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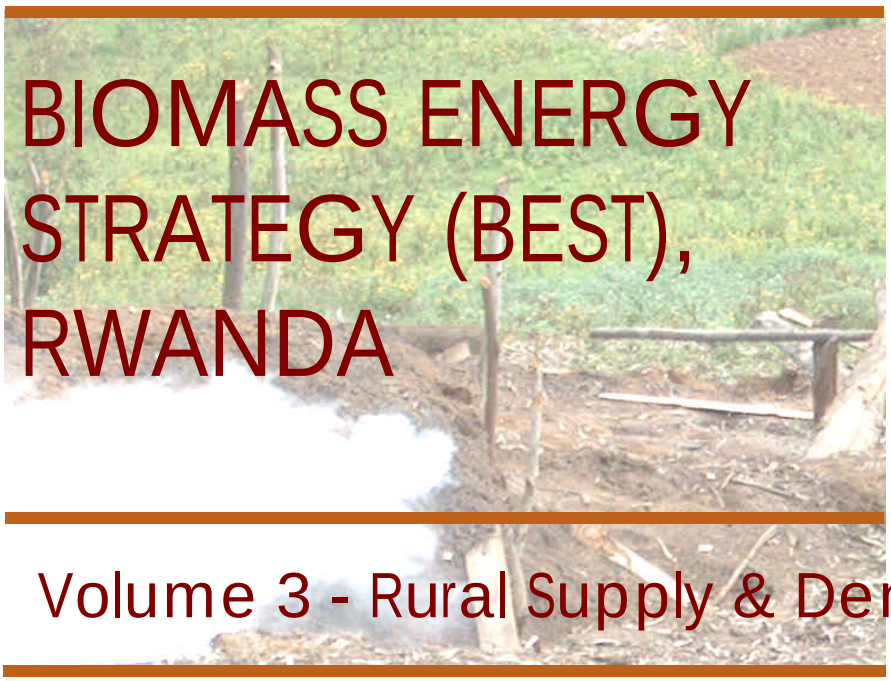
BIOMASS ENERGY STRATEGY (BEST), RWANDA



Volume 3 - Rural Supply & Demand

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Introduction

This Chapter addresses biomass energy issues in rural areas. Although the focus of the BEST is on the commercial aspects of biomass (purchased firewood and charcoal in urban areas), it is important to also look at rural aspects: the majority of Rwandans live in rural areas and in addition, they supply over 80% of the energy used in urban areas. If there is a problem with the supply or use of energy in rural areas, this may have implications for the energy situation in urban areas.

Since there are quite a few unknown aspects of rural energy, MININFRA decided to carry out a rural energy survey. This survey consisted of 3000 interviews of randomly chosen rural households, 100 in each district[1], as well as focus group discussions in each district. The results of these data collection efforts are presented below.

Rural living conditions and economic activities

Agriculture and to a lesser extent animal husbandry (cattle) are the main rural economic activities for about 80% of the households in Rwanda. The remaining 20% households are employed in the public or private sectors, or unemployed, in approximately equal proportions. See Table 1. Population density in rural areas is high and some competition between agriculture and forestry may exist. Most cows and pigs are confined in corrals or stables and are no longer allowed to roam about the land.

Trees, whether individual trees scattered about the fields, agroforestry, or plantations have become normal part of the agriculture scene in Rwanda; trees have been reported to be a good source of revenue for farmers, and this is good news for the supply of energy.

Table 1: Economic activity(% of households)

Province	Agriculture, cattle or both	Agriculture & Commerce	Commerce	Employed (public or private)	Other	No activity (unemployed, too old, disabled, etc.)
South Province	71.1%	0.9%	3.5%	5.9%	0.7%	18.0%
Western Province	69.3%	0.7%	6.1%	7.2%	1.9%	14.9%
North Province	85.7%	0.2%	5.5%	2.7%	1.9%	4.1%
Eastern Province	82.2%		5.6%	4.1%	1.2%	6.9%
Together (households Head)	**76.4%**	**0.5%**	**5.1%**	**5.1%**	**1.4%**	**11.5%**
Conjoint of households Head	*81.8%*	*0.3%*	*3.4%*	*3.0%*	*0.7%*	*10.7%*

Source : RBESS, MININFRA, 2009

Just over three quarters of rural households own a farm and have farm land. About two thirds of these farms are below 0.5 hectare, while only 8.5% are larger than 1.0 hectare. This is small, even by African standards, and this has implications on the way households meet their needs for energy. See Table 2 for more details about the size of farms in Rwanda.

[1] See the project proposal of G&C for more details about the selection procedure.

Table 2: Size of farms by Province.

Province	% of all households		% of households owning a land farm			
	No land	With land	<0.1 ha	0.1 ha-0.5 ha	0.5 ha-1 ha	> 1 ha
South Province	22.8%	77.2%	3.9%	58.7%	30.4%	7.1%
Western Province	33.9%	66.1%	1.5%	76.8%	17.2%	4.5%
North Province	12.8%	87.2%	4.5%	75.3%	14.9%	5.3%
Eastern Province	20.7%	79.3%	1.3%	43.1%	39.4%	16.1%
Total	**23.3%**	**76.7%**	**2.8%**	**62.5%**	**26.1%**	**8.5%**

Source : RBESS, MININFRA, 2009

This Chapter focuses on the main issues dealing with biomass energy in rural areas, whereby supply as well as user aspects of rural biomass energy are analyzed. There are not many parallels between urban and rural biomass energy. Whereas urban households mainly use charcoal that is produced in rural areas and desire to use electricity and LPG, rural households use firewood and agricultural residues that are largely gathered rather than purchased, and have started looking towards using charcoal. Much of the $150 million annual woodfuel turn-over is produced by rural areas and contributes to rural development. While most of the energy in urban areas is purchased, in rural areas it is gathered free of charge, although time is needed that cannot be used for other purposes.

It must be said that the situation concerning the supply of biomass in Rwanda is quite different than in most other African countries. In a way, Rwanda is ahead of the others as much if not all of the wood comes from wood plantations rather than from natural forests, and a good part comes from private plantations. There are good chances that wood in Rwanda is sustainably produced, or at least for a large part. This gives a whole different set of issues that are not always fully understood by the stakeholders in Rwanda who often continue to think that wood and charcoal continue to come from natural forests.

Before moving on to the biomass aspects, a few details are presented on the state of the household and the way of life: access to mobile phones, access to clean water and modern lighting energy, and condition of the homes. These aspects are important to show that modernization has arrived in rural Rwanda but that energy is lagging (far) behind.

Table 3: Characteristics of the rural house

	Kigali	West	South	North	East	total
Average number of sleeping rooms	2.7	2.6	3.2	3.0	2.5	2.8
Separate kitchen	77%	90%	92%	88%	74%	86%
Modern walls	60%	55%	69%	70%	30%	55%
Modern floor	94%	38%	48%	28%	20%	35%
Modern roof	98%	96%	96%	96%	97%	96%

Source : RBESS, MININFRA, 2009

The period that rural households lived in one traditional hut is definitely over, see Table 3 Rural households have between 2 and 3 rooms, on average 86% has a separate kitchen and virtually all households have a modern roof. Modern walls are present in 55% of the households and modern floors in only 35%. Generally, the Eastern Province is lagging behind the other provinces in all aspects of modernization and this may have to do with the fact that this Province accepted to settle many foreign refugees.

In terms of lighting conditions, modern times have not at all caught up with rural life, see table 4. Some 0.6% has access to electricity, with somewhat higher rates in the South and the East. Some 13% of the respondents have no lighting at home, 81% use traditional lighting, and only 5% have access to modern lighting. Modern lighting includes either an electricity connection, a PV system, or a petromax (pressurized kerosene mantle lamp); traditional

lighting includes the tomato paste tin, or a hurricane lamp, and no lighting means a candle, a flashlight only, or declared no lighting[2].

Table 4: Lighting conditions

	Kigali	West	South	North	East	Total
Access to electricity	0.0%	0.4%	0.9%	0.3%	0.8%	0.6%
Modern lighting	13%	2%	9%	4%	4%	5%
Traditional lighting	81%	82%	70%	83%	91%	81%
no lighting	6%	16%	21%	12%	5%	13%

Source : RBESS, MININFRA, 2009

About one-third of the rural households have a mobile phone and of those household with a phone, the average is almost 1.4 phones per household, see Table 5 Other than in Kigali, most of these phones are charged at a shop or store, either in their own village or in the neighboring village (or town); abut one-third are charged at home, at a neighbor's home, or at a friend's house. One might say that mobile phones are well embedded into rural life. It also shows that households do have money for something that really adds value to their lives; in the case of phones, it is not only the initial purchase price of the phone and the phone contract that they have to pay, if they want to continue to use it they will need to buy phone credit from time to time too.

Table 5: Access to mobile phones

	Kigali	West	South	North	East	total
% of hh with mobile phones	60%	28%	40%	27%	36%	34%
average nr of phones	1.7	1.4	1.6	1.3	1.3	1.4
Charging at home/neighbor	50%	22%	42%	33%	32%	34%
Charging at a shop	50%	78%	58%	67%	68%	66%

Source : RBESS, MININFRA, 2009

As a conclusion one can say that rural households are better off now than they were at any point in the past; their homes are relatively modern and they have access clean water. They have started to use mobile phones on a fairly large scale. Detailed aspects of cooking will be addressed later in this chapter, but as an advance summary, 60% of the households are equipped with an improved stove, even though this may not be exactly what they aspire. Only in terms of electricity access or lighting it is clear that much needs to be done to improve the conditions to modern life. The single largest improvement to rural life would come from improved lighting, but unfortunately there is no program dealing with this at the moment.

Rural life is mainly based on agricultural activities, and forestry is an integral part of that. In what follows, the role of trees and of plantations is described and the implications and opportunities for rural households. In a later section, the use of woodfuels for energy is described.

Private tree plantations

The 2007 Forestry Inventory Study concluded that in fact a large part of the wood supply comes from plantations that are smaller than 1 ha. GIS methods are difficult to use for such small patches of trees and therefore some uncertainty remains about the contribution from these small plantations, from agroforestry, and from individual trees in the fields and around

[2] Of the "no lighting" category, 40% do not use candles or flashlights; in Kigali 100% uses candles or flashlights.

the homestead. In addition, the Inventory also stated that a considerable part of the plantations were private.

About 14% of the households in the 3000 random rural household sample indicate to have a tree plantation on their farm; a tree plantation means that part of the farm land is dedicated to trees rather than to agricultural crops, and indeed small plantations have been observed of 10 x 10 m^2 or even less. In addition to tree plantations, almost all households have individual trees on their land and on their homestead; these trees often serve as fence or as means to provide shade and are often fruit trees such as avocado, guava, and mango. All these trees contribute to the supply of the households' energy needs (leaves, twigs, dead branches, etc).

The coverage of tree plantations varies by Province and District and for example, Nyaruguru District - one of the main charcoal supply zones of Kigali - has the lowest rate of private tree plantations: only 2% of surveyed households there declared to have a tree plantation on their own farm.

If the farm sizes are generally very small, the tree plantations are even smaller; they typically cover 0.1 hectare or less for 74% of the households with a farm. The small size of the land probably explains why farmers focus on agriculture first (see above), food production and cattle are more important for the household than energy and construction wood. Only about one household in one thousand has a tree plantation larger than a hectare, see Table 6.

Table 6: Presence and size of tree plantations in land farms

Province	Presence (% of all households)		Size (% of households with tree plantations)			
	No	Yes	< or = 0.1 ha	0.1 ha-0.5 ha	0.5 ha-1 ha	> 1ha
South Province	85.3%	14.7%	74.4%	22.1%	3.5%	
Western Province	82.1%	17.9%	75.7%	21.5%	2.1%	0.7%
North Province	80.5%	19.5%	74.3%	19.5%	4.4%	1.8%
Eastern Province	95.1%	4.9%	62.9%	31.4%	5.7%	
Total	**86.0%**	**14.0%**	**73.8%**	**22.0%**	**3.4%**	**0.8%**

Source : RBESS, MININFRA, 2009

Table 7 gives estimates for the number of households with a tree plantation, on the basis of the number of households per Province, the proportion of those having a tree plantation and their repartition according to size groups from Table 6. Some 205,000 households out of a total of about 1.5 million rural households have a tree plantation, out of which less than 10,000 households with a tree plantation covering between 0.5 and 1 hectare, and less than 2,000 households with more than 1 hectare.

Table 7: Number of rural households having a tree plantation

Province	Total number of households	No of households by size group of tree plantation				
		<0.1 ha	0.1 ha-0.5 ha	0.5 ha-1 ha	> 1 ha	Total
South Province	384,659	42,119	12,504	1,974		56,597
Western Province	403,258	54,778	15,579	1,508	503	72,367
North Province	293,067	42,381	11,100	2,523	1,009	57,013
Eastern Province	381,979	11,813	5,907	1,074		18,794
Total	**1,462,963**	**151,091**	**45,090**	**7,079**	**1,512**	**204,771**

Source : RBESS, MININFRA, 2009

Table 8 shows estimates for the maximum land surface[3] covered by private tree plantations of less than 0.5 hectare. This amounts to a total of 37,650 hectares for all farms with a small tree

[3] Using the upper limit of each size group as the average area for each tree plantation included in their group, thus for the 0.1 ha group: 0.1 ha, 0.5 ha for the group between 0.1 and 0.5 ha.

plantation combined, which nevertheless equals 61% of the area covered by private plantations of more than 0.5 hectare as detected by the 2007 ISAR Forestry Inventory (61,380 ha).

When combining data from the survey and the ISAR forestry inventory, all private tree plantations together are estimated to cover about 100,000 hectares, and this is the equivalent of the area covered by the State and District production tree plantations (104,307 ha according to the 2007 ISAR Forestry Inventory).

Table 8: Maximum areas covered by private tree plantations (< 0.5 ha)

Province	Size group		Total
	<0.1 ha	0.1 ha-0.5 ha	
Average area (ha/plantation)	*0.1*	*0.5*	
South Province	4,212	6,252	10,464
Western Province	5,478	7,789	13,267
North Province	4,238	5,550	9,788
Eastern Province	1,181	2,953	4,135
Total	**15,109**	**22,545**	**37,654**

Source : RBESS, MININFRA, 2009

The survey also gathered information about the type of trees and for what purpose they are used. Eucalyptus is considered as the most suitable tree species for wood production, by 94% of the households in all Provinces. Pinus is considered the second suitable species, cited only by 4 to 6% of households, except in Western Province where they prefer Grevillia.

Table 9: Uses of wood extracted from households tree plantations (% of households with plantations)

Province	Construction & furniture		Firewood		Charcoal	
	own use	for sale	own use	for sale	own use	for sale
South Province	64.6%	13.3%	83.2%	6.2%	1.8%	1.8%
Western Province	66.9%	10.3%	86.2%	4.1%	2.8%	0.7%
North Province	53.5%	3.5%	81.6%	5.3%	1.8%	
Eastern Province	70.3%	21.6%	59.5%	2.7%	2.7%	2.7%
Total	**62.8%**	**10.3%**	**81.7%**	**4.9%**	**2.2%**	**1.0%**

Source : RBESS, MININFRA, 2009

Table 9 shows that households use the wood extracted from their tree plantations first for firewood (87%) and construction and furniture (73%), and very few (3%) use it for charcoal making. They devote it mainly to fulfill their own needs (81% of households for firewood, 63% for construction and furniture). These results confirm those of the earlier BEST survey (2008), supporting the fact that households prefer first to sell construction wood (poles, etc.) which yields higher revenue.

Table 10: Contribution of household tree plantation vs. needs (% of households with plantations)

Province	Contribution as a percentage of households needs during last 3 years			
	Construction wood		Woodfuel	
	< 10%	> 50%	< 10%	> 50%
South Province	40.8%	14.3%	33.0%	27.0%
Western Province	56.9%	6.5%	51.2%	27.3%
North Province	76.7%	6.8%	67.3%	8.2%
Eastern Province	72.7%	6.1%	65.6%	9.4%
Total	**59.7%**	**8.7%**	**52.3%**	**19.8%**

Source : RBESS, MININFRA, 2009

The volume of wood extracted from households' tree plantations does not meet all of households' own needs. Table 10 shows that, over the past three years, 20% of households were able to supply more than half of their woodfuel needs and 9% for construction wood. Respectively 52% of households and 60% obtains less than 10% of their wood needs for woodfuels and wood construction.

The lack of self-sufficiency of rural households with a tree farm in regard to woodfuels can be explained easily: 74% of private tree plantations cover less than 0.1 hectare (see Table 6); if these yield a maximum of 25 m^3/ha, the yearly output is 0.1 ha * 25 m^3 = 2.5 m^3 or 1.75 ton of wood per household – and only if the plantation is well managed This is less than 0.9 kg of wood per person and per day. Taking into account that plantations might not be so well managed and in addition yield other products than wood for energy, the amount of wood available annually would probably be between 0.3 and 0.9 kg/person/day: such a quantity is insufficient to fulfill the needs for both woodfuels and construction wood.

It is not possible to say how much plantation wood is needed by rural households as they do not exclusively use firewood but different sources of wood and residues. Urban use is much easier to estimate, and thus also how much plantation space is needed to support an urban household:

- a charcoal using household needs 0.7 – 1.3 ha of eucalyptus plantations to support his charcoal demand;
- a firewood using household needs 0.3 – 0.5 ha of eucalyptus plantations to support his firewood demand [4].

Knowing that 97% of rural households (see below) depend on woodfuels for cooking, of whom 71% gather their firewood and only 14% have their own tree plantations which, in addition, can't fully fulfill their own needs, it is then obvious that a majority of households has to use wood from other sources, such as from neighboring public or private plantations, or use residues. At this point in time it is not known to what extent firewood comes from stand-alone trees surrounding homesteads and scattered about farm land that certainly contribute to the supply of individual households.

Table 11 below gives an estimate of the area of less-than-0.5 ha tree plantations reported to be exploited for sale of woodfuels, on the basis of the percentages of households having said to do so (see Table 9). This estimated area (2,213 ha) is smaller (41%) than the one calculated from the BEST survey (5,337 ha), and confirms the small contribution of the less than 0.5 ha plantations to woodfuel supply in urban areas.

[4] 930 kg of charcoal per household per year; 2500 kg of firewood per household per year; plantations produce 5.2 –9.8 t of wood per ha per year, and the charcoaling efficiency is 14%.

Table 11: Areas of less-than-0.5 ha plantations exploited for woodfuel sales (ha)

Province	Firewood	Charcoal	Total
South Province	648	185	833
Western Province	549	91	640
North Province	515		515
Eastern Province	112	112	223
Total	**1,824**	**388**	**2,213**

Source : RBESS, MININFRA, 2009

Rural households with a tree plantation have planted more trees than they have cut over the past 3 years. Table 12 shows that the tree cover decreased during the past three years for only 23% of the respondents while it increased for 43%. The Eastern Province is the only one where household reported that their tree cover decreased over the past 3 years; however, it is the Eastern Province (Bugesera) that is known to have gone through a complete cycle of destruction of savannah forests and reforestation with eucalyptus plantations. For one-third of the households with a tree plantation, the tree cover more or less remained equal. In fact, the overall effect is that there are now more trees than 3 years ago on plantations planted by private farmers, and this is good news as it indicates that at least households with their own tree plantation maintain their standing stock and even increase it.

Table 12: Tree cover change on households own land during the past 3 years (% of households)

Province	Increase	+/- equal	Decrease	Don't know	Increase/ decrease
South Province	45.1%	33.6%	20.4%	0.9%	2.2
Western Province	46.5%	29.2%	22.9%	1.4%	2.0
North Province	43.0%	35.1%	20.2%	1.8%	2.1
Eastern Province	27.0%	32.4%	37.8%	2.7%	0.7
Total	**43.4%**	**32.4%**	**22.8%**	**1.5%**	**1.9**

Source : RBESS, MININFRA, 2009

Households with a tree plantation were also asked the reasons for planting trees. For the majority of households, and in approximately in equal proportions, the main reasons for planting trees are to increase their revenues (57%) and satisfy their own needs (56%). Some 38% of households say that it also supports environment protection (see Table 13).

Table 13: Good reasons for planting trees on one's own land (% oh households)

Province	To increase households revenue	To fulfill households needs	To support environment	Don't know
South Province	73.8%	65.0%	69.9%	1.9%
Western Province	51.6%	57.8%	21.9%	2.3%
North Province	54.0%	45.0%	30.0%	1.0%
Eastern Province	42.9%	53.6%	10.7%	10.7%
Total	**57.5%**	**55.5%**	**37.6%**	**2.5%**

Source : RBESS, MININFRA, 2009

The above results of the rural survey strengthen the earlier BEST diagnosis and proposed strategy. Rural households may face a deficit between the production of wood on their own lands and the needs for their own use. This may lead on the one hand to over-use of their tree plantations and on the other hand to fraudulent extraction from State and District plantations. Over-use includes the fact that farmers cut trees before these are mature, or in the case of

eucalyptus plantations, they maintain a cutting rotation that is less than 6 years in order to have products to use or sell more quickly. Apparently the farmer's personal discount rate is so high that he often finds it better to sell immature wood now than to wait until it has become more valuable a few years from now. It would be possible to develop legislation providing incentives to farmers for enlarging rotation cycles.

However, it is very unfortunate that the contribution from trees around the homestead and scattered about the fields is unknown; it may actually satisfy a (large) part of the household's own needs: one does not need to cut whole trees to obtain firewood, but pick up small, dead branches, leaves, twigs, etc that do not hinder the further growth of trees. Every one with trees in his yard observed that stuff tends to fall off trees and regular cleaning of the yard is needed.

Rural households are aware of the revenue that they can generate from selling tree products, and over 40% of the households with a tree plantation have actually increased their tree cover during the last years: such a tree planting process should contribute to a reduction of deficit that may exist between the supply and the demand for woodfuels. However, the small size of farms (two-thirds are less than 0.5 hectare) and competition with food crops will physically limit the possibility of enlarging small farmers' tree plantations. These findings underline the pertinence and additionality of two of the main recommendations of the BEST strategy pertaining to the woodfuel supply: promoting and developing more productive tree planting practices and improving plantation management, both in an attempt to increase the sustainable yield of these plantations, in private, District, and State plantations.

Woodfuel supply and use

Supply of woodfuels

This section mainly deals with the supply of biomass energy, or woodfuels [5] and lower grade traditional fuels [6] at the household level. Not only do rural households depend quasi-exclusively on these fuel for cooking and heating water, they also need to ensure that they have a regular supply and for some it may even be a source of revenue. Therefore, biomass energy and woodfuels are important in the life of rural households.

Almost all rural households (98%) report to use woodfuels and residues as their main source of cooking energy: firewood and its derivatives are predominant for 92% of households and charcoal for 5% (see Table 14). The use of LPG and electricity is practically nonexistent, which is not surprising as these fuels are hardly even used in Kigali and other towns; nevertheless, 0.6% or the respondents report to use LPG which is the equivalent of 9000 households. This appears high or even too high compared to the total number of LPG cylinders in the country. The use of charcoal by more than 5% of the respondents is surprising but at the same time very well possible. The rural use of charcoal may point to a trend that rural households see their income rise and also want to modernize their lives, just like urban households do. It does not mean that they use charcoal for all purposes; they may just supplement with other fuels. However, the use of charcoal may exacerbate any demand-supply problems that may exist, given the inherent inefficiencies of the charcoaling process.

[5] Charcoal, firewood.

[6] Twigs, leaves, agricultural residues, dung.

Table 14: Main fuel used for cooking (% of households)

Province	Gas	Electricity	Wood and derivatives	Charcoal	Biogas	Residues	Other
South Province	0.4%	0.4%	91.7%	4.3%	0.1%	2.5%	0.7%
Western Province	0.5%	0.9%	88.0%	9.5%		0.6%	0.5%
North Province	0.3%	0.3%	94.0%	3.8%		0.9%	0.7%
Eastern Province	1.1%	0.8%	94.5%	2.3%		0.5%	0.8%
Total	**0.6%**	**0.6%**	**91.9%**	**5.1%**	**0.0%**	**1.1%**	**0.7%**

Source : RBESS, MININFRA, 2009

Table 15 shows that of the households that use firewood as their main fuel, about one in three purchase it and two in three gather it. Since most people who gather fuel do not cut whole trees but collect dead wood or small branches, the most likely implication is that only 1/3rd of the firewood comes from the harvesting of whole trees, possibly leading to unsustainable use of resources. For 2/3rd of the households the use of firewood is unlikely to result in cutting of whole trees and is therefore likely to reflect a sustainable use of resources. This proportion of purchased firewood and charcoal is relatively high in comparison with other rural areas in Africa.

Table 15: Supply modes of firewood (% of users)

Province	Purchase	Gathering
South Province	23.2%	76.8%
Western Province	38.6%	61.4%
North Province	27.8%	72.2%
Eastern Province	26.0%	74.0%
Total	**29.0%**	**71.0%**

Source : RBESS, MININFRA, 2009

Table 16 shows some of the details about the collection of woodfuels; of those who gather woodfuels (see Table 15), about 80% do not travel at all and reported a zero collection time; this means that they are able to obtain the fuel they need from the immediate surroundings of their home (homestead or farm). Of those who report to travel for collecting woodfuels, the average collection time round trip is about 50 minutes in the South, North, and West and 80 minutes in the East. Taken over the whole sample, average collection times are on the order of 10-12 minutes except in the east, where it is about 18 minutes. The average one-way distance ranges from 1.5 to 2.5 km for those who travel to collect woodfuels.

Table 16: Collection of woodfuel

	Kigali	West	South	North	East
% of hh use wood from own land (zero collection time)	89%	76%	76%	74%	78%
Average collection time (minutes) whole sample, round trip	8	13	12	12	18
Average collection time (minutes) respondents who do not use own land	67	54	51	48	80
Distance traveled (one-way)	2.1	1.9	1.4	2.2	2.5

Source : RBESS, MININFRA, 2009

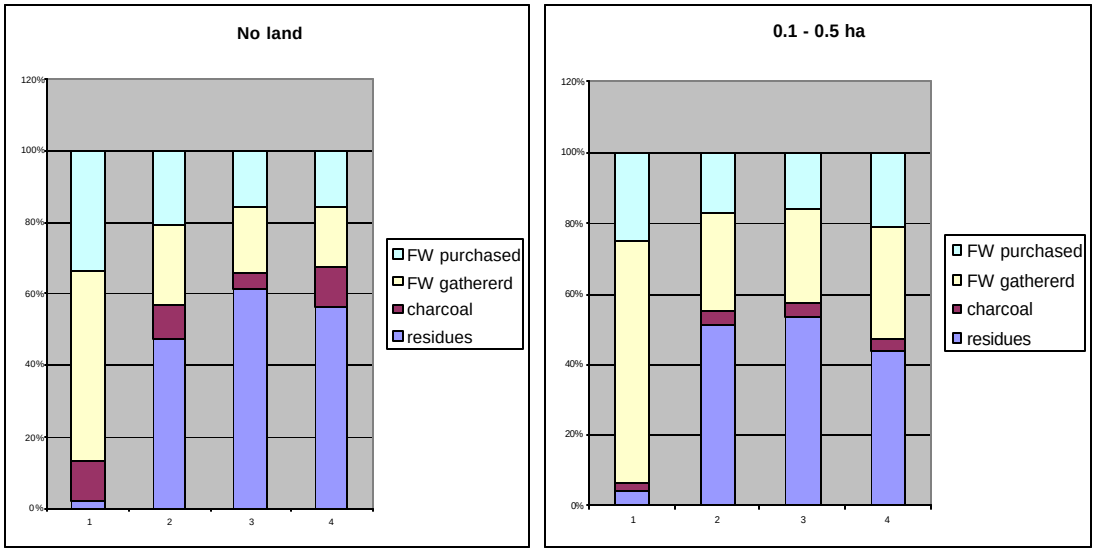
When specifically asked details about the use of biomass fuels for cooking, households indicated a higher use of residues from their fields, which is in contradiction with Table 14. However, this could be understood as households are likely to use residues if and when these are available, and only supplement these with firewood that they gather on their fields and along the road, on public areas. But when asked what their main fuel is, they are likely to

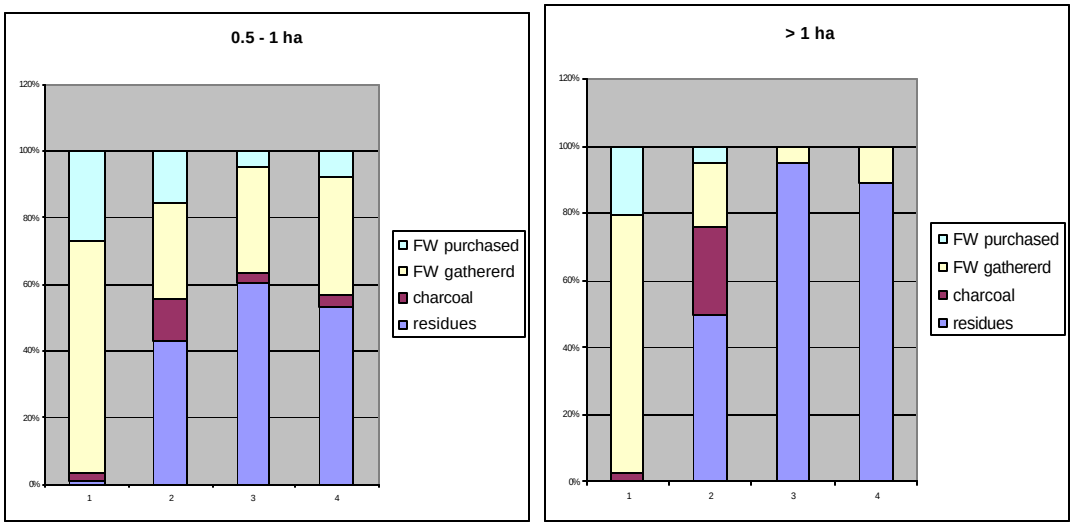
report firewood because they purchased this or because they had to organize the collection of it and think of it as a more important fuel than residues. Only when free and easily available sources of energy such as agricultural residues are depleted, are they likely to start their search for firewood from other sources or purchase it. These practices may differ by season - while during the harvesting time households are likely to be fully self-sufficient, during the agricultural off-season they may have to rely more on purchased or systematically collected firewood. More research is needed to fully understand these issues.

Table 17 and Figure 1 show the results presented by size of land holding: the larger the landholding, the less households purchase firewood or gather firewood. This confirms the hypothesis that households will first use residues when available: larger farms have more residues available and smaller farms less. Even for the smallest landholdings - the majority of rural households - about half of the households use residues as their main fuel and 1/3rd use gathered firewood. The use of charcoal increases marginally with size of landholding, which seems to confirm the income effect: a larger farm equals a richer household and has a higher tendency to use modern fuels. Charcoal use therefore is not a necessity, but a (luxury) choice made by the household.

The important implication is that the energy consumption of rural households depends only for a small part on harvested and planted trees, see Table 16: only 9% of rural households use purchased firewood and 5% charcoal that must have been harvested from plantations, but 29% of the households do use firewood but it may come from a variety of sources including plantations, dead wood, farm and homestead trees, and 57% use residues. The total plantation off-take of firewood or wood for charcoal making may therefore be less than previously thought.

Figure 1: First, second, third and fourth fuel used by size of land holding





Source: RBESS, MININFRA

Figure 1 shows the reported main fuels by size of land holding; it is best seen in color. The first graph shows the reported fuels used for households without farm land; the first column is the first fuel used, the second column is the second fuel used, etc. The second graph presents the different fuels for households with a reported land size below 0.1 ha , the third graph for households with land between 0.5 and 1 ha, and the fourth for land larger than 1 ha.

Gathered firewood is by far the main primary fuel, for all sizes of land holding. Purchased firewood is slightly higher for smaller land holdings (including no farm land), and charcoal use is only significant for households without farm land. Charcoal is also used by all groups as secondary fuel, maybe as a convenient fuel for making tea or small meals; with the largest occurrence is for large land-holdings. This seems to suggest that there is an income effect, whereby richer households purchase charcoal more often. The use of residues as 2-4th fuel is very important, and indeed confirms that households will use residues whenever available. Table 17 shows the results for the primary fuel.

Table 17: Primary Fuel Used (% of users)

Land size	Charcoal	Firewood Purchased	Firewood Gathered	Crop residues	Total
0.1ha-0.5ha	4%	12%	32%	51%	100%
0.5ha-1ha	5%	6%	29%	60%	100%
1ha and more	6%	0%	15%	79%	100%
Total	5%	9%	29%	57%	100%

Source : RBESS, MININFRA, 2009

Some 70% of households gather firewood several times a week and 30% up to every day; in 80% of cases, it is often done in combination with working in the fields or when children come back from school. Some 85% of the respondents state that firewood gathering is problematic, for themselves as well as for their neighbors; it appears to be slightly less problematic for households with a larger landholding, see Table 18. Some 10% of households indicate that there is more wood now than last year available as firewood and 19% indicate that they buy more now than last year, see table 18.

Table 18: Some Firewood Issues

Land size	Household has a problem gathering firewood	Is there more wood for gathering firewood now than last year?		Buys more fuel now than last year	
		Yes	Don't know	Yes	Don't know
0.1ha-0.5ha	86%	11%	5%	16%	9%
0.5ha-1ha	84%	8%	7%	27%	17%
1ha and more	65%	9%	16%	20%	23%
Total	84%	10%	6%	19%	12%

Source : RBESS, MININFRA, 2009

Although 84% of the respondents state that there is problem with the gathering of firewood, some 86% of respondents also state that their main fuel is either readily available or can be obtained without money, see Table 20. So, for a large percentage of the rural population fuel acquisition appears not to be a major problem, even though households complain about it; the gathering of firewood specifically may pose some problems, but this is not the main fuel used for most households. This supports the finding in Table 17 that not many households rely on firewood as their main fuel.

Table 19: Frequency of procuring woodfuels

	Buy FW	Buy Charcoal	Collect FW
Kigali	2.2	1.2	2.1
South Province	1.9	1.4	4.4
Western Province	2.4	1.6	2.9
North Province	2.1	1.1	3.5
Eastern Province	2.4	1.2	4.0
Total	2.3	1.4	3.7
Nr of responses	690 (23%)	121 (4%)	2312 (78%)

Source : RBESS, MININFRA, 2009

Table 19 shows the number of times per week that households buy or collect woodfuels; charcoal is purchased by 4% of the respondents 1 x per week, firewood is purchased 2 x per week by 23% of the sample, and firewood is collected every other day by 78% of the sample. Collecting firewood is by far the most frequently occurring mode of fuel procurement.

Table 20: Reasons for using the main fuel

Province	readily available	can be obtained without money	cooks fast	produces less smoke	Other
Kigali	87%	9%	2%	0%	2%
Southern province	65%	16%	10%	2%	7%
Western province	72%	17%	4%	0%	6%
Northern province	61%	26%	7%	3%	3%
Eastern province	80%	7%	7%	2%	3%
Total	70%	16%	7%	2%	5%

Source : RBESS, MININFRA, 2009

Table 21 shows reported problems with the gathering of firewood; these can be divided into 3 main categories: (i) access problems, such as illegal cutting or cutting in difficult locations, which is reported by 35% of the respondents as their main problem of which 1/3rd clearly relates to illegal cutting (14% of respondents) and 2/3rd to finding access to the location (i.e.,

steep hill top); (ii) inconvenience, which is reported by 57% of the respondents; cutting and carrying wood is hard work, so this will always be a problem; please note that only 13% states that it is the long distance of the collection that is their main problem; and (iii) other problems, reported by 7% of the respondents.

Table 21: Main problems encountered with gathering of firewood

Province	Kigali	South	West	North	East	Total
Access Problems						
wood inaccessible and can get hurt	4%	31%	9%	15%	28%	21%
owner doesn't like it	0%	17%	13%	9%	16%	14%
Physical Problems						
difficult in rainy season	67%	19%	24%	30%	10%	21%
hard work to cut wood	19%	9%	21%	17%	10%	14%
travel far to get it	11%	8%	14%	10%	21%	13%
heavy to carry	0%	8%	8%	14%	8%	9%
Other						
Other	0%	8%	12%	4%	6%	7%

Source : RBESS, MININFRA, 2009

The focus group discussions confirm the findings; some 35% of the respondents say that woodfuels are easy to access; 65% do not agree. Some 25% say that there are enough plantations around, 23% say that there are not enough plantations, and 52% say that there are no plantations. However, when asked about access to wood plantations, 75% cite cutting rules, limited cash to purchase, and only 11% say that there is no wood available. In short, it appears that woodfuels can be obtained, sometimes with some difficulties, but in general it is not a major problem.

There are two main problems associated with the high proportion of agricultural residues for energy purposes:

- Most of the residues should be plowed back into the soil to enhance the nutrient level; some nutrients are likely to go back into the soil when ashes of burn residues are disposed of, but this is only a fraction of the total. The quality of soils in Rwanda is poor and already quite degraded, leading to reduced agricultural and silvicultural yields; with better use of natural and artificial nutrients agricultural yields can be increased by a factor of 60% [7].
- As will become clear in the next section, the combustion of agricultural residues in non-adapted stoves causes a lot of smoke, and this influences the health of rural households. Improved stoves are designed for proper combustion of firewood and do not burn agricultural residues very well.

The fact that rural households rely on agricultural residues for much of their energy needs might be convenient for them in the short term, in the long term the effects are negative from foregone revenues and higher health costs.

Use of woodfuels

This section deals with the end-user aspects of woodfuels. Woodfuels are mainly used for cooking and/or heating water; households generally light their stove twice a day (65%, see Table 22) or three times (19%); 10% to 19% of households in the different Provinces light

[7] Ref: IFDC, Catalyst Program

their stove only once a day with the East as the Province that lights the least a fire. The survey did not ask a question about why they only use their stove once a day, and it is possible that they light it only once but that it remains burning the whole day.

Table 22: Nr of times per day lighting the fire (% of households)

Province	1	2	3	>3
South Province	19.1%	61.7%	18.6%	0.5%
Western Province	13.6%	59.2%	26.6%	0.6%
North Province	17.6%	69.6%	12.6%	0.2%
Eastern Province	10.6%	72.3%	16.1%	0.9%
Total	**15.1%**	**65.3%**	**19.0%**	**0.6%**

Source : RBESS, MININFRA, 2009

In terms of modern cooking practices, rural Rwandans score high. Table 23 shows that more than 90% of households cook indoors, generally in a separated room or specific kitchen (from 2/3rd to 3/4th of households that are cooking indoors); the exception is the Eastern Province where about a quarter of the households cook outdoors, but it is not clear why.

About 1/3rd of the respondents dry their firewood only during the raining season when it is most needed and a significant majority (57%) always dry their firewood before cooking; only some 11% never dry their firewood. More than 90% of households cover their pots when cooking, mainly in order to "keep dirt out of the food" (75% of households) and also because "food cooks faster" (40%); there are less than 3% of the respondents who chose not to cover their pots.

Table 23: Main/usual place for cooking (% of households)

Province	Outdoor	Indoor		Other
		Total	*Of which in a kitchen*	
South Province	4.3%	95.7%	*66%*	
Western Province	5.9%	94.1%	*76%*	
North Province	9.7%	90.3%	*75%*	
Eastern Province	24.2%	75.5%	*97%*	0.3%
Total	**11.0%**	**88.9%**	***78%***	**0.1%**

Source : RBESS, MININFRA, 2009

Table 24 shows the different stoves that households have; on average there are about 1.3 stoves per household. Some 53% of the stoves reported are improved firewood stoves, 16% portable firewood stoves, 2% charcoal stoves. It is surprising to find that 22% of the stoves identified are kerosene stoves and 3% LPG stoves; however, it does not mean that 22% of the households actually use kerosene! Table 3 shows that 3% actually uses kerosene. Table 25 shows the type of wood stoves that are reported to be normally used for cooking.

Table 24: Type of stoves owned by the household (%)

Type of stoves	Total
Portable firewood stove	15.5
Non-portable FW stove, improved with chimney	33.0
Non-portable FW stove, improved without chimney	20.3
Portable charcoal stove (traditional)	1.0
Portable charcoal stove (improved)	0.8
Kerosene	22.4
LPG	3.4
Other	3.3
Total nr of responses	*3657*

Source : RBESS, MININFRA, 2009

Some 48% of rural households use traditional stoves as their main cooking device, see Table 25, of which about 2/3rd a "3 stone open fire" stove and 1/4th a mud stove. This implies that 52% use improved stoves, which is very high percentage of the population. It also is an indication of the success of the Government's program to bring improved stoves to rural households; this is a very high coverage compared to other countries in Africa.

The reasons why households like the stoves they use are that these are cheap (20%), traditionally used (19%), or simple (15%). The reasons why households dislike traditional stoves are that these are dangerous or can burn house (31% together), use a lot of fuel (27%) or issue much smoke (18%).

Table 25: Normally used traditional stoves & type of stoves

Province	% of all households using traditional stoves	Type of traditional stove (% of users)		
		3 stones	Mud stove	Other
South Province	47.8%	69.8%	12.3%	18.0%
Western Province	35.1%	73.2%	14.8%	12.0%
North Province	61.9%	58.7%	32.2%	9.1%
Eastern Province	51.1%	62.8%	34.4%	2.9%
Total	**47.9%**	**65.7%**	**24.0%**	**10.3%**

Source : RBESS, MININFRA, 2009

Table 26 shows the distribution of traditional and improved stoves according to size of land holding: some 60% of the firewood users use an improved stove and 34% of the charcoal using households use an improved stove. This is high compared to improved stove coverage in other countries in Africa. Households with larger land holdings tend to use more improved firewood stoves than households with smaller land holdings.

Table 26: Use of improved stoves

	Firewood stove	% IS	Charcoal stove	% IS	Other stove	Total	
no land	450	54%	58	36%	37	545	26%
0.1 - 0.5	870	59%	45	29%	27	942	45%
0.5 – 1	427	67%	29	34%	19	475	22%
> 1 ha	113	69%	16	38%	21	150	7%
	1860	60%	148	34%	104	2112	

Source : RBESS, MININFRA, 2009

The use of stoves is further investigated in Table 27, whereby the users are divided along their normal use of fuels: gathering firewood, purchasing firewood, or using charcoal. This also shows how difficult it is to collect good information, as e.g. households claiming to use

charcoal as their primary fuel should then not report that the stove they mainly use is a firewood stove, Table 27.

Table 27: Reported stove use by type of fuel use

	Gather FW		Purchase FW		Charcoal user	
portable firewood	491	35.5%	204	34.6%	21	24.7%
fixed FW IS + chimney	416	30.1%	159	27.0%	3	3.5%
fixed FW IS – chimney	341	24.6%	170	28.9%	6	7.1%
portable charcoal TS	12	.9%	4	.7%	31	36.5%
portable charcoal IS	24	1.7%	10	1.7%	15	17.6%
Non portable charcoal	30	2.2%	12	2.0%	7	8.2%
Kerosene stove	26	1.9%	14	2.4%	2	2.4%
LPG stove	4	.3%	2	.3%		
Other	40	2.9%	14	2.4%		
	1384	100.0%	589	100.0%	85	100.0%

Source : RBESS, MININFRA, 2009

Furthermore, different uses of energy savings have been discussed, such as soaking beans before boiling them, adding soda-ash to the beans, extinguishing the fire when the cooking is finished, cutting larger pieces of wood into smaller ones, and the use of a hot box. Some 60% of the respondents claimed to know about these practices and some 50% actually use one or more of these. Table 28 gives more details. The response rate for this question was very high, more than 95% of the households responded. It is a bit surprising to see that so many rural households claim to use a pressure cooker.

Table 28: Measures to reduce fuel consumption

	Know about it	Use it
dry firewood	85%	81%
use hotbox	79%	69%
extinguish fire when done cooking	65%	58%
cut larger pieces of wood	63%	57%
use pressure cooker	61%	58%
add soda ash	50%	36%
pre-soak beans	35%	21%
Other	10%	10%

Source : RBESS, MININFRA, 2009

Table 29 shows the reasons mentioned for not using an improved stove. The main reason for introducing improved stoves is to reduce the household's fuel consumption, but particularly high fuel consumption is cited most for not wanting to use an improved stove, particularly in the East and in Kigali! Other reasons cited are smoky and dangerous. About one-third of the households responded to this question, so any new effort to disseminate improved stoves should take these results into account, households want stoves that reduce fuel consumption even more, are not smoky, and either have a chimney or are portable (see Table 30).

Table 29: Reasons for not using an improved stove

	Dirty	Smoky	Dangerous	Uses a lot of fuel	Can burn house	Other	Total respondents	% of total sample
Kigali	0%	0%	36%	55%	0%	9%	11	23%
South	5%	4%	29%	15%	22%	25%	292	38%
West	5%	28%	21%	24%	7%	16%	212	26%
North	7%	39%	17%	10%	8%	19%	236	40%
East	7%	10%	8%	53%	9%	13%	300	40%
Total	6%	18%	19%	27%	12%	18%	1,051	35%

Source : RBESS, MININFRA, 2009

Table 30 shows what type of improved households prefer and how much they are willing to pay for this. It turns out that there are two main types, 52% of the respondents would like to have a fixed stove with a chimney and 28% a portable metal stove. A total of 62% of the households would like to have such stove, which is about the same number of household that already have an improved stove. Thus, some households must not be satisfied with the stove they have now, although they have not said so in the interview nor in the focus group discussions. They also indicated that they are willing to pay roughly 1500 FRw for an improved stove, or 3000 FRw in Kigali. Particularly the response in Kigali is interesting, with twice the amount indicated in the provinces; seeing this response indicates that there may be scope for 2nd generation improved stoves after all[8]!

Table 30: Type of desired improved stove

	Kigali	West	South	North	East	Total
Non-portable stove mud/clay + chimney	100%	36%	43%	69%	62%	52%
Non-portable stove, no chimney		3%	25%	8%	6%	11%
Portable clay stove		15%	12%	6%	6%	10%
Portable metal stove		47%	19%	17%	26%	28%
Respondents (percent of total sample)	21%	62%	59%	55%	73%	62%
average price willing to pay	3,725	1,284	1,531	1,547	1,790	1,560

Source : RBESS, MININFRA, 2009

Table 31 shows the perception respondents have of smoke on household health as reported by the respondents; charcoal using households see little impact on the health of household members but firewood and residues users do see a much higher impact. Table 32 shows what households did to alleviate smoke problems, whereby the single largest response was to change the kitchen environment, which includes cook in a different room or outdoors, add a chimney, a ventilation hole, or window, etc.

Table 31: Health problems from smoke

Fuel used	No health problem	Smoke is a health problem	Nr of respondents
Wood and Derived	61%	39%	2708
Charcoal	95%	5%	164
Residues	42%	58%	33

Source : RBESS, MININFRA, 2009

It thus appears that health issues are not perceived as very important in Rwanda. This is confirmed by the Focus Group Discussions, which showed that more than 60% of the respondents had no or limited knowledge about environmental issues. In addition, the main

[8] Much more efficient than normal improved stoves, modern looking, and manufactured in

problem identified from smoke was dirty walls (25% of the respondents) or air pollution (39%) and only 29% said health problems. The focus group respondents said that for 86% that improved stoves are a good way to reduce air pollution.

Table 32: Action to alleviate smoke problems

	Wood and Derived	Charcoal	Biogas	Residues	Nr of Respondents
Nothing	42%	92%	0%	30%	1327
Dried fuel before using	15%	1%	0%	3%	419
Used improved stove	4%	1%	0%	0%	97
Kept children away while cooking	1%	1%	0%	0%	21
Changed kitchen environment	39%	5%	100%	67%	1097

Source : RBESS, MININFRA, 2009

Improved stoves are widespread throughout rural Rwanda and although they appear to be used, there are nevertheless a few issues. The focus groups mentioned that improved stoves cannot be used with agricultural residues, which is the fuel used most widely. Thus, households also need to use a traditional stove on the side. The responses from the survey and the focus groups are a bit mixed, with households largely reporting that their improved stoves burn cleaner and use less fuel, but at the same time indicating that the main reason they don't like improved stoves is the high fuel consumption. They want to have a different type of improved stove, notably a fixed stove with a chimney (this would be to make combustion cleaner) and a portable stove (to allow agricultural residues to be used, and also to cook outside). The cooking tests have not been carried out correctly and it cannot be confirmed through user tests that improved stoves are more fuel-efficient, even though this had earlier been confirmed by KIST through laboratory tests.

It is recommended to take a renewed look at improved stoves in rural Rwanda. The stoves currently used do not commensurate with other improvements that are taking place and with further modernization of daily life; in fact, they pose a damper on rural economic development. There appears to be a market for modern stoves that can efficiently burn agricultural residues as well as firewood. More than 60% of the households indicated that they are ready to buy such a stove and so now it is a matter of ensuring that new types of stoves become available. To help understanding of efficiency and health issues, an awareness campaign should be realized and if needed a financing mechanism should be developed to assist households to acquire such modern stoves.

The Charcoal Issue

Charcoal is a basic necessity; it is the main urban fuel and its use is increasing in rural areas as well. To produce the charcoal that a household uses in one year about 6.6 t of wood are needed. This is under normal circumstances because if the charcoal is illegally produced, 10-12 t may be needed. This compares to the 2.5 t of wood that is required by a household using only firewood for cooking. For farmers this is not necessarily a bad situation: they are paid for the wood that is used for charcoal production, the price they get more or less reflects the cost of the wood. This simply means that there is simply a huge and predictable market for charcoal transactions. The total commercial wood use was estimated at 2.5 million t/yr[9], of which almost half is for wood for charcoal making (1.2 million t/yr). This shows how important charcoal is for the total woodfuel market.

[9] 1.2 m for charcoal making, 0.7 m for commercial firewood, and 0.57 m for non-energy wood.

For the users of charcoal the situation is less rosy. With the current (improved) stoves, there is no comparison between charcoal and firewood: the first is a modern fuel and the second is a traditional fuel; the use of charcoal is therefore likely to increase in the future. Since the alternatives are much more expensive, it is likely that they are stuck with charcoal for many years to come. Firewood users will at one point in the future each decide whether to switch to charcoal or not, and it is likely that there will be an increase in the users of charcoal in urban and rural areas.

Thus, charcoal is already big business in Rwanda, with more than $75 million turn-over per year. However, there are quite a few uncertainties: does it originate from natural forests, as some individuals or Ministries claim? Or is it produced in plantations, as some others say? This survey addresses how farmers look at charcoal production issues and at the wood needed for this. These questions are addressed below in Tables 33 and 34. The total response on these questions was limited, with 5-20% of the total respondents replying. Nevertheless, it gives an indication of the perception of rural households on these issues. The first question of relevance is whether charcoal is a good business opportunity for farmers or not; almost half of the respondents said "yes" and 17% said "no". Thus, charcoal appears to be seen as a good business opportunity, which had been observed as well during the 2008 urban BEST surveys. On the question whether charcoal is produced with wood from natural forests, 7% said yes and 22% said no whereas 71% didn't know; the verdict remains out, although more people say no than yes. However, at the same time we should be cautious with these figures as respondents might prefer to pretend to know the source of the charcoal if they think it is from natural forests or if it is otherwise produced illegally.

Table 33: Charcoal Issues

	Yes	No	don't know	Nr of respondents
Is charcoal a good business opportunity for farmers?	47%	17%	36%	448
Does charcoal come from natural forests	7%	22%	71%	390

Source : RBESS, MININFRA, 2009

A similar result was obtained with the question "where does the wood for charcoal production come from" (Table 34): the majority stated that it originates from farmers' plantations. Two different bases have been used to express this: all respondents (15% of the total sample) say that 27% comes from farmers' plantations and 4% from natural forests, whereas 60% doesn't know the origin. If only the responses are counted from respondents who appear to know where the wood for charcoal production comes from, almost 70 % states that it comes from farmers' plantations and 11% from natural forests.

As said before, although these data should be used with care given the low number of respondents, the trend is important: most of the charcoal appears to be produced with wood from farmers rather than with wood from natural forests. This is an important result that has been hinted on before, but for which there is no real proof other than these indications in Table 34.

Table 34: Origin of wood for charcoal production

	All respondents	Only those who said they know
Natural forests	4%	11%
Plantations – farmers	27%	69%
Plantations – community	1%	3%
Plantations – government	1%	3%
Plantations – district	0%	1%
Around farmers house or fences	0%	1%
Other	5%	13%
don't know	61%	-
Nr of respondents	415	160

Source : RBESS, MININFRA, 2009

Farmers think that charcoal is a good business opportunity and they appear to produce most of it already. However, often the farmer perceives the production to be illegal, e.g. because he has not or not yet received his cutting permit and he wants to cut this own tree now. Under these conditions he will not be able to produce charcoal efficiently, causing unnecessary waste of tree resources. The fact that charcoal is perceived to be an illegal product is best described by the experience of a donor who wanted to see the impact of charcoal. This donor organized a mission to the main charcoal producing areas in the South and was not able to see bags of charcoal, as these are now kept hidden to avoid problems with authorities. The supply chain has become a network of stakeholders who only do business with one another.

The regulatory framework needs to be adapted to increase the efficiency and promote transparent development of markets. The current legislation is still based on the assumption that wood and charcoal come from natural forests, but in reality wood and charcoal are produced from trees on plantations. The permit system forces people to work in illegality resulting in inefficiencies in the production chain which have a large impact on the resource base.

Box 1 below provides an illustration of the potential savings that are estimated from taking the charcoal production out of illegality; two scenarios are considered:

(i) part of the wood used is illegal and the charcoal production process is inefficient; the part that is not illegal, the production process is efficient;

(ii) all of the wood used for charcoal making is legal and charcoalers obtain normal conversion efficiencies that they usually obtain in real life when they are not harassed.

The realized wood savings are enormous: 30% less wood is needed to produce the same quantity of charcoal, or looked at it in another way, the possibility of producing 60,000 t more charcoal using the same quantity of wood. See Box 1 for details.

Box 1: Impact of illegal charcoal production on wood needed for charcoal production

Assumed Efficiencies of charcoaling process

- illegal production 8%
- legal production 14%

charcoal consumption 150,000 t/yr

Scenario 1 - 150k charcoal produced from:	natural forests	farmers plantations	public plantations	total
total supply	10%	45%	45%	
Total supply (t charcoal)	15,000	67,500	67,500	150,000
of which				
▪ illegal production	100%	25%	75%	
▪ legal production	0%	75%	25%	
wood needed (t)	187,500	572,545	753,348	1,513,393
average resulting charcoaling efficiency				*10%*

Scenario 2 – 150 kt charcoal produced from:	natural forests	farmers plantations	public plantations	total
total supply	0%	45%	55%	
Total supply (t charcoal)	-	67,500	82,500	150,000
of which				
▪ illegal production	0%	0%	0%	
▪ legal production	100%	100%	100%	
wood needed (t)	-	482,143	589,286	1,071,429
average resulting charcoaling efficiency				*14%*

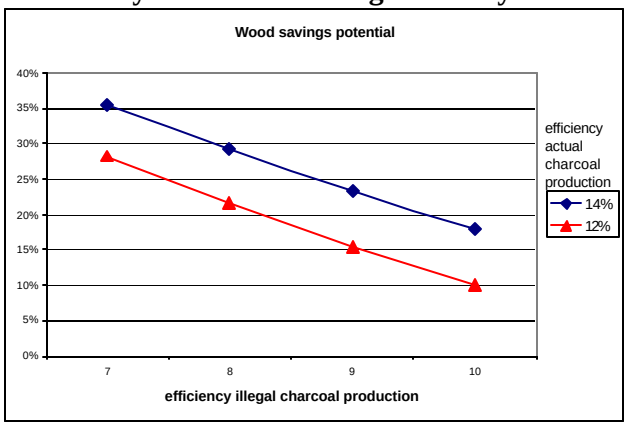
wood that is not cut when charcoal is fully legal (t/yr) 441,964

„ „ as percentage of the total volume of wood needed to make 150 kt of charcoal 29%

Figure 2 shows the results of a sensitivity analysis, whereby the efficiency of the illegal charcoaling process ranges from 7% to 10% and the normal charcoaler obtains between 12% and 14%[10]. The conclusion is that a reduction can be obtained of between 10% and 35% of the total quantity of wood needed for the production of charcoal. This would be the equivalent of 10-15% of the sustainable output of commercial woodfuels from all plantations combined in Rwanda if charcoal was not perceived to be illegal. A very large economic benefit can be obtained immediately as result of an intervention in the regulatory environment.

[10] 14% is obtained in Nyaruguru.

Figure 2: Sensitivity of the charcoaling efficiency on wood off-take



Based on this analysis, it is highly recommended that the Government reviews and addresses the current situation whereby farmers think that charcoal production is illegal. They have planted their trees in the expectation to earn money (see Table 12) and they should be allowed to decide when to cut trees in order to maximize their earnings. As soon as they see the profits of this operation, they will try to replicate or expand it! Farmers with wood plantations already said that they have more trees now than a few years ago (see Table 13), so reduced regulatory requirements are likely to only enhance this phenomenon.

Estimation of rural woodfuel consumption

The intention of the rural household energy survey was to have three different measures to estimate rural consumption of wood energy. The three measures would have provided three different and independent estimates, for comparison and cross checking. The first measure was through the questionnaire which had a number of questions to determine the use of different biomass fuels, such as charcoal, firewood (purchased and gathered), and various agricultural residues and dung. The second measure was a controlled cooking test, whereby in different locations 6-8 households would have been asked to prepare a standard meal and measure the energy use; half of the households would use a traditional stove and half an improved stove. The third measure was requested by FAO and consisted of asking a number of households to put aside a quantity of fuel for weighing and tell the surveyor for how many days this fuel can be used. However, due to inconsistencies and other anomalies, the three measurements did not provide the desired results. The survey itself also did not produce results as the enumerators were not able to note down the data for the fuel consumption (only 35% response rate). The controlled cooking tests allowed households to produce any meal they wanted, with the result that there no comparison was possible between the different households and the results were not useful. The third measure seems to give high consumption data.

In the weighing sample, 14 households (2.5%) used charcoal, with a daily average use of 2.4 kg/person; this is even higher than in Kigali where average daily consumption is less than 0.5 kg/person. The average wood consumption is 1.8 kg/person/day, which also might be on the high side, particularly since all households also use residues. The daily consumption for the 16 different fuels varied widely, from 0.3 kg/person for Ibisigazwa (agricultural residues) to 2.7 kg/person for Gereveriya (Grevillia); for Eucalyptus 1.8 kg/person was found (Inturusu), used by 83% of the sample.

Table 35: Results of fuel weighing

	Kigali	East	West	South	North
Nr of households using wood	7	97	105	177	91
Average daily wood consumption (kg/pers)	2.6	1.6	1.6	2.4	1.4
Nr of households using charcoal	0	1	5	1	7
Average daily charcoal consumption (kg/pers)	-	1.9	1.5	1.7	3.3

Source : RBESS, MININFRA, 2009

Households in Kigali and the Western Province use the most wood, ranging from 2.4 – 2.6 kg per person and per day, see Table 35; in the other provinces the use of wood is 1.4 – 1.6 kg per person per day. There are very few charcoal observations, and these are all high.

Assuming that the average is correct, the annual per capita firewood consumption is 670 kg; in addition, households will also use residues, but no estimate was made. In addition, the information is not available about the origin of the wood, whether it is collected or purchased, and whether households will use this quantity throughout the year. It is quite possible that households stock up on wood but do not use it every day, in which case the obtained data are an over-estimation.

An estimation of the total consumption of firewood based on survey data is given in Annex 1. The choice of 1st, 2nd, 3rd, and 4th type of fuel and the percentage of households using these fuels are tabulated while incorporating the charcoaling efficiency. Only the use of firewood obtained from cutting whole trees is considered, i.e., wood for charcoal making is counted for 100%, purchased firewood is counted for 100%, but gathered firewood is counted for 33% as quite a bit is dead wood, residual wood, or wood from the homestead trees are used rather than wood that is cut on purpose from plantations. This gives a total demand of about 1.4 million t of wood, or 2.1 million m^3 per year.

This should be compared to the total available wood from private and public plantations, which are now estimated at about 281,000 ha[11], and assuming that all wood has to come from such plantations. The Forest Inventory showed that the average annual productivity is 7 m^3/ha, or 4.5 t/ha/yr, giving a total production of about 1.3 million t/year. At this rate, the combined rural and urban demand cannot be met from plantations, unless the productivity more than doubles triples. However, it must be recognized that these estimations are very rough, with a lot of uncertainty at all levels. In fact, a better estimation can only be done after a much more specific survey into the rural consumption of wood and residues.

Such a survey should consist of a number of household visits in different geographical zones, whereby an enumerator remains in the household for a number of days to describe, understand, and quantify the energy consumption patterns. This will be a complicated affair, as the patterns change with each season.

What is important is to realize some of the main messages from the rural survey: (i) farmers plant trees because they want to earn more money; (ii) farmers who already have a tree plantation state that they have more trees now than 3 years ago; (iii) the focus group discussions showed that 11% of the households find that there is not enough wood to be collected, and the survey showed that 14% of the households collected wood while "the owner didn't like it" (i.e., illegal collection); these two observations convey the same message, that a small percentage of the households does have a problem obtaining enough

[11] Available public plantations: 104k ha; institutional plantations: 23k ha; private plantations: 100k ha; in addition, some 54k ha are destined for protection.

firewood; (iv) 70% of the households say that their fuel can be obtained without any problem and 16% that it can be obtained without money; and (v) more than 75% of the households collect all their woodfuel from their own land and homestead and reported a zero collection time. Thus, some problems exist but these appear to be minor for the time being.

Conclusions and recommendations for the biomass energy strategy

Given the above observations, it appears that although there are some problems with the sustainable supply of biomass energy in rural Rwanda, these problems appear to be not as large and as threatening as in some other African countries. Much of the wood In Rwanda comes from man-made plantations and a sustainable market for wood products appears to be functioning. Despite many surveys, the Forestry Inventory, and several forestry projects it is still not exactly known how much wood is produced, where and in what form. The same is true for quantities of fuels used by rural households where data are lacking. The survey did unfortunately not really clarify these issues and gave quite mixed result.

Rural biomass supply seems to be in a semi stable equilibrium at the moment and the levels of supply and demand could well be in approximate balance. This situation is caused by the fact that rural households mainly use low grade fuels such as agricultural residues rather than firewood. Rural households may prefer this for cost reasons but it is not a desirable long-term economic solution as it deprives soils from much needed nutrients and it creates unhealthy conditions in the household. When incomes rise and more health awareness is gained, the demand for charcoal or purchased firewood in rural areas may increase and disturb the current semi stable balance. If at the moment the present private and public plantations can still satisfy the demand for biomass energy is unknown, although it is highly likely that any larger-scale increased demand for commercial wood products can no longer be met in a sustainable manner. That's when the real supply problems will start.

Interventions are therefore needed now to avoid problems in the future. It is not too late yet, but the issues need to be taken more seriously from now on to prepare for a sustainable use of biomass for many years to come.

This will require, as already outlined in the urban BEST, the following action to be taken:

(i) legislation should reflect and facilitate the most efficient woodfuel supply chain as possible, with a greater participation of the stakeholders at local level

(ii) end-users should use the most energy efficient equipment possible and should have access to substitution energy sources;

(iii) the productivity of the existing plantations should be increased, including renewal of old stock plantations;

(iv) the supply chain should be made as efficient as possible;

(v) The institutional framework to deal with Rwanda's largest source of energy should be strengthened.

Annex 1 – Estimated rural woodfuel demand

Assumptions

1. *use of fuels in Kigali, per year*:

- charcoal 930 kg/hh or about 2.5 bags/month
- firewood purchased 2500 kg/hh; cut fresh wood
- firewood collected 30% is cut fresh wood, consumption is the same as for hh that purchase
- charcoaling efficiency 12%

2. *use in rural areas, per year*

- charcoal 60% of urban consumption, because they will also use other fuels
- firewood purchased 50% of urban consumption, because they will also use other fuels
- firewood collected 30% of the purchased consumption (as in urban)
- „ „ 15% of the households cut illegally
- „ „ 20% has a problem

- for the second fuel, consumption is 50% of the consumption for the first fuel
- „ 3rd 50% „ 2nd
- „ 4th 50% „ 3rd

3. *Distribution of fuel use*

	1st Fuel	*2nd*	*3rd*	*4th*
residues	3%	48%	60%	53%
fw gathered	65%	25%	23%	26%
fw purchased	27%	17%	13%	15%
charcoal	5%	9%	4%	6%

Source: RBESS survey

4. *Quantity of fuel per hh*

	1st Fuel	*2nd*	*3rd*	*4th*
charcoal	558	279	139.5	69.75
wood for charcoal	4650	2325	1163	581
firewood purchased	1250	625	313	156
firewood collected (kg)	375	188	94	47

5. *Total wood consumption*

	1st Fuel	*2nd*	*3rd*	*4th*
wood for charcoal	651000	130200	15113	8719
firewood purchased	1013750	65625	13750	6250
firewood collected	721500	28875	7500	3188
total wood offtake (t)	2386250	224700	36363	18156

Total for the sample: 2,665,469 kg, with a specific consumption of 900 kg/yr per hh; there are 1.5 million rural hh, giving a total fresh cut wood in rural areas of 1,350,288 t of wood, or 2,077,366 m3 of wood.