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Energy Supply for Three Cities in Southern Africa

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Stuttgart, July 2002

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Kurzfassung

Energie aus Biomasse, meistens in Form von Holzkohle, wird im südlichen Afrika überwiegend von städtischen Haushalten mit niedrigem Einkommen verwendet. Durch steigendes Bevölkerungswachstum wächst der Druck auf den Wald.

Anhand von Modellrechnungen wird analysiert, welche Einflüsse für die zunehmende Waldzerstörung verantwortlich sind und welche Strategien und Maßnahmen ergriffen werden können, um die Situation nachhaltig zu verbessern. Hierfür wurde die Modular Energy Systems Analysis and Planning Sofware (MESAP) verwendet.

Das Wachstum der städtischen Bevölkerung ist als wesentliche Größe des zukünftigen Energiebedarfs anzusehen, da davon auszugehen ist, dass sich die Bevölkerung in Maputo, in Dar es Salaam und Lusaka in den nächsten 20 bis 30 Jahren verdoppeln wird.

Der Haushaltsenergiebedarf in Maputo wurde 1980 bis 2000 zu 85-90% aus Holzprodukten gedeckt. In Dar es Salaam spielen Feuerholz, Elektrizität und Gas kaum eine Rolle. Der Holzkohleanteil ist hoch, jedoch zwischen 1980 und 2000 um 11% gesunken, der Paraffinanteil stieg um 12%. Die Haushaltsenergienachfrage von Lusaka erhöhte sich um 220% im gleichen Zeitraum und wurde zu 55% aus Holzkohle und 23% aus Feuerholz gedeckt.

Unter der Annahme, dass die Tradition der Biomassenutzung weiter anhält, wird der Holzkohleverbrauch in Maputo im Jahr 2020 auf 240.000 t ansteigen und sich im Vergleich zum Jahr 2000 ebenso verdoppeln wie in Lusaka. In Dar es Salaam ist auf Grund des Bevölkerungsdrucks im gleichen Zeitraum mit einem Faktor von 2,3 auf 720.000 t zu rechnen.

Durch die Einführung verbesserter Meilerbauweisen und Herde kann der Verbrauch erheblich reduziert werden. Damit könnte der Holzkohleverbrauch im Jahr 2020 in Maputo auf 180.000 t, in Dar auf 390.000 t und in Lusaka auf 260.000 t verringert werden.

Im sambischen Untersuchungsgebiet lässt sich durch Verbreitung beider Strategien der Bedarf im Vergleich zum Referenzfall um bis zu 54% im Jahr 2020 reduzieren.

Der Waldtyp im mosambikanischen Untersuchungsgebiet ist Savanne und unterscheidet sich deutlich von Tansania und Sambia, wo Miombo Wälder heimisch sind. Wachstumsraten von Savannenwäldern liegen mit maximal 57 t/km^2 a unter denen der Miombogebiete in Tansania und Sambia von 100 t/km^2 a.

Da 90% des Holzkohlebedarfs aus dem mosambikanischen Untersuchungsgebiet bezogen werden, ergibt sich im Vergleich zu den anderen Ländern eine zusätzliche Brisanz. In Tansania kommen 80%, in Sambia lediglich 25% aus dem Untersuchungsgebiet.

Ohne Maßnahmen und anhaltenden Druck auf die Untersuchungsflächen wird das Studiengebiet in Mosambik im Jahre 2018 vollständig entwaldet sein. Selbst eine Kombination der zuvor erläuterten Strategien mit allen forstwirtschaftlichen Maßnahmen kann eine fortschreitende Flächendegradation nicht aufhalten.

Durch den Bevölkerungsdruck in Dar es Salaam wird der Entwaldungstrend im tansanischen Untersuchungsgebiet weiter anhalten. Aufgrund der Regenerationsfähigkeit der Miombo Bestände kann jedoch unter Einführung der beschriebenen Maßnahmen die weitere Degradation im Jahr 2015 aufgehalten werden.

Im sambischen Untersuchungsgebiet ist der Einfluss durch das Köhlern am geringsten. Unter Durchführung eines Strategie Mix kann die ursprüngliche Dynamik in den Beständen im Jahr 2010 wieder erreicht werden.

Diese Strategien sind nur durchsetzbar, wenn einerseits verbesserte Technologien in den Städten verfügbar sind und vertrieben werden. Andererseits muss die angrenzende Dorfbevölkerung die Umsetzung der forstwirtschaftlichen Pläne mittragen.

Abstract

Biomass energy, mostly in the form of charcoal, is used predominantly by low-income urban households in Southern Africa and through its use, it places severe pressure on the natural woodlands from which it is obtained.

The objectives of this project were to model the different influences on the woodlands in three sample areas i.e. Maputo Province (Mozambique), Dar es Salaam (Tanzania) and Lusaka (Zambia). The final aim of the model was to help to indicate sustainable charcoal potential areas by defining strategies.

The methodological approach was made by using a method from the systematic energy analysis planning. With the help of the Modular Energy Systems Analysis and Planning software, (MESAP) the different models with different options were simulated.

Designed at the University of Stuttgart, MESAP is a decision support system for energy and environmental management on a local, regional or global scale.

For the household energy system of the three examined cities, the most important driver is the growth of the urban population, which is determined through three different scenarios for each city. The population of Dar es Salaam, Lusaka and Maputo is going to be doubled in the next 20 to 30 years.

In Maputo almost 85-90% of the energy demand in the households is satisfied by wood based fuels. In the Dar es Salaam household energy market, fire wood, electricity and gas play no big part. The part of charcoal sunk of 11% between 1980 and 2000 and the part of paraffin rose to 12% of the consumed toe in 2000. The household energy demand of Lusaka increased of nearly 220% between 1980 and 2000. The biggest part of consumed energy are the wood fuels with 78% consumed toe in 2000, 55% charcoal and 23% firewood.

The actual charcoal consumption of Maputo is about 140.000 t, of Dar is 314.000 t and of Lusaka City is 240.000 t in the year 2000. The modelled urban charcoal consumption for the year 2020 is 240.000 t (Maputo), 720.000 t (Dar) and 507.000 t (Lusaka) in the reference case.

The wood consumption of the cities can be reduced in an enormous way by using different strategies and cases, which are the propagation of improved kilns and / or stoves.

With the measure “propagation of improved stoves”, this can be reduced to 180.000 t (Maputo), 390.000 t (Dar) and 260.000 t (Lusaka) for the year 2020.

For Zambia also, these strategies were chosen to remain on the wood-fuel related level, Lusaka already uses many kerosene and electrical stoves.

In Zambia 80% of the total wood demand is used for charcoaling and is also calculated with 80% in the reference case in 2020. The part of wood for charcoaling can be reduced to 60% by using other measures such as the substitution of wood stoves for example.

The simulation of Zambia with the strategy “improved stoves” leads to a total wood demand of 2,27 Mio t in the year 2020 and with the strategy “improved kilns” to a demand of 2,7 Mio t in 2020. The strategy “improved stoves and kilns”, which combines the two measures, comes to a total wood demand of about 1,7 Mio t in 2020. That means 54% of wood can be saved compared to the reference case in 2020. Although the population of Lusaka City is increasing, it is possible to reduce the wood consumption to a smaller volume than today by using more efficient stoves and kilns.

The strategy " improved stoves and kilns " in the “optimist” case leads to an evident decrease of wood consumption in Zambia, where the simulated wood demand is 20% under the demand in 2000.

Woodland development of the three countries is different. The vegetation of the study area in Mozambique is savannah with low growth rates of about 57 t/km² a. In Tanzania and Zambia it is Miombo with average growth rates of more than 100 t/km² a.

90% of the wood or charcoal demand of Maputo is satisfied through the study area. Without measures, the woodland in this area would be completely finished before the end of 2018. Even the immediate implementation of certain strategies with forest measures would not prevent the woodland from decreasing as the demand from the study area is much higher.

Combined strategies are only suitable to prevent the forest from a complete destruction in the next 30 years. The biggest issue is the increasing demand of charcoal because of population growth rate in Maputo and Matola. It is assumed that about 80% of the total charcoal demand is satisfied through the study area. By using consequent forest strategies as well as the introduction of some household measures the woodland could be prevented from exploitation.

The trends of degradation in Tanzania is going to increase in the next years due to the enormous population growth rate. The increasing population in Dar es Salaam and the expansion around the city could have big impacts on the not yet exploited woodland areas. But as Miombo is supposed to regenerate itself better than savannah a turnaround can be achieved with all measures at the year 2015.

For the woodland development of the Zambian study area, it is important to know that only 25% of the charcoal for Lusaka comes from the study area. Zambia could be divided in three land types: plateau, hill and flat topography.

The development in the plateau area of Zambia declined constantly from about 9.550.000 in 1989 to 7.140.000 t in 1998. The further development is down to 4.270.000 t in 2020, ie. the wood production would be bisected within less than 30 years, due to the weakening of the re-growth woodland through erosion and cutting and to the conversion into agriculture.

In comparison, the development of the hill stand is totally different, as the nature woodland only decreases slightly from 1989 to 2020 and the re-growth woodland increases a lot. Therefore the total possible wood production only decreases of 4% between 1989 and 2020.

The re-growth wood production of the flat country stand development has increased as well between 1989 and 1998. As there seem to be a quite good potential in this area for making charcoal, the development should decline up to 2010 and likely grow again because of coppicing and re-growth from former agriculture.

In the Zambian study area the influence of making charcoal seems to be less than in the other countries. With a mix of strategies, it should be possible to come back to the same wood productivity level under a low population growth rate.

The most important factor for implementing forest measures in Mozambique, Tanzania and Zambia is the involvement of the villagers, which is only guaranteed if a profitable participation of the villagers is found.

1 Introduction, Objective and Methodological Approach

1.1 Introduction

Biomass energy, mostly in the form of charcoal, is used predominantly by low-income urban households in Southern Africa as it is seen in the other reports of this volume. While charcoal is an affordable and available energy source, its use places severe pressure on the natural woodlands from which it is obtained.

So that all current data could flow into the model this final report of the CHAPOSA Volume was worked out by IER after the final meeting held in Maputo on October 30th 2001. The report is based on the methodological approach as seen in section 1.3 and the input data of the partners in Africa as well as data from SEI, from IER and other institutions e.g. the GTZ.

The focus was to define the model and build up strategies on the basis of scenarios for the three sample areas i.e. Maputo Province (Mozambique), Dar es Salaam (Tanzania) and Lusaka (Zambia). After discussion in Maputo certain changes and proposals were taken into account, especially proposed scenarios or strategies. The model structure with the input data of the partners including estimated data was prepared in an iterative process as it can be seen in Figure 1-1. The purpose was to fill the model with more and more data from the countries due to replace data coming from other regions of Africa to expand the model structure and to build up strategies for the household and the woodland sectors and to combine the strategies.

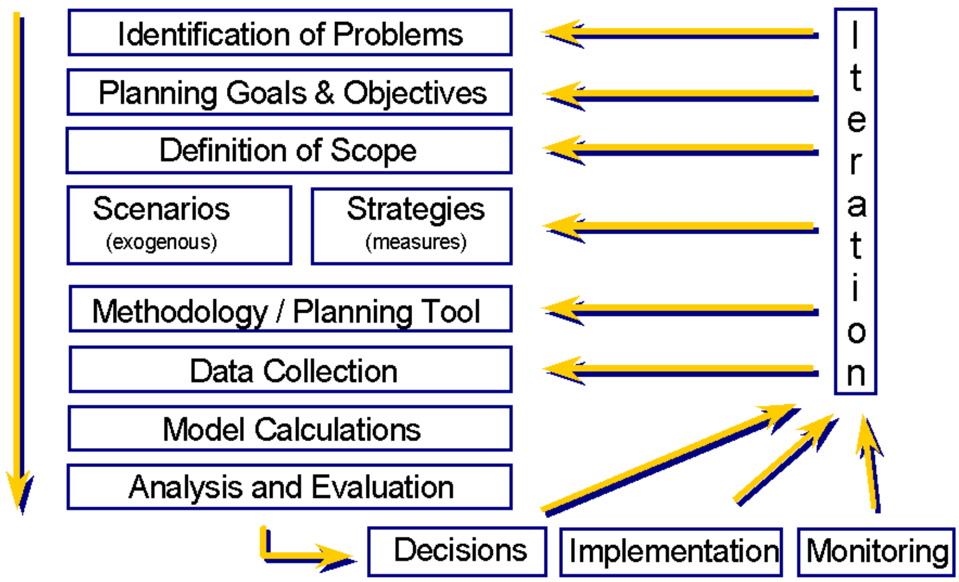


Figure 1-1: Phases of Structured Energy Planning

Figure 1-1 gives an overview on the structured energy and environmental planning. The first step of the planning is to identify the existing problems. In the second step the goals are defined. The next phase is to determine the time period and the regional allocation of the analysed system. The limits of the RES-Structure are also defined. Phase 4 is to collect all necessary data. This is an ongoing process as there are always some gaps which have to be filled. The iterative process leads to a more and more precise data base. The next steps are to define scenarios and to calculate strategies. These items are mentioned in Scenarios, Strategies. The decision makers have to decide if and how the strategies will be implemented. This phase should be accompanied through monitoring.

The structure of the RES is demonstrated and explained in section 2.1 RES-Structure of the Energy Model. The scenarios include possible developments which depend neither on planning nor on decision makers. Strategies are measured in the circle of influence of the decision makers. The scenarios and strategies are described in section 1.3.5 Scenarios, Strategies. The results of the modelling work are carried out in chapters 3 to 5 for each country separately.

The models provide integrated views of the drivers of charcoal, the demand structure, the transport and conversion system and woodland resources.

1.2 Objectives of this part of the CHAPOSA-Project

The objectives of this part in the interdisciplinary project were to model the different influences on the woodlands beginning from the demand side, the transportation and the charcoal making processes. The model should give an idea of what happens to the different study areas under certain scenarios in the future and what could be defined as strategies to prevent the forest from degradation in the last consequence of the circle. With help of the model the possibility to ensure an affordable and sustainable supply of biomass energy for low-income households should be definable.

The model takes into account the perspectives of natural resource management, social and economic development as it can be found in different scenarios of the population growth rates and appropriate policy intervention. The final aim of the model was to help to indicate sustainable charcoal potential areas.

1.3 Methodological Approach

The methodological approach was made by using a method from the systematic energy analysis planning. In the field of energy and environment, planning models are used frequently to avoid the risks of experiments on real energy supply systems on the one hand. On the other hand it is sometimes not possible to make experiments with the system because of risks or financial limitations /Voß, 1999/

As there are several options that can be taken into account, a method was searched that could be adopted on the issues of this project. Convenient modelling tools are simulation tools. The following description gives an overview on the used planning system.

1.3.1 Description of MESAP

MESAP (Modular Energy Systems Analysis and Planning Software) has been designed as a decision support system for energy and environmental management on a local, regional or global scale. MESAP consists of a general information system based on relational database theory which is linked to different energy modelling tools. In order to assist the decision making process in a pragmatic way, MESAP supports every phase of the structured analysis procedure (SAP) for energy planning. MESAP offers tools for demand analysis, integrated resource planning, demand-side management and the simulation or optimisation of supply systems. In addition, MESAP can be used to set up statistical energy and environmental information systems to produce regular reports such as energy balances and emission inventories.

MESAP is a technology transfer product designed at the University of Stuttgart and developed according to professional software engineering standards. It has been designed as a tool for experts working in the field of strategic analysis of energy and environmental problems. Therefore, it can be used by planning departments of ministries, consulting companies, donor agencies, research institutions and energy utilities. The close connection to the university assures that the most recent and sophisticated methodologies developed in research projects are rapidly integrated into MESAP and thus are quickly made available for the daily tasks of planning /Baumhögger et al., 1998/.

1.3.2 Concept of the planning tool PlaNet

The energy demand and supply module PlaNet of the energy and environmental planning instrument MESAP has been created for long-term strategic planning on a national, regional or local level. Like all modules of MESAP, it is based on the network database NetWork with the Reference Energy System (RES) as a structuring principle /Schlenzig, 1997/.

The basic principles as well as the theoretical background of the flow calculation module are described as follows.

The PlaNet flow calculation uses a transparent set of linear equations, which can be solved sequentially. It is also possible to integrate non-linear equations if required. In standard energy planning studies, the user specifies the activities or drivers of demand represented as quantities of a commodity, for example the population as it was used in the case studies. With the help of intensities (ratios between flows) like electricity consumption per person, the demand in final energy or energy services (both are quantities of a commodity) is determined as the product of an activity and an intensity. If a commodity is produced by more than one process, market shares for these processes have to be specified to determine which fraction of the commodity is produced by which process. Using the market share the necessary output of a process is determined. In order to calculate the required input flow into a process, a process efficiency has to be multiplied with the process output flow.

The required inputs for the PlaNet flow module are:

- One or more quantities of a commodity (normally for drivers of the energy system)
- Market shares
- Efficiencies of processes (and ratios for processes with more than one input or output flow)

The flow module calculates:

- The quantities of all remaining commodities
- Quantities of input and output flows of all processes

The Flow module performs calculations defined for balancing periods, starting with the base period. Usually balancing periods are one year. The time span between the base period and the last period analysed is called the modelling horizon. Normally not every period within the modelling horizon is calculated. The periods actually calculated are called support periods. The cost calculation module uses the same time scale as the simulation model /Baumhögger et al., 1998/.

1.3.3 Flow Calculation in PlaNet

The equation system of the flow calculation consists of five types of linear equations.

- Transformation Equations relate input and output flows of a process to each other.
- Exogenous Definitions assign a fixed value to a variable.
- Commodity Consumption and Production Equations balance the quantity of a commodity. The flows leaving this commodity equal the flows entering.
- Allocation Equations determine the proportions of flows producing a commodity.

The equations and their usage are described in the following sections. For details on working with the PlaNet Flow model refer to the chapter “The Models menu” in the User's Guide.

Transformation Equation (TR) of a process

The quantity of each flow not defined otherwise (exogenously defined or independent variables) is called “calculated flow” and is determined by a TR. The quantity of a flow $quan\_flow_{i0}$ of a process i is determined by summing all relevant flows $quan\_flow_{ij}$, j=1...n each multiplied with the corresponding ratio. The general format of a transformation equation is presented in the equation mentioned below.

$$quan\_flow_{i0} = quan\_flow_{i1} * eff_{i1} + quan\_flow_{i2} * eff_{i2} + \ldots \tag{1-1}$$

Exemplary TRs:

- The quantity of coal $quan\_flow_{i0}$ required in a power plant i with a specific efficiency eff_{i1} to produce a certain amount of electricity $quan\_flow_{i1}$
- The amount of CO2 emissions of a coal power plant using an emission factor eff1, [kg CO2 per kg coal] and the quantity of coal quan_flowi0 consumed.
- The quantity of heat $quan\_flow_{i0}$ produced in a power plant with co-generation per quantity of produced electricity $quan\_flow_{i1}$ using a relation between the output flows effi1.

For the specification of the TRs, following rules apply:

- At least one TR has to be specified for each process.
- One TR is specified for each flow, that is not defined otherwise.
- The maximum number of TRs is the number of flows of a process minus one
- Each flow has to be referred to in a TR.

Exogenous Definition (EX)

Quantities of flows and commodities can be defined exogenously. The format of EXs is:

$$\mathrm{var} = \mathrm{exog} \tag{1-2}$$

Variables often specified with EX are:

- The final energy demand
- The supply of renewable energy, and
- Activities like the size of the population.

Commodity Consumption Equation (CC)

Commodity consumption equations (CC) determine the balance of flows leaving a commodity, hence the balance of consumption. For each commodity with consuming processes, a CC is established. The quantity of a commodity is determined by adding up all flows consuming this commodity:

$$quan\_com_j = \sum_{i = cons.\, procesess} quan\_flow_{ij} \tag{1-3}$$

Commodity Production Equation (CP)

The commodity production equation (CP) is the balance of flows entering a commodity, hence the balance of production of a commodity. For each commodity (except primary energy carriers, which are usually not produced within the regarded energy system) a CP is established. The total quantity of a commodity is determined by adding up all flows producing the concerned good:

$$quan\_com_j = \sum_{i = prod.\, processes} quan\_flow_{ij} \tag{1-4}$$

The CC and CP are established automatically. No specifications by the user are required.

Allocation Equation (AL)

Allocation equations (AL) allocate a certain fraction ("Market Share") of the production of a commodity to a process. For a given quantity of a commodity the quantity of the flow producing this good is calculated using the AL:

$$quan\_flow_{ij} = quan\_com_j * market\_share_{ij} \tag{1-5}$$

For the usual direction of calculation (the demand of products is specified in order to calculate the demand of primary energy carrier), the fractions of the production have to be specified for all entering flows except one. This last flow is the so-called residual flow and is calculated automatically by the system.

For example to determine the flows coming from different types of power plants producing electricity, the producing flows have to be allocated. Different flows of electricity are produced by different power plants. The percentage of these fractions are called "Market Shares":

- 30% are produced by coal power plants,
- 20% by hydro-electric power plants,
- 10% by wind converters, and
- the residual by gas power plants (40% = 100% - 30% - 20% -10%).

It is also possible to allocate the consumption of a commodity: a certain quantity of electricity is consumed by different sectors. The percentages are then called "Product Shares".

- 35% are consumed by households,
- 50% by the industry, and
- the residual by the service sector (15% = 100% - 35% - 50%).

The concept of the residual flow does not apply to all commodities. For example, if one activity (like "Population") is the driver for several different energy services, in this case, instead of a market or a product to share, the market or product assignment applies. Thus, "Market Assignments" do not add up to 100%.

$$quan\_flow_{ij} = quan\_com_j * market\_assignment_{ij} \tag{1-6}$$

Flows that are determined through allocation equations are regarded as independent variables for the corresponding process.

With these six equations an equation system can be established where the number of equations is equal to the number of unknown variables. Hence, all variables can be determined. /Baumhögger et al., 1998/.

1.3.4 Forest Model Calculations

In unmanaged woodlands, forest development follows a succession of periods of undisturbed natural growth, interrupted by intermediate loss or damage of trees caused by fire, wind and other natural hazards. In managed woodland, thinning operations have a significant effect on the future evolution of the source. Thus the models must include the natural growth and the thinning /Gadow, Gangying, 1999/.

This is represented by highly aggregated yield-over-age equations and used in resource forecasting, specifically for predicting the development of a given age-class distribution in response to a series of periodic harvest levels /Gadow, Gangying, 1999/. For the modelling process, the regional yield model methodology of /Gadow, Gangying, 1999/ was adapted to the study areas of CHAPOSA.

The saket vegetation index from the partners were assumed to three principal land use forms: natural forests, grass lands and agricultural land as well as re-growth woodlands. The woodland development depends on decreasing factors like fire and increasing factors like the growth rate as it is mentioned in equation (1-7).

Forest development reacts to different thinnings or clear cut technologies that are additionally influenced by other factors like bush fires, erosion or grazing which are near-referred in the equations as follows.

The equations presented in this section refer to the time scale definition of figure 1-2.

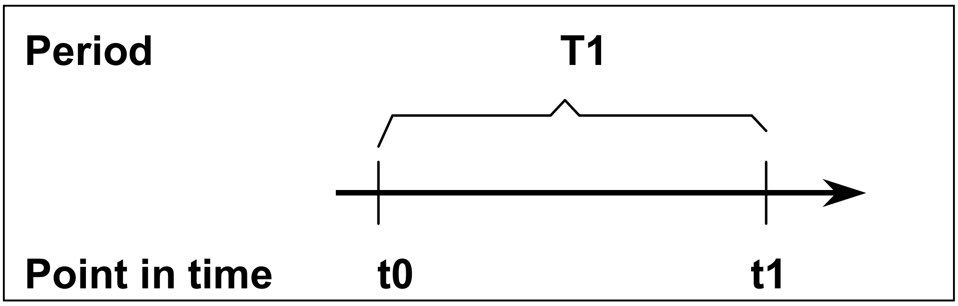


Figure 1-2: Definition of Time Scale.

In the first equation (1-7) the balance of standing volume of the forests is presented. This differential equation is used to calculate the future development of the standing volume for different scenarios. Each type of forest land can be balanced separately. The total forest cover of these types can be determined by aggregating the standing volumes of each type.

$$F_i\,(t1) = F_i\,(t0) + F_i\,(t0).r - D_i\,(t1) - (a + b + c) \qquad (1\text{-}7)$$

with

$F_i\,(t1)$	volume standing in t1
$F_i\,(t0)$	volume standing one year ago t = t0
$F_i\,(t0).r$	growth of wood in year 1 (t1)
$D_i\,(t1)$	consumed in period t1
a (t0 -t1)	forest destroyed by bush fires in period t0 to t1
b (t0 -t1)	forest destroyed by erosion in period t0 to t1
c (t0 -t1)	forest destroyed by grazing in period t0 to t1

In the second equation (1-8) the balance of covered areas is performed. Again each type of forest cover can be balanced separately and the total is determined by summing the areas of each type. The balance of covered areas is used to calculate the future land use for different assumptions. The change of land use is the fundament for the determination of two indicators that hint at a lack of sustainability of the charcoal system:

- The degree of reduction of land covered with forest
- The reduction of the areas of a certain type of forest

$$A_i\,(t1) \;= A_i\,(t0) + Ar_i - D_i\,(t1)/d_i{*}x_i - X_i\,(t1)/d_i \qquad (1\text{-}8)$$

$A_i(t1)$	area covered with forest of type i in t = t1
A_i (t0)	area covered with forest of type i in t = t0
Ar_i	areas of regenerated forests (naturally or artificially)
D_i (t1)	demand in period t1
d_i	density of forest type i
x_i	fraction of wood provided by harvesting
X_i (t1)	forest destroyed by bush fires, erosion and grazing in t1

The study areas were divided depending on their altitudes (as far as there is a significant difference) and in each case into three different types of charcoal production areas such as:

- natural forests or woodlands
- re-growth woodland
- agricultural and grassland.

Depending on the type of wood generation the wood gained has to be assigned to different parts of the equations (decrease in standing volume combined with a decrease in forest area or not).

The next section gives an overview in principle to the structure of scenarios, strategies and cases.

1.3.5 Scenarios, Strategies

Scenarios

The definition of different scenarios require a large range of different realistic or possible future socio-economic developments, to take into account the uncertainty of future simulation or planning. A socio-economic scenario is defined as a logical and consistent continuation of the exogenous parameters, meaning the parameters which cannot be influenced by the decision makers. Examples for scenarios are the demographic and economic development of a country or a region, world market prices of energy carriers, the technological progress, the behaviour of consumers, etc.

In the CHAPOSA model it was calculated with three scenarios based on different population growth rates. Economic developments do not influence the modelling. The scenario “Reference” simulates the increase of the population with average-estimated growth rates. The scenario

"Optimist" calculates with the lowest, the scenario "Pessimist" with the highest estimated growth rates.

Strategies

A strategy is a logical and consistent bundle of measures, to reach the targets defined before. These measures influence the energy system directly. It must be in the power of the decision makers to put these measures into action. A strategy as a bundle of measures comprises technical, financial and institutional aspects. Measures can be for example the installation of new technologies with better efficiencies, or the switch to other energy carriers.

In discussion with all responsible research managers of the three countries, the CHAPOSA team decided to concentrate on two measures concerning the household energy side of the model. First the effects of a higher market share of charcoal produced by improved kilns on the forest wood supply are calculated. As a second measure, higher market shares of charcoal stoves are defined. As charcoal is regarded as the main household energy carrier, and no information about drivers for fuel changing are available, neither fuel substitution-measures nor measures to propagate improved fire wood stoves are calculated. Based on these two calculated measures, three strategies are defined and calculated: an "Improved Kilns" strategy, an "Improved Stoves" strategy and an "Improved Stoves and Kilns" strategy.

In the forestry sector there are several options. One strategy to improve the forest development could be a forestation or reforestation in terms of sustainable forest management on agriculture land and the coppicing with the stands. In combination with this it could lead to a more optimal ground wood area index of around 0,85. /Chidumayo, 1997/ describes the effects of fire control (on above ground wood biomass) in re-growth dry miombo. The effects of fire control are significant. Due to the results of Chidumayo the average can be calculated as about 350 t/km² in the age of 3 years up to 2.700 t/km² in the age of 25. Other authors calculate over a whole stand period with -20% of the growth rate /Goldammer, 1993/. But these results are not completely comparable as Goldammer gives it as an average of several countries as well as other continents. In comparison to the results of Chidumayo, Goldammer underestimated the power of fire destruction in the study area. Therefore + 40% to 50% was taken into account for the strategy with fire control.

Cases

The *Case Manager* is a tool which allows the user to structure and to systematically compare model runs. A model is called a "Case" in the *MESAP* terminology. Within a case, *MESAP* distinguishes between scenarios and strategies. The *Case Manager* allows you to describe various scenarios by using consistent specifications of the key input parameters for the model run. A case finally represents a model run and consists of a scenario combined with one or several strategies. Thus a case definition contains for every model parameter the necessary hypothesis which will be used during the model run. If no hypothesis is explicitly assigned to a time series, the default hypothesis called “Reference Hypothesis” is used. This object-oriented approach of the *Case Manager* facilitates the combination of scenarios and strategies to form new and consistent cases and corresponds to the approach of establishing decision trees. Therefore, this principle of case management is called “Case Decision Tree” in *MESAP*. In addition to this sophisticated approach, *MESAP* also offers a simplified possibility for case management which automatically associates a single hypothesis with a case. In this case all modelling parameters use the same hypothesis /Baumhögger et al., 1998/.

For the CHAPOSA model several cases consisting of scenarios and strategies were defined and calculated. All cases must be compared to the “Reference Case”, which describes the ongoing of the modelled system with the reference population increase and no measures concerning the energy system at all (Business as usual). A strategy, which leads to the requested results or future developments based on all scenarios is defined as a robust strategy.

Analyst

The *Analyst* is a spreadsheet-oriented software for the visualisation of time series in *MESAP*. It allows to create user-defined reports like in a spreadsheet. Reports are stored in the database and contain tables and charts and allow the user to perform spreadsheet formula calculations. The number of reports in a database is not limited. Any time series from the database may be referred to a report. The *Analyst* establishes a “hot link” to the database, which means that the reports may be easily updated when data values change in the database. In addition, the data in a report is only shown in a user-defined time window (“reporting period”) of the time series. This facilitates the time window shifting when updating entire reports. The reports can be printed out or exported to MS EXEL or other spreadsheet programs.

Every *Analyst* report is organised like a spreadsheet. In the Analyst report a unlimited number of tables can be defined to represent the desired time series. The layout of all tables within one report is based on the same time period, the “reporting period”. In addition to the tables an unlimited number of charts, to present the data attached to the time series in a graphical format, can be defined. These user-defined charts may contain any range from the report. Furthermore, texts, titles and single independent values can be added to a report.

2 RES-Structure

For the structured description of the energy and land use system in Mozambique, Tanzania and Zambia the representation of the reference energy system (RES) /Beller, 1975/ was used. The philosophy is based on a process-engineering representation of real energy systems. The energy system is represented as a network of commodities and processes, the Reference Energy System (RES). The RES is a graphical technique to design network oriented models of complex real systems as a bipartite graph. It is a portrayal of the energy system in network form, in which the production, transformation and utilisation of energy are portrayed as network links.

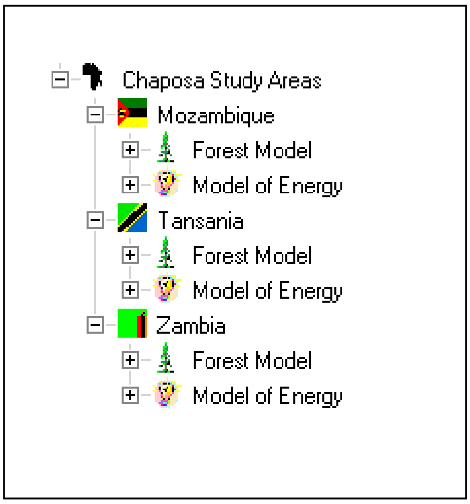
Great emphasis is placed on the structure of end use demand, with energy demands projected as much as possible on physical outputs (e.g. tons of wood from forest produced, demand on wood and other primary sources). Each path through the energy system network indicates a possible route for the flow of energy from an energy resource to a given demand category. Alternate paths and branches reflect the substitutability of various resources and technologies for one another. In order to perform impact analysis of future options, the RES is changed for the future years of interest, and the aggregate characteristics of the system are determined. The measures involve technology and resource substitution. In all cases the basic procedure is to:

- Identify processes or sectors in which the new resource or technology will be substituted,
- Establish feasible rates of introduction of the resource / technology and levels of introduction in the future reference years,
- Produce a new system description reflecting the changes for the appropriate years,
- Calculate the change in resource consumption, cost, and other objective functions.

The linear network contains all commodities and conversion processes of the modelled system. Commodities can represent any kind of physical good. Processes convert any number of commodities into other commodities. Links connect commodities and processes. The level of detail, i.e. the number of commodities, processes and links in the RES, is defined by the modeller and is not limited by the system.

It was useful to divide the RES-Structure in different dimensions. This is possible through hierarchical levels of regional and technological subdivisions of the RES. The new graphic item for the subdivision of the RES-Structure is the container. The container contributes to the arrangement of the RES. Each container can contain regions, land forms, processes etc. as well as commodities and also further containers. Figure 2-1 shows the principal hierarchical levels of CHAPOSA.

The regional containers of Mozambique, Tanzania and Zambia are divided into the containers of the energy and woodland sector with the interface “wood from forest”.



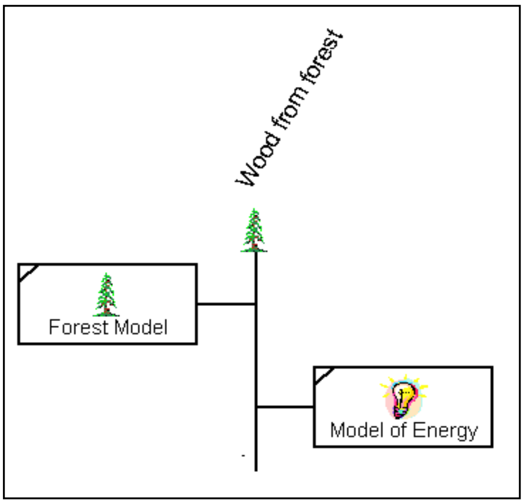
By opening one container the next RES level is presented as shown in Figure 2-2. This improves the clarity of the RES-Structure because of the possibility to nest the processes. The nesting of the processes is illustrated in Figure 2-1 .

There is also a possibility of inter regional exchange. That is the exchange of commodities between different regions of the energy system model by feed processes. Inter regional exchange is the prerequisite for regional energy models. It is possible to consider the place dependent production of resources and their feed into other regions.

Figure 2-1: Principal hierarchical levels of the RES

Section 2.1 shows the basic principle of the supply and demand model of the charcoal sector in RES form followed by the woodland model in section 2.2.

The Model is divided in two main sectors: the energy model and the forest model. The interface between the models is the commodity wood from forest as shown in Figure 2-2.



The demand and supply model is set up in MESAP to cover the entire charcoal system excluding the woodland. The two models can be regarded separately to analyse RES-Structures of the household and woodland sectors.

Figure 2-2: Interface between household and forest model

2.1 RES-Structure of the Energy Model

The driving force of the household energy model is the population of the three cities which is seen in the opened container in Figure 2-3 . The energy model ends with the simulation of the fuel-wood demand in the commodity “wood from forest”.

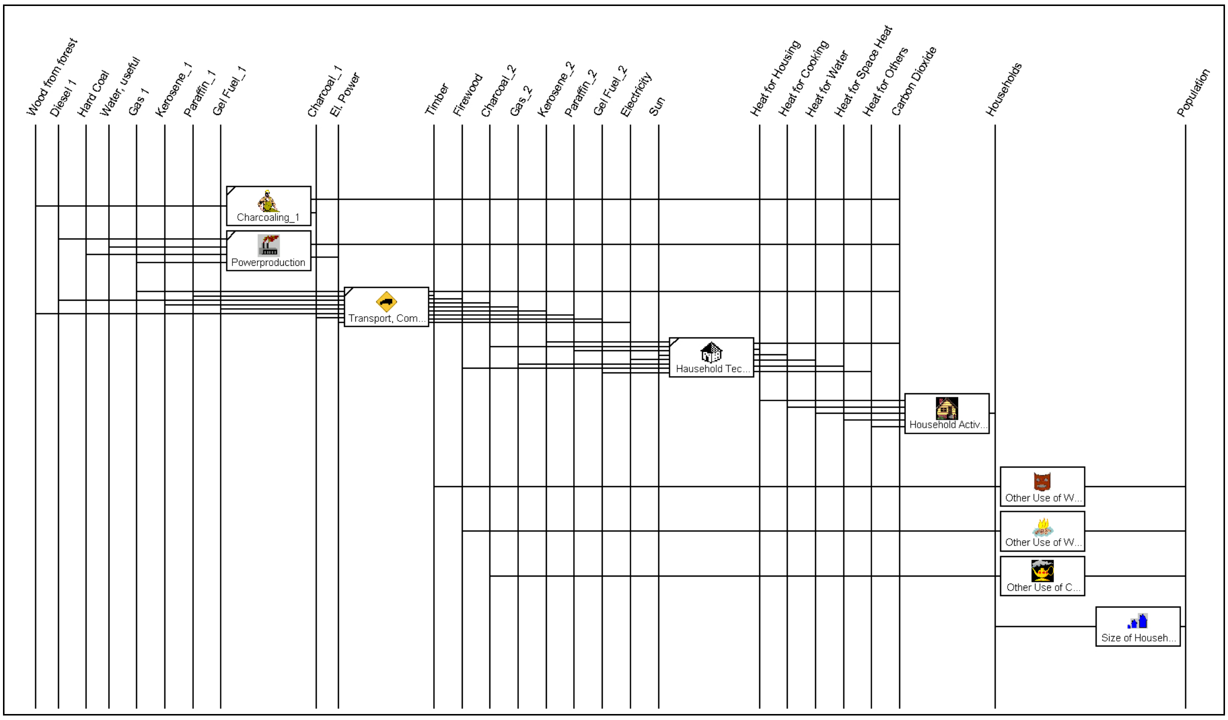
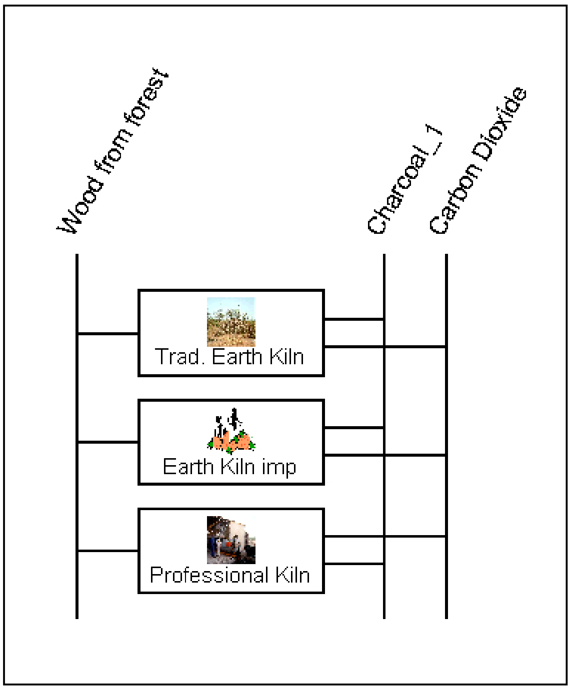


Figure 2-3: Household RES of CHAPOSA

The charcoal system model is driven by the number of households in the desired region. With the process “household activity”, the required heat for cooking, preparing warm water, others and space heat per year in this region are determined. Market shares are used to assign portions of these commodities to the different stove technologies. For each technology the fuel consumption in the region is determined. Then the transportation and conversion of the household fuels are considered and the respective losses are subtracted. There is only one wood resource as this is the issue of the woodland model. The results of these calculations are the quantities of fuel consumed by the regarded system.

The following figures show the unfolded containers of the RES in the household sector: “wood harvest”, “charcoaling”, “power production”, “transport”, “household technologies” and “household activities”.



In the container "charcoaling", charcoal is produced by different methods. Beside the traditional earth kiln, options for improved and professional kilns are defined. The percentage of charcoal produced by a certain technology is defined by changing market shares in the different strategies, as described in the chapters 3, 4 and 5 for the different countries. At the moment almost 100% of the charcoal demand is produced by traditional earth kilns in Southern African countries.

Figure 2-4: Opened container of process "charcoaling"

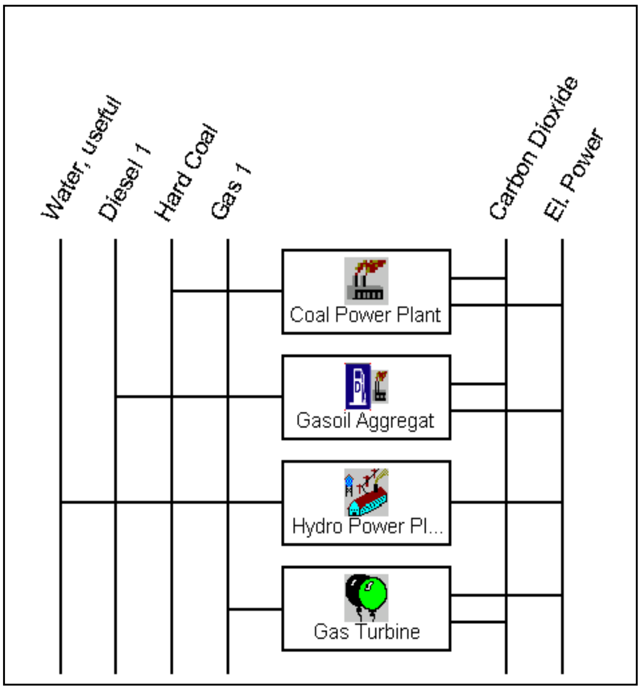


Figure 2-5 shows the different options of energy generating. With the coal power plant, the gas oil aggregate, the hydro power plant and the gas turbine, these four different technologies are part of the energy systems of the three countries. These processes have no direct influence on the energy model output commodity "wood from forest". Electricity is part of the household energy market with a certain market share. As the strategy "substitution of charcoal stoves by electric stoves" could be used some day, the electricity generating system must be examined as well. The part of electric stoves used for cooking is between 4% (Tanzania) and over 15% (Zambia) today.

Figure 2-5: Opened container of process "power production"

The "transport and commerce" container (Figure 2-6) has no influence on the energy system as long as no monetary calculations are executed and no bigger losses of commodities take place. In the Chaposa model the container was not calculated with transportation losses, e.g. theft, except for the power line with its technical transmission loss per kilometre. The transport processes are defined to make it possible to calculate fuel consumption as well as specific and total costs of the transport sector. At the moment no data are available to take these processes into account for simulating the household energy system. This could also be seen as a driving force if the price building factor could have been taken into account.

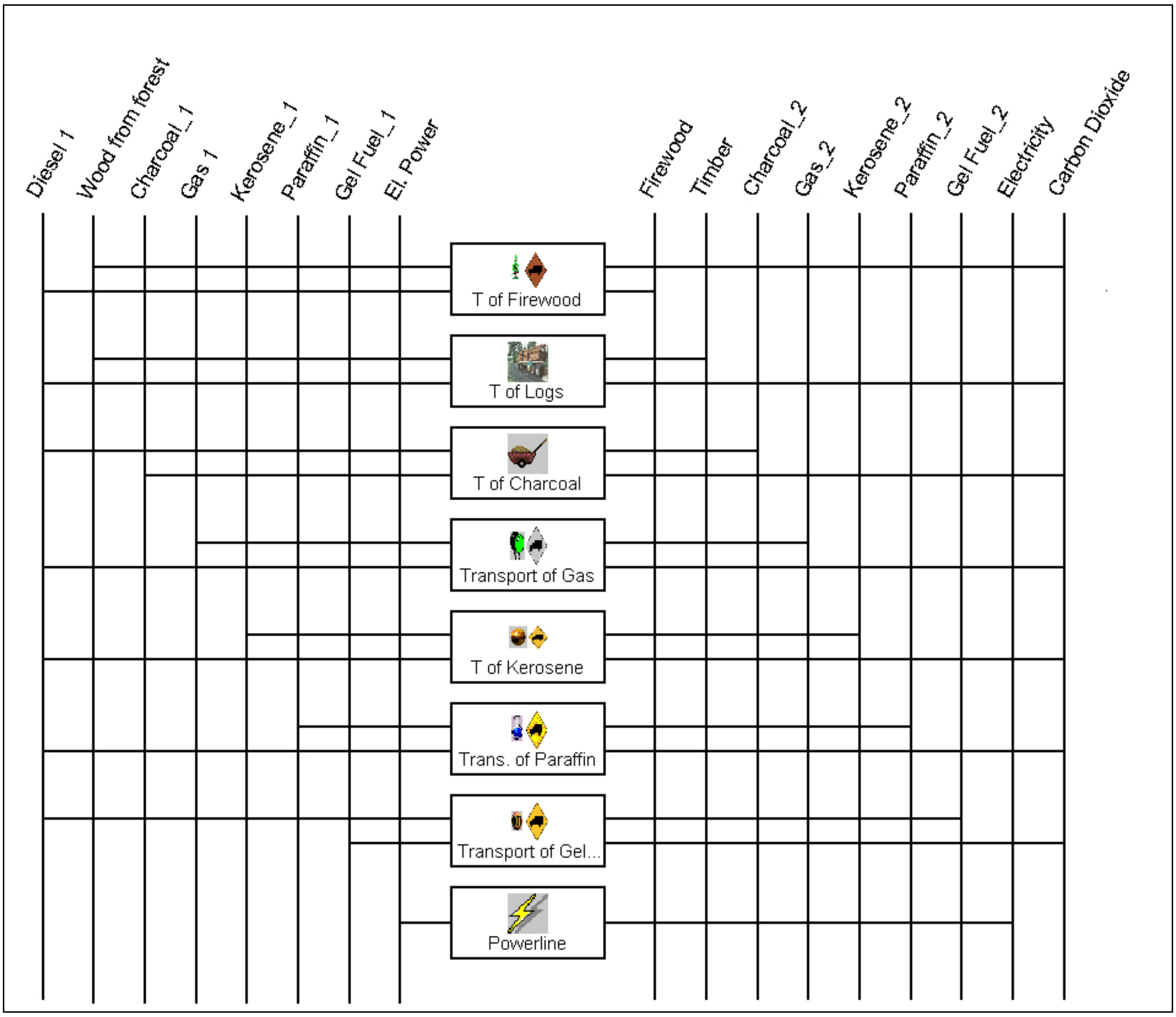


Figure 2-6: Opened container of process “transport”

Finally the “household technology” container puts up all utilised technologies for cooking, preparing warm water, heating and others, see. Figure 2-7 Beside the common technologies like traditional wood or charcoal stoves, gas, kerosene and electric stoves, all possible options for a future technology change by certain strategies like improved charcoal or wood stoves or solar stoves are defined here as well. The part of meals, etc., produced by the different stoves are defined by the different market shares of the stoves. The measure “improved stoves” for example is calculated with a higher market share of improved stoves. In that case, the market share of the residual technology, which is that for the traditional charcoal stove, is decreasing. The market shares for the reference case and the different calculated strategies for the three countries are described in section 3.2, section 4.2 and section 5.2.

On this level, the consumption of household fuels is calculated by the demand of heat for cooking, preparing warm water, space heating and others. As these desegregated data are only available in Zambia, the model calculates with the demand of total heat for household activities for Mozambique and Tanzania.

The processes not shown explicitly are “size of households”, “household activities”, “other use of wood 1”, “other use of wood 2” and “other use of charcoal”. These processes are not situated in containers and can be seen directly in the total view of the household energy model, Figure 2-3 .

The processes “size of households” and “household activities” calculate the heat demand in the household for the described activities, beginning with the urban population, over the number of households to their specific heat demand. The “other use...” processes calculate the demand of fire wood, timber and charcoal for restaurants, barracas, hotels, house construction and artist works in the urban region. This demand is directly linked to the population and therefore is exogenously defined.

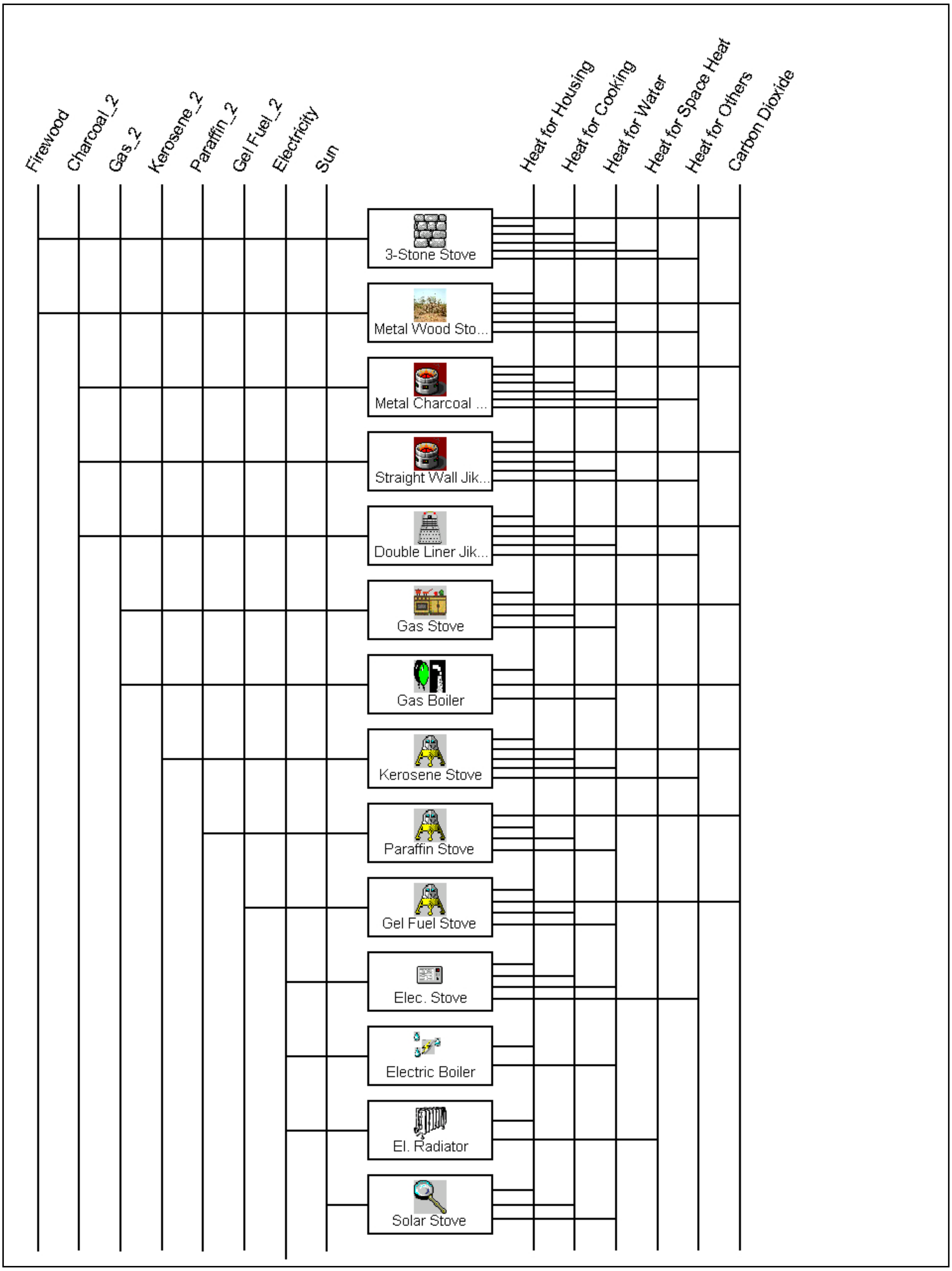


Figure 2-7: Opened container of process "Household Technologies"

2.2 RES-Structures of the Woodland Model

To combine the forest model with the energy model, the RES-Structure for energy and environmental planning was adopted to the requirements of forests. It was used to identify and to determine the technical structure of woodland in the CHAPOSA Project.

As the RES-Structure should lead to the possibility to compare the countries and their forests, the structure is nearly the same for all countries. As there are different data available the forest models are more or less refined as seen in this chapter as well.

The woodland model consists of two instances for each type of woodland. It is divided into 3 land forms: plateau, hill and flat topography. Furthermore the model is subdivided in different stands like nature woodland, re-growth woodland and possible areas of A forestation and connected to different growth rates and other indicators as listed below and shown in the RES as follows.

- Stand [t] divided in nature forest, re-growth woodland and possibility of A forestation
- Growth of wood with different factors for different stands
- Treatments because of fires, grazing and erosion, regarded with negative factors
- Study area [km²] and their variation in plateau, hill and flat country if possible
- Change of land use with time
- Additional area for charcoal production which is beyond the study area, as it is important in relation to the charcoal demand from the energy model.

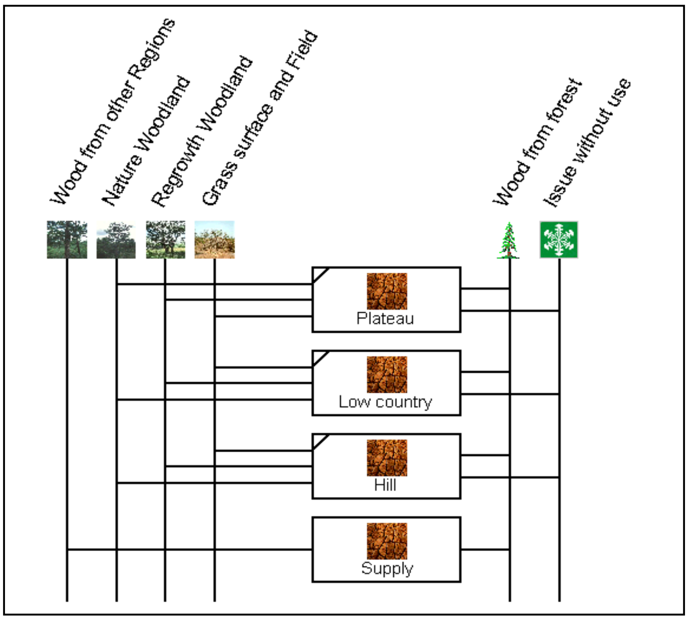


Figure 2-8: Reference woodland system of CHAPOSA

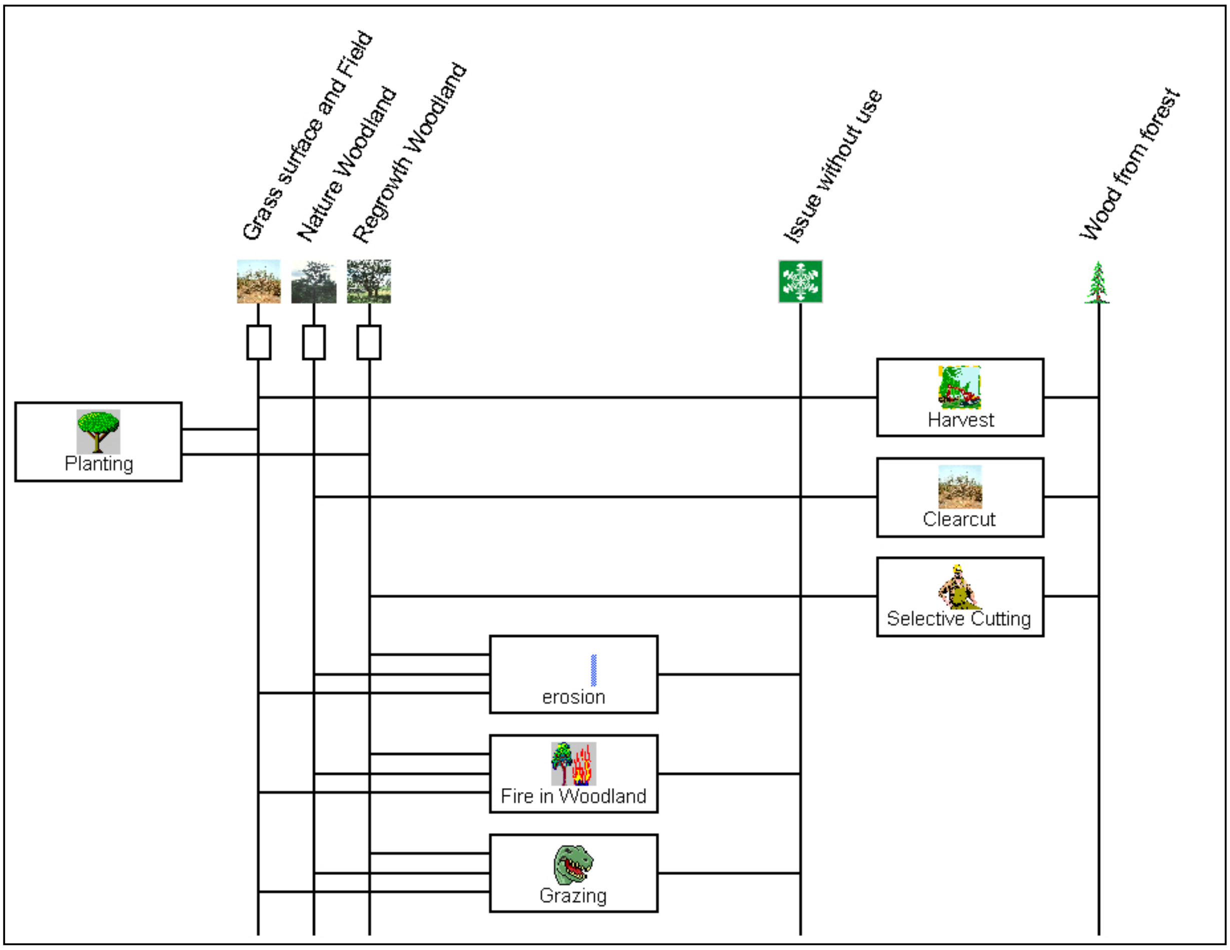


Figure 2-9: Woodland of one region

The demand of the energy model is satisfied through the wood from forest. The wood comes from the three land use forms. Another limiting factor for woodland development are erosion, fire and grazing what is not usable anymore and goes out of the system. These limiting factors can be reduced by sustainable forest management, i.e. fire control. Another strategy can be planting or additional planting which is meaningful for agriculture, grassland or re-growth woodland only. Therefore the nature woodland is not linked to planting.

The RES of MESAP 4.0 is directly linked to a mathematical model. This can be either a simulation or an optimisation model. For CHAPOSA the simulation PlaNet was used as it seemed to be an adequate mathematical model for the task and agreed among the partners /Baur, 1999/ /Frey, 2000/. It is described in Section 1.3.3. The following chapters are based on the calculation with PlaNet.

3 Mozambique

3.1 Scenarios

As described in chapter 1.3.5, scenarios simulate developments of activities or drivers for the energy system, which cannot be influenced by the energy planner. For the household energy system of the three examined cities, the most important driver is the growth of the urban population. So, three different scenarios for a possible population growth are determined for the three cities.

Figure 3-1 shows the scenarios for the population of urban Maputo/Matola. In Figure 3-2, the growth rates as base for the population increase are shown. In the beginning of the scenario definition, the "reference" scenario is determined (blue line, middle). The fix point is Mozambique's second census in 1997. At that time Maputo had about 966.800 inhabitants and Matola about 424.900 inhabitants. In the discussion with Carla Pereira we came to the conclusion to add up the population of the whole urban area Maputo/Matola. Altogether, urban Maputo/Matola had a population of 1. 391.700 inhabitants in 1997. This will increase up to about 2.032.500 inhabitants in 2010 and 2.653.999 inhabitants in 2020 with average growth rates of 2,7% - 2,8% /Pereira, 2001a/.

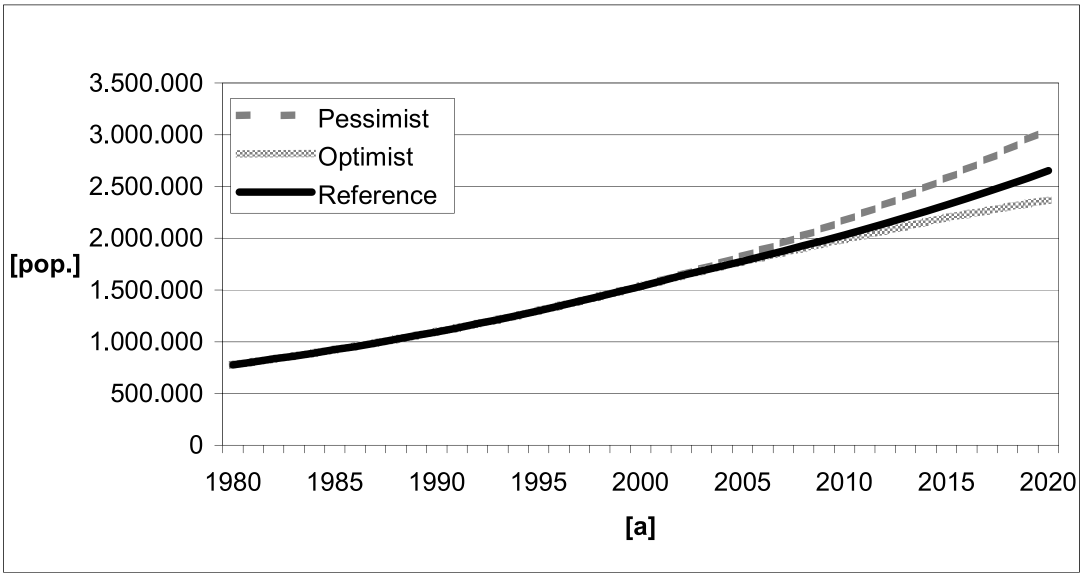


Figure 3-1: Population of Maputo/Matola

The scenarios "optimist" (grey line, down) and "pessimist" (dashed line, above) calculate with higher or lower growth rates. The names of the scenarios were chosen to describe different expectations on the population development. So the "pessimist" scenario is based on ongoing

3,5% growth rates, like in the period from 1980 to 1997. The "optimist" scenario is described by regularly decreasing growth rates until 1,5% in 2020. The simulation leads to a urban population of 3.054.400 (scenario "pessimist") or only 2.370.300 inhabitants (scenario "optimist") in the year 2020. Reality should lie between the two extreme scenarios, see Figure 3-2.

According to the Mozambican researches it is likely possible that the Population of Maputo and Matola is going to be doubled in the next 20 to 30 years /Pereira, 2001a/. According to these figures the city will increase of at least 65%. Since the birth rate will not continue to rise (or rather decrease), the population proportion might grow as well because of itself settling humans.

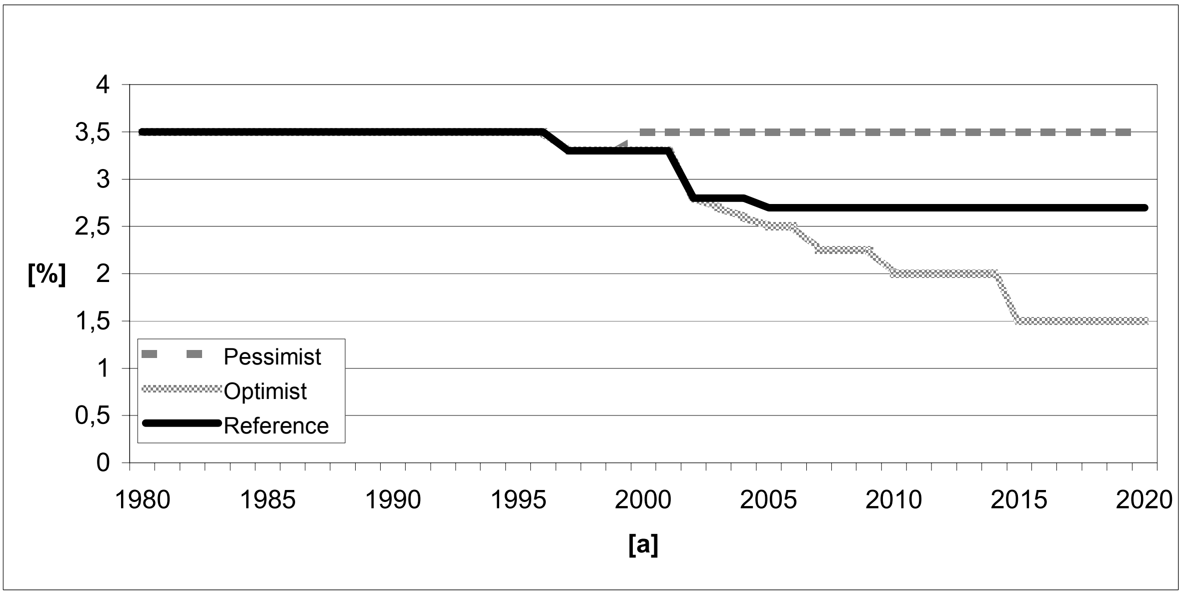


Figure 3-2: Growth rates Maputo/Matola

3.2 Strategies of the energy sector

For the household energy sector, different measures can be taken into account and bundled to strategies. For the CHAPOSA model, the searching group came to the conclusion to define two measures (propagation of improved kilns and stoves) and three strategies ("improved kilns", "improved stoves", "improved stoves and kilns"), see section 1.3.5 Scenarios, Strategies. For Mozambique and the other countries the propagation of better kilns and stoves were chosen to remain on the wood-fuel related level. The propagation of other stoves like electrical or gas stoves was not seen as a real alternative in the next years for Maputo and Matola.

3.2.1 Propagation and implementation of kilns with higher efficiency

The following strategy is the same for all countries as it is independent of local special features.

The propagation of the use of improved kilns could be feasible due to several trials which were made in the study area of Mozambique. The strategy of kilns with higher efficiency is described in this section only as it is the same in all countries.

According to /Sawe, 2001/ in Tanzania the strategy is quite simple and could be transferred into other countries of East Africa. The target was to increase the market share for professional kilns from almost 0% up to 100% in 15 years. The efficiency of the professional kiln is up to average 25% compared to average 15% of the traditional earth kiln /Sawe, 2001/, as shown in Figure 3-3. The exact efficiencies for the kilns vary between the regions. For the model calculations, it was calculated with regional specific kiln efficiencies determined by the different research teams.

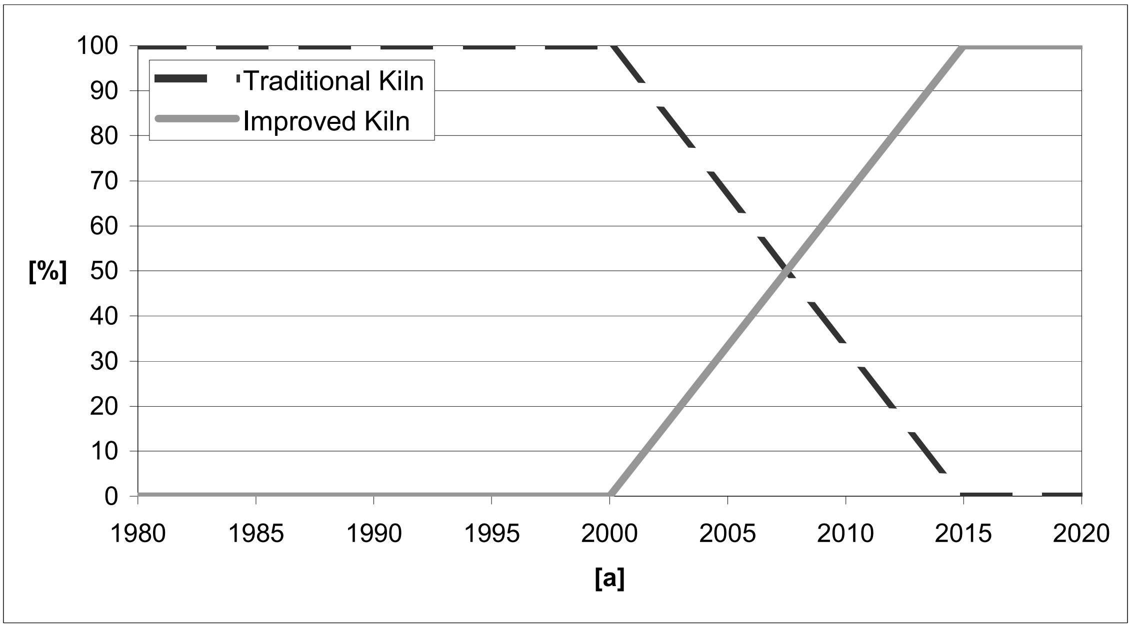


Figure 3-3: Market shares of kilns

3.2.2 Propagation of improved stoves

The following table gives an overview of the market shares of the available stoves in Mozambique or other East African countries. Basically there are five main technologies for cooking and producing heat in Maputo/Matola households: wood stoves, charcoal stoves, gas, paraffin and electric stoves. Behrens and Ellegård describe the market shares of cooking technologies before 1997, /Ellegård, 1997/. There is a noticeable change between 1995 and 2000. Firewood as household combustible was almost totally replaced by charcoal /Brouwer, Falcão, 2001/.

The available literature shows that every household uses a mix of different combustibles. This may have its reasons in time dependent financial situations, adaptation of a combustible to a special meal or a certain independency of the local market situation. Fact is that the main source of household energy today is charcoal.

It was so defined: households have different technology options for cooking, preparing warm water, ... Their first choice is charcoal, when the household has a charcoal stove and charcoal is available. The market shares for the technologies used in the model are based on household interviews made by Brouwer, Falcão. 71,7% of the interviewed households use charcoal as household combustible. The residual 28,3% missing to 100% are allocated to the other available household energy carriers by their specific weight on the energy market and their availability in the households.

Table 3-1: Market Shares of different stoves in Mozambique

Stove	*Unit*	1980	1985	1990	1995	2000	2005	2010	2015	2020
Reference Case										
Traditional Wood Stove	%	59,6	59,6	59,6	49,28	4,6	4,6	4,6	4,6	4,6
Improved Wood Stove	%	0	0	0	0	0	0	0	0	0
Traditional Charcoal Stove	%	17,7	17,7	17,7	34,9	71,7	71,7	71,7	71,7	71,7
Improved Charcoal Stove 1	%	0	0	0	0	0	0	0	0	0
Improved Charcoal Stove 2	%	0	0	0	0	0	0	0	0	0
Gas Stove	%	14,2	14,2	14,2	5,03	6,6	6,6	6,6	6,6	6,6
Paraffin Stove	%	2,4	2,4	2,4	5,03	10	10	10	10	10
Electric Stove	%	6,1	6,1	6,1	5,75	7,1	7,1	7,1	7,1	7,1
Strategy “Improved Stoves”										
Traditional Wood Stove	%	59,6	59,6	59,6	49,28	4,6	4,6	4,6	4,6	4,6
Improved Wood Stove	%	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Traditional Charcoal Stove	%	17,7	17,7	17,7	34,9	71,7	54,7	37,7	20,7	3,7
Improved Charcoal Stove 1	%	0,0	0,0	0,0	0,0	0,0	17,0	34,0	51,0	68,0
Improved Charcoal Stove 2	%	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Gas Stove	%	14,2	14,2	14,2	5,03	6,6	6,6	6,6	6,6	6,6
Paraffin Stove	%	2,4	2,4	2,4	5,03	10	10	10	10	10
Electric Stove	%	6,1	6,1	6,1	5,75	7,1	7,1	7,1	7,1	7,1

In the household technology sector the measure “propagation of improved stoves” was defined. The reference case gives an idea of the development without any changes in the future. The measure “propagation of improved stoves” publicises the implementation of more efficient stoves. M. Sawe of TaTEDO Company in Dar es Salaam proposed to increase the market share of improved charcoal stoves. According to him, it should be possible to reach a market share of 70% in 2020 /Sawe, 2001/ with the improved charcoal stove 1. This stove has a thermal efficiency of 27% /Staiger, 1999/, compared to 20% for the traditional charcoal stove /Ellegård et al., 1990/. The improved charcoal stove exists, according to our literature, only in Tanzania and Zambia and has a thermal efficiency of 37,5% - 44% /Westhoff, Germann, 1995/, /van Asperen, 2001/. In the Mozambique model the improved charcoal stove reaches a market share of 68% until 2020 by the measure “improved stoves”. In the meantime the market share of the traditional stove decreases to 3,7%.

3.3 Energy model calculations

In this section the results of the model calculation for Mozambique are shown and discussed. Issues are the wood consumption in Maputo/Matola City, desegregated in the different demands, the development of the wood consumption after different scenarios for the urban population, the charcoal consumption in the city and the development of the Maputo/Matola household energy market in general.

3.3.1 Wood consumption in Maputo/Matola City

Figure 3-4 shows the model results for the wood consumption in urban Maputo/Matola. The figure compares the calculations for the cases scenario “reference” and strategies “improved kilns”, “improved stoves” and “improved stoves and kilns”. In the year 2000 the total wood consumption in Maputo/Matola City was about 1,16 Mio t (reference case). This amount will rise up to about 2 Mio t of wood in the year 2020. The results of the different calculated cases show that it is possible to reduce the wood consumption of the city in an enormous way. The best case reference “improved stoves and kilns” comes to an amount of only about 1,1 Mio t of wood demanded for the year 2020 in Maputo/Matola City

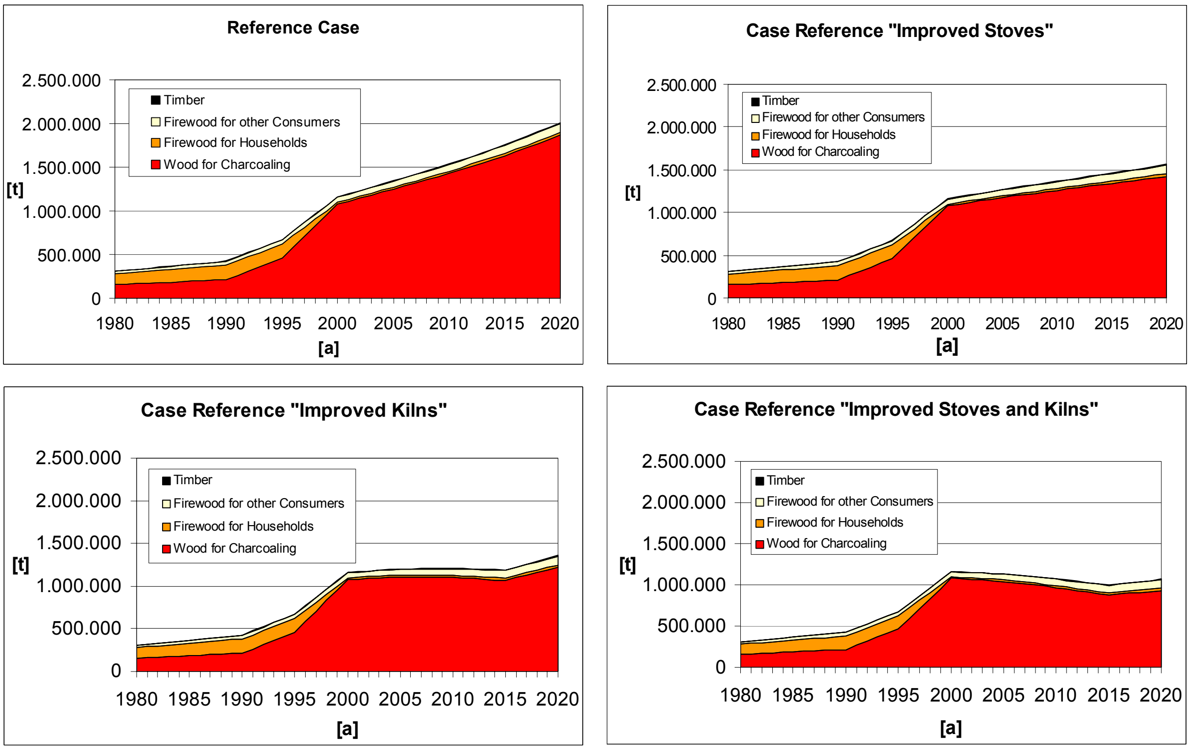


Figure 3-4: Wood consumption in Maputo/Matola City

The very high increase of wood consumption between the years 1990 and 2000 is a result of the change from fire wood to charcoal in the urban households, also see Figure 3-5 , or market shares of charcoal stoves in Maputo/Matola (strategies of the energy sector, reference case). The orange band, symbolising the demand for fire wood for households almost vanishes until 2000. The cases "reference improved stoves" and "reference improved stoves and kilns" show a stagnation or even a decrease of wood consumption between the years 2000 and 2015. The reason of the re-beginning increase after 2015 is based on the limitation of the strategy "improved kilns". Like described in chapter 3.2 Strategies of the energy sector, the propagation of improved kilns finishes with a market share of about 100% for these types of kilns in the year 2015. The increasing need of wood for a larger amount of charcoal by a growing population starts again.

3.3.2 Charcoal consumption in Maputo/Matola City

The biggest part of the wood demand is consumed by the charcoaling process with about 1,1 Mio t of wood in the year 2000 for the reference case. This is about 95% of the total wood demand of Maputo/Matola.

The actual charcoal consumption of Maputo/Matola City is about 140.000 t in the year 2000. Carla Pereira calculated the urban charcoal consumption being 117.000 t in 1997 /Pereira et al., 2000b/. Figure 3-5 shows the development of the charcoal consumption until the year 2020 for the reference case and the case reference “improved stoves”. This case has a direct influence on the charcoal consumption as it calculates with a higher market share of improved charcoal stoves (see Chapter 3.2 Strategies of the energy sector).

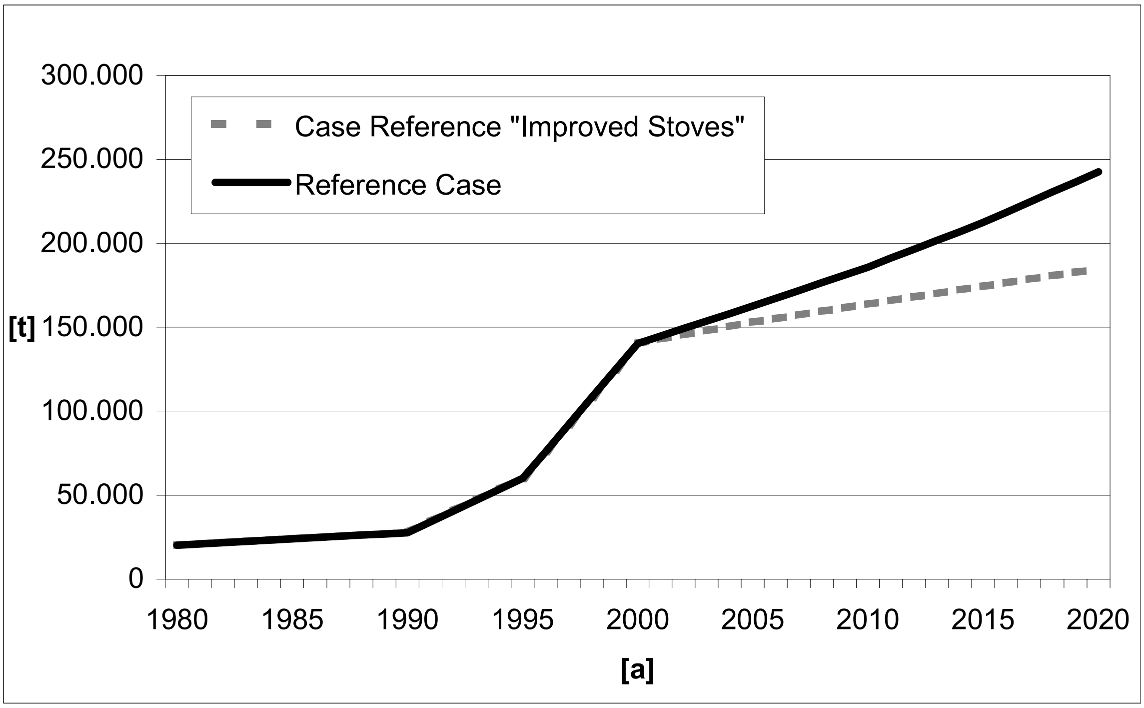


Figure 3-5: Charcoal consumption in Maputo/Matola

The modelled urban charcoal consumption for the year 2020 is about 240.000 t in the reference case. With the “improved stoves” strategy this can be reduced to about 180.000 t in the year 2020, which means about 25% less consumed charcoal compared to the reference case.

Figure 3-5 also shows the impacts of the fuel change between 1990 and 2000 as mentioned above, with a higher increasing charcoal consumption.

3.3.3 Population growth

Another big impact on fuel consumption is the development of the urban population. The population of Maputo/Matola City is still characterised by high growth rates of some 3% (see chapter 3.1 Scenarios).

Figure 3-6 shows the model’s results for the aggregated Maputo/Matola wood consumption. Every defined strategy was calculated with each of the three scenarios: reference scenario with the actually estimated population growth rates, “pessimist” scenario with higher and “optimist” scenario with lower growth rates.

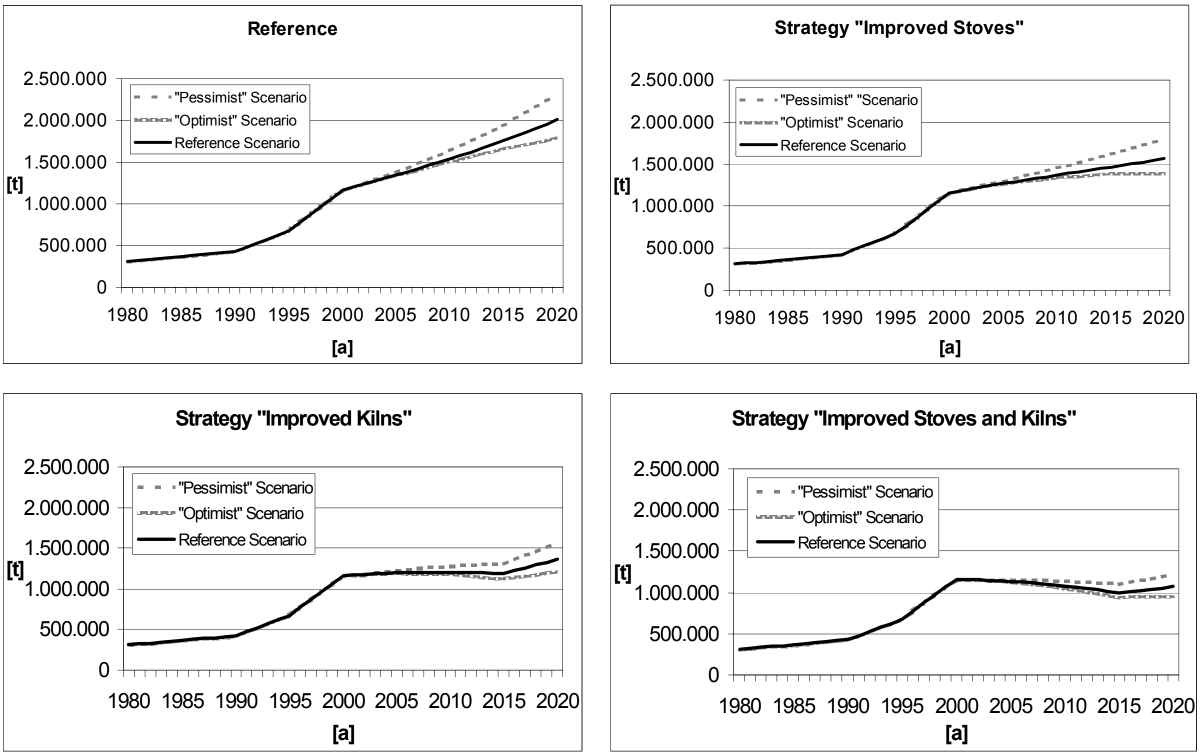


Figure 3-6: Wood consumption after Scenarios

Figure 3-7 puts all calculated cases on the same graph to illustrate the variety of the different scenarios. The worst case for the future development is therefore the case reference “pessimist” with a modelled total urban wood consumption of about 2,3 Mio t in the year 2020. The best case is the case “improved stoves and kilns, optimist” with an urban wood consumption of about 950.000 t in 2020.

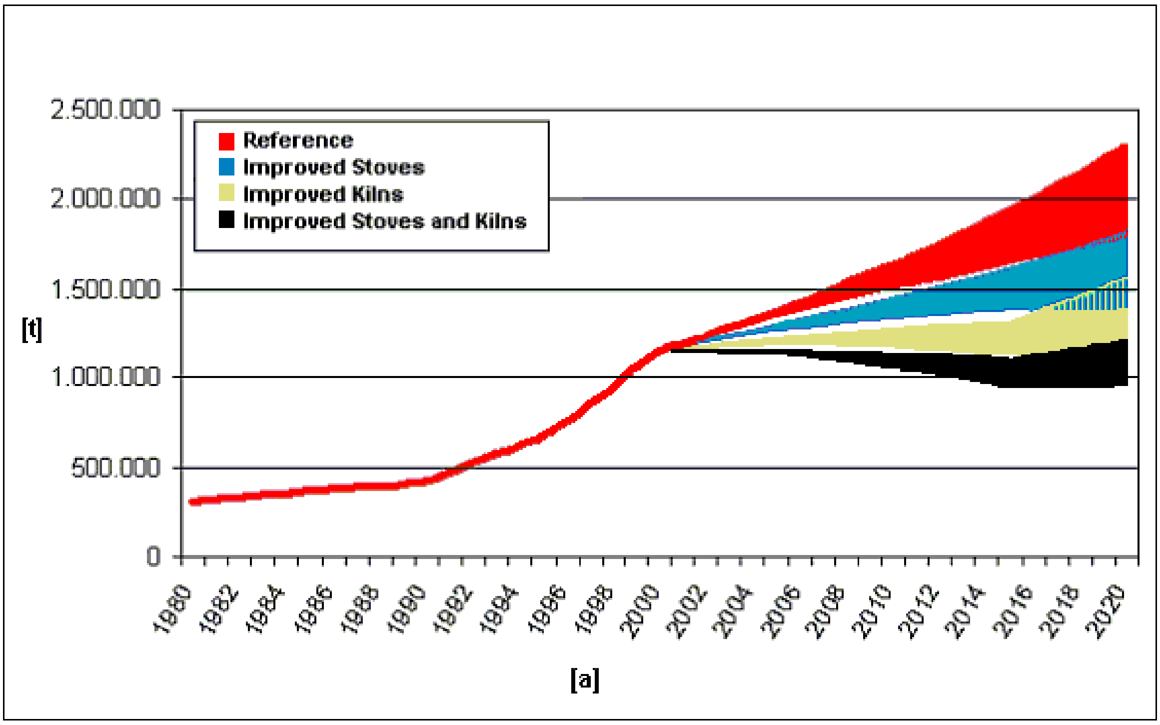


Figure 3-7: Wood consumption in Maputo/Matola, different cases

The strategies "improved kilns" and "improved kilns and stoves" seem to be robust strategies concerning the household energy level. With a total wood consumption of about 1,2 Mio t, this strategy, even in the worst scenario ("pessimist"), remains on about the same level as today. Nevertheless it shows an increasing tendency for the years after 2020.

3.3.4 Household energy

Figure 3-8 shows the market share of household combustibles in Maputo/Matola City for the years 1980 and 2000 in the reference case and 2020 in the best case "reference improved stoves and kilns". The total household energy demand is presented in ton oil equivalents to compare the different energy carriers.

Independent of the used combustibles, the energy demand increased from 71.000 toe in 1980 to about 119.000 toe in 2000. The change from fire wood to charcoal in this time is evident. Other household combustibles like gas, paraffin or electricity only play a minor part, as almost 85-90% of the energy demand in the households is satisfied by wood based fuels.

There is no big change on the household energy market between 2000 and 2020, as no strategies of replacing wood fuel by other combustibles was discussed. The total market proportion for charcoal changes due to the higher efficiency of improved stoves.

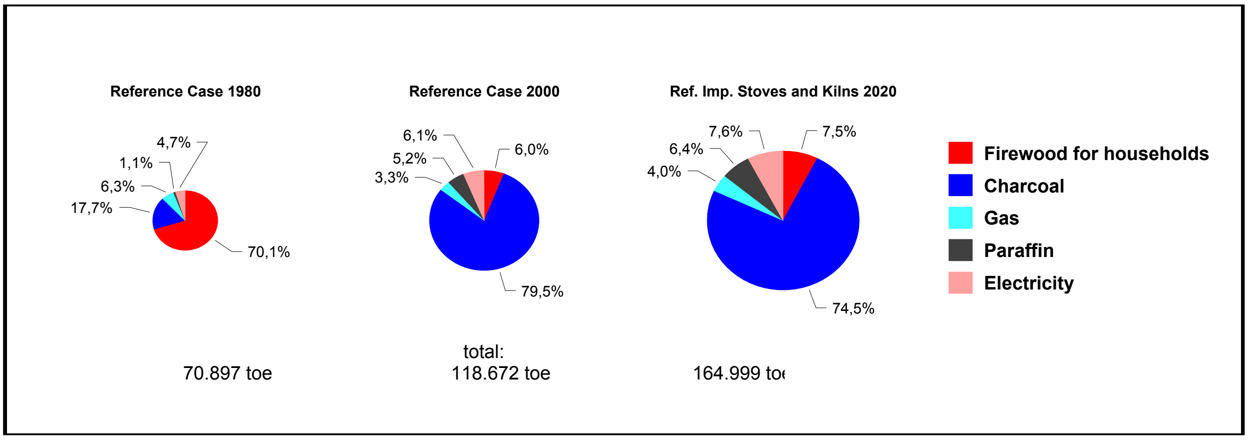


Figure 3-8: Household energy

3.4 Woodland development

The vegetation of the study area is savannah biome /Pereira et al., 2001b/ and is different in comparison to Tanzania and Zambia in terms of growth rates and ecology. Figure 3-9 indicates what happens in terms of development without any further strategies for the wood and charcoal demand and without any strategies for the forests.

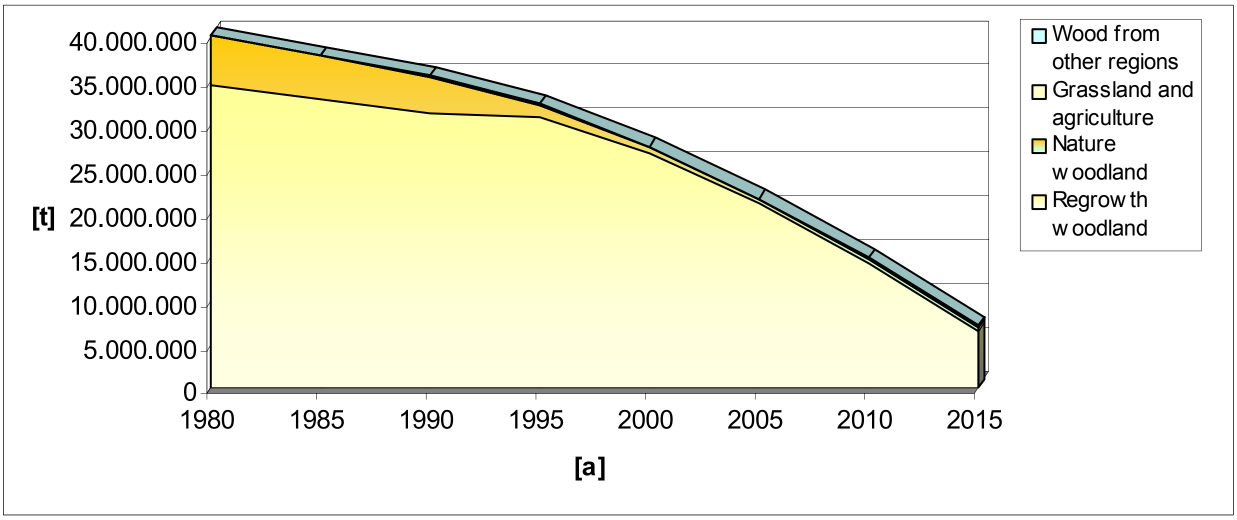


Figure 3-9: Woodland development of Mozambique study area from 1980 to 2015

Because of woodland development one big item was discussed during the last meeting held in Maputo. For the whole period of the project the actual wood amount coming from the study area was searched out. 90% of the wood or charcoal demand is satisfied through the study area /Pereira et al., 2001b/ which causes serious problems to the target of sustainable charcoal production. Therefore a quite strong declination of the modelled woodland can be seen in Figure 3-9. The woodland in this area would be completely finished before the end of year 2018. This would mean that the sacred area would also be gone which is completely theoretical and which became clear after the visit of the study area during the final presentation in Maputo. As this forest can not be regarded as a potential source the exploitable woodland would end before year 2013.

The following strategies shall give ideas on possibilities to protect the study area. A very simple one would be to reduce charcoal production in the study area as it was discussed in the final meeting. Even if this could be feasible in the next years the pressure in the next future is supposed not to be decreased. Therefore the following strategies are based on the scenario that 90% of wood will come from the study area.

The woodland development beyond the study area could not be involved as an item for the strategies. But the area around the study area is supposed to be the same so that the examined area can be regarded as representative.

The strategies are combined with the population growth rate of the reference case. The first action it to look on the production side. There are several options that can be taken into account. The important issues that can be done in the field are described in section 1.3.5 Scenarios, Strategies. The option of additional forestation can be regarded as a maximum at the available area with an average growth rate of 54t/km²a on the grassland and agriculture areas and additional 5,4t/km²a in the open woodland areas beginning in the year 2003.

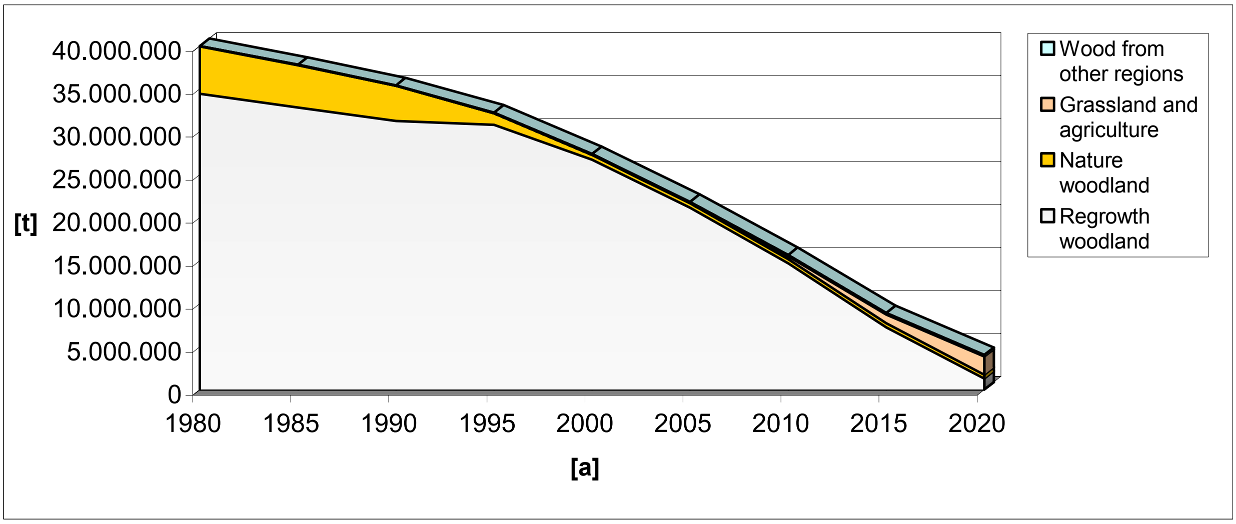


Figure 3-10: Woodland development with fire control, coppicing with the stands and sustainable forest management

Woodland development reacts very slowly to woodland strategies. Even the immediate implementation of certain strategies would not prevent the woodland from decreasing. This situation in the Mozambiquen study area has even intensified through the slow growth rates of the savannah biome. Therefore sustainable forest management practices become difficult.

But as it is can be seen on Figure 3-10 there is a chance to improve the situation with forest measures over a long term period. It seems that with the consistent application of this strategies and measures a significant part is reachable. Nevertheless the strategy with forest measures would not be sufficient as the demand from the study area is much higher.

A big chance to change the situation in shorter time is to also involve household strategies. There are different obstacles to replace one technology by an other one as it was seen in different countries. But according to /Sawe, 2001/ some introductions can be regarded as feasible. Therefore the following additional strategies were consulted: the propagation of improved charcoal stoves and kilns with higher efficiencies.

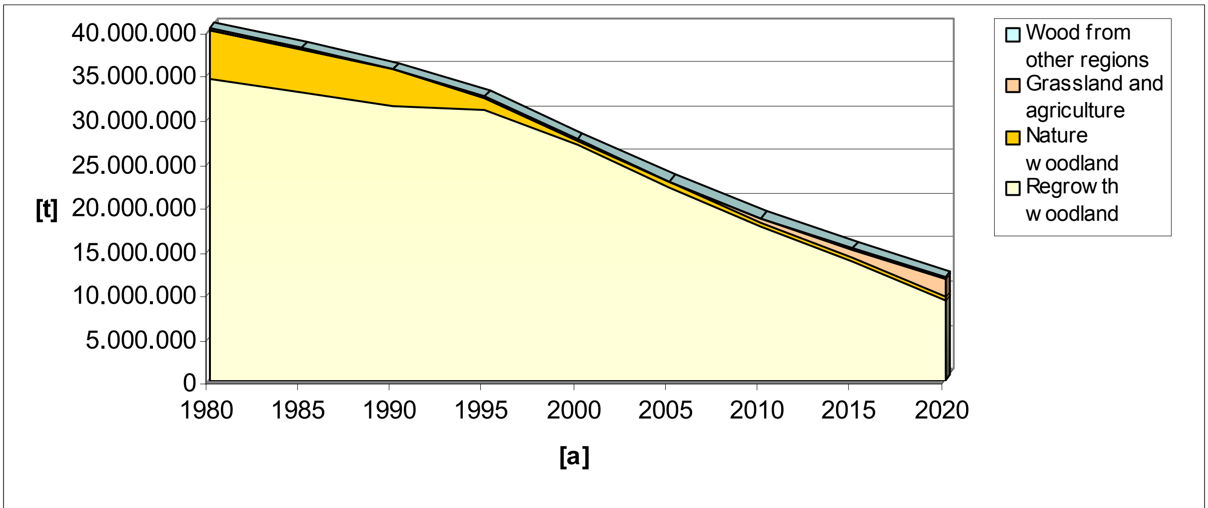


Figure 3-11: Woodland development with woodland and household measures.

The above mentioned figure shows clearly that combined strategies are only suitable to prevent the forest from a complete destruction in the next 30 years. The biggest issue is the increasing demand of charcoal because of population growth rate in Maputo and Matola.

Figure 3-12 shows the most optimistic conditions under the presumed scenarios and strategies. There was no further strategy such as the propagation of electrical stoves etc. involved as it did not seem to be feasible in the next years.

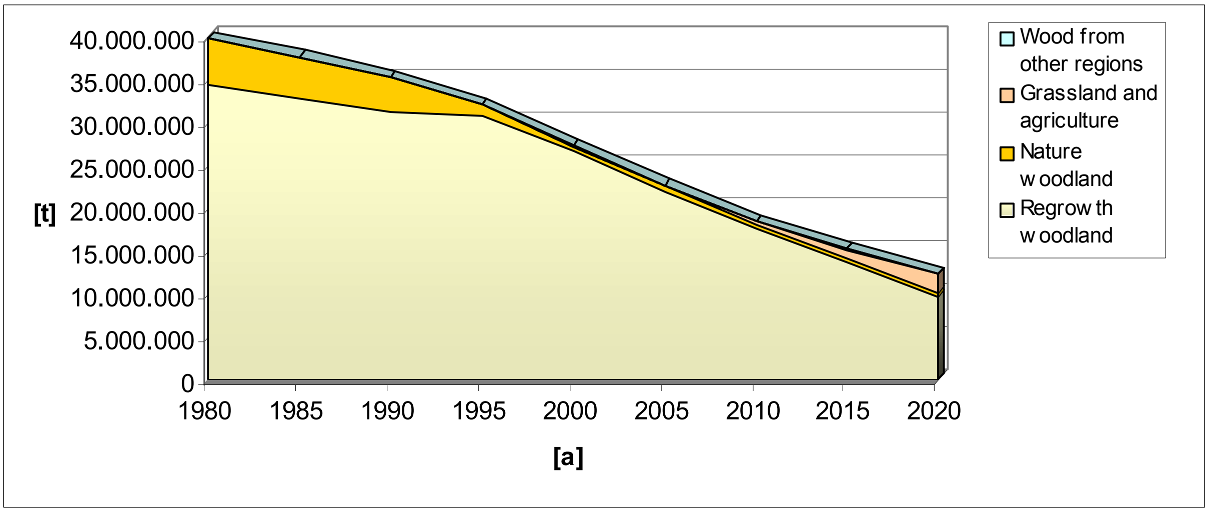


Figure 3-12: Woodland development with woodland and household measures under low population growth rates.

The strategies as mentioned above are based on the population growth rates as mentioned on Figure 3-1. Aids or any other health factors could become more significant in the future as discussed during the final meeting. But it seems to be impossible at the moment to indicate the influence on the population development as well, as it is already partly involved in some estimations.

4 Tanzania

4.1 Scenarios

The scenarios for the Tanzania model calculations are shown in Figure 4-1. The growth rates on which the scenarios are based are illustrated on Figure 4-2.

According to Hosier, Dar es Salaam has an urban population of 1.214.251 inhabitants in 1988 /Hosier, 1994/. Until 2000 the city showed an enormous increase of the population. Today about 3 Mio inhabitants live in Dar es Salaam /Malimbwi, 2001/. The population growth rate was an incredible 7,8%. Nevertheless it is also possible that in a few years the tendency of the Word Bank, who talks about 3%, becomes more realistic. A population growth rate of 4% over 20 years is unlikely. After a discussion with G. Jambiya from the University of Dar es Salaam, the conclusion was made to define a reference scenario with decreasing growth rates after 2005, as comparative cities like Nairobi have shown in the past. Under these conditions a doubling of the population is probable in the next 20 years. So the growth rates for the reference scenario decrease to 5% between 2005 and 2010 and to 2% after 2010. This leads to a population of almost 6,9 Mio in 2020 for the reference scenario.

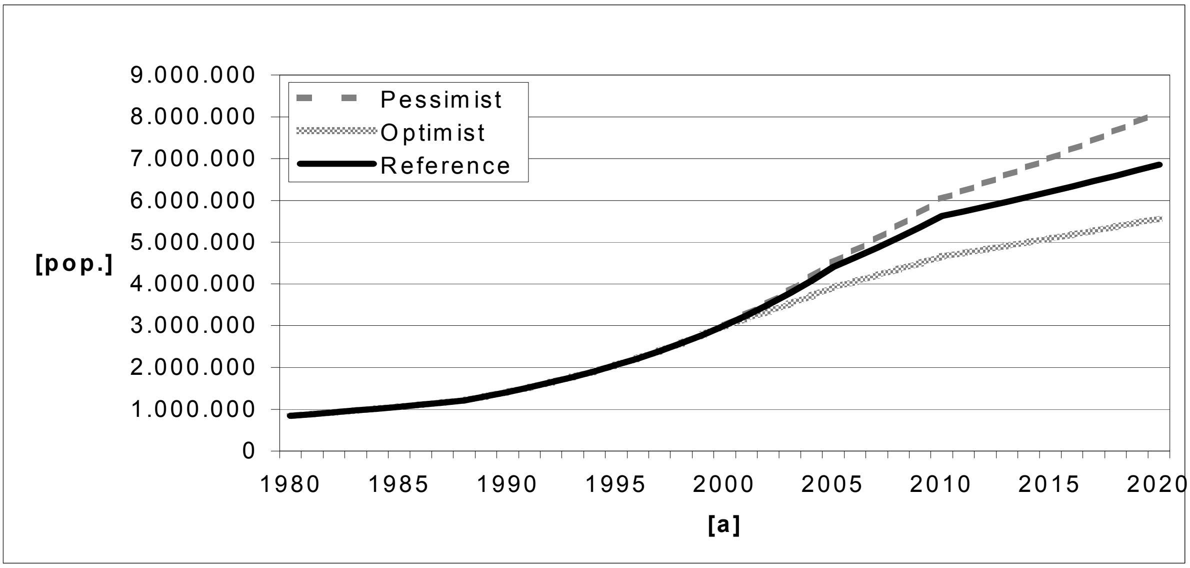


Figure 4-1: Population of Dar es Salaam.

The scenarios “optimist” and “pessimist” show tendencies similar to those in the reference scenario, see Figure 4-2. In the “pessimist” scenario the enormous growth rate of 8% is even topped to 8,5% until 2005. The next development until 2020 follows the reference development, but on a higher level. In 2020 Dar es Salaam has 8,1 Mio inhabitants according to this scenario. The “optimist” scenario calculates with a growth rate of 5,5% in 2000, which decreases to 3,5% in

2005 and to 1,8% in 2010. At the end the scenario "optimist" leads to a urban population of about 5,6 Mio inhabitants. Reality should be in the middle of the two extreme scenarios. But as the settlement around Dar es Salaam is obviously growing very fast, the estimations with high growth rates ("Reference", "pessimist") seem realistic. The calculations for the woodland development are therefore based on the reference scenario but should be controlled in 2005

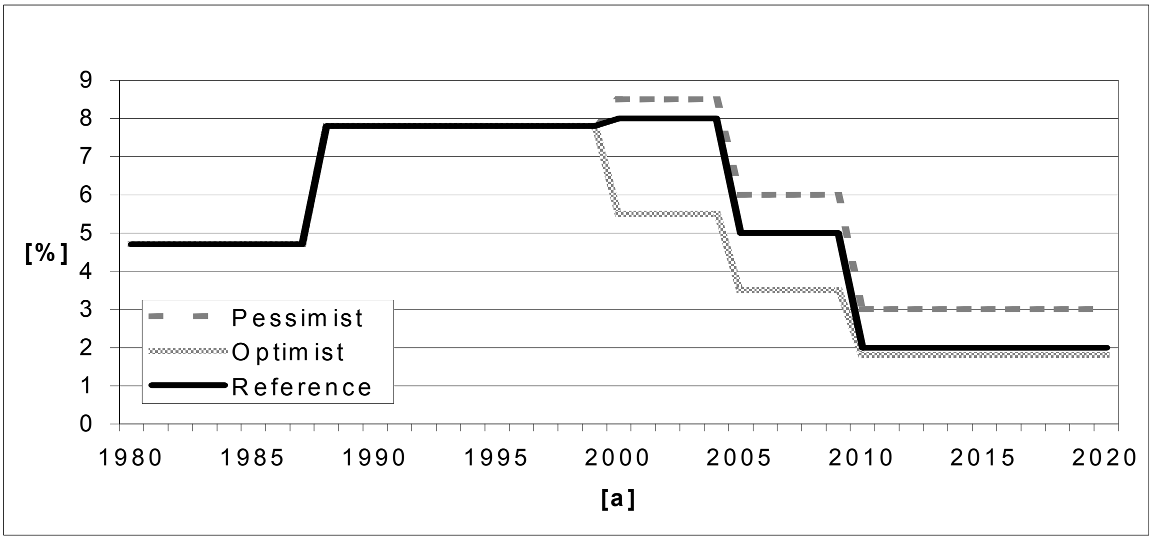


Figure 4-2: Growth rate of Dar es Salaam.

4.2 Strategies of the energy sector

Like in the Mozambique model, three strategies based on two measures were defined. Measures are: propagation of improved kilns and propagation of improved stoves. Strategies are: "improved kilns", "improved stoves" and "improved stoves and kilns". For Tanzania also, these strategies were chosen to remain on the wood-fuel related level. The propagation of other stoves like electrical or gas stoves was not seen as a real alternative in the next years for Dar es Salaam. It is not seen as a real alternative from other authors as well. I. e. Individual partner Report, Faculty of Forestry, Sokoine University of Agriculture, Tansania In: CHAPOSA 3rd Annual Report, Stockholm Environmental Institute, Stockholm, 2001

/Mayer-Leixner, 1999/ do not see good possibilities to substitute traditional wood-fuel through other primary energy carriers until 2010 in Southern Africa.

4.2.1 Propagation and implementation of kilns with higher efficiency

The measured propagation of improved kilns is exactly the same as for Mozambique, so please compare section 3.3.1 Wood consumption in Maputo/Matola City and Figure 3-3. Today all charcoal in Tanzania is produced by traditional earth kilns with an efficiency of 15% /Sawe, 2001/. Until 2015 all charcoal producers could change to more efficient technologies by propagation of this type of improved kilns with about 20% - 25% efficiency.

4.2.2 Propagation of improved stoves

The following table gives an overview on the market shares of the available stoves in Tanzania.

The reference case gives an idea of the development without any changes in the future. The so called "improved stoves" strategy publicises the implementation of more efficient stoves.

Table 4-1: Market shares of different stoves in Tanzania

Stove	*Unit*	1980	1985	1990	1995	2000	2005	2010	2015	2020
Reference Case										
Traditional Wood Stove	%	1,00	0,908	0,815	0,723	0,63	0,63	0,63	0,63	0,63
Improved Wood Stove	%	0,00	0,10	0,19	0,29	0,38	0,38	0,38	0,38	0,38
Trad. Metal Charcoal Stove	%	84,50	74,30	64,10	53,90	43,70	43,70	43,70	43,70	43,70
Straight Wall Jiko Bora	%	0,00	6,56	13,13	19,69	26,25	26,25	26,25	26,25	26,25
Double Liner Jiko Bora	%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Paraffin Stove	%	12,5	15,63	18,75	5,03	21,88	25,00	25,00	25,00	25,00
Electric Stove	%	2,00	2,50	3,00	3,50	4,00	4,00	4,00	4,00	4,00
Strategy "Improved Stoves"										
Traditional Wood Stove	%	1,00	0,908	0,815	0,723	0,63	0,63	0,63	0,63	0,63
Improved Wood Stove	%	0,00	0,10	0,19	0,29	0,38	0,38	0,38	0,38	0,38
Trad. Metal Charcoal Stove	%	84,50	74,30	64,10	53,90	43,70	36,70	25,70	14,60	3,50
Straight Wall Jiko Bora	%	0,00	6,56	13,13	19,69	26,25	31,50	40,83	50,17	59,50
Double Liner Jiko Bora	%	0	0	0	0	0	1,75	3,50	5,25	7,00
Paraffin Stove	%	12,5	15,63	18,75	5,03	21,88	25,00	25,00	25,00	25,00
Electric Stove	%	2,00	2,50	3,00	3,50	4,00	4,00	4,00	4,00	4,00

Today the households in urban Dar es Salaam use mainly three household combustibles: charcoal, paraffin and electricity. Fire wood, saw dust or gas only play a subordinate role. Jambiya and Mchome defined the choice of household energy carriers in the households /Jambiya, Mchone, 2001/. Like in other African countries, Tanzanian households use different types of fuel. So Jambiya and Mchone asked the households about their first, second and third choice. In a discussion with M. Jambiya in Dar es Salaam, it was decided to take the defined first choice as model input for household technology market shares. So in Dar es Salaam today, 70% of household energy is produced on charcoal stoves, followed by paraffin stoves with 25% and electric stoves with 4%. Before 2000 more charcoal was used. So the market shares for kerosene and electric stoves for 1980 are estimated as half of the market shares for 2000. According to M. Sawe from TaTEDO, even today, improved charcoal stoves, such as the Straight Wall Jiko Bora, are common in Tanzania. The propagation of the Straight Wall Jiko Bora was already successful, as mentioned in the table above. The estimations of /Sawe, 2001/ lead to a use of 35%-40% improved stoves for all used charcoal stoves.

The measure "propagation of improved stoves" suggests to implement an even higher market share of improved charcoal stoves. Traditional metal charcoal stoves in Tanzania have a thermal efficiency of 12% - 15%. Beside the Straight Wall Jiko Bora with 35% thermal efficiency, there exists an even better alternative with 44% thermal efficiency, the Double Liner Jiko Bora /van Asperen, 2001/. By the measure "propagation of improved stoves", the market share of the Straight Wall Jiko Bora increases from 26% in 2000 to 60% in 2020, the market share of the Double Liner Jiko Bora rises from 0% in 2000 to 7% in 2020. In meantime the market share of the traditional metal stove decreases from 44% to 3,5%.

4.3 Energy model calculations

In this chapter the results of the model calculation for Tanzania are shown and discussed. Issues are the wood consumption in Dar es Salaam City, desegregated in the different demands, the development of the wood consumption according to different scenarios for the urban population, the charcoal consumption in the city and the development of the Dar es Salaam household energy market in general.

4.3.1 Wood consumption in Dar es Salaam City

Figure 4-3 illustrates the wood consumption of Dar es Salaam City. The cases compare the different strategies to the reference case, all based on the reference scenario. In the year 2000 the total wood consumption in Dar es Salaam City was about 2,23 Mio t. This amount will rise up to about 5,1 Mio t of wood in the year 2020 for the reference case. The results of the different calculated cases show that it is possible to reduce the wood consumption of the city in an enormous way.

The strategy "improved stoves" leads to a wood fuel saving of about 40% related to the reference case. The demand of wood fuel decreases to 2,9 Mio t in the simulation for 2020. The strategy "improved kilns" has a wood fuel saving of about 30% compared to the reference case. In this case Dar es Salaam has a wood fuel demand of about 3,5 Mio t in 2020. Both measures added in the strategy "improved stoves and kilns" can reduce the demand of fuel wood by 60% in 2020 which is then simulated to 2 Mio t. An important result of these calculations is: in spite of an increasing population in Dar es Salaam, the wood-fuel consumption of the city can be pushed under the amount of today by using more efficient stoves and kilns. This is a saving of 60%

compared to the amount of wood in the reference case for 2020.

The increase of wood consumption has a braking point at about 2010. After that the demand on wood-fuel clearly rises slower (reference case). The reason for this development can be found in the estimation of population growth for the city of Dar es Salaam. The population growth rates are estimated much smaller then, than the previous years (see also 4.1 Scenarios).

The strategy "Improved kilns" is characterised by a decreasing wood consumption between 2010 and 2015. The re-beginning increase of wood consumption after this period has its reason in the now reached limit of the strategy "improved kilns". Like described in Chapter 4.2 Strategies of the energy sector, all traditional kilns are now replaced by improved technologies. The market share of improved kilns reached 100%. By now, the influence of the population growth characterises the development once again. The development of wood consumption in the case "reference improved stoves and kilns" shows this also, but only in a soft braking point for the decreasing wood demand. The influence of the "improved stoves" measure is stronger than those of the measure "improved kilns" in that case.

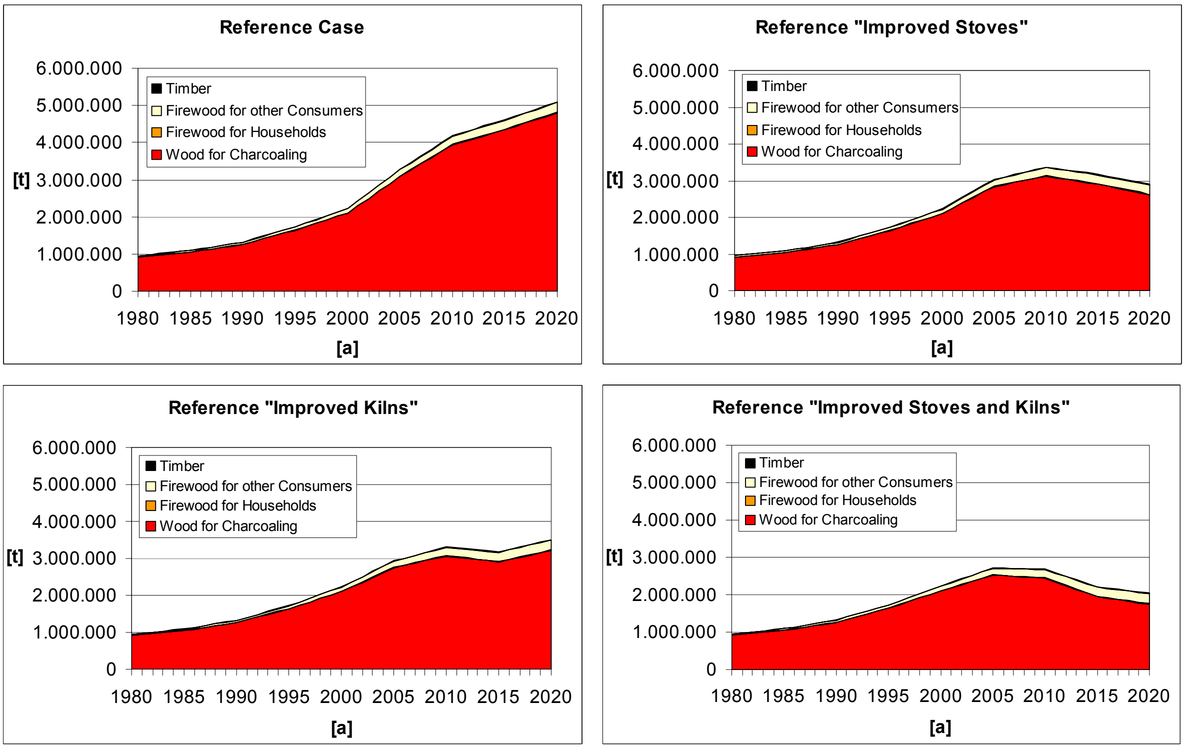


Figure 4-3: Wood consumption in Dar es Salaam City

4.3.2 Charcoal consumption in Dar es Salaam City

The biggest part of the wood demand is consumed by the charcoaling process with about 2,1 Mio t of wood in the year 2000 for the reference case. This is about 94% of the total wood demand of Dar es Salaam.

The actual charcoal consumption of Dar es Salaam City is about 314.000 t in the year 2000. The Tanzania Traditional Energy Development (TaTEDO), an environment organisation, even speaks about 360.000 t in the year 2000 /van Asperen, 2001/ /Sawe, 2001/.

Figure 4-4 shows the development of the charcoal consumption until the year 2020 for the reference case and the case reference “improved stoves”. The strategy “Improved stoves” has a direct influence on the charcoal consumption as it calculates with a higher market share of improved charcoal stoves (see Chapter 4.2 Strategies of the energy sector). The strategy “Improved kilns” doesn’t touch the demand of charcoal, as it determines only the demand of wood for the charcoaling process.

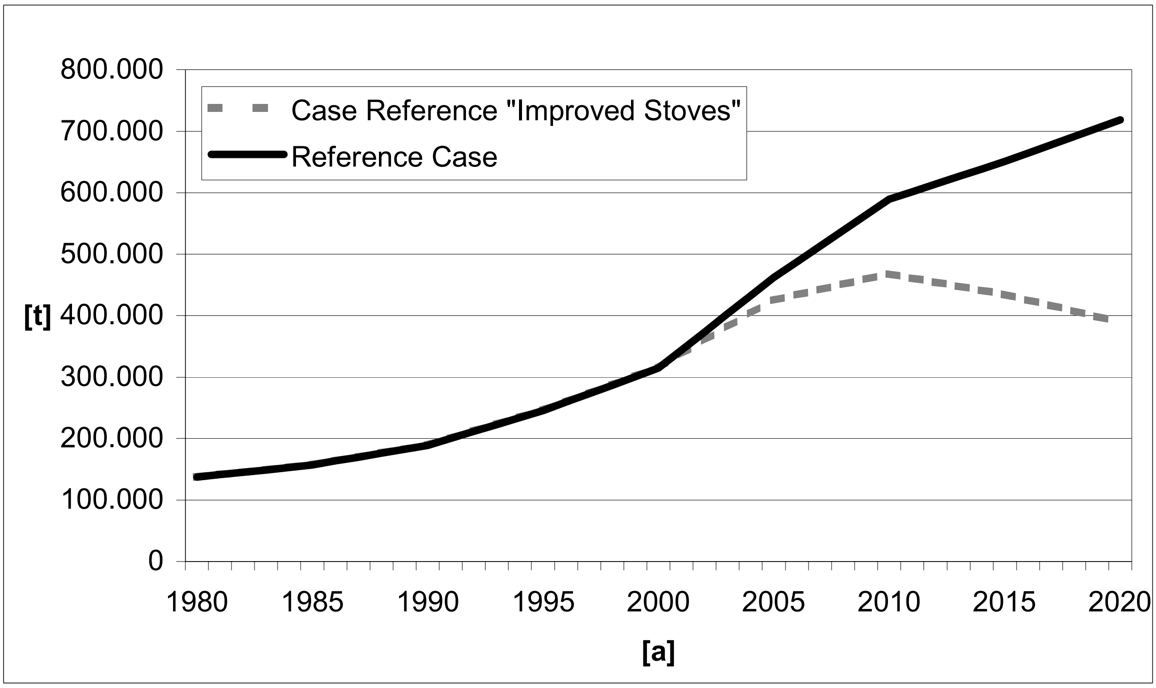


Figure 4-4: Charcoal consumption in Dar es Salaam

The modelled urban charcoal consumption for the year 2020 is about 720.000 t in the reference case. By the strategy “improved stoves” this can be reduced to about 390.000 t in the year 2020, which means about 46% consumed charcoal less.

Figure 4-4 also shows the impacts of the higher population growth rates between 2000 and 2010 and the lower estimated growth rates up from the year 2010.

4.3.3 Population growth

Like already mentioned the development of the urban population has a big impact on urban fuel consumption. The population of Dar es Salaam is characterised by very high growth rates of some 5 to 8% till 2010 (see Chapter 4.1 Scenarios). Not until 2010 do they sink to estimated 2%.

Figure 4-5 shows the models results for the aggregated Dar es Salaam wood consumption. Every defined strategy was calculated with each of the three scenarios: reference scenario with the actually estimated population growth rates, “pessimist” scenario with higher and “optimist” scenario with lower estimated growth rates. Figure 4-6 shows all calculated cases on the same graph to illustrate the development of the different strategies, based on the different scenarios. The worst case for the future development is therefore the case reference “pessimist” with a modelled total urban wood consumption of about 6 Mio t in the year 2020. The best case is the case “optimist, Improved stoves and kilns” with an urban wood consumption of about,66 Mio t in 2020.

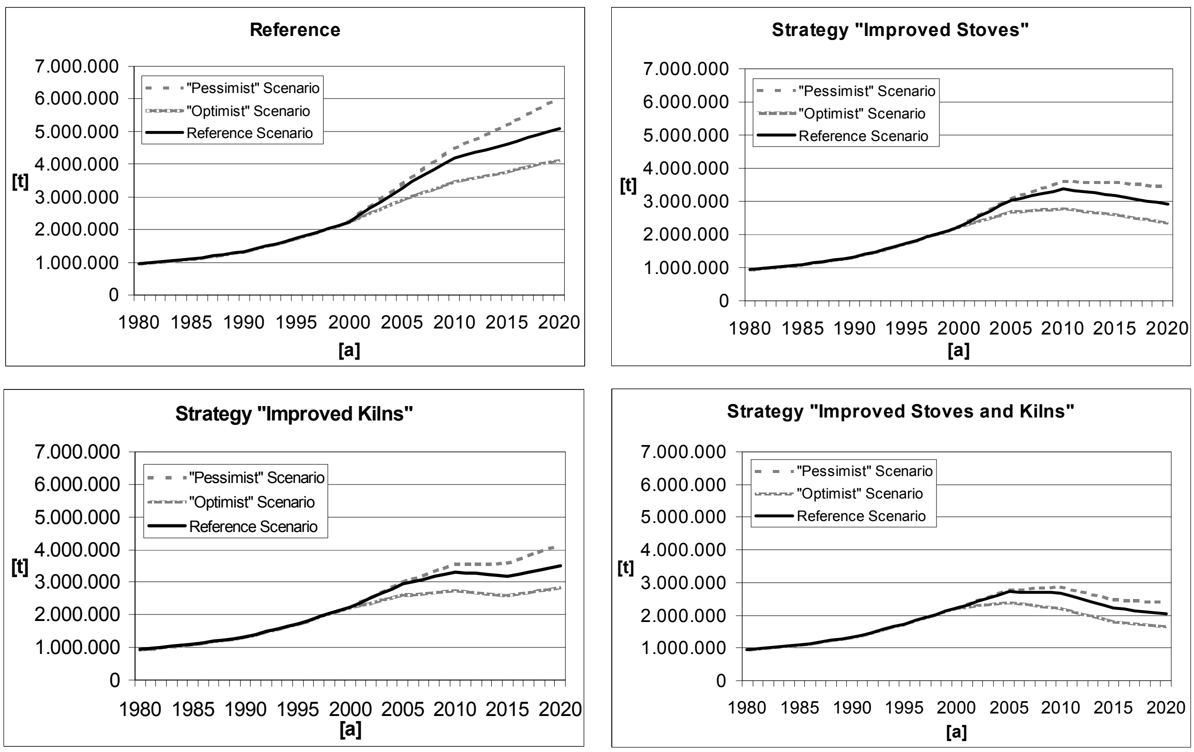


Figure 4-5: Wood consumption after scenarios

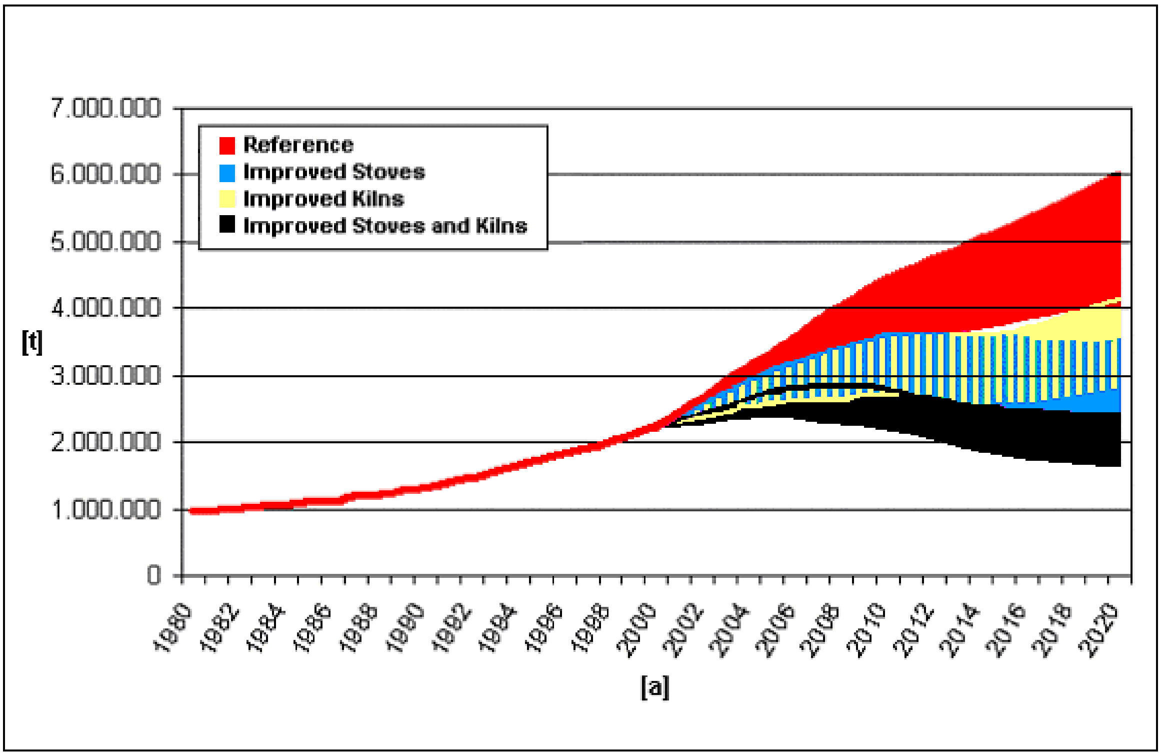


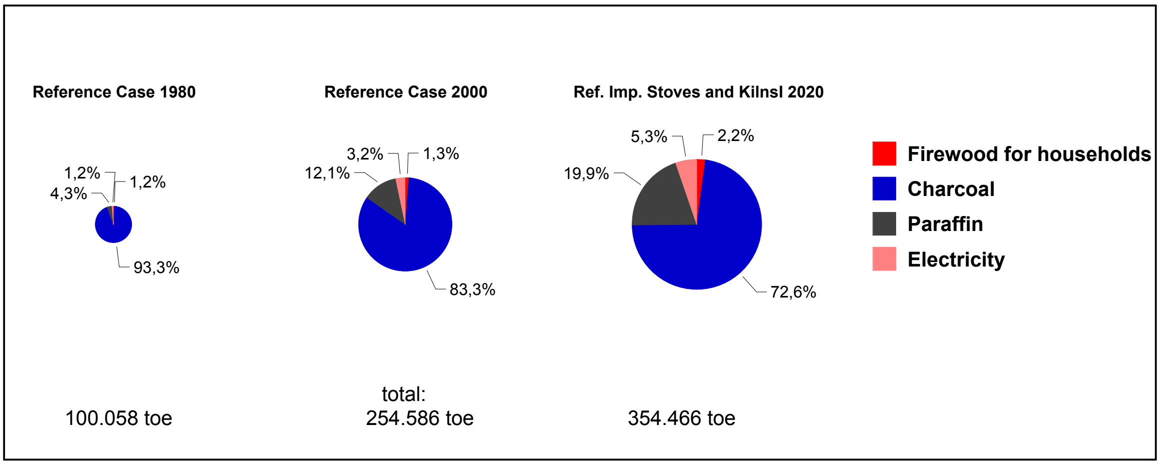
Figure 4-6: Wood consumption in Dar es Salaam, different cases

The graph marks that the strategies “improved stoves” and “improved kilns” lead to almost the same reduction on reducing wood consumption. Both strategies show an evident decrease of wood consumption. If they are so called robust, strategies must be examined in the forest model. There, they are linked to forest management strategies and calculated in the forest simulation.

4.3.4 Household energy

Figure 4-7 shows the market share of household combustibles in Dar es Salaam City for the years 1980 and 2000 in the reference case and 2020 in the best case “reference improved stoves and kilns”. The total household energy demand is presented in ton oil equivalents to compare the different energy carriers.

Independent from the used combustibles, the energy demand increased from 100.000 toe in 1980 to about 250.000 toe in 2000. Fire wood plays no big part in the Dar es Salaam household energy market, so does electricity. There is even no gas used as household combustible in urban Dar es Salaam. The part of the charcoal as energy carrier sunk from 93% in 1980 to 83% of the consumed toe in 2000. In the same time the part of paraffin rose to 12% of the consumed toe in 2000 to become the second important energy carrier in Dar es Salaam’s households. There is no big change on the household energy market between 2000 and 2020, as no strategies of replacing wood-fuel by other combustibles were discussed. Charcoal demand decreases by using charcoal



stoves with higher efficiencies.

Figure 4-7: Household Energy

4.4 Woodland Development

A lot of charcoal entering Dar es Salaam comes from the closed and open miombo woodlands. /Malimbwi et al., 2001/. It is assumed that about 80% of the total charcoal demand is satisfied through the study area that was discussed during the final meeting in Maputo. The following figure is based on the reference population growth rate of Dar es Salaam as shown in Figure 4-1.

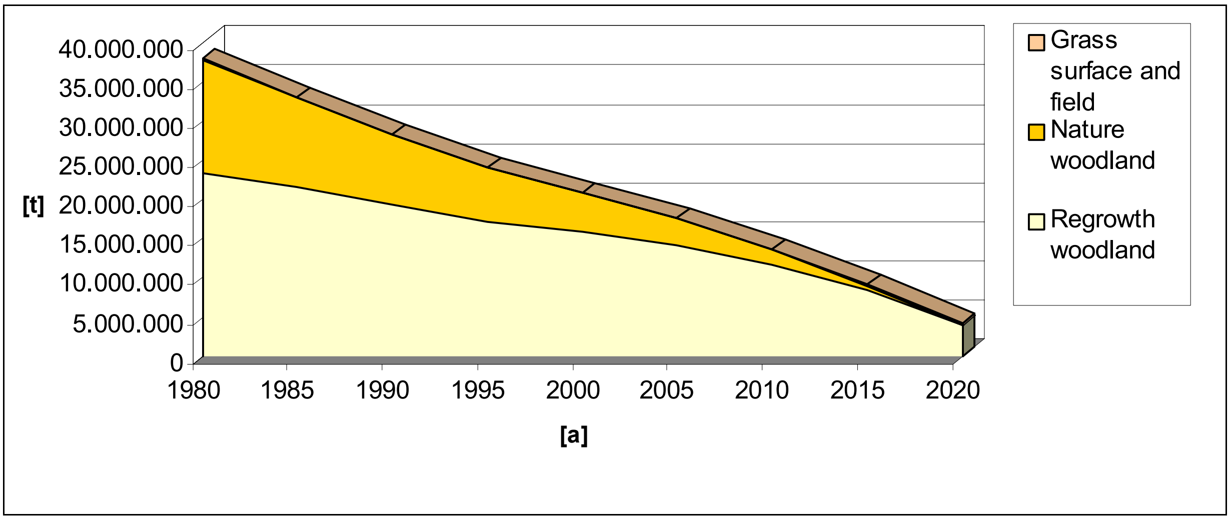


Figure 4-8: Woodland development of Tanzania study area without measures.

The trend between the measured years 1991 and 1998 by /Malimbwi et al., 2001/ was extrapolated into the past as well as into the future by using a linear equation. The trends of degradation is going to increase in the next years due to the enormous population growth rate. The increasing population in Dar es Salaam and the expansion around the city as presumed by

/Jambiya, Mchone, 2001/ could have big impacts on the not yet exploited woodland areas.

In Figure 4-9 possibilities of protecting the study area are given. This is the sustainable forest management inclusive additional afforestation.

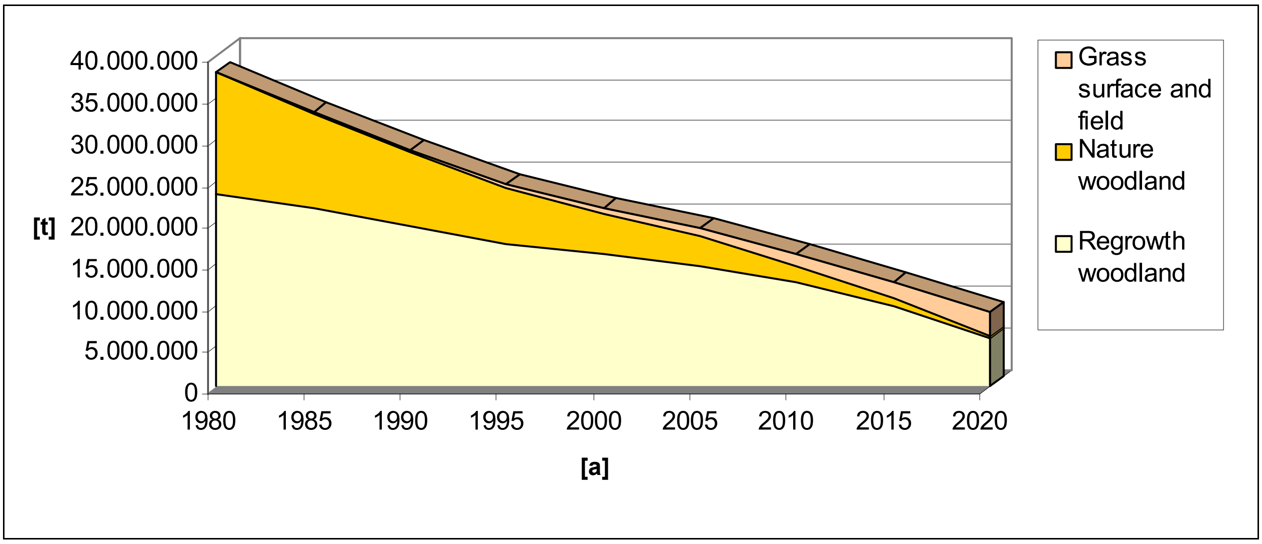


Figure 4-9: Woodland development of Tanzania study area with forest measures.

But these measures are not sufficient, as it is the case in Mozambique, to take the pressure away from the woodland if the strategies are based on the scenario that 80% of wood will come from the study area.

The strategies are combined with the population growth rate of the reference case. The first action it to look on the production side. There are several options which can be taken into account. The important issues that can be done in the field are described in section 1.3.5 Scenarios, Strategies. The option of additional forestation can be regarded as a maximum in the available area with a growth rate of about 116t/km²a on the grassland and agriculture areas and an additional 11 t/km²a in the open woodland areas beginning in the year 2003. The big difference in defining growth rates is seen in /Malimbwi et al., 1997/: the annual average growth rates in four Miombo vegetation types around Morogoro, Tanzania are going from 35 to 525t/km³. Other authors like /Trapnell, 1959/ defined annual average growth rates of miombo woodland of about 100t/km³.

The following strategy is based under the assumption that beside the forest measures household strategies are also taken into account.

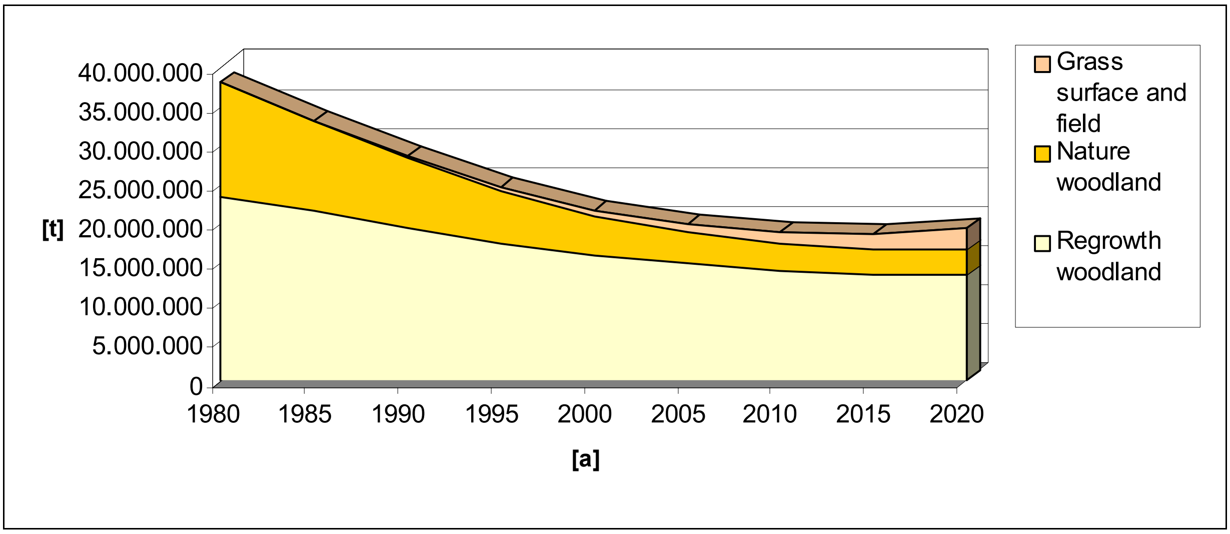


Figure 4-10: Woodland development under forest management and improved technologies.

Figure 4-10 gives a clear picture of the possibilities of sustainable forest management and the propagation of improved stoves and professional kilns. The results on the above mentioned figure could be reached by using consequent forest strategies such as fire control, coppicing with the stands and additional reforestation in the re-growth areas. The additional reforestation starts in 2003 with an area of 0,5% to 1% of the study area per year. From 2010 it is less than 0,5% per year.

The most important factor for success is the involvement of the villagers. This is guaranteed only if a profitable participation of the villagers is found. Possibilities on this item are well known at the Universities of Morogoro and Dar es Salaam.

Figure 4-11 shows the possible woodland under the optimistic scenario.

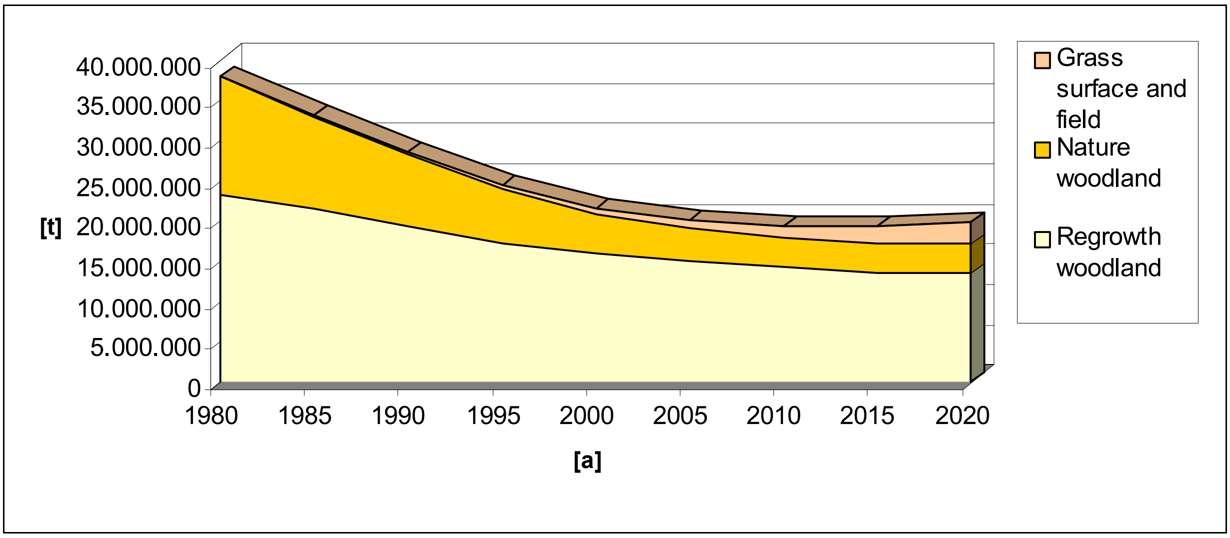


Figure 4-11: Woodland development under forest management and improved technologies with the optimistic scenario.

As seen in Figure 4-10 and Figure 4-11, there is not much difference between the two scenarios. With both scenarios the trend is reversible.

5 Zambia

5.1 Scenarios

The following scenarios show the trend of growth rates and the development of the population of Lusaka. Figure 5-1 illustrates the population growth of Lusaka city and Figure 5-2 show explicitly the growth rates on which the scenarios are based.

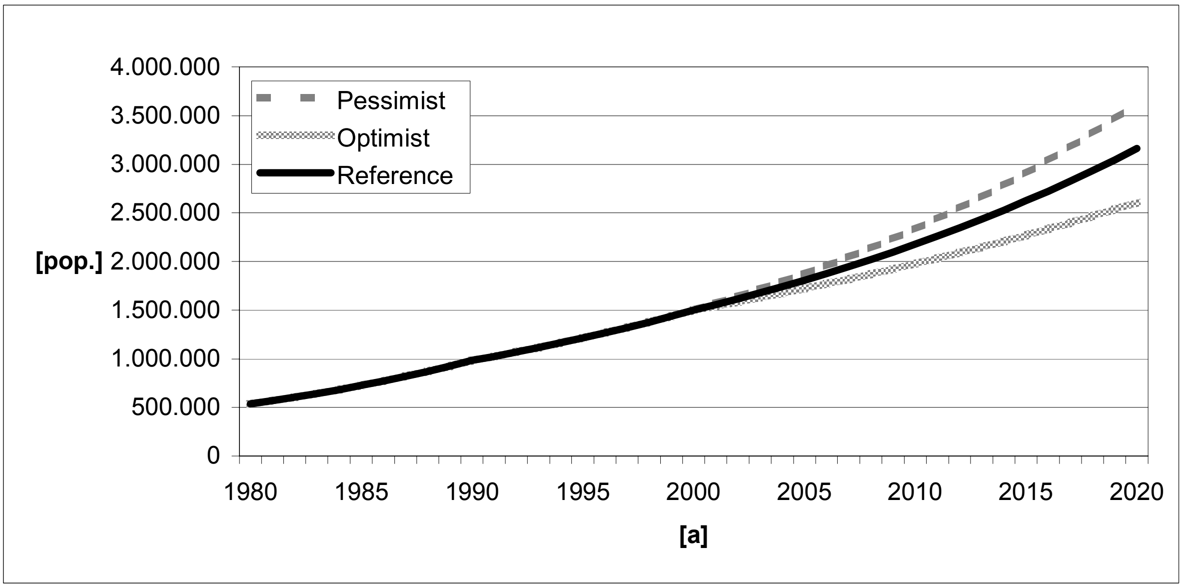


Figure 5-1: Population of Lusaka.

Lusaka City had about 980.000 inhabitants in 1980 /Hibajene, Ellegård, 1994/. The German ministry of foreign affairs gives a number of about 1,3 to 1,8 Mio inhabitants for Lusaka City in 2000. In discussion with the Zambian project partners a population number of 1,5 Mio was taken for the scenario modelling.

The calculation of a possible development for the Lusaka population development in the future is based on the information given by Hibajene /Hibajene, Ellegård, 1994/. Between 1980 and 1990 the population growth rate was at about 6,2%. Between 1990 and 2000 the growth rate sunk to still high 4% /BMA, 2001/. For the reference case the population growth was calculated with 3,8%, which simulates an ongoing increase like in the decade before. This reference scenario simulates a number of 3,1 Mio inhabitants for the end of the modelling period in 2020. The "optimist" scenario calculates with a lower growth rate of 2,8% up from the year 2000. This slower increasing development leads to about 2,8 Mio inhabitants in 2020. The growth rates for the "pessimist" scenario are estimated at 4,5% which simulates an even faster increasing development compared to the reference scenario. In 2020 Lusaka City will have about 3,6 Mio inhabitants calculated with the "pessimist" scenario.

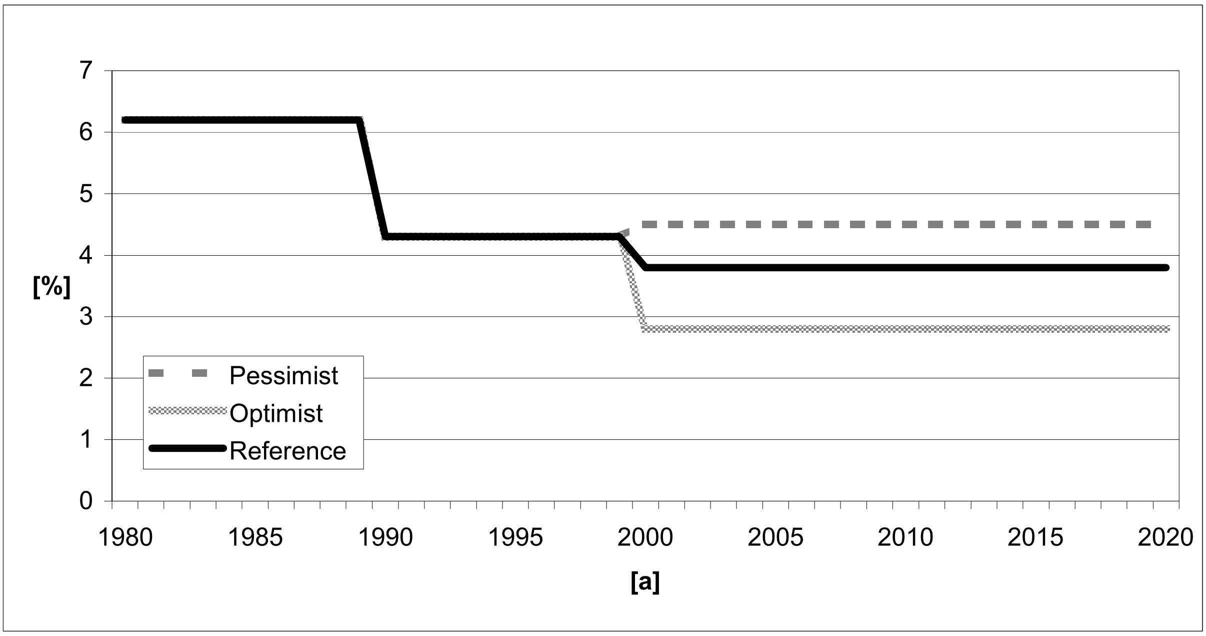


Figure 5-2: Growth rate of Lusaka.

5.2 Strategies of the energy sector

Like in Mozambique and Tanzania models, three strategies based on two measures were defined. Measures are: propagation of improved kilns and propagation of improved stoves. Strategies are: “improved kilns”, “improved stoves” and “improved stoves and kilns”. For Zambia also, these strategies were chosen to remain on the wood-fuel related level. The propagation of other stoves like kerosene, gas or stoves was not seen as a real alternative in the next years for Lusaka City. The Lusaka City household energy market is already characterised by a higher number of kerosene and electrical stoves.

5.2.1 Propagation and implementation of kilns with higher efficiency

The measure “propagation of improved kilns” is exactly the same as for Mozambique or Tanzania, so please compare section 3.3.1 and Figure 3-3. Today all charcoal in Zambia is produced by traditional earth kilns with an efficiency of 16,5% /Chidumayo et al., 2000a/. Until 2015 all charcoal producers could change to more efficient technologies by propagation of this type of improved kilns with about 25% efficiency /Staiger, 1999/. Please compare with section 4.2.1.

5.2.2 Propagation of improved stoves

The following tables Table 5-1 and Table 5-2 give an overview on the market shares of the available stoves in Zambia. Unlike in Mozambique and Tanzania, it was possible in Zambia to calculate with disaggregated market shares of stoves for different types of use.

Table 5-1: Market shares of different stoves in Zambia, Reference Case

Stove	Purpose	*Un.*	1980	1985	1990	1995	2000	2005	2010	2015	2020
Reference Case											
Traditional Wood Stove	Cooking	%	19,55	19,55	19,55	19,55	19,55	19,55	19,55	19,55	19,55
Traditional Wood Stove	W. Wat.	%	34,76	34,76	34,76	34,76	34,76	34,76	34,76	34,76	34,76
Traditional Wood Stove	Heating	%	35,58	35,58	35,58	35,58	35,58	35,58	35,58	35,58	35,58
Traditional Wood Stove	Others	%	15,31	15,31	15,31	15,31	15,31	15,31	15,31	15,31	15,31
Improved Wood Stove	Cooking	%	0	0	0	0	0	0	0	0	0
Improved Wood Stove	W. Wat.	%	0	0	0	0	0	0	0	0	0
Improved Wood Stove	Others	%	0	0	0	0	0	0	0	0	0
Trad. Mbaula	Cooking	%	54,36	51,79	49,22	49,22	49,22	49,22	49,22	49,22	49,22
Trad. Mbaula	W. Wat.	%	61,03	58,14	55,26	55,26	55,26	55,26	55,26	55,26	55,26
Trad. Mbaula	Heating	%	61,47	61,47	61,47	61,47	61,47	61,47	61,47	61,47	61,47
Trad. Mbaula	Others	%	7,40	7,05	6,70	6,70	6,70	6,70	6,70	6,70	6,70
Imp. Mbaula	Cooking	%	0,0	2,6	5,1	5,1	5,1	5,1	5,1	5,1	5,1
Imp. Mbaula	W. Wat.	%	0,0	2,9	5,8	5,8	5,8	5,8	5,8	5,8	5,8
Imp. Mbaula	Others	%	0,0	0,4	0,7	0,7	0,7	0,7	0,7	0,7	0,7
Clay Stove	Cooking	%	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Clay Stove	W. Wat.	%	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Clay Stove	Others	%	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Kerosene Stove	Cooking	%	10,39	10,39	10,39	10,39	10,39	10,39	10,39	10,39	10,39
Kerosene Stove	W. Wat.	%	0	0	0	0	0	0	0	0	0
Kerosene Stove	Others	%	67,62	67,62	67,62	67,62	67,62	67,62	67,62	67,62	67,62
Electric Stove	Cooking	%	15,70	15,70	15,70	15,70	15,70	15,70	15,70	15,70	15,70
Electric Stove	W. Wat.	%	4,21	4,21	4,21	4,21	4,21	4,21	4,21	4,21	4,21
Electric Stove	Others	%	9,67	9,67	9,67	9,67	9,67	9,67	9,67	9,67	9,67
El. Radiator	Heating	%	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95

Chidumayo determines the demand of heat for four different processes in the households: cooking, preparing warm water, space heating and others /Chidumayo et al., 2001/. For every single process, the part of used household combustible was given. So it was possible to calculate the market shares of the used household technologies for every defined household process. This desaggregation makes it possible to calculate special measures as for example the propagation of electrical boilers for preparing warm water. Nevertheless in the CHAPOSA model for Zambia the measures for the household energy sector were restricted to the propagation of improved charcoal stoves like in Mozambique and Tanzania.

Table 5-2: Market shares of stoves in Zambia, strategy "Improved stoves"

Stove	Purpose	Un.	1980	1985	1990	1995	2000	2005	2010	2015	2020
Strategy "Improved Stoves"											
Traditional Wood Stove	Cooking	%	19,55	19,55	19,55	19,55	19,55	19,55	19,55	19,55	19,55
Traditional Wood Stove	W. Wat.	%	34,76	34,76	34,76	34,76	34,76	34,76	34,76	34,76	34,76
Traditional Wood Stove	Heating	%	35,58	35,58	35,58	35,58	35,58	35,58	35,58	35,58	35,58
Traditional Wood Stove	Others	%	15,31	15,31	15,31	15,31	15,31	15,31	15,31	15,31	15,31
Improved Wood Stove	Cooking	%	0	0	0	0	0	0	0	0	0
Improved Wood Stove	W. Wat.	%	0	0	0	0	0	0	0	0	0
Improved Wood Stove	Others	%	0	0	0	0	0	0	0	0	0
Trad. Mbaula	Cooking	%	54,36	51,79	49,22	49,22	49,22	39,00	28,79	18,57	8,36
Trad. Mbaula	W. Wat.	%	61,03	58,14	55,26	55,57	55,89	44,92	33,96	22,99	12,03
Trad. Mbaula	Heating	%	61,47	61,47	61,47	61,47	61,47	61,47	61,47	61,47	61,47
Trad. Mbaula	Others	%	7,40	7,05	6,70	6,70	6,70	5,37	4,05	2,72	1,40
Imp. Mbaula	Cooking	%	0,00	2,57	5,14	5,14	5,14	13,86	22,57	31,29	40,00
Imp. Mbaula	W. Wat.	%	0,00	2,89	5,77	5,46	5,14	14,36	23,57	32,79	42,00
Imp. Mbaula	Others	%	0,00	0,35	0,70	0,70	0,70	1,78	2,85	3,93	5,00
Clay Stove	Cooking	%	0,00	0,00	0,00	0,00	0,00	1,50	3,00	4,50	6,00
Clay Stove	W. Wat.	%	0,00	0,00	0,00	0,00	0,00	1,75	3,50	5,25	7,00
Clay Stove	Others	%	0,00	0,00	0,00	0,00	0,00	0,25	0,50	0,75	1,00
Kerosene Stove	Cooking	%	10,39	10,39	10,39	10,39	10,39	10,39	10,39	10,39	10,39
Kerosene Stove	W. Wat.	%	0	0	0	0	0	0	0	0	0
Kerosene Stove	Others	%	67,62	67,62	67,62	67,62	67,62	67,62	67,62	67,62	67,62
Electric Stove	Cooking	%	15,7	15,7	15,7	15,7	15,7	15,7	15,7	15,7	15,7
Electric Stove	W. Wat.	%	4,21	4,21	4,21	4,21	4,21	4,21	4,21	4,21	4,21
Electric Stove	Others	%	9,67	9,67	9,67	9,67	9,67	9,67	9,67	9,67	9,67
El. Radiator	Heating	%	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95

Today, the mostly used stove for cooking in Zambia is the charcoal one using traditional Mbaula with almost 50% market share also used for preparing warm water (55%) and space heating (60%). A small number of improved charcoal stoves, such as the improved Mbaula are used already today. The second part on the household sector is taken by the wood stove. It produces about 20% of the heat for cooking, 35% of the heat for preparing warm water and 36% of the heat for space heating. The electrical or the kerosene stoves don't play such a dominant part with one exception. The kerosene stove produces almost 70% of the heat for other purposes.

According to the measure "propagation of improved stoves", the traditional Mbaula with its thermal efficiency of about 10% /Westhoff, Germann, 1995/ was replaced by better improved stoves. Two types of improved stoves are available in Zambia: the improved Mbaula with a thermal efficiency of about 15% - 30% /Westhoff, Germann, 1995/, and the clay stove with 27% - 48% thermal efficiency /Westhoff, Germann, 1995/. For the simulation with the measure "propagation of improved stoves", the market shares of the improved Mbaula increases from about 5% in 2000 to about 40% in 2020 for the purpose of cooking and preparing warm water. The market shares of the clay stove rise in the same period from 0% to about 5% for the same purposes. For the purpose of space heating the market share of the available charcoal stoves was not changed, as the efficiency for heating depends on the energy content of the fuel and not on the thermal efficiency of the stove, if there is no special heating technology with radiators or chimneys. The market share for heat for other purposes does not differ much as well, as no strategy of fuel substitution was decided, and on this sector the kerosene and the electrical stove already carry the biggest market share with about 70% together.

5.3 Energy model calculations

In this section the results of the model calculation for Zambia are shown and discussed. Issues are the wood consumption in Lusaka City, desegregated in different demands, development of the wood consumption after different scenarios for the urban population, the charcoal consumption in the city and the development of the Lusaka household energy market in general.

5.3.1 Wood Consumption in Lusaka City

Figure 5-3 shows the aggregated wood consumption for Lusaka City. The three defined strategies for Lusaka were compared to the reference case. In the year 2000 the total wood consumption in Lusaka City was about 1,8 Mio t. This amount will rise up to about 3,8 Mio t of wood in the year 2020 in the reference case. The results of the different calculated cases show that it is possible to reduce the wood consumption of the city in an enormous way.

The figure illustrates as well that more than 80% of the total wood demand is used for charcoaling, another 10% as firewood in the year 2000. The residual part is demanded as fuel by other consumers, such as restaurants, hotels,...or as timber. Only the part of the wood for the charcoaling process can be reduced by the defined strategies. In Zambia the part of wood which has other uses than for charcoaling plays a bigger role than in Mozambique or in Zambia. Therefore this aspect should be regarded specially. The part of wood for charcoaling is calculated with 80% in the reference case in 2020, like in 2000. By execution of all discussed measures until 2020, the part of wood for charcoaling can be reduced to 60%. This shows that there is also a big potential in saving wood by searching for other measures, such as the substitution of wood stoves for example.

The simulation with the strategy “improved stoves” leads to a total wood demand of 2,27 Mio t in the year 2020, meaning a wood saving of almost 40% to the reference case. The wood saving of the strategy “improved kilns” is about 28%, with a simulated demand of 2,7 Mio t in 2020. The strategy “improved stoves and kilns”, which combines the two measures, leads to a total wood demand of about 1,7 Mio t in 2020. This means about 54% of wood can be spared compared to the reference case in 2020. In the best case reference "improved stoves and kilns" the total demand of wood is even smaller than today. Nevertheless the population of Lusaka City is increasing, and with it the household energy demand, so it is possible to reduce the wood consumption to a smaller volume than today by using more efficient stoves and kilns.

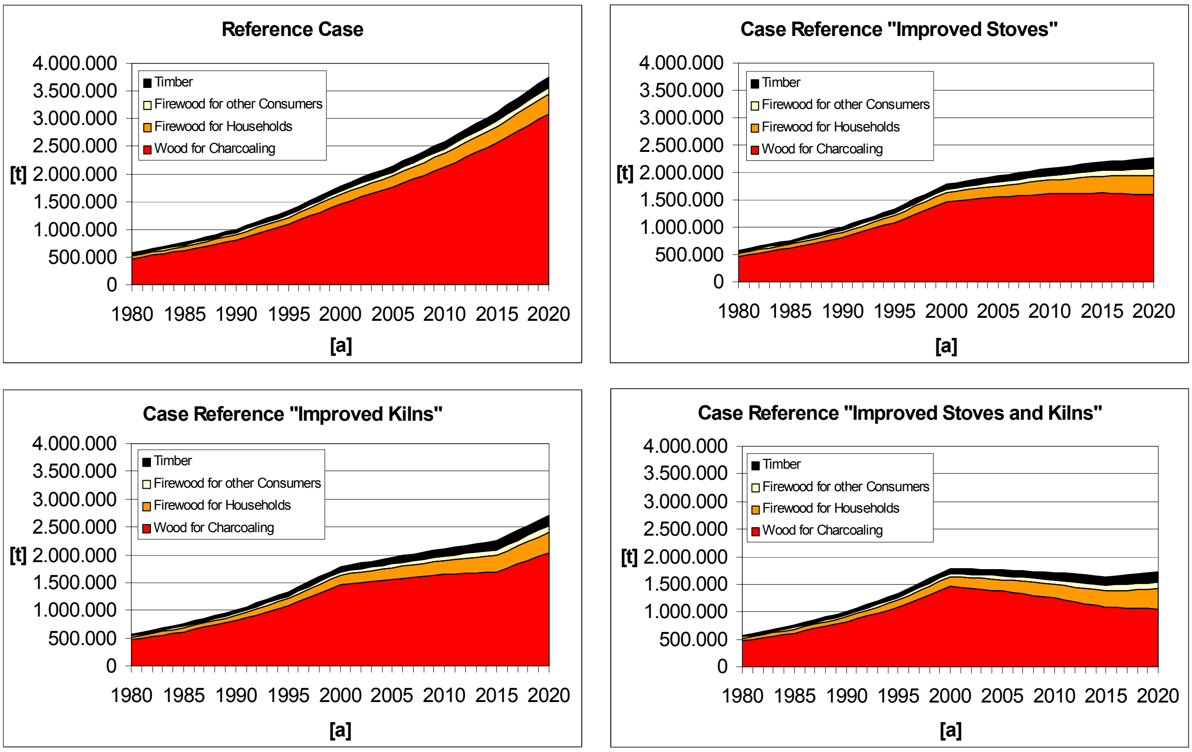


Figure 5-3: Wood consumption in Lusaka City

The cases “reference improved stoves” and “reference improved kilns” show a braking point in the year 2000 when the measures of the strategies start. From 2000 onwards, the wood consumption of the city increases much more slowly by increasing use of better technologies for household purposes or charcoaling. After the year 2015 the increase will be higher again. This has its reason in the now reached limit of the strategy "improved kilns".

Like described in section 5.2 Strategies of the energy sector, the traditional kilns are replaced by improved technologies. In 2015 the propagation of the improved kilns comes to an end by getting to a market share of about 100%. The increasing need of wood for a larger amount of charcoal by a growing population starts again. The development of wood consumption in the case "reference improved stoves and kilns" shows this, as well. In this case one can even recognise a decreasing wood consumption from 2000 to 2015.

5.3.2 Charcoal consumption in Lusaka City

The biggest part of the wood demand is consumed by the charcoaling process with about 1,5 Mio t of wood in the year 2000 for the reference case. This is about 83 % of the total wood demand of Lusaka. The actual charcoal consumption of Lusaka City is about 240.000 t in the year 2000. Prof. Emmanuel Chidumayo calculates with about 230.000 in the Scientific Annual Report for CHAPOSA of 2001 /Chidumayo et al., 2000b/.

Figure 5-4 shows the development of the charcoal consumption until the year 2020 for the reference case and the case reference “improved stoves”. The measure “propagation of improved stoves”, related to this case, has a direct influence on the charcoal consumption as it is calculated with a higher market share of improved charcoal stoves.

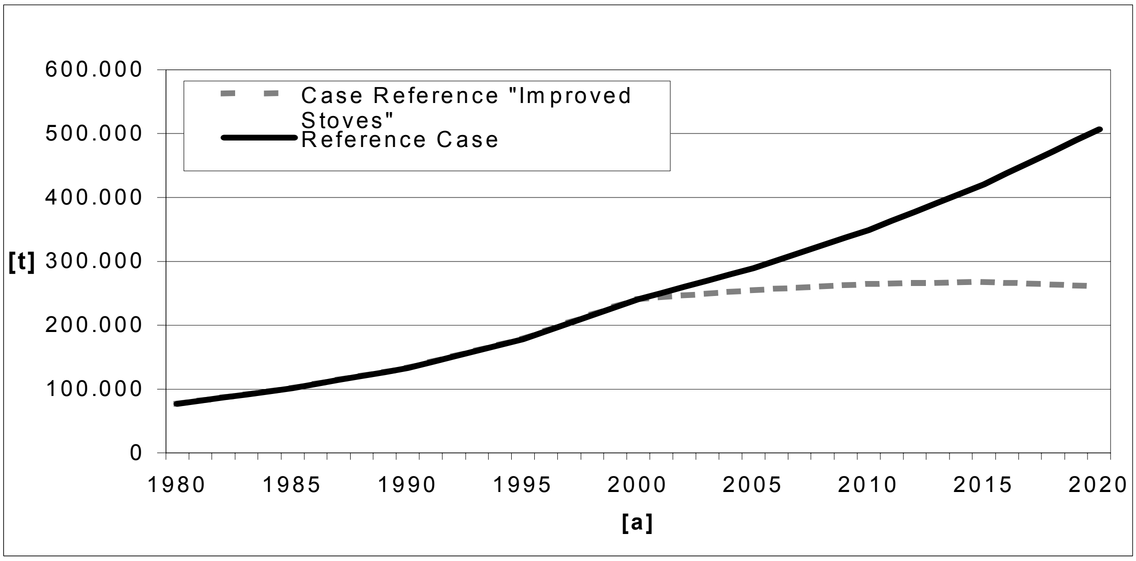


Figure 5-4: Charcoal consumption in Lusaka

The modelled urban charcoal consumption for the year 2020 is about 507.000 t in the reference case. With the measure “propagation of improved stoves”, this can be reduced to about 260.000 t for the year 2020, which is a reduction of consumed charcoal of about 60%.

5.3.3 Population growth

The development of the urban population has big impacts on urban fuel consumption. The population of Lusaka is characterised by high growth rates of about 2,8% - 4,5% with 3,8% in the reference case (see section 5.1 Scenarios).

Figure 5-4 shows the model's results for the aggregated Lusaka wood consumption. Every defined strategy was calculated with each of the three scenarios: reference scenario with the actually estimated population growth rates, "pessimist" scenario with higher and "optimist" scenario with lower estimated growth rates.

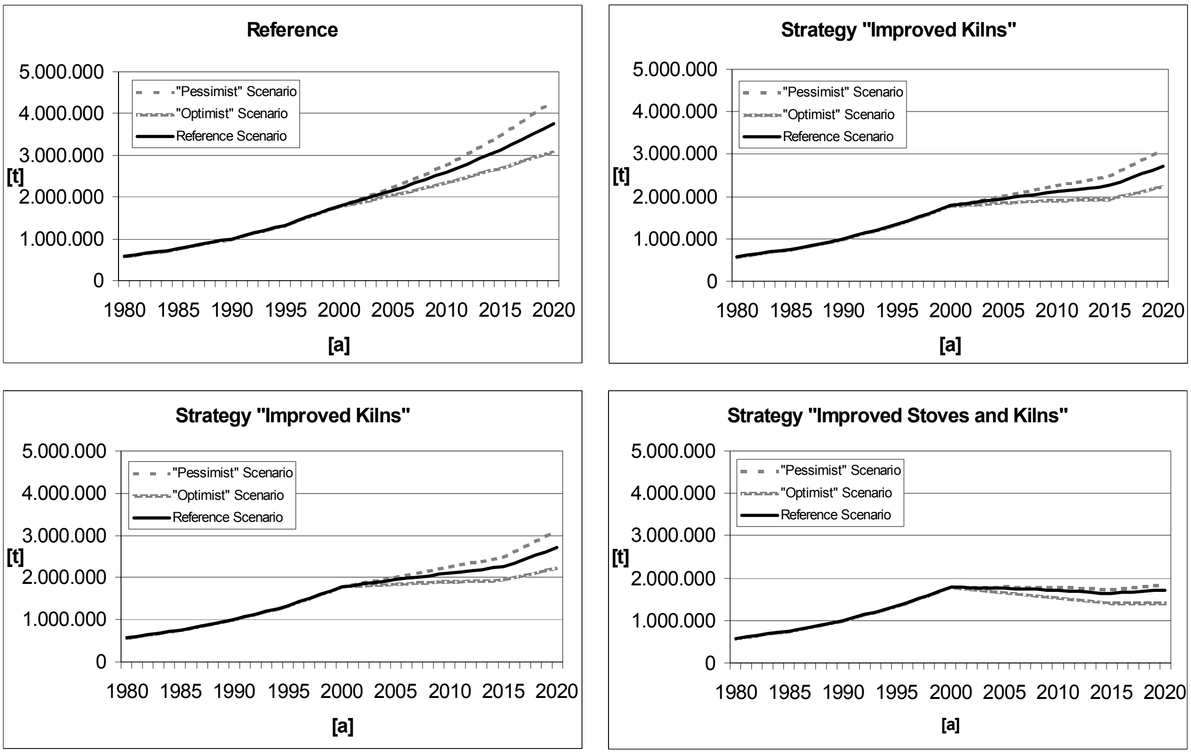


Figure 5-5: Wood consumption after scenarios

Figure 5-5 puts all calculated cases on the same graph to illustrate the range which is due to the different scenarios. The worst case for the future development is therefore the case reference "pessimist" with a modelled total urban wood consumption of about 2,6 Mio t for the year 2020. The best case is the case "improved stoves and kilns, optimist" with an urban wood consumption of about 1,4 Mio t for 2020.

The graph marks that the strategies "improved stoves" and "improved kilns" lead to almost the same reduction on wood consumption. Both strategies show an evident decrease of wood consumption. The best strategy "improved stoves and kilns" stays at any time of the modelling period on the same level of the year 2000 for the total wood consumption. Combined with the “optimist” scenario in the case “optimist, improved stoves and kilns” the simulated wood demand is with 1,4 Mio t even about 20% under the demand of today, meaning an absolute saving of 360.000 t in 2020 compared to 2000.

If these wood savings are sufficient for the goal defined before, we must show the calculations in the forest model, when the strategies of the household energy sector are linked to strategies of sustainable forest management.

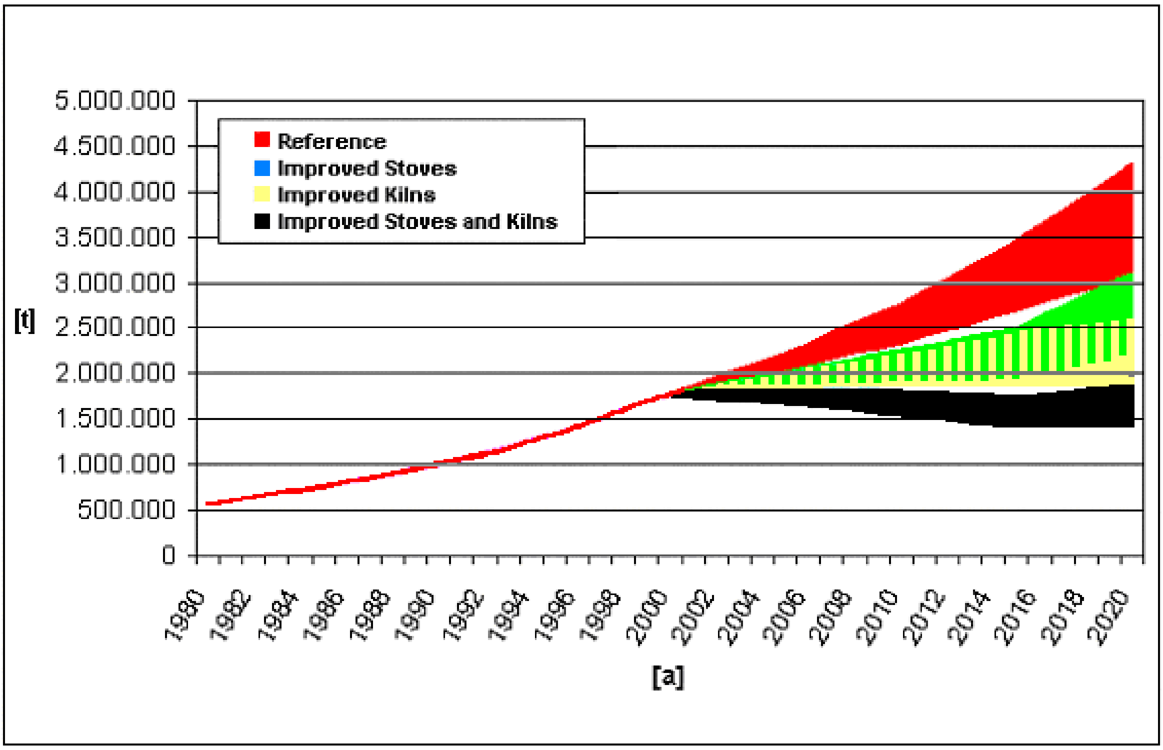


Figure 5-6: Wood consumption in Lusaka, different cases

5.3.4 Household energy

Figure 5-7 shows the market share of household combustibles in Lusaka City for the years 1980 and 2000 in the reference case and 2020 in the case "reference, improved stoves and kilns". The total household energy demand is presented in ton oil equivalents to compare the different energy carriers.

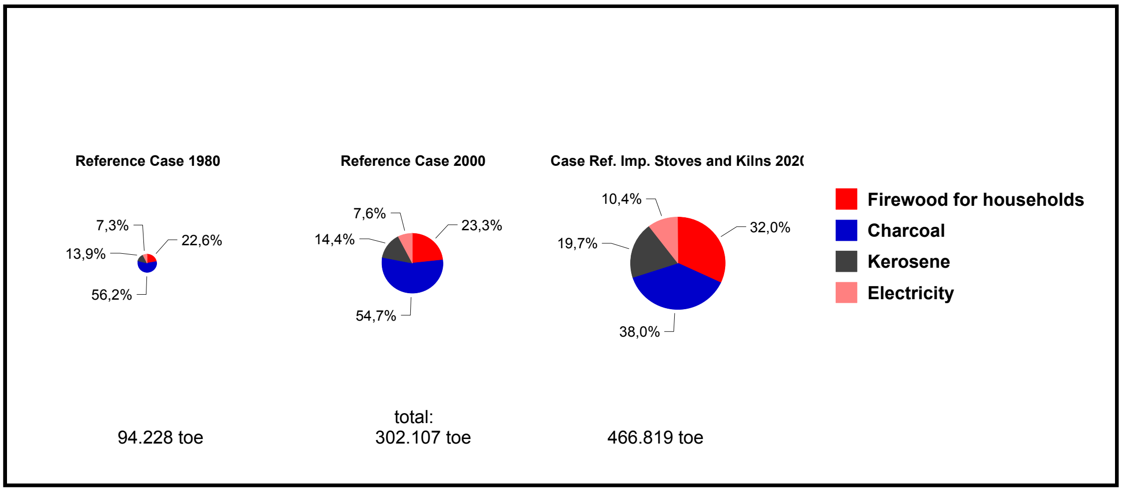


Figure 5-7: Household energy

Independent of the used combustibles, the energy demand increased from 94.000 toe in 1980 to about 300.000 toe in 2000. There are four important energy carriers on the Lusaka household combustible market: charcoal, firewood, kerosene and electricity. The biggest part of consumed energy are the wood fuels with about 78% consumed toe in the year 2000, about 55% charcoal and 23% firewood.

Although there is no big change on the household energy market between 2000 and 2020, as no strategies of replacing wood fuel by other combustibles was discussed, the part of charcoal decreases compared to the other household energy carriers. The reason is the higher efficiency of improved stoves, introduced by the strategy "improved stoves". There are not fewer charcoal stoves used by the Lusaka City households, but they consume much less.

In that case, the part of firewood on the urban energy market will be some 32%. So it could be sensible to think about wood fuel substituting measures. This can be either the introduction of gas stoves or propagating kerosene stoves or extending the measure “improved stoves” on wood stoves too. This is another possibility to reduce the wood consumption and weaken the pressure on the local forests.

5.4 Woodland Development

Zambia was divided in the three land types: plateau, hill and flat topography (flat country). This was possible according to the available data. In accordance with information from /Chidumayo et al., 2001/ it is important to know that only 25% of the charcoal for Lusaka comes from the study area. 75% are from other areas that are not mentioned, as the study area can be seen as representative of all areas. The small influence on the land use development of the Zambezian study area is completely different from the other areas of Mozambique and Tanzania.

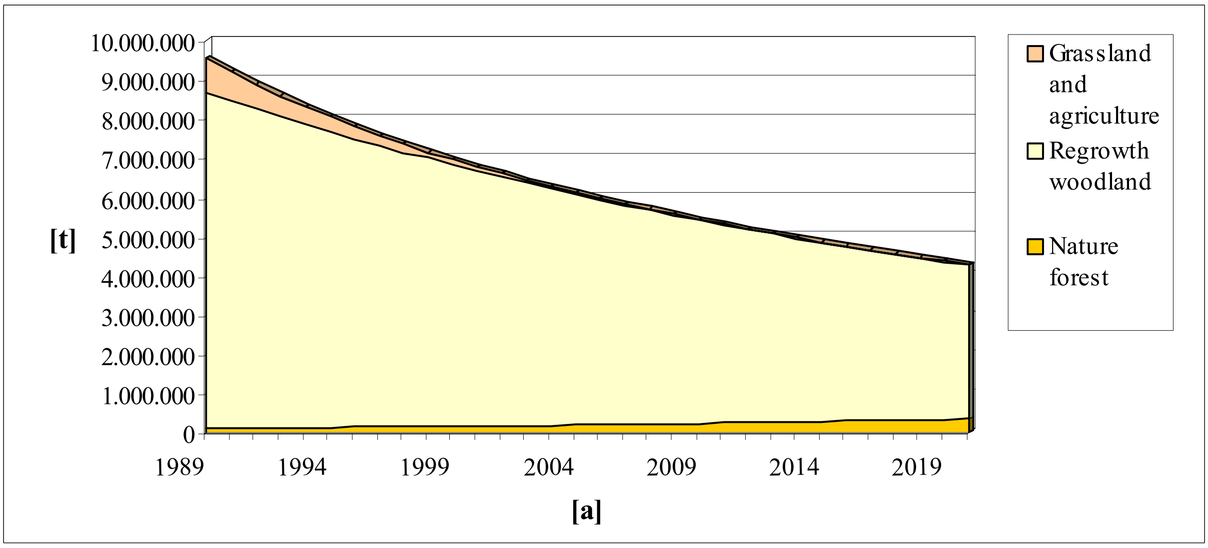


Figure 5-8: Plateau stand development from 1989 to 2020 without measures

As seen above the development in the plateau area of Zambia declined constantly from about 9.550.000 in 1989 to 7.140.000 t in 1998. These figures are calculated on the input data from /Chidumayo et al., 2000a/. The figure shows the further development down to 4.270.000 t in 2020. That means that the wood production in the same area would be bisected within less than 30 years. It can be assumed that the potential of the re-growth woodland after certain cuttings becomes weaker and probably soil erosion takes place as well as fire. Another part of former re-growth or nature woodland was converted into agriculture.

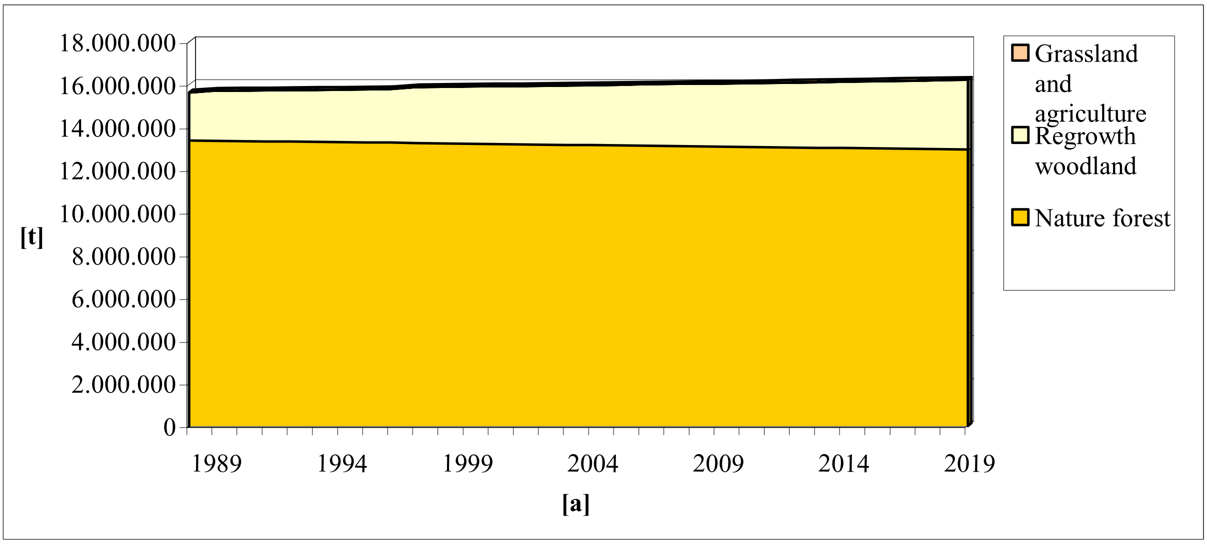


Figure 5-9: Hill stand development from 1989 to 2020 without measures

In comparison to the plateau development, the development of the hill stand is totally different. The nature woodland goes slightly down from 1989 to 2020. At the same time the re-growth woodland is increasing from almost 2.250.000 to 3.370.000 t. Therefore the possible wood production of this region decreases only from about 13.370.000 in 1989 to 12.950.000 in 2020.

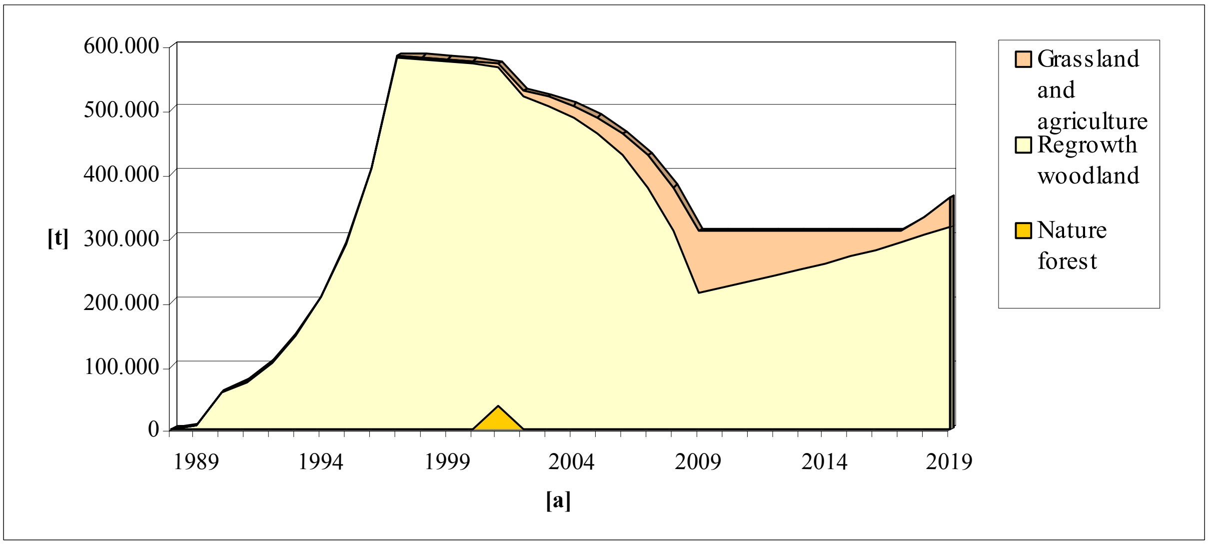


Figure 5-10: Flat country stand development from 1989 to 2020 without measures

As it is seen in Figure 5-10 the re-growth wood production has increased a lot between 1989 and 1998. It is supposed that there was nature woodland before and other parts were under agriculture or cutting areas. As there seems to be a quite good potential in this area for making charcoal, the development should decline up to 2010 and likely grow again because of coppicing and re-growth from former agriculture.

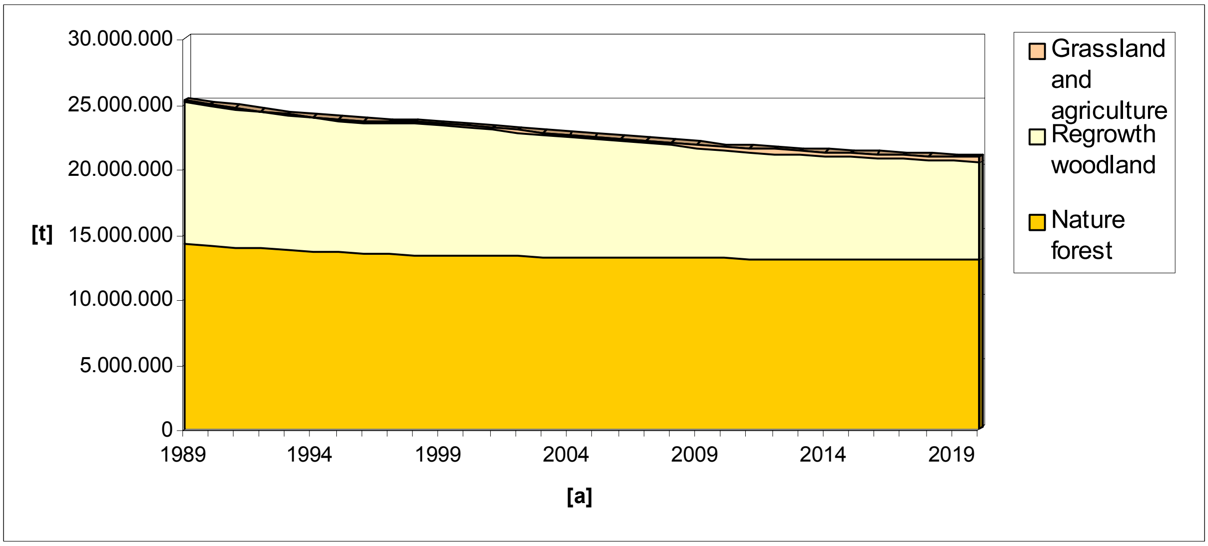


Figure 5-11: Woodland development of the zambezian study area

Figure 5-11 shows that in the Zambian study area the influence of making charcoal seems to be less than in the other countries.

But nevertheless it is possible to improve the situation. The next figure shows what effects fire control, coppicing with the stands and additional A forestation or reforestation can have. Beside this the strategies are combined with the propagation of improved stoves and professional kilns on a basis of the reference growth rate.

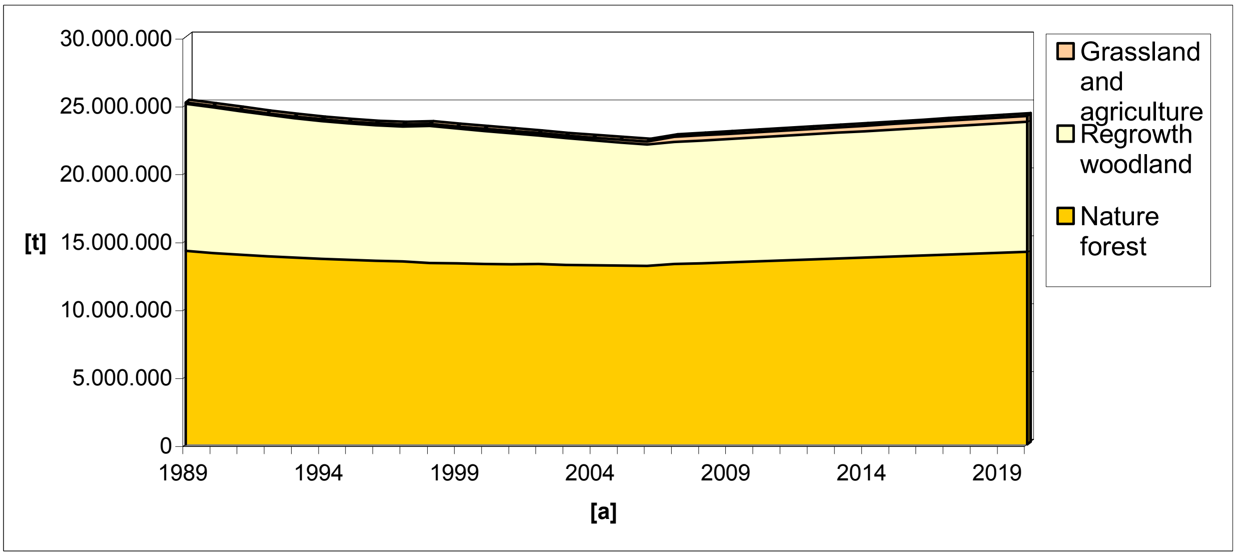


Figure 5-12: Wood productivity in Zambia with fire control and forest management

According to Figure 5-12 it seems to be possible, with a mix of strategies, to come back to the same wood productivity level under a low population growth rate. The above mentioned strategies are calculated under the condition that 75% of the wood demand for Lusaka comes from regions beyond the study area.

6 Conclusions

The following conclusions are based on the common recommendations of the CHAPOSA project compiled by the Stockholm Environment Institute. /Ellegård et al., 2002/

Biomass will remain the dominant fuel source for the households of Southern Africa. The results of the project show that the use of biomass leads to an extreme pressure on the woodlands, which partly causes unsustainable development in the rural regions.

Combined strategies are required to improve the actual situation The wood and charcoal consumption of the cities can be reduced in an enormous way by the propagation of improved kilns and / or stoves. The involvement of the villagers is one of the most important issues, which is only guaranteed if a profitable participation of the villagers is found.

Charcoal is not a minor forest product but a major one, and in most cases the only one. The natural forest surrounding large cities in Southern Africa are being depleted, partly due to charcoal extraction. In spite of this, the forest resources are likely to be able to supply charcoal for at least another decade through the re growth. The depletion is more severe around Maputo, where the natural closed forest is essentially removed, already today. In Zambia and Tanzania the resource situation is less severe, but ecologically sensitive areas are increasingly becoming exploited. There is a need for natural resource management measures.

Enforcing the licensing systems is an option to induce changes in the system. This will increase consumer prices and reduce income and is politically sensitive. At the same time, this is also the seed to a thorough change in the system, and to development.

The demand for alternatives and saving measures induced by the price increases must be met by other measures. In the rural production areas this can be done by improving the situation for agricultural production and by offering roles for rural people in the natural resource management and extraction.

Measures like the enforcement of the fiscal system for natural resources will provide the impetus and market for changes in the other sectors, but if implemented in isolation, they will cause severe hardship to many poor people. Agricultural smallholder production needs support and consistent long-term policies in order to be able to provide alternatives to charcoal production or illegal logging.

In urban areas, the use of fuel efficient stoves should be encouraged but the demand for alternative energy sources could be met as well. Nevertheless the change from charcoal to electricity in households did not seem to be feasible in the model period. Even the population of urban households uses rather charcoal because of economic and traditional reasons. Fossil options are not considered here for environmental and economic reasons.

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