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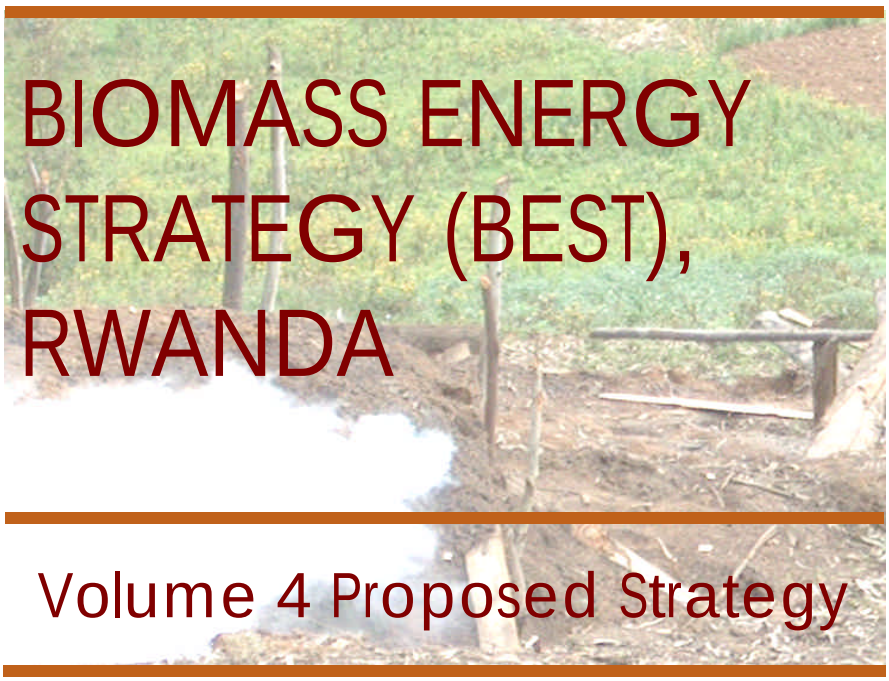
BIOMASS ENERGY STRATEGY (BEST), RWANDA



Volume 4 Proposed Strategy

June 2009

MARGE

Volume 4: The Proposed Strategy

June 2009

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Table of Contents

Tables

Figures

Summary

In this Volume 4 an investment package of US$ 120 million is presented for the implementation of the proposed biomass energy strategy to render the supply of wood and charcoal sustainable. The package includes four parallel programs dealing with energy conservation, rehabilitation of plantations, fuel substitution, and capacity building. Some regulatory changes are required to change the current rules that govern the cutting of wood for energy purposes: the law and decrees consider that wood comes from natural forests whereas today most if not all wood comes from man-made plantations. This makes firewood and charcoal just another product from the farm or the plantation and the legislation should take this into account. In addition, the applied taxation system on woodfuels is no longer adequate and should be improved. A different system is proposed whereby benefits are offered to stakeholders as long as they improve the efficiency of their operations. Without such changes it does not make much sense to implement the investment package.

It is expected that 36% of the investments can be borne by beneficiaries, such as households, private firms, farmers, and community plantation owners. An additional 20% can be raised through the aforementioned improved taxation system on the transport of charcoal and the valorization of environmental benefits. Of the $52 million that remains to be financed over the project period, a total of more than $30 million are already in place or will be in place soon through contributions from a bilateral donor.

The rate of return of the investment is high: 27% if environmental benefits are not accounted for and 49% if they are.

Volume 1 presents the executive summary of the biomass energy strategy; Volume 2 presents the background and analysis; Volume 3 rural demand and supply.

1 INTRODUCTION

1.1 Biomass energy strategy

The Biomass Energy Strategy (BEST) deemed optimal from an economic point of view is presented in this document, BEST Strategy Rwanda - Volume 4. It presents the results of the proposed intervention at the demand and supply side as well as at the policy level. Alternative development scenarios as well as background data and analysis on the energy situation in Rwanda are presented in the larger introductory report, BEST Strategy Rwanda - Volume 2, Analysis. An executive summary is presented in Volume 1.

It is not the intention to provide a set of activities that is detailed enough and ready for implementation immediately; although implementation is obviously recommended, further detailed preparatory work will still be needed. The scenario presented in this Volume shows the merits of fully integrating biomass issues into the economic development of the country. To that end, it presents what can be done, how this should be done, and what the approximate costs and benefits are. The proposed strategy has above all educational value, since it demonstrates the value of carrying out a reasonable development alternative that depends on biomass rather than trying to get rid of its use as quickly as possible. It is shown that higher economic benefits are obtained if biomass is indeed fully incorporated into the development objectives of the country.

It should be mentioned that the strategy has been prepared through discussions with numerous organizations and individuals involved. Five of these organizations are actually testing or already implementing parts of the strategy and their results should be closely monitored, evaluated, and incorporated in further implementation of the strategy in the near future. The five activities pursued are the following:

- CARE pursues improved stoves and kilns, mainly in the southern districts. Stoves involved are both urban (charcoal) and rural (firewood) and the focus is on implementation issues. With reference to kilns, the proposed strategy in this Volume to modernize the charcoaling business are tested, creating professional charcoaling groups that operate as small businesses and charcoal depots where charcoal transporters can come to collect their charcoal. The system to issue cutting permits is also reviewed together with District authorities to develop a more effective system.
- The World Bank's GEF project intends to pursue improved stoves in Kigali, and it is hoped and expected that the labeling idea can be fully incorporated.
- FAO is carrying out another biomass energy strategy and will specifically look at small-holder plantations and papyrus.
- The Royal Netherlands Embassy has recently started a €10 million PAREF II program, to be implemented by MINIRENA in collaboration with the CTB in 9 districts (North and West) to assist communities with small wood plantations. The objective is to rehabilitate and increase the productivity of 10,000 ha of these plantations and include better management systems, including more efficient charcoaling techniques. As part of this program a map of forestry resources is prepared based on aerial photos, including tree plantations below 0.5 ha in size. In addition, the Royal Netherland Embassy is developing a €30 million regional program[1] to assist small-scale farmers (in the 0.5 ha range) to improve agroforestry productivity, including the use of trees; in principle, Rwanda has access to 1/3rd of this program and this is expected to cover also around 10,000 ha. It is expected to be

[1] Burundi, Congo, and Rwanda

implemented by MINIRENA in collaboration with the International Fertilizer Development Center (IFDC).

- The Hunter-Clinton Foundation has started a planting program among small-farmers, reaping benefits from the carbon offset mechanisms.

1.2 EDPRS

The proposed biomass energy strategy follows as much as possible the Energy Sector Strategic Plan included in the Economic Development and Poverty Reduction Strategy (EDPRS). Its objective is to contribute to the accelerated sustainable socio-economic development so as to improve the well-being and the quality of life of the population by powering the social and economic sectors to meet the essential needs. The following specific objectives have been identified:

- Increased Access to Electricity for Enterprises and Households
- Reduced cost of service, and introduce the cost reflective tariff
- Diversified the sources of energy and ensure security of supply
- Strengthened governance framework and institutional capacity of the energy sector.

It is clear that the first and second specific objectives are necessary but not sufficient conditions for development. These objectives mainly serve the urban population as it is expected that the rural population will need more time to be ready for such access. The government expects to have 35% of the population connected to electricity by 2020, but that would only include a small portion of the rural population. Urban population density and income are in favor of lower cost of connections and lower cost of service, hence the priority will go to urban customers first.

Cost-reflective tariffs for electricity are close to reality and it is unlikely that tariff levels will fall substantially in the near future. It will remain difficult for most households to use electricity for other purposes than lighting and ICT; cooking will remain out of bounds for the majority of households with an electricity connection. So in fact, most households with electricity will use a different cooking fuel than electricity.

The second specific objective has also been achieved for biomass since most firewood and charcoal stems from man-made plantations and the products from these plantations are sold at prices that reflect their cost of production; this already generates a large part of the rural income.

The third and fourth specific objectives are particularly valid for biomass, which supplies 85% of the total energy demand and highly contributes to the energy security of the country. Petroleum fuels remain too expensive for the majority of households and are not likely to be used except by the richest parts of the population. Biomass-based alternatives such as briquettes or peat have not been developed and this should be pursued to diversify the supply of fuels – if it can be demonstrated that these fuels can develop a market for themselves. Other local sources are better suited for electricity production (geothermal, methane, solar, wind) than for thermal application such as cooking.

The governance framework and institutional capacity should indeed be improved. The BEST strategy has been prepared with this in mind, taking into account the facts that biomass actually provides a major contribution to the rural economy, contributes to the national energy security, provides a stable and cheap supply of energy for urban households, and doesn't depend on external factors such as the price of crude oil. The most important changes

required to further improve the biomass energy supply are first in the regulatory framework and institutional capacity and second in the rehabilitation and better management of plantations.

2 PRESENT SITUATION AND TRENDS

A summary of the main energy sector issues is presented first, dealing with the most important demand and supply aspects of biomass fuels. The analysis is limited to the commercial use of wood fuels and focuses on charcoal: the use of gathered wood fuels as is practiced in most rural areas has not been considered as this practice is expected to have a negligible effect on the state of the wood resources. For the production of charcoal and commercially sold firewood, entire trees are cut; for the production of gathered firewood, dead wood, twigs, or sometimes cut branches etc are used that generally do not destroy the resource base. The focus on charcoal is justified as charcoal is just 8% of the secondary energy balance but 23% of the primary energy balance and a small reduction in the end-use of charcoal will have large implications on the primary supply side.

Nevertheless, some rural intervention is foreseen as well; not only does the largest population group live in rural areas, the way they use energy has a negative impact on the economy, and the unsustainable supply of woodfuels for rural use may increase in the future if no action is undertaken now. If this occurs, the supply of urban woodfuel will also be affected and there are no quick fixes if this does happen. In short, it is necessary to take action now as the alternative, do nothing until it is too late, will encounter much higher economic costs.

2.1 Demand aspects

Firewood and charcoal

Woodfuels are the main source of energy in the country[2] and a major contributor to rural development[3]. Not everyone fully appreciates this – yet – and the consequences thereof are far reaching. The prevailing trend appears to find substitutes to biomass as quickly as possible. This document argues that it this would not be necessary – on the contrary, it would be advantageous if the supply of biomass is made sustainable. The net economic benefits of creating a sustainable biomass supply are much higher than those of importing more petroleum fuels to meet the energy demand[4].

Combined, firewood and charcoal represent more than 98% of urban cooking energy consumption and close to 100% for the rural population. In Kigali most of the demand is for charcoal whereas in other towns firewood is still heavily used; it is just a matter of time before urban households in secondary towns and rural areas will increase their share of charcoal: first as a secondary fuel, to complement the main fuel (firewood) but gradually more and more charcoal will be used as it is a more convenient and modern fuel. This phenomena has been observed in other countries as well, notably in Madagascar, Mali and Senegal. If this happens, the supply of woodfuels may rapidly become unsustainable.

The point has been made in the analytical document that in countries such as the USA, Germany, etc. quite a few households and firms recently started to use biomass and abandoned electricity and petroleum fuels: it is cheaper and greener to use biomass. There, biomass is considered to be the modern fuel and petroleum fuels are considered to be traditional and outdated. However, they use modern appliances that are as convenient and as energy efficient to use as the ones they used before. So, the recommendation made in this

[2] It was estimated that 85% of the primary energy balance is from biomass in 2007; this was 95% in the mid-1980s.

[3] US$ 115 million, of which more than 50% remains in rural areas; this is about 5% of GDP.

[4] The benefits of a sustainable supply of woodfuels are rural employment, local and global environmental benefits, and supply of a low-cost urban fuel; they outweigh by far the costs of creating this sustainable supply. The benefits of access to a higher quality fuel are better urban living conditions; the costs are loss of rural income and importing petroleum fuels and these are much higher than the benefits.

Volume is to promote modern appliances and continue to use biomass rather than start using petroleum fuels and electricity.

Comprehensive survey data, assumptions, and estimates form the basis for the modeling carried out to develop the scenarios of the presented strategy. The GLOBUS computer model that has been developed by MARGE was used to explore the different scenarios [5]. Market penetration rates of different energy options are evaluated based on population projections and the population's preferences for different fuels and different stoves. Quantities of the different fuels used, of the different stoves used and needed for replacement, and the production of woodfuels from different sources are estimated over time; for a write up on the GLOBUS model, see the Annex for more details.

Using mainly existing data as input in this model, it is possible to assess the present consumption of commercial fuels as follows:

- for commercial firewood use, and excluding gathered firewood by the rural population and a limited number of urban households, the total national commercial wood consumption has been estimated at about 700,000 t per year;
- for charcoal, the total national consumption has been estimated at around 150,000 t per year, with the following breakdown:

Table 1: Charcoal demand in '000 t

	2008 (estimate)	%
Kigali City	86	58%
Other urban area	37	25%
Rural areas	26	17%
Total	149	100%

Source: BEST team estimates based on population statistics; See also the Annex for more details on the assumptions.

Given the low efficiency of the charcoaling process, another 1,200,000 t of wood are needed, giving a total commercial firewood demand of about 1.9 million t per year and 0.57 million t for non-energy purposes. Although an average efficiency of the charcoaling process of 12% is used (this is 24% on an energy basis), it will not be realistic to obtain efficiencies of more than 20-22% on a weight basis.

At the moment the supply does match the demand, although a portion of this is non-sustainable and reflect over-harvesting. In fact, if all known tree plantations, including those earmarked for protection, are harvested at a sustainable level and for 100% converted into woodfuels, there is a deficit of some 1.1 million t of wood (See table 3). However, if the productivity of these plantations is not 7 m3/ha as found by the Forestry Inventory, but instead 13 m3/ha, the supply would be enough to fully cover the demand. In other words, the situation is not yet disastrous, and intervention has a chance to render the supply sustainable while covering the entire demand.

When comparing this to former evaluations (2000 and 2003), it is evident that the share of Kigali in the overall national charcoal demand is falling. Households in other towns and even rural areas now use more charcoal as and when their incomes rise. This consumption level is very low at the moment, but would increase rapidly if the consumption of charcoal augments. As an example, if the national charcoal consumption were doubled today, 22% more wood

[5] GLOBUS is used for the BEST Malawi and is in use in 11 countries in West Africa for the development of their biomass energy strategy under the PREDAS program.

would be needed to cover this new demand for charcoal. Therefore, it is important to manage the consumption and the production of charcoal.

In a way it is good that the price of charcoal is already relatively high, certainly compared to other countries in the region, as this may explain in part why the market for improved stoves has significantly developed in urban areas. The price in constant terms has remained constant and fairly low until about 2004, when it suddenly doubled over a period of 3 years (See Figure 6 in Volume 2). An explanation has not been found other than the fact that a more strict regulation was introduced and enforced on the cutting of trees. It has been estimated that the market penetration of improved stoves in Kigali is around 50% and not far from that in secondary towns. Given the trend of increasing charcoal prices and the low price elasticity of charcoal consumption, it is likely that the proportion of households using an improved stove will keep increasing at a more or less significant pace.

This is good news and bad news at the same time. Introducing more improved stoves will only give a small incremental improvement, as the baseline already uses a relatively efficient stove. If all urban households that do not already use a 40% more efficient improved stove start using it, the total primary wood savings would be 7%. Although the uptake of such stoves by all urban households should be pursued, it is also time to identify 2nd generation improved stoves that are much more efficient than the current ones. This is not only in-line with trends elsewhere, it would also promote the notion that it is not a shame to continue using biomass. Such 2nd generation improved stove could be a fan-driven stove, a gasifier stove, etc.[6]

Other fuels

Other fuels include kerosene (paraffin), LPG and electricity; consumption is very low, mainly as a result of the high retail prices applied. A large part of the present consumption comes from the use of secondary fuel. Projections for 2008 for these cooking fuels are as follows:

- around 300 tonnes of LPG; not only is LPG very expensive but lately there have also been supply problems due to unrest in Kenya;
- 900 tonnes of kerosene (slightly over 1000 m3) for cooking; note: rural lighting is not included; households do not appreciate kerosene as a cooking fuel, even though Chinese and Indian stoves can be found on the market and even though cooking costs are not much more expensive than with a traditional charcoal stove; having a better stove model is seen as a serious constraints for the accelerated uptake of kerosene;
- electricity market share is very small but with under 0.5% of households in Kigali cooking with electricity as their primary energy source and much less in other cities and rural areas. Cooking nevertheless represents around 6.5 MW in power requirement and that is not so far from 10% of the peak capacity; cooking consumes 9 GWh in energy per year or around 2% of the overall electricity demand. Particularly during peak hours electricity supply is constraint in certain sections of town, which overlaps with prime cooking times.

Combined these three sources represent less than 2% of the overall domestic energy demand for Kigali, and this is very low by almost any standard. The explanation for this varies, mainly due to price gaps, supply problems, and probably in the case of kerosene, non-acceptance. Woodfuel supply constraints make substitution a necessity, at least in the medium

[6] There are at least 2 different multinational firms selling such stoves in different countries; in Africa, trials are ongoing in Ghana and Kenya. Such stoves cost around €45 or FRw 38,000. See also www.aprovecho.com for more information and stove tests.

and long term, and this may become a serious issue. Vision 2020 anticipates an even more accelerated switch to modern fuels then presented here in the strategy. In the short term no mass markets will develop, although LPG and electricity could get a slightly greater share of the better-off market, due to new supply conditions:

- Electricity supply problems are less than a few years ago, when a shortage of national generation capacity had to be resolved through expensive thermal generation in leased power plants. As a result the price of electricity is now close to 24 US cents/KWh. Rwanda was one of the first countries in the region to increase its prices to cover the costs and now Uganda and Kenya have followed suit. Further improvement of the national generation capacity will bring a larger availability of power, but not necessarily lower generation costs. Prospects for a slightly reduced tariff may come from the possible generation capacity of 60-200 MW from Lake Kivu at an estimated cost of electricity of around 10 US cents/kWh at the generation level, leading to some 16 US cents/kWh at the retail level. At the current charcoal prices, the break-even tariff of electricity (threshold of competition with charcoal) ranges around 13 US cents/KWh (against about 24 US cents now). Even if it is unlikely that future tariffs are cut in half, a reduced tariff will result in customers who start to use electricity for cooking.

  This is not without danger: only 0.5% of Kigali households using electricity for cooking are able to increase the demand for power by 10% of the current peak. Imagine if 5% of Kigali households using electricity for cooking, new generation capacity would be needed just to satisfy the cooking needs. The risks of low tariffs relative to charcoal need to be evaluated very carefully when electricity tariffs are adjusted downwards.

- Therefore, it is advisable to propose other non-electricity alternatives to better-off customers, the first of which is LPG. The main problem with LPG is a chicken and egg situation: it is expensive and therefore households don't use much of it; but there are substantial scale-economies to be had in which a larger consumption will result in much lower prices. The strategy for boosting LPG use is therefore based on kick-starting its use: (i) temporary de-taxation of duties and taxes on LPG, which will be gradually reintroduced as the market picks up; and (ii) counting on the fact that households are likely to accept paying more once they are accustomed to using LPG; see also Box 3 in Volume 2.

  As a matter of fact, LPG is subject to large scale-economies and at the current low consumption rate, it is highly likely that LPG remains expensive. An increase in consumption of a factor of 10 (starting from a very low base) will already show substantial CIF price decrease: now empty bottles are taken to Eldoret for filling; at 3000 t/yr, a filling station in Kigali is fully justified. At the current consumption rate, revenue from duties and taxation is very small (< US$ 300,000/y). It is proposed to exonerate duties for 5 years and VAT for 3 years to increase the market share of LPG. If needed or desired, both duty and VAT could be reintroduced gradually over a number of years. Because of the projected higher future LPG volumes used and the resulting lower CIF value, the tax and duty charges will not weigh as much to the final consumer price as it does now: a win-win-win situation[7]. The experience in Senegal showed that household do not switch back to charcoal when LPG taxes are re-applied, but accept to pay more for LPG because of the higher comfort level associate with it.

[7] Consumer: LPG is now a real alternative cooking fuel; MINECOFIN: tax & duty revenue much higher than today; LPG supplier: large market share.

- Although kerosene is not accepted today in Rwanda, it is fully accepted in some other countries: Djibouti, Ethiopia, Kenya, South Africa. One of the reasons why Rwandan households don't like kerosene is the low performance of the stoves, which in part is due to their low quality. One of the first actions should be to introduce better stoves into Rwanda; tax incentives could be envisioned to kick start the market for more efficient kerosene stoves and in particular pressure stoves[8]. When such stoves are available it is likely that kerosene will find a larger market share given that the cost of cooking with kerosene are not much more than those for cooking with charcoal and much lower than those of LPG.

2.2 Supply aspects

The three key characteristics that determine the present wood supply situation are (i) the fact that virtually all wood comes from planted trees rather than from natural resources; (ii) that the majority of trees come from private lands rather than common or public land; and (iii) that the regulatory environment is degrading, despite the fact that there are quite a few rules in place; wood owners and charcoalers are slowly beginning to ignore the rules and illegal operations are increasing. Much has to do with the status of charcoal: it is unclear among consumers and supply chain operators whether it is a legally produced fuel or an illegal one?

Forestry areas vs. plantations

Even if there is some illicit woodfuel production from the few remaining natural forests and parks in Rwanda, the overwhelming part of the commercial firewood and charcoal supply stems from man-made plantations. The recent forest inventory showed that 60% of the plantations are public, but was unable to determine the shares of national and local public resources[9]. In addition, this information contradicts common knowledge that much of the woodfuel supply comes from private small holder plantations.[10] The BEST surveys did not corroborate that information as it found that indeed many farmers have woodlots of less than 0.5 ha, but they prefer to sell pole wood and timber rather than energy wood[11]. The 2009 survey found that 14% of rural households have a tree plantation, and in addition, they indicated that they have more trees now than 3 years ago. In the scenarios, the contribution from smallholder plantations has deliberately been kept low as to present a more pessimistic scenario than might be the case. Public plantations officially do not contribute to the woodfuel supply as harvesting operations are not authorized. However, the inventory found that 80% of all plantations showed signs of human intervention, i.e., harvesting, and public plantations therefore contribute in reality to the woodfuel supply – but the community as a whole doesn't benefit, only the few individuals who illegally cut trees.

The estimated potentially sustainable supply is compared to the estimated demand for woodfuels, to determine whether the existing resource base is able, or at least has the potential, to satisfy the demand now and in the future. Non-energy use such as poles, stakes, construction wood, should also be taken into account since it comes from the same resource base as energy wood. Table 2 below shows the estimated resource base for energy wood:

[8] As opposed to wick stoves; pressure stoves use kerosene fuel under high pressure and the result is a burning compared to LPG stoves.
[9] Community based plantations.
[10] Hearsay even suggests as much as 80%.
[11] Firewood, wood or trees for making charcoal, and charcoal.

Table 2: Plantations by ownership

Plantations	Area (000 ha)
GoR plantations	45
Community plantations	60
Institut ions plantations	23
Private plantations	61
Small farmer plantations (<0,5ha)	38 [12]
Total	237

Source: MINERENA, BEST surveys

About 30% of public plantations ha ve been set aside for soil protection on steep hillsides; these plantations do currently not contribute to the woodfuel supply and have not been incorporated in Table 2 above. However, there is no reason why these plantations could not be harvested as long as this is done carefully so that soil protection is not affected at any time. Regarding small farmer woodlots, the BEST survey found information contradicting earlier mentioned common knowledge. Figure 1 shows the distribution of products sold from the woodlots and it is shown that the smallest size plantations yield the largest share of non-energy wood. This can be understood because non-energy wood (i.e., poles, construction wood) fetches higher prices than energy wood. As a result, smaller lots have significantly higher revenue per hectare than larger ones.

This is not surprising as the w ood product market has the following characteristics:

- Non-energy products (poles, etc) are far more valuable than energy products (firewood, charcoal, and wood for charcoal making),
- but represent a smaller market in quantity (near 20% of the wood),
- proximity is a major factor: while scattered small plantations may serve near-by markets, larger plantations quickly saturate these markets and need to valorize their wood with products of lesser value, such as charcoal and firewood, but which they can easily sell in larger quantities.

[12] The small farmer contribution follows from the 2009 rural survey; this is the only estimate available for now until the forestry map is available. The range is large: if all rural households have just a patch of 5 x 10 m2 of trees, the total contribution would be 5000 ha; if they have 30 x 30 m2, the total contribution would be 100,000 ha.

Figure 1: Sale of wood products by size of plantation

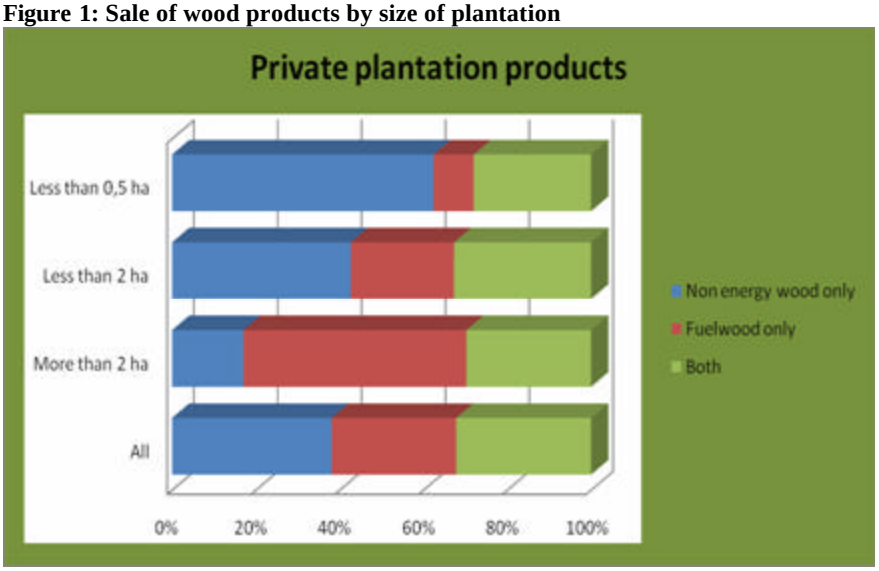
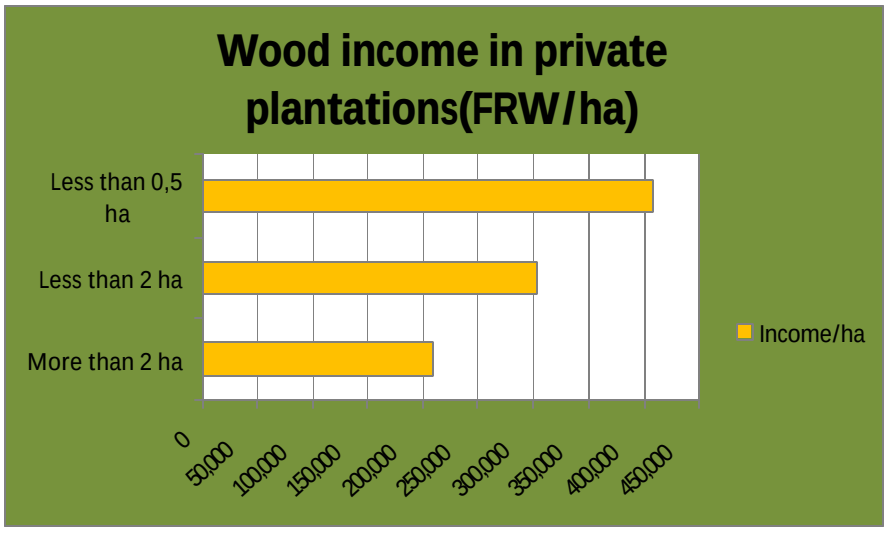


Figure 2 confirms this information by looking at it from a different angle: the average earnings per hectare are larger for smaller size plantations, reflecting both a tendency to sell more products and sell higher valued products. Again, even a small farmer must earn his living and that can only be done by selling the fruits of his labor: the crops he produced. Such crops include agricultural products and wood products. He does not have the luxury to not valorize his tree crops as the land available to him is very limited. The difficult felt by this type of farmer by the current legislation is particularly worrisome: in order to survive, he needs to earn money. He planted trees, and finds it difficult to sell these at the time most suitable to him. If he plants maize or any other crop, he's free to harvest and sell anytime he wants, but for trees he is under severe legal strain. What if he decides not to plant trees any more? This seems to be the current attitude among farmers and that may have ramifications on the woodfuel supply situation.

Figure 2: Earnings per ha and plantation size



Yields

The forestry inventory showed an average tree productivity of around 5 t/ha/year; for the supply side modeling used in the BEST analysis an estimated yield of around 6 t/ha/year for private plantations and 4 t/ha/year for public plantations was considered. The estimated yield in private plantations is higher because there is likely to be more tree-cutting: public plantations - at least theoretically - are protected and as a result standing trees are likely to be older and less productive than in private plantations.

Comparing overall demand of commercial wood (firewood, charcoaled wood) with the overall plantation sustainable production does not give a rosy picture; See Table 3 below.

Table 3: Estimated wood energy balance, 2008

Supply/demand	' 000t/yr
Commercial firewood demand	696
Charcoal wood demand	1209
Total energy wood	1905
Other non energy products	571
Total demand	2476
Plantation production	1320
Balance	-1150

Although this table shows a clear "deficit", with a sustainable production of plantations (taking both private and protected public plantations) representing about 47% of the estimated commercial wood demand, it is not necessarily a cause for immediate panic as different conclusions may be drawn from the previous table:

- there is probably a substantial underestimation of both the area and productivity of small farmer plantations and the agroforestry contribution to the supply of wood in the country; for example, if 75% of rural households each has a woodlot of just 0.1 ha of, this would provide a combined total of 75,000 ha of plantations. Without a substantial survey visiting a large number of rural households, it will not be possible to estimate more definitely to what extent rural households contribute to the woodfuel supply;
- there probably is a phenomena of over-cutting in plantations, or better said, a reduced harvesting rotation in spite of recommendations by local forestry officers;
- there is probably a large use of public plantations as an illegal source of supply (not counted);
- even if the average productivity is as low as indicated by the forestry inventory, given the soil conditions and the climate, there is no reason why productivity could not be at least doubled; and
- The forestry inventory data need to be verified; there are no margins of error indicated and indeed there may be considerable differences in productivity between different plantation owners. In the analysis carried out, the low average data have been used.

Regulation

It would be necessary that MINERENA intervenes and advocates to local administrations that charcoal is not an illegal fuel but a regular commodity. It can be produced relatively efficiently if the conditions are right. It already is a major contributor to the economic

development of the sectors and the districts. Prohibiting the production doesn't help anyone: neither farmers, the urban population nor the local administration either. It would be best if regulation for private farmers is as light as possible to promote efficient transformation. For public plantations appropriate regulation should be in place, but improved and simplified over the current set of rules. This in itself would be able to reduce the wood harvesting by 15-25%, as explained in Box 1 of Volume 3, the rural demand and supply.

Taxation is applied, albeit differently in different districts or sectors. The decentralization process allowed local authorities to levy local taxes and most have cutting permits, charcoal permits, and transport permits in place. In general however, since the illegal production started increasing, more and more charcoal is transported without permit. Down the charcoal supply chain several individuals use this fact to extort payments from transporters. The BEST survey showed that all taxed combined make up 7% of the retail price. It would be better if a transparent and uniform taxation system is in place, one that does not punish good behavior as is the case now, but one that gives incentives for good behavior.

3. STRATEGY PARAMETERS

The BEST provides an alternative development scenario compared to current trends (baseline) that would occur if no intervention were to take place. It is then possible to compare the baseline scenario (current trends, no strategy), and several scenarios as result of active public intervention. Although the Government takes the initiative to intervene and initiate changes, most of the intervention will be carried out by private actors. See volume 4 for more details. Intervention is built up of the following elements:

Demand side Intervention:

- Active and aggressive promotion of improved charcoal stoves, in order to nearly eradicate inefficient traditional stoves and reach at least 80% of the urban market by 2015 (86% in 2020) and 50% of the rural market (63% in 2020); 2nd generation improved stoves will be increasingly incorporated;
- Similar promotion of improved wood stoves among customers who pay for fuel, with 80% of the Kigali market in 2015 and to a lesser extent in other urban areas (50%) an rural areas (50%);
- Selection and promotion of more efficient and modern stove models (all fuels) through labeling and realization of awareness campaigns to promote the use of efficient equipment, explain health issues, promote more efficient charcoal and wood equipment, and reduce specific consumption of other fuels (electricity and LPG) by 5% by 2015;
- Energy conservation among large non-domestic users of wood and charcoal, with the objective to reduce their specific consumption as a whole by 5% by 2015;
- Promote a reasonable development of LPG, kerosene and electricity (with a cumulative 10% of the market by 2015) due to (a) for LPG a support to bottling plant in Kigali and temporary relaxation of import duty and taxes and (b) for electricity a better power supply and relative moderation of tariffs. The simulation considers a similar development for both fuels;
- Develop alternative fuels to reach 2% of the market in 2015, 4% in 2020, mainly focusing on briquettes of peat, charcoal dust, and carbonized papyrus, plus biogas for institutions.

Supply side intervention:

- Replace the regulatory and tax system for wood products with a new simplified system by 2010: (a) decentralized but under national guidelines; (b) unique control and tax collection systems at transport level; (c) contribution to districts and national forestry fund; (d) slightly higher tax level in order to cover forestry plantation and/or management costs (estimated to about 5 FRW/kg of wood); and (e) with level around 10% of the product retail prices [13];
- Establish a comprehensive efficient system to collect taxes and verify compliance, with the objective to reach a 70% collection rate by 2015 (over 80% in 2020), compared to the present estimated 55%;
- Stop illegal cutting in public plantations, set up management plans for restoring public national and district plantations, develop and promote adapted tree management and

[13] This would be approximately FRw 500 per bag of charcoal when from a properly managed plantation or twice that amount when from poorly or non-managed plantations.

rational cutting methods, train local bodies and professionals, in order to have 50% of public plantations under management and rational cutting by 2015 (75% by 2020), with considerably better forestry productivity (x 2 in managed areas); allow private management of public plantations;

- Develop and promote silvicultural practices among private plantation owners, in order to preserve and improve their standing stock, increase the forestry productivity (at least x 2 in managed areas) and favor rational and sustainable tree-cutting; no-one said that this will be easy but better management, fertilizers, more efficient water usage should bring the productivity back in-line with text book conditions for the climatic zone; and
- Train charcoaling professionals, disseminate efficient methods and equipment to produce charcoal, with the objective to reach 15% of efficiency in weight (against 12% now) among at least 50% of the producers by 2015 (over 60% by 2020).

4 STRATEGY RESULTS AND IMPACTS

4.1 General

Tables 4 and 5 present the most important parameters that describe the baseline and the development scenarios for the year 2020; the baseline is when no particular action is undertaken to improve the situation, or which could also present a program that is not successful. The project scenario represents the fact that intervention is successfully implemented Table 4 shows the expected contribution from different fuels today and in 2020 under the 2 scenarios; Table 5 give some salient details about the supply situation.

Demand

Table 4: Demand Scenarios

	2008 (estimated)	2020 (baseline)	2020 (scenario)
Commercial firewood (tonnes)	696,000	866,000	845,000
Charcoal (tonnes)	149,000	301,000	230,000
LPG (tonnes)	300	800	8,600
Electricity Energy for cooking (GWh)	8.9	29.5	75.2
Electric Capacity needed for cooking (MW)	6.4	20.7	54.7
Alternative biomass fuel	0	0	18,000
Improved stoves sales (units, urban)	75,000	190,000	229,000
Improved stoves rural (units)	900,000	900,000	1,200,000 *)

*) the stoves used under the scenario are not the same as the ones under the baseline; under the scenario a mix of existing improved stoves and new improved stoves (2nd generation) are used. Since at this time a more precise estimate of the rural commercial use of woodfuels is not available, it is assumed that no woodfuel savings are obtained (i.e., residues are used), and the benefits therefore are mainly a reduction of health costs.

Supply

Table 5: Supply Scenarios

	2008 (estimated)	2020 (baseline)	2020 (scenario)
"Deficit" (*)	61%	78%	0%
Plantations under management (hectares)	0	0	144,000
Charcoal making national average efficiency	12%	12%	14%
% of woodfuel products under tax	46%	48%	83%
Extra tax product for FFN (M RWF)	0	0	1,128
for decentralized bodies (M RWF)	0	0	3,826
Total extra tax product (M RWF)	0	0	4,954

(*) According to the previously used definition whereby the demand exceeds the sustainable yield of available plantation areas.

4.2 Trends

Demand trends

On demand level, this leads to the following projections:

- Little impact on the consumption of firewood in the strategy scenario; See Figure 3;
- A more significant impact on the consumption of charcoal (remaining under the

250,000 t/yr barrier in the strategy scenario, aga inst a fast growth trend reaching 300,000 t/yr in the baseline scenario in the year 2023[14]; See Figure 4;

Figure 3: Demand of firewood (commercial)

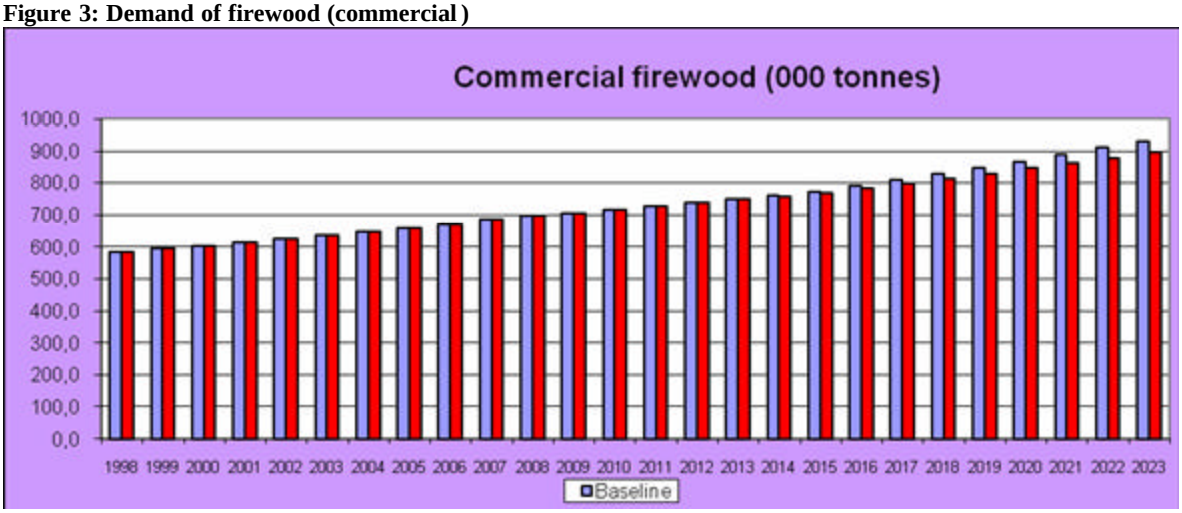
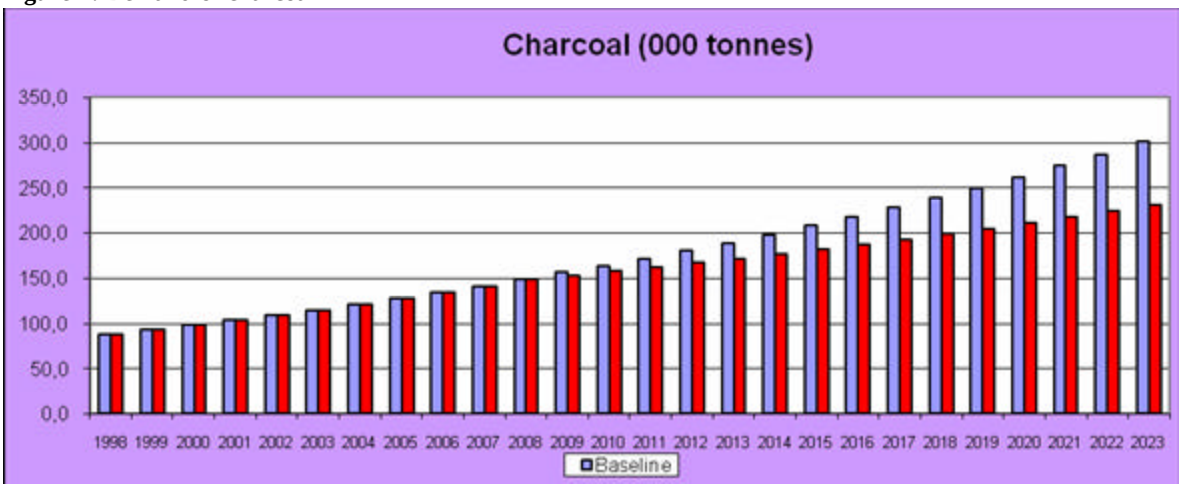


Figure 4: Demand of charcoal



Concerning the development of other fuels, attention is needed especially for the power sector; even short term consequences are likely the result of the possible developments of electricity for cooking, particularly as a result of tariff reductions. The following Figures 5 and 6 describe the power and energy requirements for the strategy scenario, that consider for 2015 a market share for electricity of 5% of users in Kigali and 2% in other cities[15].

[14] The GLOBUS model uses 15 years as the period for projections between the baseline and the intervention scenarios.

[15] Source : SDIPP 2005-2010, ELECTROGAZ activity report et estimations BEST study estimates

Figure 5: Capacity of power generation

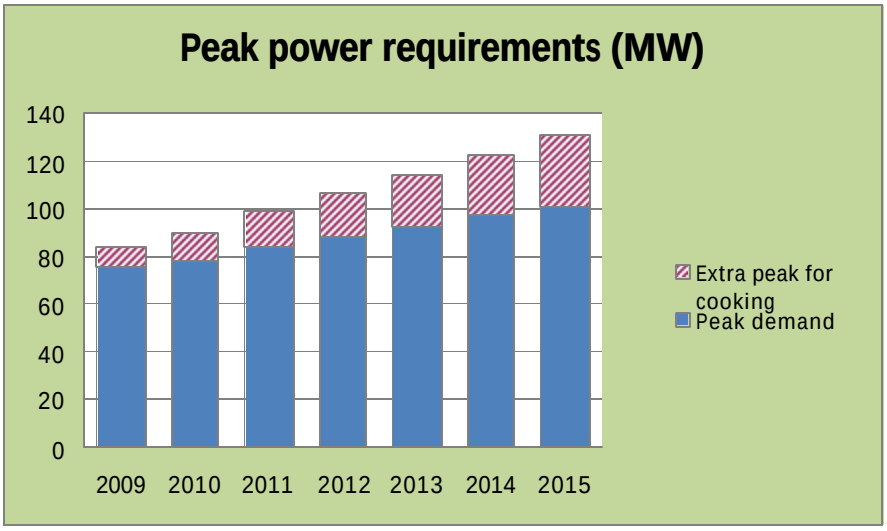
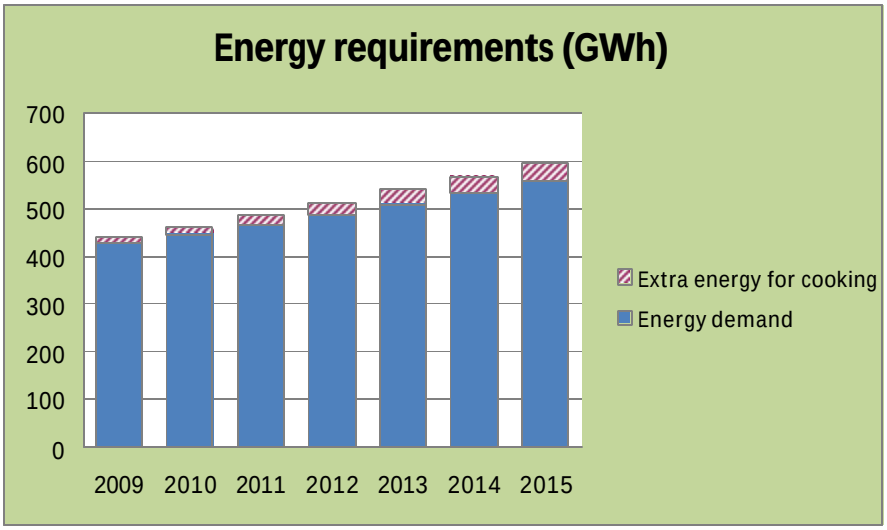


Figure 6: Energy requirements for cooking



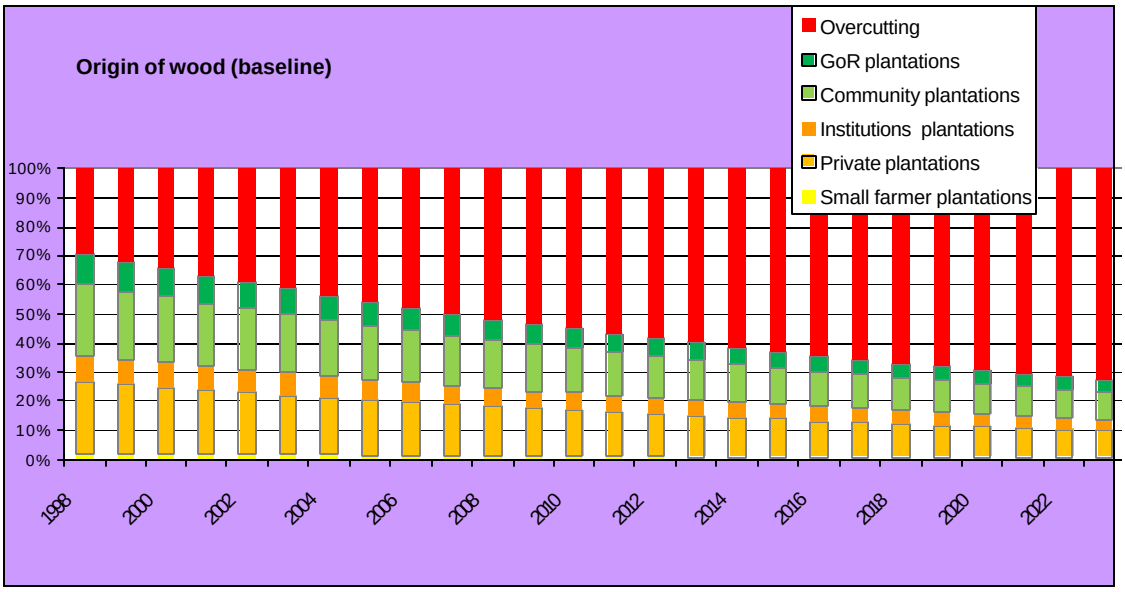
Electric cooking has a significant impact on peak power requirements for the national power system may provoke difficulties in a tight electric power supply situation. The tariff has much to do with this, since a low tariff will see more households starting to use electricity for cooking. The power needed to cover this demand may quickly exceed the installed capacity particularly since most households will cook around the same time. As shown, a modest use of electric cooking for about 5% of Kigali's households in 2015 demands an additional capacity of 25 MW to cover the peak demand. Since the peak demand occurs early evening, it overlaps to a great extent with the evening cooking period.

Supply trends

Differential evolution of supply may be illustrated by the two following Figures 7 and 8. It is shown that the overcutting practiced today will continue and becomes alarming over the next decade when irreversible damage will start to occur. When the above BEST is implemented,

the supply situation will be balanced again before 2020 as shown in Figure 8.

Figure 7: Origin of wood, Baseline Scenario



This type of graph should be considered with caution only. The supply-demand situation is not static, as in the model, but dynamic. If and when demand for wood far exceeds the supply, shortages become clearly noticeable, prices rise, and farmers and households will react accordingly: farmers will start planting more trees, households will switch to other, less expensive fuels. The scenario in this figure has been predicted before, for several countries actually, but never happened in reality. Nevertheless, this type of modeling is useful as it shows trends: if nothing happens the supply resource base becomes very low indeed, and if there is appropriate intervention, the supply could become sustainable.

Figure 8: Distribution of Woodfuel Supply, Strategy Scenario

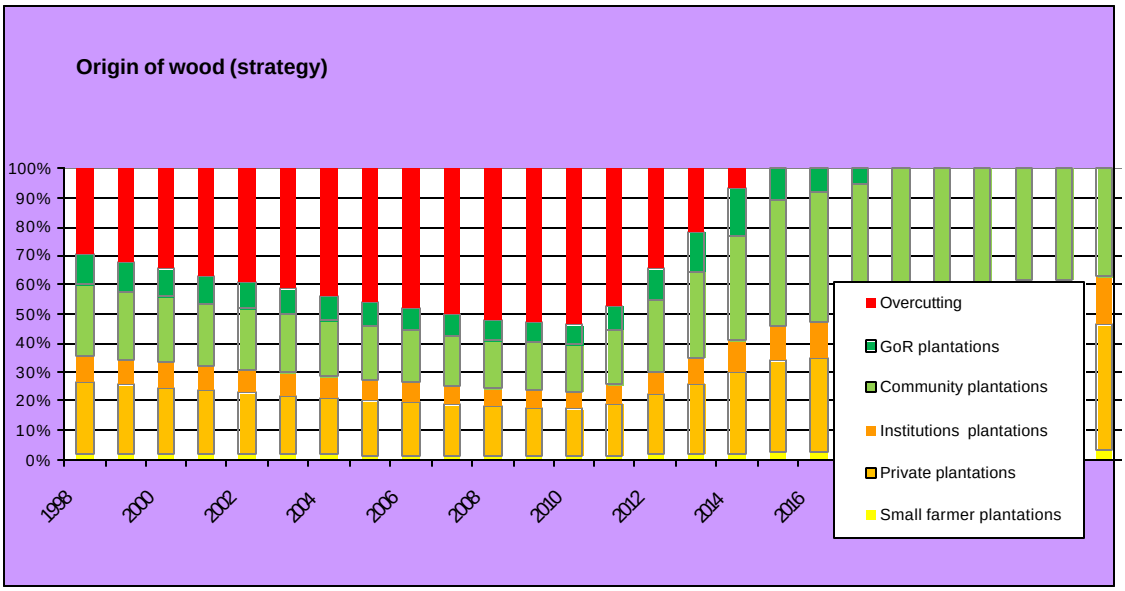


Figure 8 shows that with reasonable and realistic efforts on substitution and conservation, a proper strategy to reinstate normal productivity of existing plantations and start a limited effort to plant in new areas, plantations could constitute sufficient resources to sustainably supply the energy and non-energy wood markets in Rwanda in the near future.

4.3 Main strategy objectives and potential results

Objectives and results

Strategy conditions and hypothesis are summarized in the following tables. The objectives are set to be as realistically as possible, so that these can be obtained under normal circumstances. In addition, the approach is that of development of markets

Table 6: Objectives of the BEST and Results Anticipated

Programs - Present situation	Strategy objectives	Results for a five year program (2009-2013)
Regulatory aspects of wood supply Estimated yields of inventoried plantations are not sufficient to satisfy the demand. Consistent smuggling from public plantations (State, local bodies) Charcoal production perceived to be illegal.	Sustainable production of plantations is sufficient to respond demand. State and district plantations are managed and legally harvested, producing consistent and sustainable products for forestry, energy and other development activities, benefiting the plantation owners. Charcoal production is considered just another crop from farms and plantations.	Laws and decrees adapted. Production of wood from public and private plantations is legalized and professionally organized. Forestry management plans for public plantations and silvicultural assistance methods for private plantations are ready 2009-2010
Plantation management Large quantities of woodfuels are produced without care of the health of the plantations. Average yields are low (around 7 m3/ha/year) and applied rotations appear to shorten	Objective to reach 20 m3/ha/year in plantations, through rehabilitation, management, rational tree cutting, better water management and fertilizers in public plantations, and silvicultural support to private plantation owners to obtain the same results. The average over all plantations will be about 12 m3/ha/yr or 8.6 t/ha/yr.	Public plantations managed through subcontracts to private operators 50,000 hectares of public and private plantations under proper management by 2013 Modalities ready for 50,000 hectares more by 2015

Programs - Present situation	Strategy objectives	Results for a five year program (2009-2013)
Better efficiency throughout the entire charcoal supply chain Former support and high resource price have improved the efficiency compared to 90s, with differences between regions. Average conversion efficiency about 12% in weight	Increase efficiencies through a more professional supply chain, with a large majority of charcoal makers using more efficient kilns (15% in weight) and using centralized charcoal depots by 2020	50% of charcoalers use efficient kilns; transport costs reduced improved through depots, 50% of flows by 2015. National average efficiency exceeds 13% in weight
Taxation system Decentralized system, without national general guidelines, too bureaucratic for both producers and local authorities, and not enough efficient (it is estimated that about 50% of the products evade taxes)	Elimination of cutting permits for private plantations, unified standard system based on the taxation of products at transport level, decentralized decision on rates, objective average 10% of the product	New taxation system in place and support to a better control and collection system. An extra RWF 8 billion collected over 5 years.

	retail values Better tax collection (70% by 2015, more than 80% by 2020)	

Programs - Present situation	Strategy objectives	Results for a five year program (2009-2013)
Improved stoves, for wood and for charcoal Good response from the market with some 50% already using them, but still half of the urban population to convince. Some 60% of rural households have an improved stove but want a different stove	Increase penetration rates and nearly eliminate inefficient stoves in urban areas, with an objective of 80% by 2015 and 90% by 2020 Select and promote more efficient models (2nd generation improved stoves, labeling, etc)	Around 80,000 additional urban households with improved stoves, of which over 70,000 charcoal stoves; 5% of households have a 2nd generation improved stove by 2020. Some 300,000 rural stoves will be disseminated
Savings in household energy consumption Fuels are getting expensive for the poorest households	Promote better kitchen practices (hotbox, lids, soaking pressure cooker)	Average of 5% of savings on specific consumption
Savings in non-domestic consumption (small industries, institutions) Some former users have shifted to other fuels to proper regulation, other should get assistance to improve their wood use	Promote better practices in non-domestic uses of woodfuels as well as further substitution (see be low)	Average of 5% of savings on specific consumption

Programs - Present situation	Strategy objectives	Results for a five year program (2009-2013)
Substitution Nearly inexistent, due to non competitive conditions. Necessity to develop markets for substitute fuels, both petroleum and biomass based. Some possibility to use other national biomass resources such as peat, papyrus, jatropha., agroresidues but no significant action taken	Around 20% of Kigali and 5% of other city dwellers use other fuels than firewood and charcoal in 2020. Setting conditions for LPG development, and to a more limited extent, electricity. Development of the use of alternative national biomass resource, particularly based on peat for industries and papyrus and jatropha for households as well as biogas for institutions.	Temporary tax reduction on LPG leading to an LPG bottling industry in Kigali. Monitored development of the electricity use, due to better availability and prices. Development of commercial production and sales of biomass briquettes: looking for 2% of the market, 18,000 tonnes sold in 5 years. Virtually all institutions use biogas systems.

Programs - Present situation	Strategy objectives	Results for a five year program (2009-2013)
Sector coordination No coordination, biomass largely falls between the cracks of 3 ministries: MINIRENA, MININFRA, and MINAGRI	Fully integrate biomass into the economic development scenarios of the country, based on poverty alleviation, rural development, energy security, and environmental reasons. EDA fully responsible for planning, monitoring, and funds raising, together with NAFA	EDA in place, all strategic programs implemented.

5. INVESTMENT PLAN ASSOCIATED TO THE STRATEGY

Even if it is premature to build up a detailed investment program related to the proposed Strategy, it is possible to give an indicative estimate of the investment costs, benefits and economic return.

The program is expected to last about 7 years as follows:

- 2 years (2009-2010) of preparation (studies, institutional, regulatory and tax changes, human resource training), completion of most urgent tasks, mostly using existing resources, and mobilizing more important funds from national budget;
- A 5-year program of large-scale investment as such (2011-2015), based on the proposed strategy: plantation management and (on a lower scale) extension, better efficiency in charcoal making, transport and commerce, conservation and substitution by alternative fuel.

The program involves two categories of costs:

- public costs (from the State budget, funded by own or external sources); and
- counterpart costs (local administration at Cellule, Sector or District level, private firms, farmers and households, and NGOs).

Public costs will cover

- own State expenses (policy management and monitoring, investment in State plantations, etc); and
- subsidies to counterparts (support to districts and other decentralized bodies, participation in public-private partnerships, etc).

The investment program is split into three main components:

- a supporting component for regulatory aspects, capacity building and project management; and
- three "operational" components, on energy conservation (demand-side management), on plantation management (supply-side management), and on and substitution fuels.

Not all of the expenses can be evaluated with accuracy but for some reasonable data are available such as new and existing plantation management costs, others are based on assumptions, using current ratios seen in the national biomass energy strategy and investment plan for other African countries mainly in West Africa. Presented costs are indicative only, but that is sufficient for the time being.

5.1 Investment plan

Investment in demand side management

Investments required to realize objectives for the demand-side management program have been estimated at about US$ 20 million over the 7 year period. This period is long enough to create awareness among households and to convince private firms to carry out their responsibilities. The following mechanisms are foreseen:

- Public subsidies to support and catalyze private investments in the framework of public-private partnership schemes, such as an investment subsidy for producers of alternative fuels, energy-efficient equipment producers or importers, etc.;
- Technical assistance and training (local authorities, professionals), public awareness campaigns and grass-root sensitization, some investigation and specific schemes

(equipments, labels),

Considering the size of the targeted markets, it is not unreasonable to consider that investments will be around FRW 7 billion over the period, excluding power sector investments, implying that overall cost of the component could reach FRW 11 billion (around 20 US$ million) when an additional 50-60% are taken for support costs.

Included in these costs are all investment costs for equipment, capacity building, awareness rasing, etc. A significant share will be financed by the private sector: as an example, stoves will be purchased by end-users who are therefore co-financing the program; stove makers will pay for most of the investments to produce better stoves, etc. Public costs have been estimated at around FRW 4 billion (US$ 8 million), assuming an average 20% of subsidies and 75% of public participation in supporting costs.

Investment in supply side management

Most of the costs for the supply side management program will be for restoring the plantations and increase their productivity to commensurating soil and climate conditions. To restore public plantation productivity investment costs at the plantation level have been estimated at RWF 280,000 per hectare[16], a figure slightly higher than the normal establishment costs of a plantation. This is needed because of stump removal and other work to reinstate a long neglected plantation. To be added are the costs of management, improved organization of the charcoal supply chain actors, etc. The total costs for all activities included amount to $89 million and will cover 116 thousand ha, or a total of about $770 per ha. Please note that a better and more detailed estimation of the costs is needed, based on in-country experiences[17]. Installing management systems, training to public administration and private management first, improve the charcoal, production chain will need to be added. As average operation costs, around RWF 25,000 per hectare and per year were taken to which harvesting costs should be added. The average cost of wood, stacked in the plantation, is estimated at RWF 4.3 per kg, i.e. slightly over FRW 1600 per stere (stacked m^3)[18]. This is about half of the present price of the wood and shows how interesting it is for the economy to carry out the rehabilitation activities. To obtain a productivity level of about 20 m3 per ha per year, improved water management is needed as well as the use of fertilizers.

If a 7 year plantation management plan is considered in two phases, one 2-year preparation phase and one 5-year implementation phase, with an objective of obtaining about half of the existing public plantations rehabilitated and under proper management (100,000 ha, plus 16.000 hectares of new plantations), the following investment costs are expected:

- with a direct investment around FRW 30 billion in direct costs for rehabilitating existing plantations and increasing their productivity;
- approximately FRW 49 billion (US$ 90 million) with indirect costs related to supporting activities (adapting the regulatory and taxation systems, studies, training, technical assistance and support to professionals, such as plantation management firms, charcoaler- or rural woodfuel producer groups).

Although these costs appear high, they are fully justified from an economic point of view : the rate of return on the investments is high. Included in the costs are all investments by all

[16] Around US$ 500/ha, ref: MINERENA

[17] MINIRENA has recently started implementation of a project for the rehabilitation of public plantations that will be able to give better cost-data; another project dealing with agroforestry and private smallholder plantations is under preparation that could also provide better cost-data in the near future.

[18] Air dry wood

participants (State, decentralized public bodies, private and private plantations owners). Included in the benefits are just the increased supply of wood products, not the rural employment, not the continued availability of low-cost urban fuels, and not the environmental benefits from soil restoration and protection.

Assuming that the share of public contribution to the costs is 60% for direct investment (full cost for its own plantations, a subsidy to other district and sector public plantations and private owners) and 75% for other costs, the overall cost for the component would be around FRW 32 billions (US$ 59 millions) over 7 years. The contribution from plantation owners is fully justified as they will be the ones reaping the benefits once the plantations are rehabilitated.

There is one major caveat: the total contribution to the wood supply from small private farmers has been estimated at the equivalent of 5000 ha of plantations. This urgently needs to be verified, particularly since it is generally acknowledged that a major part of the wood supply comes from private farmers including small farmers. As an example, if the equivalent is not 5000 but 50,000 ha, then the need to rehabilitate public plantations becomes less, resulting in a reduced investment package and encountering reduced costs.

Investments for capacity and institution building, and project management

Institution and capacity building costs do not exceed 15% of the public costs dedicated to the forestry and energy components, representing an overall cost of FRW 5,5 billion (US$ 10 million) over the 7 years, 100% fully covered by public budget. This includes support for EDA, NAFA as well as MININFRA and MINIRENA, and needs to be detailed further. At this point in time, it is indicative only based on the experience with implementing such strategies elsewhere.

Overall investment plan

This leads to an overall budget of about US$ 120 million, of which about 63% in the form of a public contribution (US$ 76 million). Some three quarters of the public contribution is for the plantation component: the rehabilitation of existing plantations, and in particular public plantations represents a large share of this budget (and justifies the related quite important amounts), Moreover, one has to take into account that:

- the rehabilitation of public plantations, rational harvesting and charcoal production, and new plantations are cost-effective activities (average financial IRR of 22%);
- the revised tax system will contribute considerably to the investments
- substantial environmental benefits exist that are not incorporated here.

Table 7: Investment Plan

	total costs		Public contribution	
	M US$	%	M US$	%
Plantation management	89.2	75%	58.5	76%
Conservation and substitution	19.7	17%	8.0	10%
Institutional building and project management	10.0	8%	10.0	13%
Total	118.8	100%	76.5	100%

5.2 Financing the investment plan

Financing for the investment plan could come from a variety of different sources. The

Government could provide funds from the Budget, obtain funds from donors, use Carbon Trade mechanisms, and provide financing from the receipts of the improved taxation system. In addition, a number of activities that would fit directly under one or more of the above components are under implementation or will start implementation soon.

As said before, these estimates are preliminary and based on unit cost data provided to the team. The Netherlands Government public plantation support project will be able to shed more light on the rehabilitation costs in the near future. Alternative scenarios are thinkable too, particularly reducing the supply-side management component, such as whereby public plantations are not fully rehabilitated but where the management systems are put in place immediately and rehabilitation is realized over a much longer period of time.

Finally, co-financing could come from the taxation system and possibly from a carbon trading mechanism; the experience of the Clinton-Hunter Foundation could be used as an example for how to set this up in Rwanda.

Revenues from the taxation system

Expected revenues from an improved taxation system as described in Volume 2 have been estimated as follows:

Table 8: Projected Tax Revenues

	2009	2010	2011	2012	2013	2014	2015	Total
Forestry fund (MRWF)	601	638	676	715	756	798	842	5027
(MUS$)	1.1	1.2	1.2	1.3	1.4	1.5	1.5	9.1
Local bodies (MRWF)	332	697	1073	1461	1860	2271	2694	10390
(MUS$)	0.6	1.3	2.0	2.7	3.4	4.1	4.9	18.9
Total (MRWF)	933	1335	1750	2177	2616	3069	3536	15416
(MUS$)	1.7	2.4	3.2	4.0	4.8	5.6	6.4	28.0

The new taxation system could generate extra revenues on the order of MUS$ 28 over the 7 year period of which MUS$ 9 are destined for the national forestry fund and MUS$ 19 for local organizations (districts and sectors). Such revenues could significantly contribute to the financing of the investment plan. The forestry fund contribution and a significant percentage of the local institutions' contribution (e.g. 30%) would bring around MUS$ 15 that can also be used for financing of the investment plan.

Revenues from CO_2 mitigation and climate change

Benefits of the project include local and global environmental benefits. The global benefits include a reduction of the CO_2 emissions in Rwanda and this could be used to contribute to the financing of the investment costs.

A comparison between the baseline and strategy scenario can be done in terms of CO_2 emissions, using the following figures:

Table 9: Specific CO_2 emissions

Fuel/origin	Specific CO2 emission	Unit
Firewood from plantation	0.00	T CO_2/T
Firewood from managed area	0.33	T CO_2/T
Firewood from non managed area	1.67	T CO_2/T
Charcoal from plantation	0.00	T CO_2/T
Charcoal from managed area	1.50	T CO_2/T
Charcoal from non managed area	7.59	T CO_2/T
Electricity (diesel generation)	1.96	T CO_2/MWh
LPG	3.51	T CO_2/T
Kerosene	3.46	T CO_2/T

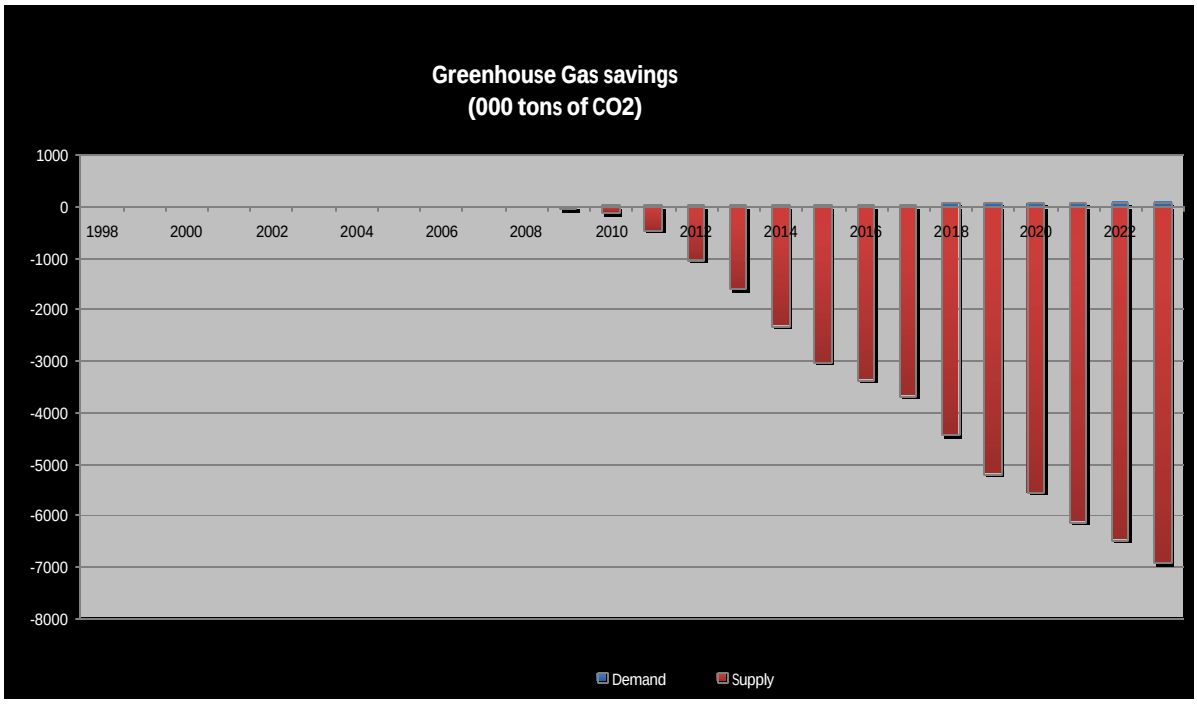
Source: Electricity, LPG, Kerosene from UNFCCC, wood from WB estimates for managed and non managed areas, charcoal derived from wood through average kiln efficiency according to WB method.

Compared to the baseline scenario, the strategy scenario:

- generates a moderate excess CO_2 emission rate from the larger consumption of fossil fuels for cooking;
- mitigate emissions due to demand-side management (reduction of energy consumption, including of woodfuels that are not sustainably produced, other); and
- as well as through improved plantation management and development of new plantations, preventing resource degradation, preserving and improving the existing standing stock (sequestration) and annual yield.

Compared to the base-line scenario, the balance is largely in favor of the proposed strategy scenario, with an estimated reduction of 0.9 million t of CO_2 in the 5 next years (most of it from 2011 to 2013), and as much as 50 million t in the next 15 years. With a value of about US$ 10 per t of CO_2 on the voluntary market, some $ 9 million could in principle be arranged over the first 7 years. Following years the contribution would be $ 3 million - and increasing - every year.

Figure 9: CO_2 emission savings



Such environmental performance paves the way for possible substantial cofinancing of related investments through the Clean Development Mechanism or other climate financing arrangements.

Summary Co-Financing Plan

Table 10 shows the financing plan as it could be realized if the Government decides to incorporate biomass energy into the economic development of the country and implements the strategy. It is estimated that some 36% can be contributed by households (stoves), private firms (briquetting plant, LPG bottling plant), farmers (rehabilitation plantations), and community plantation owners (rehabilitation plantations).

Table 10: Cofinancing contributions

Potential Co-Financing Contributions	Public	private	Total
private wood owners & communities	58.5	30.7	89.2
private firms, households	8	11.7	19.7
Capacity building	10	0	10
Total	76.5	42.4	118.9
Forestry Fund (tax)	9		
Districts, Sectors (tax)	6		
CDM	9		
Subtotal	24		
Public funds still required	52.5		

It appears that the investment plan could be implemented without too much difficulty. Accounting for possible contributions from future beneficiaries, about $52 million are still needed from other funding sources. This is less than it appears as about $30 million are

already available or will be available soon from the Royal Netherlands Embassy for forestry intervention for public plantations and for small private plantations, and through GEF some funds are available for capacity building, for improved stoves, and a few other smaller activities. An inventory of funding sources for biomass energy that are either already available or are programmed to be available in the near future does not exist.

5.3 Economics of the proposed investment plan

The usefulness of the strategy for the national community is expressed by the economic rate of return of the investment program, taking into account expected costs and benefits. Expected benefits are derived from:

- energy savings due to the use of more efficient equipment, energy-conservation and substitution policy;
- increased supply of woodfuels due to better plantation management, new plantations and charcoal transformation efficiency;
- environmental benefits;
- the economic value of the following additional benefits have not been estimated: health benefits rural income generation, energy security, local energy source vs imported, social benefits, from continued availability of a low-priced fuel; these benefits have not been taken into account but could indeed be large.

Evaluating benefits and costs of the investment program cost shows why it is interesting for the community to realize the investment plan: the net present value (NPV) of the costs and benefits is US$ 38 million, representing an economic internal rate of return of 27%. Table 11 shows the NPV without environmental benefits and Table 12 the NPV with environmental benefits.

Table 11: Net Present Value of the Costs and Benefits of the Investment Plan (no environmental benefits)

Net present value (15 years, 12% discount rate)	M US$
Costs	
Plantations rehabilitation component	53.8
Energy conservation and substitution component	12.9
Institutional building and project management component	6.4
Total	73.0
Benefits Forestry component	73.4
Energy conservation and substitution component	37.7
Total	111.0
Net benefits	38.0
Economic internal rate of return	27%

Environmental benefits can be added by valuing the CO_2 emission reduction: taking a conservative hypothesis of US$ 5 for the pricing of one mitigated ton of CO_2 increases the net present value of the program with $77.6 million over the 7 year period. The economic internal rate of return increases to about 49%, which is a high performance for an infrastructure project.

Table 12: Net Present Value of the Costs and Benefits of the Investment Plan (with environmental benefits)

Net present value (15 years, 12% discount rate)	M US$
Net benefits without environment	38.0
Environmental benefits	77.6
Net benefits with environment	115.6
Economic internal rate of return with environment	49%

Annex

GLOBUS MODELIZATION

The GLOBUS model is not a tool to predict future, but to set up scenarios in order to develop a comprehensive and sensible biomass strategy, and analyze the consequences of the actions, in terms of impacts, results, means and budgets.

Although it is purposely based on best estimates, it cannot pretend to reflect the exact figures of a somehow cursed sector, where data are scarce, little reliable and sometimes contradictory. But its hypothesis are transparent and easy handled, with the advantage that in any case more accurate estimates are made available, they may be immediately incorporated to the model.

The GLOBUS model has different objectives:

- analyze at national or the terms of competition between wood, charcoal and other fuels used by households and non domestic customers for cooking and similar uses,
- simulate the situation of fuel demand and supply on a reasonable period: reconstitution of the last 10 year past evolution, projections over the next 15 years, according to different scenarios,
- test the consequences of tentative strategies for biomass and other fuels on sector evolutions, comparing a baseline scenario (current trends without voluntary policy) with one or several strategy scenarios,
- build up and quantify an investment program (public and private) related to a selected strategy scenario,
- assess financially, economically and environmentally the investment program.

The GLOBUS model has to be customized according to each country. Typically it contains:

- one page on demand
- one page on supply
- descriptive pages (indicators, graphs)
- supporting pages (comparisons of fuels, prices, sources, etc...)

When building up an investment program, it has two additional pages:

- one page on project costs
- one page on assessment

ASSUMPTIONS ON DOMESTIC FUEL MARKETS

The description of the charcoal and other domestic fuel market is based on several assumptions:

- past and present demographic evolution,
- market share according to existing surveys
- average quantities in use

Demography

Demographic projections are based on the National Institute of Statistics 2002 census and projections. Figures part on the following estimates:

Table A1: Number of households

	2002	2008
Kigali	121574	162921
Other urban	151407	191578
Rural	1484445	167172
Total	1757426	2026225

Source : team estimates, based on National Institute of Statistics figures

Market share

Market share is based on the results of the household condition of life surveys:

Table A2: Market share (2000 and 2005)

	EICV1	EICV2	EICV1	EICV2	EICV1	EICV2	EICV1	EICV2
	City of Kigali		Other urban		Rural		National	
Wood	21,4%	23,1%	81,7%	73,7%	97,7%	95,5%	90,4%	88,2%
Charcoal	75,8%	72,4%	16,3%	19,6%	0,8%	1,1%	8,0%	7,9%
Gas	0,5%	0,2%	0,2%	0,1%	0,0%	0,0%	0,1%	0,0%
Electricity	0,5%	0,2%	0,2%	0,3%	0,2%	0,0%	0,2%	0,1%
Kerosene	0,3%	0,8%	0,1%	0,3%	0,1%	0,0%	0,1%	0,1%
Miscellaneous burning	0,0%	0,1%	0,9%	2,5%	0,7%	3,0%	0,7%	2,7%
Other	1,5%	3,3%	0,6%	3,4%	0,5%	0,4%	0,6%	0,9%
	100,0%	100,1%	100,0%	99,9%	100,0%	100,0%	100,1%	99,9%

Source : National Institute of Statistics, December 2006, data EICV 1 (2000-01) and EICV 2 (2005-06)

very comparable to those given by another source:

Table A3: Market share (2002)

	Urban	Rural	Total
Firewood	52,0%	90,4%	84,4%
Charcoal	39,5%	1,3%	7,2%
Gas	0,3%	0,0%	0,1%
Electricity	0,7%	0,0%	0,1%
Kerosene	0,3%	0,1%	0,2%
Vegetable mat	3,6%	7,4%	6,8%
Other	2,7%	0,3%	0,6%
NS	0,9%	0,5%	0,5%

Source : PRSC-World Bank, March 2004, data Census 2002

as well as, in order to separate commercial and non commercial fuels, from another table from the last household condition of life survey:

Table A4: Proportion of foraged wood to total wood consumed

	Proportion of foraged wood to total wood consumed
City of Kigali	39,9%
Other urban	66,2%
Rural	82,9%
Total	79,7%

Source : National Institute of Statistics, December 2006, data EICV 2 (2005-06)

The analysis conducted for the domestic market parts from the hypothesis that an household needs a certain amount of "useful energy" (the energy that goes into the pot), whatever may be the fuel he uses. This useful energy depends of the specific energy content of the fuel, and also of the average efficiency of the cooking equipments.

Results are presented herebelow:

- for woodfuels, using traditional and improved stoves,
- for other fuels, either in use (electricity, LPG or paraffin) or considered as possible alternative (ethanol, gel fuel)

They show that for 1 kg of charcoal used for cooking, a household would require 2,6 kg of wood, 0,4 liter of paraffin, 0,3 kg of LPG, 2,5 KWh of electricity...

Table A5: Comparison of fuels for main cooking

Fuel	Stove	MJ/kg	stove eff.	MJU/kg	%	kg
Firewood	Three stones	15,5	16,0%	2,5	257%	2,6
	Improved	15,5	20,8%	3,2	198%	2,0
Charcoal	Traditional	29,0	22,0%	6,4	100%	1,0
	Improved	29,0	28,6%	8,3	77%	0,8
Kerosene		43,7	42,8%	18,7	34%	0,3
LPG		47,3	45,0%	21,3	30%	0,3
Briquettes	Improved	17,0	28,6%	4,9	131%	1,3

	Density (kg/l)	MJ/l	stove eff.	MJU/l	%	liter
Kerosene	0,83	36,3	42,8%	15,5	41%	0,4

	MJ/KWh	stove eff.	MJU/KWh	%	KWh
Electricity	3,9	65%	2,5	252%	2,5

Quantities in use differ according to authors. ESMAP (1991) gives 1000 g/cap/day for firewood and 510 g/cap/day for firewood, which would represent 1650 kg/hh/year of firewood and 850 kg of charcoal for an average household of 4.5 persons. An USAID report, 2007, quoting Munyankusi, 2006, gives for charcoal use 75 kg/hh/month, i.e. 900 kg/hh/year.

Figures of 2 to 2.5 bags per month (from 720 to 900 kg/hh/year) for charcoal, and 1 to 1,3 kg/cap/year (1670 to 2150kg/hh/year) are also quoted in different reports.

The simulation will use a conservative figure of 700 kg of charcoal, of which derive quantities of other fuels in the following way:

Table A6: Quantities in use

	Stove	kg/HH/year	Price/kg	Yearly budget	% charcoal
Fuelwood	Three stones	1642	57	93589	70%
	Improved	1263	57	71992	54%
Charcoal	Traditional	700	191	133700	100%
	Improved	538	191	102846	77%
Kerosene		239	751	179214	134%
LPG		210	2470	518253	388%
Briquettes		812	174	141418	106%

	Density (kg/l)	liter/HH/year	Price/l	Yearly budget	% charcoal
Kerosene	0,83	288	623	179214	134%

		KWh/HH/year	Price/KWh	Yearly budget	% charcoal
Electricity		1909	132	251928	188%

Source for prices: firewood, mission measurement in Kigali, April 2008, charcoal, INS, average January-May 2008.

Non domestic consumption is reputed to be 15% of domestic demand for commercial firewood, 5% for charcoal and 20% for LPG.