of growth of the metropolis (FAO, 1997c).

The ecological settings of cities have paramount influence on the typology and intensity of wood energy systems and their social, economic and environmental impacts. Similarly, there are no standard remedial actions or management solutions. Appropriate land management options and best practices must be identified on a case-by-case basis with relation to the ecological setting.

In general, land management and best practices for the production of woodfuels in urban and peri-urban contexts and, more widely, for the sustainable supply of woodfuels to satisfy urban demand may be oriented towards the following.

Broad strategic planning level

- The integration of urban, peri-urban and rural strategic planning must be a prerequisite for operational land management planning at this level and for the objective assessment of urban/rural interactions. This requires a preliminary evaluation of i) current woodfuel supply practices; and ii) potential sustainable supply capacities in a comprehensive analytical context, ideally covering the entire national territory and including eventual import/export fluxes. The baseline WISDOM analysis, which provides information on woodfuel deficit and surplus areas, appears particularly suited to this preliminary planning phase.

Urban and peri-urban planning level

- Tree species and management prescriptions must be identified and promoted to guarantee woody biomass production together with other environmental services such as protected areas; watershed protection forests; natural reserves and parks; and social, educational and recreational areas. Annex 6 lists the main pan-tropical fuelwood species and briefly describes the fuelwood species suitable for different land use systems and main environmental services.
    - Integration of fuelwood and charcoal production in multipurpose urban and peri-urban forestry.
    - Use of preferred fuelwood species with good coppicing capacities in water regime and soil protection plantations.
    - Local knowledge is valuable on suitable woodfuel species with a multifunctional character (since research on suitable species is extremely limited and often not oriented towards local solutions). When planting crops for fuelwood and charcoal production, preference should be given to indigenous species that are usually best adapted to local conditions and appreciated for their fuel quality. In silviculture, however, focus is often put on exotic species, since they grow quickly and provide good timber. But exotics may have detrimental effects in the long term; some indigenous species are equally fast-growing.
- The integration of agroforestry practices must be promoted in urban and peri-urban farming systems in order to increase woody biomass production.
- Urban development standards must be redefined that, together with minimum green area prescriptions for recreation and other environmental benefits, specify a minimum "woody biomass productivity" quota for new urbanized areas.[10]
- The recovery of all woody biomass from tree care and management of street trees and urban parks should be promoted.

[10] Using as reference the 9 m^2 of minimum per capita green area used in European urban development standards, it could be said that one or two trees per person could be dedicated to wood energy purposes; not enough, but certainly a significant contribution to per capita energy needs.

Integrated urban/rural planning level

- Formal agreements between urban authorities and peri-urban and rural associations (e.g. smallowners' associations) should be established, as well as other forms of alliance for the continued and sustainable supply of fuelwood and charcoal as part of urban planning.
- Contracts and guarantees on the wood energy chain should be under the responsibility and coordination of urban agencies or urban/rural consortia.
- Demonstration, education and extension events should be promoted for both urban and rural dwellers.