Economic evaluation of the improved household cooking stove dissemination programme in Uganda

Dissemination of the Rocket Lorena stove in the districts of Bushenyi and Rakai and dissemination of the improved charcoal stove in Kampala in the years 2005 and 2006

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Abbreviations

ARI	acute respiratory infection
ALRI	acute lower respiratory infection
CBA	cost-benefit analysis
CEA	cost-effectiveness analysis
CH_4	methane
CO_2	carbon dioxide
COPD	chronic obstructive pulmonary disease
EAP	Energy Advisory Project
EUA	EU allowance
EUR	Euro
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (German Agency for Technical Cooperation)
HERA	GTZ Household Energy Programme
HH	household or households
kg	kilograms
LPG	liquefied petroleum gas
MJ	mega joules
NPV	net present value
p. a.	per annum
USh	Uganda shilling
t	metric tons
WHO	World Health Organization

Currency Conversion: 1 EUR = 2,357 USh (December 2006)

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Foreword

Since 1999, the German Agency for Technical Cooperation (GTZ) has been cooperating with the Ministry of Energy and Mineral Development (MEMD) of the Republic of Uganda to support the Energy Department (ED) through the Energy Advisory Project (EAP) to develop and implement successful energy policies and strategies. The programme has been co-funded by the Dutch Directorate-General for International Cooperation (DGIS) since 2005.

One of the components of the Energy Advisory Project (EAP) has been the promotion of improved firewood- and charcoal- saving stoves. Districts with extreme wood scarcity were selected for scaling up the firewood-saving Rocket Lorena stove dissemination in rural areas. In the southwest and central districts of Bushenyi and Rakai a total of 211,220 Rocket Lorena stoves were disseminated from 2005 to 2006. In and around Kampala the project disseminated 8,224 improved charcoal cooking stoves during the same period.

Improved stove dissemination programmes promote not only the use of improved stoves, but also the application of health and energy-related techniques through the households when using the improved stoves, i.e. they provide energy-saving tips and information about measures which can be undertaken to protect the health of the family member during the cooking and wood-burning process.

This study presents the results of the economic evaluation of the improved household cooking stove dissemination programme of the years 2005 and 2006. The economic analyses assessed the economic benefits for the households using the improved stoves and the economic benefits derived from health and environmental impacts due to the use of the improved stoves on national and global level. It assessed the economic efficiency of the stove dissemination programme from an overall economic view as well as that of the Rocket Lorena stove's use for the individual household.

The Executive Summary provides the main results and key assumptions of the economic evaluation.

The favourable results of the economic evaluation show that the improved stove dissemination programme in the context of the EAP was very successful. They also prove that improved household cooking stove dissemination programmes yield high returns compared with the expenses for these programmes.

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Executive Summary

The improved household cooking stove dissemination programme in the context of the Energy Advisory Project (EAP) started in March 2005. The project has been implemented by the German Agency for Technical Cooperation (GTZ) on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) in cooperation with the Ugandan Ministry of Energy and Mineral Development (MEMD). A total of 211,220 Rocket Lorena stoves were disseminated by the end of 2006, 122,933 stoves in the district of Bushenyi and 88,287 in the district of Rakai. In and around Kampala 8,224 improved charcoal cooking stoves were in use by the end of 2006.

The economic evaluation assessed the economic benefits for the households using the improved stoves and the economic benefits derived from health and environmental impacts on national and global level, and provided a comparison between benefits and costs. The economic efficiency of the stove dissemination programme from an overall economic view, and that of the Rocket Lorena stove's use for the individual household, are favourable. It could be shown that improved stove dissemination programmes yield high returns compared with the expenses for these programmes.

The benefit-cost ratio compares the present value of the benefits with the present values of the costs. The investment of one EUR yields a return of 25 EUR, considering all economic benefits (fuel saving, cooking time, health, soil fertility, emissions); the investment of one EUR gives a return of 13 EUR, taking only the benefits due to fuel savings into account.

Economic analyses effectuated and general assumptions

The economic evaluation comprised a cost-benefit analysis (CBA), a cost-effectiveness analysis (CEA), the calculation of other macroeconomic criteria and a microeconomic analysis revealing the economic benefits of firewood savings for the individual household.

The cost-benefit analysis considered benefits due to fuel savings, reduced cooking time, better health, preservation of forest reserves, greenhouse gas reduction and benefits of preventing declines in soil fertility.

The economic analyses are based on conservative hypotheses and assumed that the values of all parameters remain constant in future years (from 2006). A utilization rate of the firewood-saving stoves of 90% was applied. It reflects the possibility that in the future not all disseminated stoves will be used or replaced after their average life span of four years. Furthermore, it was assumed that 5% of the households use two improved stoves.

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Project and stove costs considered

The total annual expenses for the improved household cooking stove dissemination programme amounted to 413,000 EUR in 2005 and 2006. For 2007 and the following years the annual costs for monitoring and retraining were estimated to be 17,500 EUR. The average cost of the Rocket Lorena stove was 4 EUR (life span: 4 years), that of the charcoal-saving stove 10 EUR (life span: 3 years).

Number of stoves and households considered

Number of improved stoves and households by the end of 2006	Improved stoves disseminated	Improved stoves in use	Households using improved stoves
Firewood-saving stoves	211,220	190,098	180,593
Charcoal-saving stoves	8,224	8,224	7,813
Total	219,444	198,322	188,406

The economic analyses considered approximately 190,000 households using 200,000 improved cooking stoves from 2006 onwards.

Fuelwood and charcoal consumption and savings

Annual fuel consumption per HH and total annual savings in 2006	Using the traditional stove	Using the improved stove	Savings of all HH using improved stoves
Firewood	2,044 kg	920 kg	203,023 t
Charcoal	444 kg	200 kg	1,908 t

The mean household size came to 5 persons. The average fuel saving rate for both stoves was 55%. It was assumed that 50% of the amount of firewood consumed by all households was purchased and 50% collected. Conversely, we assumed that 50% of the firewood savings were savings in collected firewood and that these savings resulted in a corresponding reduction of firewood collection time. The amount of charcoal saved was converted into a corresponding firewood saving amount by assuming that 10 kg of firewood is needed to produce 1 kg of charcoal. The total annual firewood savings achieved with the use of the improved firewood and charcoal stoves amounted to 222,103 tonnes for 2006 and the coming years.

Shadow wage for time saved and fuel prices

A shadow wage for time saved was applied in the economic analyses. It was assumed that 50% of the time saved by the households would have been used for productive activities by the women, such as farming and household activities improving the living conditions of their families, participating in social community activities as well as income generation. A monetary value was only assigned to these

productive time-periods. It was derived from the average monthly income of the households using the Rocket Lorena and amounted to 0.10 EUR per hour. The corresponding shadow price of firewood collected was 0.01 EUR/kg.

The fuel prices applied were 2006 market prices, 0.04 EUR/kg for firewood, 0.09 EUR/kg for charcoal and 1.32 EUR/kg for LPG.

Economic benefits considered in the CBA

The economic benefits due to fuel savings in 2006 were as follow:

Avoided fuel costs; collected firewood savings (valued at 0.01 EUR/kg)	Economic Benefits in EUR in 2006	Economic Benefits in million EUR in 2006	Reduced firewood collection time in million hours in 2006
Firewood purchased	4,263,478	4.3	
Firewood collected	1,007,057	1.0	20
Total firewood	5,270,535	5.3	
Charcoal purchased	171,719	0.1	
Economic benefits due to fuel savings	5,442,254	5.4	

In 2006, the economic benefits due to fuel savings were 5.4 million EUR. In 2005, they amounted to 2.6 million EUR.

The economic benefits of 2006 considered in the CBA were as follows:

Economic benefits considered (time saved valued with shadow wage)	Economic Benefits in EUR in 2006	Economic Benefits in million EUR in 2006	Time saved in million hours in 2006
1. Benefits due to fuel savings	5,442,254	5.4	
2. Benefits due to reduced cooking time	1,499,600	1.5	30
3. Benefits due to better health	770,771	0.8	5
4. Benefits due to preserved forest cover	781,801	0.8	
5. Benefits due to better soil fertility	75,604	0.1	
6. Benefits due to CO_2 and CO_4 reduction	1,754,610	1.7	
Total economic benefits	10,324,640	10.3	

The total economic benefits were 10.3 million EUR in 2006 and 4.9 million EUR in 2005.

Benefits due to reduced cooking time when using the Rocket Lorena stove:

Women were 1.82 hours less in the kitchen or near the stove. 25% of this time reduction, namely 0.455 hour per day, was assumed to be time which could be effectively considered as time saved.

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Benefits due to better health when using the Rocket Lorena stove:

Exposure to indoor air pollution from the combustion of firewood is an important cause of morbidity and mortality of women and small children. It is in particular responsible for respiratory and eye diseases. The use of the Rocket Lorena stove significantly reduces the smoke in the kitchen, resulting in better health conditions for the family members. The CBA considered economic benefits due to better health derived from the reduction of acute respiratory and eye diseases of women and small children as well as burns. Economic benefits derived from saved time and costs for health care were taken into account as follows:

Economic value of time saved for the households in 2006: 268,723 EUR

Avoided costs for the households in 2006: 361,186 EUR

Avoided costs for the public health system in 2006: 140,863 EUR

Benefits due to the preservation of forest resources:

It was assumed that 10% of the firewood savings preserved forest resources and that the value of forest reserves equals the derived afforestation costs of 0.0352 EUR per kg firewood.

Benefits of preventing declines in soil fertility:

It was assumed that 5% of the firewood consumed comes from cut and damaged trees of woodlands, inducing a reduction in soil fertility of 10%. Conversely, it was suggested that the preservation of woodlands increases the soil fertility resulting in a higher agricultural production which can be assigned a monetary value. Since all base data had to be derived from studies not effectuated in Uganda (Anderson, 1988; Habermehl, 1994), the average values were formed in a very conservative way.

Benefits due to greenhouse gas reduction (CO_2 and CO_4):

It was assumed that the economic value of one tonne of CO_2 avoided due to reduced firewood burning is the price of the traded EUA (EU Allowance) for one tonne of CO_2. (5 EUR was applied). For methane emissions, we assumed a 20 times higher price than for carbon dioxide emission derived from the 20 times higher potency of methane compared with carbon dioxide.

Results of the CBA

The main results of the key model calculations based on a period of 10 years, a discount rate of 10% and fuel savings of 55% were as follows:

Period of 10 years; discount rate: 10%	Model 9 (considering all economic benefits)	Model 10 (considering only fuel savings)
Net present value in million EUR	56.97	28.42
Benefit-cost ratio	24.55	12.75
Internal rate of return	1,158%	602%

Regarding the stove dissemination programme as an investment project, the net present value represents the sum of all costs and benefits derived from this programme during 10 years and valuated at the point of the programme's start (2005). It amounts to 57 million EUR. The present value of the economic benefits is 59.39 million EUR, whereas the present value of the costs comes to only 2.4 million EUR.

The benefit-cost ratio compares the present value of the benefits with the present values of the costs. The investment of one EUR yields a return of 25 EUR, considering all economic benefits; the investment of one EUR gives a return of 13 EUR, taking only the benefits due to fuel savings into account.
The internal rate of return is the rate of interest earned on the capital (cost of the stove dissemination programme) tied up in the programme during the period under consideration. The costs of the stoves were considered as recurrent annual costs. The internal rates of the stove dissemination programme are very high compared with successful private investment projects.

The present values of the different economic benefits were as follows:

Period of 10 years; discount rate: 10%	Benefits due to fuel savings	Benefits due to reduced cooking time	Benefits due to better health	Benefits due to preservation of forest reserves	Benefits of preventing declines in soil fertility	Benefits due to greenhouse gas reduction	Total benefits
Present value (million EUR)	30.84	8.51	4.37	4.42	1.33	9.92	59.39
Percentage of total benefits	51.92%	14.32%	7.36%	7.45%	2.24%	16.71%	100.00%

Alternative calculations:

The following tables present the main results of two alternative calculations. Model 7 and 8 are based on the most pessimistic assumptions applied in the CBA, Model 9 and 10 on optimistic assumptions.

Period of 5 years; discount rate: 10% Saving rate: 40%	Model 7 (considering all economic benefits)	Model 8 (considering only fuel savings)
Net present value in million EUR	25.67	11.52
Benefit-cost ratio	15.77	7.63
Internal rate of return	916%	434%

Period of 20 years; discount rate: 3% Savings rate: 55%	Model 9 (considering all economic benefits)	Model 10 (considering only fuel savings)
Net present value in million EUR	149.51	73.56
Benefit-cost ratio	33.30	16.89
Internal rate of return	1,161%	604%

Results of the CEA

The CEA values the benefits in natural units. The dynamic cost-effectiveness was calculated by dividing the discounted annual amounts of firewood savings by the discounted annual costs (project and stove costs). Firewood and charcoal savings of 55% were considered. The cost-effectiveness ratios of the stove dissemination programme were as follows:

Cost-effectiveness in kg/1 EUR

Period considered	Discount rate: 10%	Discount rate: 3%
5 years	422	478
10 years	519	605
20 years	723	1043

The expenditure of one EUR results in firewood savings of 519 kg (10 years; 10% discount rate).

Other macroeconomic criteria

Regional economic efficiency of firewood savings in the districts of Bushenyi and Rakai

The districts Bushenyi and Rakai had a population of 1,373,722 in 2006. More than 99% of the 274,744 households in these two districts used firewood for cooking purposes. Under the assumption that all of these households were using the three-stone fire, the total firewood consumption for cooking would have been 561,578 tonnes in 2006. Assuming a utilization rate of 90% for the Rocket Lorena stove, a total of 180,593 households or 65% of the households in these two districts used 190,098

firewood-saving stoves in 2006 and saved 203,023 tonnes of firewood. This means that 36% of the firewood consumption for cooking purposes of all households could be saved in these two districts in 2006.

Comparing areas of forest cover with firewood savings

1. Areas of forest cover preserved in 2006:

Since 10% of the firewood consumed for cooking purposes came from the felling of forest cover, it was assumed that 10% of the firewood savings preserved forest resources. Converting firewood savings into woodland (hypotheses: 17m^3/ha stock density, wood weight of 850 m^3/kg, 30% losses), the 222,103 tonnes of fuelwood saved preserved 2,196 ha of forest cover.

2. Area of forest cover equivalent to the total firewood savings of 2006:

This criterion was calculated in order to illustrate the extent of total fuelwood savings achieved. It should not lead to the conclusion that the savings in fuelwood actually prevented the cutting of wood of such a large area. The stock volume of a forest cover of 21,958 ha would have been equal to the total amount of fuelwood saved in 2006.

Firewood savings valued at shadow prices for fuelwood

Despite the shortage of fuelwood and the high ecological value of tree stands, fuelwood is treated almost like a so-called “free” good which is available in random supply. Shadow prices for the fuelwood were calculated based on the market price of the substitution product LPG and on afforestation costs in order to show which economic values from a macroeconomic view could be assigned to the total amount of firewood saved. These values were as follows:

Firewood savings valued at afforestation costs: 7,818,011 EUR in 2006

Firewood savings valued at the LPG-shadow price: 24,057,064 EUR in 2006

The higher heating value of LPG and the higher cooking efficiency of an LPG cooker were considered.

Results of the microeconomic analysis for the individual household

The economic calculations were carried out for three different household types: a) firewood is only purchased, b) firewood is only collected, c) firewood is purchased at 50% and collected at 50%.

The following table presents the main results:

Economic criteria	a) Household purchasing firewood	b) Household collecting firewood	c) Household collecting and purchasing firewood (50%/50%)
Payback period in months	1	4.4	1.7
Net benefit during stove’s life	185 EUR	41 EUR	113 EUR
Rate of return (factor)	46	10	28
Annual avoided fuel costs	47 EUR	11 EUR	29 EUR
Ratio of annual avoided fuel costs to mean annual income	19%	4%	11%

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The **payback period** of the stove is the amount of time it takes for cumulative savings in the firewood expenses of the household to offset the initial costs of the stove.

The **net benefit during stove's life** is the sum of the total savings in fuelwood costs during this period minus the costs incurred for the stove during the same time period. The **rate of return** indicates by what factor this net benefit exceeds the expenses for the stove. During the life of the improved stove of four years, the household that only purchased its firewood will have a net benefit of 185 EUR. The avoided costs due to firewood savings minus the total cost of the stove will be 46 times higher than the costs spent for the stove.

Ratio of annual avoided fuel costs to mean annual income:

The approximately highest income per month of 50% of the households in Bushenyi was 21.21 EUR (254 EUR p.a.). The firewood savings amount to 47 EUR in the second year of the stove's use for the household purchasing firewood and represent 19% of this average annual income.

Annual costs of cooking with LPG compared to cooking with the Rocket Lorena stove:

The total annual costs of cooking with the Rocket Lorena stove (40 EUR) were compared with the total annual costs of cooking with a 'one-burner' LPG cooker. Based on the assumption that a household can cook all dishes with a 'one-burner' gas cooker and that a continuous supply of LPG is assured in the rural areas - which in reality would not be the case, the calculated total annual costs of cooking with an LPG cooker amount to 238 EUR per household and thus are approximately 600% of the total annual costs of cooking with the Rocket Lorena stove. Moreover, the majority of the households in the districts of Bushenyi and Rakai cannot afford to purchase LPG cookers and the required accessory devices, entailing costs of 90.55 EUR per unit.

The firewood-saving stove Rocket Lorena is the best alternative for the households to reduce the burden of energy costs as well as the burden of disease due to indoor air pollution caused by the open fire.

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1 Introduction

The improved household cooking stove dissemination programme in the context of the Energy Advisory Project (EAP) started in March 2005. The project has been implemented by the German Agency for Technical Cooperation (GTZ) on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) in cooperation with the Ugandan Ministry of Energy and Mineral Development (MEMD).

A total of 211,220 Rocket Lorena stoves were disseminated by the end of 2006, 122,933 stoves in the district of Bushenyi and 88,287 in the district of Rakai. The project also comprised the dissemination of 8,224 improved charcoal cooking stoves from 2005 to 2006 in and around Kampala.

The economic evaluation comprises a cost-benefit analysis (CBA), a cost-effectiveness analysis (CEA), and the calculation of other macroeconomic criteria such as the calculation of the regional economic efficiency of firewood savings, the areas of forest cover equivalent to firewood savings and shadow prices for firewood savings from an overall economic view. It also includes so-called microeconomic calculations revealing the economic benefits of firewood savings for three different household types.

The methods applied in the economic analyses have been described in the “The Economics of Improved Stoves, Guide to micro- and macroeconomic analysis and data assessment” (Habermehl, 1999).

The economic analyses are based on conservative assumptions and estimates. They considered only the costs and benefits of the number of improved household stoves disseminated until the end of 2006 and still in use.

The CBA is both an ex post and an ex ante analysis. On the one hand, it assessed the economic benefits achieved in the years 2005 and 2006. On the other hand, it assessed the relation between the economic benefits and the costs (project and stove costs) over a longer period, also including future years (periods of 5, 10 and 20 years were considered).

The CBA considered economic benefits derived from
- avoided fuel costs and reduced firewood collection time due to fuel savings,
- reduced cooking time and better health due to the use of the Rocket Lorena stove,
- national and global impacts derived from firewood and charcoal savings; in particular, the prevented declines in soil fertility, the preservation of forest reserves and the greenhouse gas reduction.

Aside from these benefits, the use of the improved firewood stoves and the practise of efficient cooking techniques as well as the lower number of fuelwood collection trips generate further

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advantages which also improve the living conditions of the family and especially that of the women and children. Other important advantages which were not considered in the economic analyses are:
Improved nutrition and hygiene
Less pain and physical stress caused by smoke, burns, accidents and heavy loads
Reduced exposure to unsafe conditions and therefore to violence.

Important positive effects of the stove dissemination project itself for the local population that were also not considered in the economic analyses are:
Income- and employment-generating effects
Acquisition of new skills and knowledge
Creating and raising the level of environmental awareness
Improvement of the community's life
Enhancement of the social status of women
Greater social recognition for women's work and tasks
Increasing the time available for children for learning and playing
Protection of water, flora and fauna and maintaining the biodiversity
The project's experience will set an example for future projects in the region.

All data and assumptions used in the economic analyses were based on results of socio-economic, health and household energy surveys, data collection and monitoring surveys, statistical documentations, impact studies and field tests on fuelwood consumption, effectuated in Uganda. Only in a few cases were they based on estimates derived from the results of studies effectuated in other countries, as for example, studies evaluating the health impacts of improved stove use.

In particular, "The impact monitoring study of the Rocket Lorena stove dissemination in Bushenyi district" by Britta Malinski (see References) provided reliable statistical data to derive base data applied in this economic evaluation study.

The author wishes to thank the programme officers of the EAP, Ulrich Laumanns and John Kasagga Kuteesakwe, for collecting and deriving base data and average values applied in the economic analyses. Their good knowledge of the local and specific project conditions made it easy to obtain realistic and precise base data.

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2 General base data

This chapter presents general base data used in the economic analyses. Specific base data and average values applied in the CBA are presented in Chapter 3.3. The project and stove costs can be found in Chapter 3.4.

2.1 Number of stoves and households considered

The number of improved cooking stoves disseminated in 2005 and 2006 were as follows:

Household stoves	2005	2006	Total
Firewood-saving stoves	101,402	109,818	211,220
Charcoal-saving stoves	2,326	5,898	8,224

Based on monitoring studies and reports, it was conservatively supposed that 5% of the households used two improved stoves. Therefore, the number of households reached with improved cooking stoves amounted to 208,472 by the end of 2006. Of this total, 200,659 households bought or installed Rocket Lorena stoves and 7,813 households bought improved charcoal-saving stoves.

The so-called “number of people served on household level” with Rocket Lorena stoves amounted to 1,003,295, that of “people served with improved charcoal stoves” to 39,064.

In order to be more pessimistic than optimistic in our assumptions, we introduced a utilization rate of 90% for the Rocket Lorena stoves in our calculations. This utilization rate considers the possibility that not all disseminated stoves may be used in the future; although in reality there was no indication that this was the case or could be the case in coming years. It also reflects the possibility that a few households would not replace the Rocket Lorena stove after its life span of four years.

Therefore, the number of households using Rocket Lorena stoves amounts to only 180,593 in the economic analyses from 2006 onwards. Including the households with charcoal-saving stoves (7,813), the total number of households using improved stoves was 188,406. The number of improved stoves from 2006 onwards amounted to 198,322, i.e. 8,224 charcoal stoves and 190,098 firewood-saving stoves.

In general, it can be said that the economic evaluation considered approximately 190,000 households using 200,000 improved stoves from 2006 onwards.

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2.2 Fuelwood and charcoal savings of the improved stoves

The fuelwood consumption of households using the open fire as well as the Rocket Lorena stove varies over the course of a year and from one location to another. Seasonally influenced crop residues as well as dung are also used in various quantities as additional fuel besides firewood. Moreover, local eating and cooking habits as well as firewood scarcity influence the amount of fuelwood consumed. Furthermore, numerous other factors influence the firewood consumption of the individual household, such as the size of the family, its living standard, the fuelwood price, the available supply of firewood, the moisture content of the wood and the varieties of wood used.

In deriving the average value for the per capita fuelwood consumption, all the above-mentioned factors were considered as well as the fact that on average, half of the households also used the three-stone fire in addition to the Rocket Lorena stove, but only to a very small extent.

The mean household size came to 5 persons in the regions where the improved stoves were disseminated. The per capita consumption of firewood was 1.12 kg per day, when the traditional stove, i.e. the three-stone fire, was used. Thus, a household using a three-stone fire consumed 5.6 kg fuelwood per day on average; the annual firewood consumption amounted to 2,044 kg.

If correctly installed and properly used, the Rocket Lorena stove saves at least 60% of the firewood that would be consumed by the three-stone fire. A good number of households achieved these fuelwood savings.

It must be pointed out that the firewood savings achieved with the use of the Rocket Lorena stove is always the result of the use of the stove and a wide range of energy-saving tips.

The average firewood savings were 55% and reflected the circumstance that the firing technique, the preparation of firewood and the stove itself were sometimes inefficient. Based on the savings rate of 55%, a household consumed 2.52 kg firewood per day and had savings of 3.08 kg. The annual savings amounted to 1,124 kg per household.

The total amount of firewood saved due to the use of the Rocket Lorena stoves came to 97,467 tonnes in 2005 and 203,023 tonnes in 2006.

It was assumed in the economic analyses that the fuel savings achieved with the improved stoves in the years 2005 and 2006 were achieved with the number of improved stoves actually in use at the end of the respective year. This simplification in the calculations is justified by the fact that a utilization rate of 90% for the improved stoves was also applied in the years 2005 and 2006.

A household using the traditional charcoal stove consumed 1.2165 kg per day on average and 444 kg per annum. The daily amount of charcoal per household using the improved charcoal stove was

0.5474 kg on average. The annual savings of the 7,813 households considered in the economic analyses came to 1,908 tonnes per annum.

The following table gives an overview of the annual fuel consumption per household and the total annual fuel savings in 2006:

Annual fuel consumption per HH and total annual fuel savings in 2006	Using the traditional stove	Using the improved stove	Savings of all HH using improved stoves
Firewood	2,044 kg	920 kg	203,023 t
Charcoal	444 kg	200 kg	1,908 t

In the CBA, the CEA and the other effectuated macroeconomic analyses (see Chapters 6, 7, 8) we converted the amount of charcoal saved into a corresponding firewood savings amount by assuming that 10 kg of firewood is needed to produce 1 kg of charcoal (Kisakye, 2006).

The firewood savings due to the use of the charcoal-saving stoves amounted to 5,396 tonnes in 2005 and 19,080 tonnes in 2006.

The annual firewood savings achieved with the use of the improved firewood and charcoal household stoves amounts to 222,103 tonnes for 2006 and the coming years.

The fuel saving rate of 55% was applied for both stoves in the economic analyses. Alternative calculations based on firewood savings of 40% for the Rocket Lorena stove were carried out in the framework of the cost-benefit analysis.

2.3 Fuel prices and shadow wage for time saved

The fuel prices applied in the economic analyses were based on 2006 market prices.

The average market price of the firewood in the stove dissemination areas amounted to 0.042 EUR per kilogramme. The price of one kilogramme charcoal was 0.09 EUR. The price for one kilogramme LPG amounted to 1.32 EUR.

In order to assess the economic benefit of the time saved for the households and the national economy, a shadow wage for half of the time saved was introduced, i.e. a monetary value was assigned to 50% of the time saved.

It reflects the consideration that even if the household members did not have to be able to transfer the time saved directly into money-making activities, they would have used it at least for other highly

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valued productive activities - this from the viewpoint of the economy as a whole as well as from the households' viewpoint.

In other words, it was assumed that 50% of the time saved would have been used for productive activities by the women, such as farming and household activities improving the living conditions of their families, child caring, participating in social community activities as well as income generation. A monetary value was only assigned to these productive time-periods and was called “shadow wage”.

The shadow wage was derived from the mean monthly income of a household in the stove dissemination areas of Bushenyi district (Malinski, 2006), which amounted to 45.28 EUR per month. Based on the conservative hypotheses that two persons earned this income within 30 days and assuming an 8-hour working day, the shadow wage for labour came to 0.10 EUR per hour.

The corresponding shadow price of firewood collected was 0.01 EUR/kg.

3 Scope of the CBA and CEA

3.1 Time horizon

The cost-benefit analysis (CBA) as well as the cost-effectiveness analysis (CEA) were conducted over a period of 10 years. Alternative calculations were carried out for periods of 5 and 20 years.

All benefits and costs were discounted to the beginning of the year 2005, which was the first year of the dissemination programme.

3.2 General assumptions

The economic analyses were based on the hypotheses that the values of all variables such as the number of stoves used, the fuel prices and the fuel savings rate of the improved stoves remain constant in future years (from 2006), and that the improved cooking stoves are replaced after their average life spans.

A discount rate of 10% p.a. was applied. Alternative calculations were carried out with a discount rate of 3%, reflecting the rate of return of long-term public securities, such as government bonds. The interest rate of the latter is generally recommended for the discount rate of the economic evaluation of

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stove dissemination programmes, which always include highly valued social and environmental aims and are in the interest of the public and the respective government.

Nevertheless, we used the discount rate of 10% per annum, since we derived all assumptions and base data used in the economic analysis conservatively.

3.3 Economic benefits considered in the CBA

3.3.1 Avoided fuel costs and reduced firewood collection time

The CBA considers the avoided fuel costs and the reduced firewood collection time derived from the use of the Rocket Lorena stoves as well as charcoal-saving stoves as economic benefits. These economic benefits are outlined in the following and in the CBA “Benefits due to fuel savings”.

Fuelwood savings were valued with the average market price of firewood when firewood was purchased, and with a shadow price when firewood was collected.

The shadow price of firewood collected was derived from the average amount of firewood collected per hour (5 kg) and the average daily income in the stove dissemination areas, taking only 50% of the saved collecting time into account (see Chapter 2.3). Only the “net” fuelwood collection time has been considered; in other words, not counting the amount of time it takes to return home from work in the field or to collect herbs along the way, for example.

The market price amounted to 0.04 EUR per kg fuelwood. The shadow price of one kg collected fuelwood was 0.01 EUR (0.0099 EUR).

Based on monitoring studies and reports, it was assumed that 50% of the amount of firewood consumed by all households was purchased and 50% collected. Conversely, we assumed that 50% of the firewood savings were savings in collected firewood and that these savings resulted in a corresponding reduction of firewood collection time.

The avoided costs due to firewood savings that would have been purchased amounted to 4,263,478 EUR in 2006.

The hours of fuelwood collecting time saved were 20,141,147 in 2006 and corresponded to an economic benefit of 1,007,057 EUR.

The economic benefits due to the use of the Rocket Lorena stoves totalled 2,530,266 EUR in 2005 and 5,270,535 EUR in 2006.

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Charcoal savings were valued with the average market price of 0.09 EUR per kg. The avoided costs due to charcoal savings came to 48,567 EUR in 2005 and 171,719 EUR in 2006.

The total economic benefits due to fuel savings were 2,578,833 EUR in 2005 and 5,442,254 EUR in 2006.

The author wishes to mention that, from an overall economic view, the total amount of firewood saved should be valued at the afforestation cost of the firewood, which can be regarded as a shadow price of fuelwood (see Chapter 8). But, because all of the base data and assumptions of the economic analyses were derived in a conservative way, and the results of the economic evaluation should also convince sceptical readers of the efficiency of stove dissemination projects, the firewood savings were valued with the firewood's market price (in the case of firewood purchased) and with a shadow price of fuelwood collected, derived from the benefits of reduced firewood collection times.

The following table gives an overview of the economic benefits due to fuel savings achieved in 2006:

Avoided fuel costs; reduced collection time valued with the shadow wage	Economic Benefits in EUR in 2006	Economic Benefits In million EUR in 2006	Reduced firewood collection time in million hours in 2006
Firewood purchased	4,263,478	4.3	
Firewood collected	1,007,057	1.0	20
Total firewood	5,270,535	5.3	
Charcoal purchased	171,719	0.1	
Total firewood purchased and charcoal	4,435,197	4.4	
Benefits due to fuel savings	5,442,254	5.4	

3.3.2 Benefits due to reduced cooking time

Monitoring studies and reports found that the average cooking time per household was reduced by 1.82 hours per day when using the Rocket Lorena stove. For the woman, that means being 1.82 hours less in the kitchen or near the stove.

We assumed that 25% of this time reduction, namely 0.455 hour per day, was time which could be effectively considered as time saved, since household activities other than the preparation of food are also effectuated during the cooking process, and the household energy conservation techniques (cutting of firewood, for example) afford additional time. This effectively-saved time amounted to 166,075 hours p.a. per household.

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We assigned a monetary value to 50% of this time saved (called “reduced cooking time” here and in the CBA) as described in Chapter 2.3 in order to derive the economic benefits due to the reduced cooking time.

Based on 180,593 households using the Rocket Lorena stoves, the hours saved due to the reduced cooking time amounted to 29,991,999 in 2006. The corresponding economic benefit was 1,499,600 EUR. (Remember that only 50% of the “25%-time saved” as described below were valued at the shadow wage.)

3.3.3 Benefits due to better health

Emissions caused by the combustion of firewood contain carbon monoxide, nitrogen oxides, formaldehyde, respirable particulates and hundreds of other simple and complex organic compounds, including polyaromatic hydrocarbons. Human exposure to these pollutants exceeds recommended WHO levels by factors of 10, 20 and more. The use of the open fire for cooking purposes caused high health hazards. Exposure to indoor air pollution from the combustion of firewood is an important cause of morbidity and mortality of women and small children. It is in particular responsible for respiratory and eye diseases. The use of the Rocket Lorena stove decisively reduces the smoke in the kitchen, resulting in better health conditions for the family members.

The following assumptions were derived from the observed reduction in burns, acute respiratory diseases of the women and small children and eye diseases in the stove dissemination areas as well as from results of health studies conducted in Kenya and other countries.

It was supposed that 21% of the households using the Rocket Lorena stove no longer suffered from acute respiratory diseases, 36% of the households no longer from eye diseases as they did before (when using the open fire) and a 90% reduction in burns.

The author assumed that on average a household using the open fire lost 8 hours per annum due to burns of family members, 80 hours due to acute respiratory diseases of the woman and her small children and 16 hours due to eye diseases of the same members of the household.

We assigned a monetary value (shadow wage) to only 50% of the time saved due to better health as described in Chapter 2.3.

The total number of hours saved was 5,374,451 and corresponds to an economic benefit of 268,723 EUR in 2006.

Avoided costs for health care on household level (361,186 EUR) as well as for the public health system (140,863 EUR) were taken into account and derived in the following way.

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The annual costs of health care (medication, other costs) due to the above-mentioned diseases caused through smoke and burns during cooking time was assessed by the stove dissemination project at an amount of 12 EUR per household using the traditional stove and at an amount of 8 EUR per household using the Rocket Lorena stove. Based on monitoring studies, we supposed that only 50% of the households are able and willing to pay for health care.

For the public health system the author derived the government expenditure on health as a share of the total expenditure on health based on per capita expenditure figures of the years 1999 to 2003 in Uganda, published in the World Health Report 2006. The share calculated in this way was 28%. The author assumed that this percentage would also be the public health system's share of the total avoided costs due to the better health of the households using the Rocket Lorena stove. Based on the reduced annual costs of health care per household using the improved stove, the amount of avoided costs for the public health system could then be concluded. It was assumed that 95% of the households are treated by public health centres (there is no official fee in Uganda; medical treatment is free).

The total economic benefits from better health came to 770,771 EUR in 2006.

Benefits derived from a reduction in injuries caused by reduced fuelwood collection time and the reduction in the frequency of fuelwood collection trips were not taken into account.

3.3.4 Benefits due to preservation of forest reserves

The benefits due to preservation of the districts' forest resources were determined based on the following hypotheses:
10% of the firewood consumed for cooking purposes comes from the felling of forest cover, and vice versa: 10% of the firewood savings preserve forest resources.

The value of forest reserves equals the assumed afforestation costs of 0.0352 EUR per kg firewood. These costs were derived from several reference sources as well as the average afforestation costs of a forest plantation of 1.2 million USh/ha (base data calculated by the NFA/Uganda). An average stock density of 17 cubic metres per hectare of forest cover and an average wood weight of 850 per solid cubic metre were assumed. Losses derived from unmarketable wood species, overly thick trunks or destruction from fire were not taken into account in calculating the afforestation costs of 0.0352 EUR per kg firewood.

The economic benefits of forest cover preserved by annual firewood savings due to the use of the Rocket Lorena and improved charcoal stoves is 781,801 EUR p.a. up from 2006.

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3.3.5 Benefits of preventing declines in soil fertility

Trees and woodlots increase the soil fertility because they protect the soil from wind, sun and rain, improve its nutrition recycling and reduce erosion. The author estimated conservatively that 5% of the firewood and charcoal consumed comes from cut and damaged trees of woodlands, inducing a reduction in soil fertility of 10%. Conversely, the author suggested that the preservation of woodlands increases the soil fertility, i.e. that 5% of the total amount of fuelwood savings achieved through the use of the improved household stoves result in annual benefits due to higher soil fertility, which can be assigned a monetary value. The author derived this value from different reference sources and calculations she has effectuated in the framework of another study.

The author assumed that 9,800 kg of firewood saved could protect one hectare of farmland. The average annual income from agricultural production was estimated to be 456 EUR/ha. The respective annual benefit of one kilogramme firewood saved that could prevent a decline in soil fertility amounted to 0.0047 EUR per kg firewood, i.e. it was less than one cent. This very low value was arrived at on the basis of the very pessimistic assumptions. It must also be pointed out that, according to the above-mentioned hypothesis, only 5% of the fuelwood and charcoal savings were considered in calculating the benefits of preventing declines in soil fertility.

The annual benefits of the increase in soil fertility due to the annual fuelwood savings considered (5%) accumulate from year to year in the calculation, since the damage from woodcutting and clear felling is irreversible and the corresponding reserve of woodland is lost forever.

The annual benefit of preventing declines in soil fertility amounted to 23,931 EUR in 2005 and to 75,604 EUR in 2006 (23,931 EUR due to firewood savings of the year 2005 and 51,673 EUR due to firewood savings of the year 2006.)

3.3.6 Benefit due to greenhouse gas reduction

A global environmental impact of firewood and charcoal savings due to the improved household stoves is the reduction of greenhouse gas emissions. In the CBA we assigned a monetary value to the amount of emission of CO_2 and CH_4 caused by the combustion of fuelwood.

We used a conversion factor of 1500 g CO_2 for each kg fuelwood burned. The emission factor of CH_4 applied was 4 g for 1 kg firewood.

We assumed that the economic value of one tonne of CO_2 avoided is the price of the traded EUA for one tonne of CO_2. One of the lowest prices in 2006 was 5 EUR per one tonne of CO_2 , which the author applied in the economic calculation. For methane emissions (no prices or other economic values exist), we assumed a 20 times higher price than for carbon dioxide emissions derived from the

20 times higher potency of methane compared with carbon dioxide. The corresponding value was 100 EUR per one ton CH_4.

Concerning the charcoal-saving stoves, we simplified the calculation in converting the amount of charcoal saved into a corresponding amount of firewood saved with the factor of 10 (see Chapter 2.2).

The annual benefits through CO_2 and CH_4 emission reduction due to the use of the improved household stoves valued at prices for EUA was 1,754,610 EUR (from 2006).

3.3.7 Total economic benefits

The following table gives an overview of the economic benefits of 2006 considered in the CBA:

Economic benefits considered (time saved valued with shadow wage)	Economic Benefits in EUR in 2006	Economic Benefits In million EUR in 2006	Time saved in million hours in 2006
1. Benefits due to fuel savings	5,442,254	5.4	
2. Benefits due to reduced cooking time	1,499,600	1.5	30
3. Benefits due to better health	770,771	0.8	5
4. Benefits due to preserved forest cover	781,801	0.8	
5. Benefits due to better soil fertility	75,604	0.1	
6. Benefits due to CO_2 and CO_4 reduction	1,754,610	1.7	
Total economic benefits	10,324,641	10.3	

In 2006, the total economic benefits were 10.3 million EUR. In 2005, they amounted to 4.9 million EUR.

3.4 Costs considered in the CBA and CEA

3.4.1 Costs of the stoves

The average cost of the Rocket Lorena stove is 4 EUR. The average life span of the stove is 4 years. No other costs, e.g. maintenance or repair costs, had to be taken into account,

The cost of the charcoal-saving stove amounts to 10 EUR. Its life span is 3 years.
No other costs for this stove had to be taken into account.

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For the CBA as well as for the CEA, the annuities of the stoves were calculated to determine the stoves' annual costs. The respective discount rates of the economic analyses were therefore applied (10% or 3%).

3.4.2 Costs of the stove dissemination programme

The annual expenses for the improved household cooking stoves dissemination programme amounted to 350,000 EUR in 2005 and 2006. These costs included all costs, also the costs of local partners, but not the GTZ overhead costs.

GTZ overhead cost amounted to 18% of these annual expenses, in 2005 as well as in 2006. The total annual expenses for the improved household cooking stoves dissemination programme was 413,000 EUR in 2005 and 2006.

Annual costs for monitoring and retraining in the years 2007 to 2009 and the following years were estimated to be 5% of the initial dissemination programme costs (17,500 EUR).

4 Main results of the cost-benefit analysis (CBA)

4.1 Key model calculations

In Chapters 4.2 to 4.4, we present the main results of four key model calculations, which were carried out in the framework of the CBA. These four key model calculations were based on a period of 10 years. That means that the key model calculations considered the benefits and costs derived from the stove dissemination project (i.e. the use of the improved stoves) over 10 years.

The four key model calculations were as follows:
Model 1: Discount rate of 10%, considering the total economic benefits
Model 2: Discount rate of 10%, considering only the economic benefits due to fuel savings
Model 3: Discount rate of 3%, considering the total economic benefits
Model 4: Discount rate of 3%, considering only the economic benefits due to fuel savings

Chapter 4.5 presents the results of alternative calculations varying the period considered and the assumed firewood saving rate. In order to show that the stove dissemination programme was still very effective even under more pessimistic assumptions, periods of 5 years, and additionally a firewood saving rate of 40%, were assumed (Chapter 4.5.1 and Chapter 4.5.2). Chapter 4.5.3 presents the

main results of an alternative calculation based on more optimistic assumptions, which from the author's point of view better reflect the reality of stove dissemination projects.

4.2 Net present value of the stove dissemination programme and present value of economic benefits

Regarding the stove dissemination programme as an investment project with a duration of 10 years, the net present value (NPV) represents the sum of all costs and benefits derived from this programme during 10 years and valuated at the point of the programme's start (2005). The net present value was calculated in discounting the annual cash flows (annual benefits minus annual costs) to the beginning of the year 2005.

Four net present values (NPV) are presented, corresponding to the key model calculations:
NPV 1: Discount rate of 10%, considering the total economic benefits
NPV 2: Discount rate of 10%, considering only the economic benefits due to fuel savings
NPV 3. Discount rate of 3%, considering the total economic benefits
NPV 4: Discount rate of 3%, considering only the economic benefits due to fuel savings

The following table presents the results in million EUR:

NPV 1	NPV 2	NPV 3	NPV 4
56.97	28.42	81.32	40.71

The present values for the different economic benefits (as described in Chapter 3.3) were also calculated and the share of each economic benefit as a percentage of the total economic benefits determined.

The following table presents the results of the calculations effectuated at the discount rate of 10%:

Period of 10 years; discount rate: 10%	Benefits due to fuel savings	Benefits due to reduced cooking time	Benefits due to better health	Benefits due to preservation of forest reserves	Benefits of preventing declines in soil fertility	Benefits due to greenhouse gas reduction	Total benefits
Present value (million EUR)	30.84	8.51	4.37	4.42	1.33	9.92	59.39
Percentage of total benefits	51.92%	14.32%	7.36%	7.45%	2.24%	16.71%	100.00%

The following table presents the results of the calculations effectuated at the discount rate of 3%:

Period of 10 years; discount rate: 3%	Benefits due to fuel savings	Benefits due to reduced cooking time	Benefits due to better health	Benefits due to preservation of forest reserves	Benefits of preventing declines in soil fertility	Benefits due to greenhouse gas reduction	Total benefits
Present value (million EUR)	43.64	12.03	6.19	6.26	2.08	14.05	84.25
Percentage of total benefits	51.80%	14.28%	7.34%	7.43%	2.47%	16.68%	100.00%

4.3 Benefit-cost ratio

The benefit-cost ratio compares the present value of the benefits with the present values of the costs. This ratio was calculated by dividing the discounted benefits by the discounted costs.

The present values of the costs were as follows:
Discount rate of 10%: 2,419,532 EUR
Discount rate of 3%: 2,938,404 EUR

The following table presents the benefit-cost ratios of the key model calculations:

Model 1	Model 2	Model 3	Model 4
24.55	12.75	28.67	14.85

The benefit-cost ratio of Model 1 indicates that the investment of one EUR gives a return of 24.55 EUR, when all economic benefits are considered and a discount rate of 10% is applied.

The benefit-cost ratio of Model 2 indicates that the investment of one EUR gives a return of 12.75 EUR, when only the benefits due to fuel savings are considered and a discount rate of 10% is applied.

The benefit-cost ratio of Model 3 indicates that the investment of one EUR gives a return of 28.67 EUR, when all economic benefits are considered and a discount rate of 3% is applied.

The benefit-cost ratio of Model 1 indicates that the investment of one EUR gives a return of 14.85 EUR, when only the benefits due to fuel savings are considered and a discount rate of 3% is applied.

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4.4 Internal rate of return

The internal rate of return is the rate of interest earned on the capital (cost of the stove dissemination programme) tied up in the programme during the period under consideration.

The costs of the stoves were considered as recurrent annual costs.

The internal rates of the four model calculations are very high compared with successful private investment projects.

Internal rates of return:

Model 1	Model 2	Model 3	Model 4
1,158%	602%	1,161%	604%

4.5 Main results of alternative calculations

4.5.1 Considering a period of 5 years and a discount rate of 10%

The following are the main results of the CBA for the model calculations 5 and 6, considering a period of 5 years and a discount rate of 10%.

Model 5: Considering the total benefits
Model 6: Considering only the benefits due to fuel savings

Net present values in million EUR:

Discount rate	NPV 5	NPV 6
10%	32.65	16.29

Present values of economic benefits in million EUR:

Period of 5 years; discount rate: 10%	Benefits due to fuel savings	Benefits due to reduced cooking time	Benefits due to better health	Benefits due to preservation of forest reserves	Benefits of preventing declines in soil fertility	Benefits due to greenhouse gas reduction	Total benefits
Present value (million EUR)	18.03	4.98	2.56	2.58	0.44	5.79	34.38

Benefit-cost ratios:

Model 5	Model 6
19.79	10.38

Internal rates of return:

Model 5	Model 6
1,158%	602%

4.5.2 Considering a period of 5 years, a discount rate of 10% and a firewood saving rate of 40%

The following are the main results of the cost-benefit analysis for the model calculations 7 and 8, considering a period of 5 years, a firewood saving rate of 40% and a discount rate of 10%.

Model 7: Considering the total benefits
Model 8: Considering only the benefits due to fuel savings

Net present values in million EUR:

Discount rate	NPV 7	NPV 8
10%	25.67	11.52

Present values of economic benefits in million EUR:

Period of 5 years; discount rate: 10%	Benefits due to fuel savings	Benefits due to reduced cooking time	Benefits due to better health	Benefits due to preservation of forest reserves	Benefits of preventing declines in soil fertility	Benefits due to greenhouse gas reduction	Total benefits
Present value (million EUR)	13.26	4.98	2.56	1.93	0.33	4.34	27.40

Benefit-cost ratios:

Model 7	Model 8
15.77	7.63

Internal rates of return:

Model 7	Model 8
916%	434%

4.5.3 Considering a period of 20 years, a discount rate of 3% and a firewood saving rate of 55%

The following are the main results of the model calculations, which are probably the models that correspond the most to the reality of the stove dissemination programme, because they were based on a period of 20 years and a discount rate of 3%.

Model 9: Considering the total economic benefits
Model 10: Considering only the economic benefits due to fuel savings

Net present values in million EUR:

Discount rate: 3%	NPV 9	NPV 10
Period: 20 years	149.51	73.56

Present values of economic benefits in million EUR:

Period of 20 years; discount rate: 3%	Benefits due to fuel savings	Benefits due to reduced cooking time	Benefits due to better health	Benefits due to preservation of forest reserves	Benefits of preventing declines in soil fertility	Benefits due to greenhouse gas reduction	Total benefits
Present value (million EUR)	78.19	21.55	11.08	11.22	6.91	25.19	154.14

Benefit-cost ratios:

Model 9	Model 10
33.30	16.89

Internal rates of return:

Model 9	Model 10
1,161%	604%

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5 Results of the cost-effectiveness analysis

The CEA values the benefits in natural units. It determines the efficiency of the project as a function of lowest costs.

The author assessed the cost-effectiveness of the stove dissemination programme in terms of firewood saved. The dynamic cost-effectiveness was calculated by dividing the discounted annual amounts of firewood savings by the discounted annual costs.

The costs included the costs for the stoves as well as the costs of the stove dissemination programme. Charcoal savings were taken into account by converting the amounts of charcoal saved into amounts of firewood saved as described in Chapter 2.2.

The cost-effectiveness ratios of the stove dissemination programme considering periods of 5, 10 and 20 years and discount rates of 3% and 10% as well as firewood and charcoal savings of 55% are presented in the following table.

Cost-effectiveness in kg/1 EUR:

Period considered	Discount rate: 10%	Discount rate: 3%
5 years	422	478
10 years	519	605
20 years	723	1043

The cost effectiveness in a period of 10 years amounts to 519 kg/1 EUR based on the discount rate of 10%. This ratio shows that the capital outlays (or expenditure) of one EUR result in firewood savings of 519 kg. Based on the discount rate of 3% the expenditure of one EUR results in firewood savings of 605 kg.

6 Regional economic efficiency of firewood savings in the districts of Bushenyi and Rakai

The regional economic efficiency of the Rocket Lorena stove dissemination programme is the amount of firewood saved due to the use of the Rocket Lorena stoves, expressed as a percentage share of the total firewood consumption for household cooking purposes in the stove dissemination districts.

The figure of total firewood consumption is based on the amount of firewood that would have been consumed if no Rocket Lorena stoves had been used. It must be indicated for a particular year.

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The southwest and central districts Bushenyi and Rakai had a population of 1,373,722 in 2006. More than 99% of the 274,744 households in these two districts used firewood for cooking purposes. Under the assumption that all these households would have been using the three-stone fire, the total firewood consumption for cooking would have been 561,578 tonnes in 2006 based on 5.6 kg firewood consumed per household and day (see Chapter 2.2).

By the end of 2006, a total of 211,220 improved firewood cooking stoves (Rocket Lorena stoves) were disseminated (see Chapter 2.1). This means that 73% of the households (200,659) in these two districts had once bought or installed Rocket Lorena stoves (dissemination rate).

Assuming a utilization rate of 90 % for the Rocket Lorena stove (see Chapter 2.1), a total of 180,593 households or 65% of the households in these two districts used 190,098 firewood-saving stoves in 2006 and saved 203,023 tonnes of firewood.

Thus, the regional economic efficiency of the Rocket Lorena stove dissemination project in the districts Bushenyi and Rakai was 36%. This means that 36% of the firewood consumption for cooking purposes of all households could be saved in these two districts in 2006.

7 Comparing areas of forest cover with firewood savings

7.1 Area of forest cover preserved in 2006 through firewood savings

The annual firewood savings achieved through the use of the improved firewood and charcoal stoves were 222,103 tonnes in 2006 (see Chapter 2.2).

Since 10% of the firewood consumed for cooking purposes came from the felling of forest cover (local conservative estimates), it was assumed that 10% of the firewood savings preserved forest resources. Converting firewood savings into woodland, the 222,103 tonnes fuelwood saved preserved 2,196 ha of forest cover in 2006.

This calculation is based on the following hypotheses:
1. The average stock density per ha of forest cover is 17 cubic metres per hectare.
2. The total stock of a forest, if cleared, cannot be used as fuelwood. Approximately 30% of the wood is lost due to unmarketable wood species, overly thick trunks or destruction from fire. These losses were taken into account.
3. The average wood weight per solid cubic metre is 850 kg/m^3.

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7.2 Area of forest cover equivalent to the total firewood savings

In order to illustrate the extent of the total fuelwood savings achieved, the fuelwood savings of 222,103 tonnes in 2006 were converted into the standing volume of a forest, and the size of the area of forest calculated whose stock volume would have been equal to the fuelwood savings.

This is certainly problematic, as it might easily lead one to conclude that the savings in fuelwood actually prevented the cutting of wood in the area of forest calculated. As the reader can see in Chapter 7.1, it was estimated that only 10% of the firewood savings were freshly cut exclusively for fuel.

Based on the three hypotheses presented in Chapter 7.1, the stock volume of a forest cover of 21,958 ha would have been equal to the total amount of fuelwood saved in 2006.

Again, the author wishes to point out that fuelwood savings do not automatically lead to a corresponding decline or halt in the destruction of standing trees and sections of forest. It is a matter of a calculation which serves to illustrate the size of forest area whose growing stock would have been equivalent to the savings in fuelwood.

8 Firewood savings valued at shadow prices for fuelwood

The macroeconomic or overall economic view takes the economic values of the products into account. If the market prices do not reflect these values, or if there is no market price for a good, so-called shadow prices are introduced to include macroeconomic costs that are not reflected in the market price or do express scarcity aspects.

The market price of fuelwood does not reflect the economic value of the fuelwood. Despite the shortage of fuelwood and the high ecological value of the forest resources, woodlands and tree stands, fuelwood is treated almost like a so-called “free” good which is available in random supply and thus has no price. A significant share of its production costs from an economic and ecological standpoint, the costs of producing the “raw material” tree, are not included in the market price of fuelwood.

Shadow prices for the fuelwood were calculated based on the market price of the substitution product LPG and on afforestation costs. World market prices were not applied, i.e. the respective prices or costs were not adjusted for customs, taxes and subsidies. The use of world market prices would not have made much difference in the results obtained.

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The shadow prices for one kilogramme of fuelwood can be regarded as the substitution costs for one kilogramme of fuelwood saved and then compared with the costs of one kilogramme of fuelwood that is saved through the use of improved stoves.

8.1 Firewood savings valued at afforestation costs

The firewood savings (including the charcoal savings converted into firewood) were valued at the calculated afforestation costs of 0.0352 EUR per kg firewood (see Chapter 3.3.4).

The economic value of the total amount of firewood saved in 2006 based on shadow prices for fuelwood derived from afforestation costs amounted to 7,818,011 EUR.

8.2 Firewood savings valued at the LPG-shadow price for fuelwood

The higher heating value of LPG and the higher cooking efficiency of an appropriate LPG cooker was considered in the formation of the LPG-shadow price for fuelwood in the following way.

Fuel energy contents were assumed to be 15 MJ/kg for fuelwood and 45.7 MJ/kg for LPG. A device efficiency of 15% was supposed for the three-stone fire and 60% for the LPG cooker. The annual amount of LPG was calculated on the basis of these figures and the household's annual firewood consumption if the three-stone fire is used.

The market price of LPG came to 1.32 EUR per kilogramme. The price for the LPG-cooker and accessory devices were not be taken into account. They were negligible compared with the total fuel costs (see Chapter 9.6). The firewood savings (including the charcoal savings converted into firewood) valued at the LPG-shadow price for fuelwood amounted to 24,057,064 EUR in 2006.

The substitution cost for one kilogramme firewood based on the LPG-shadow price was approximately 0.11 EUR and can be compared with the market price for one kilogramme firewood (0.04 EUR). Such a comparison, however, amounts to a rough calculation, since it does not include costs for the LPG-cooker and the improved fuelwood stove. Chapter 9.6 present the comparison between the annual costs of cooking with the alternative fuel LPG and the costs of cooking with the Rocket Lorena stove for the individual household.

9 Results of the microeconomic analysis for the Rocket Lorena stove

9.1 Economic criteria at household level

Savings in fuelwood expenditure or shorter collection times are definitely a tangible benefit from the use of improved stoves. However, these two factors alone cannot convey how relevant this benefit is for the household, nor whether the use of improved stoves is indeed economic. In order to evaluate the profitability of using the firewood-saving stove for the household, the following five economic criteria were calculated:

- payback period,
- net benefit,
- rate of return,
- the net benefit as a share of the household's income,
- total annual costs of cooking with an alternative energy source.

The economic analysis was effectuated for three different household types:

a) a household that only purchases the firewood consumed;

b) a household that only collects the firewood consumed (the shadow price of firewood as derived in Chapter 2.3 was applied for the saved amount of firewood collected);

c) a household that purchases its firewood at a rate of 50% and collects the other 50% of firewood needed.

Case b) and c) comprise the hypothesis that 50% of the firewood collecting time saved can be used for productive activities improving the living standard of the household (income-generation, farming or other highly valued activities) and that these time periods yield an economic value for the household equivalent to the shadow wage of 0.1 EUR for one hour.

9.2 Base data

The main base data for the microeconomic analysis were presented in Chapters 2.2, 2.3 and 3.4.1. They were as follows:

- average household size: 5 persons,
- average daily firewood consumption of the household using the three-stone fire: 5.6 kg,

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- saving rate of the Rocket Lorena stove: 55%,
- amount of firewood collected per hour: 5 kg,
- average price of firewood per kg: 0.042 EUR ,
- average shadow price of firewood collected per kg: 0.01 EUR ,
- average price of the Rocket Lorena stove: 4 EUR ,
- life span of the Rocket Lorena stove: 4 years.

The annual fuelwood savings of a household using the Rocket Lorena stove amounts to 1,124 kg. For a household that only purchases its firewood, the reduction in annual firewood expenses is 47 EUR. For a household that only collects its firewood, the reduction in firewood collection time amounts to 225 hours per annum and corresponds to an economic benefit of 11 EUR for the household.

9.3 Payback period

The payback period of the stove is the amount of time it takes for cumulative savings in the firewood expenses of the household to offset the initial costs of the stove.

Results for the three household types:

Time period	a) Household purchasing firewood	b) Household collecting firewood	c) Household collecting and purchasing firewood (50%/50%)
Payback period in days	31	131	50
Payback period in months	1	4.4	1.7

Case b) and c) comprise the hypothesis that 50% of the firewood collecting time saved can be used for productive activities and that these time periods yield an economic value equivalent to the shadow wage of 0.1 EUR an hour (see Chapter 2.3).

The calculated payoff times are average values. In reality, the payback periods can be longer or shorter. The period of amortization for the household purchasing firewood (one month) is very short.

The relationship between the payback period and the life of the stove (4 years) is a rough indication of the profitability of the investment in the stove.

9.4 Net benefit and rate of return during the life of the stove

The net benefit during the life span of the stove is the sum of the total savings in fuelwood costs during this period minus the costs incurred for the stove during the same time period.

The rate of return indicates by what factor the net benefit exceeds the expenses for the stove.

Results for the three household types:

	a) Household purchasing firewood	b) Household collecting firewood	c) Household collecting and purchasing firewood (50%/50%)
Net benefit	185 EUR	41 EUR	113 EUR
Rate of return	4,622%	1,015%	2,818%

During the life of the improved stove of four years, the household that only purchased its firewood will have a net benefit of 185 EUR. The avoided costs due to firewood savings minus the total cost of the stove will be 46 times higher than the costs spent for the stove.

9.5 Ratio of net benefit to the household income

The importance of the net benefit for the woman and her family can be determined if the net benefit is compared with various items of the household budget, such as the average household income or certain expenses.

The net benefit per annum was calculated as a percentage of the annual amount of the household's income. Two different average values for the income were taken into account:

Case1: The average mean income of the households in the Bushenyi district at 45.28 EUR per month (Malinski, 2006)

Case 2: The approximately highest income per month of 50% of the households in Bushenyi (Mueller, 2003): 21.21 EUR

The following tables present the net benefit for year 1 and 2 and the respective ratios of net benefit to the household income.

Net benefit of year 1 and 2:

Case 1 and 2	a) Household purchasing firewood	b) Household collecting firewood	c) Household collecting and purchasing firewood (50%/50%)
Net benefit in year 1	43 EUR	7 EUR	25 EUR
Net benefit year 2	47 EUR	11 EUR	29 EUR

Ratio of net benefit to the household income (Case 1):

Case 1	a) Household purchasing firewood	b) Household collecting firewood	c) Household collecting and purchasing firewood (50%/50%)
Ratio year 1	8%	1%	5%
Ratio year 2	9%	2%	5%

Ratio of net benefit to the household income (Case 2):

Case 2	a) Household purchasing firewood	b) Household collecting firewood	c) Household collecting and purchasing firewood (50%/50%)
Ratio year 1	17%	3%	10%
Ratio year 2	19%	4%	11%

The net benefit and the ratio of the second year are higher than the corresponding values of the first year, because in the first year the benefit has to be reduced by the initial investment costs of the improved stove. Since as of the second year, the household does not have to spend any money on the stove (repair and maintenance costs do not occur), the net benefit equals the benefits of the firewood savings.

The approximately highest income per month for 50% of the households was 21.21 EUR, or 254 EUR per annum (Case 2). The firewood savings amount to 47 EUR in the second year of the stove's use for the household purchasing firewood and represent 19% of the highest income for 50% of the households.

In the case of the household that also collects firewood at a rate of 50%, this ratio is still high at 11%.

The ratios of net benefit to the household income show the degree to which the use of the Rocket Lorena stoves improves the living conditions of the women and their families in terms of quantifiable data.

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9.6 Total annual costs of cooking with LPG

Very few households in the districts of Bushenyi and Rakai use paraffin or biogas as a cooking fuel in order to boil water or prepare small and light meals, whereas the main meals can only be prepared using woody biomass resources. In Kampala, the wealthier households use LPG or grid electricity for cooking purposes.

In order to illustrate the cost interval between cooking with the improved firewood stove and cooking with a modern fuel, the total annual costs of cooking with the Rocket Lorena stove were compared with the total annual costs of cooking with LPG. This was the only modern fuel in the two districts which could have been available for a larger number of households.

The total annual cooking costs comprise the costs of fuel and the straight-line depreciation per annum for the stove and accessory devices employed. The straight-line depreciation p.a. was derived by dividing the purchase prices of the stove and the required accessory devices by the number of the stove's and devices' service years. The cheapest LPG stove, a 'one-burner' gas cooker, was chosen with a life span of 4 years. Its average price amounted to 55 EUR. The price of the LPG container (a 13 kg gas bottle) was 19 EUR. The price of the other accessory devices (regulator and tube) was estimated to be 30% of the gas cooker price (16.55 EUR). The life spans of all accessory devices were estimated to be 10 years. All prices were prices of the markets in Kampala. Transportation costs to the districts of Bushenyi and Rakai were not taken into account. The market price of LPG came to 1.32 EUR per kilogramme.

Fuel energy contents were assumed to be 15 MJ/kg for fuelwood and 45.7 MJ/kg for LPG. A device efficiency of 15% was supposed for the three-stone fire and 60% for the LPG cooker. The annual amount of LPG was calculated on the basis of these figures and the household's annual firewood consumption if the three-stone fire was used.

The annual amounts of fuel consumed and the annual costs of cooking were as follows:

Stove	Rocket Lorena stove	Gas cooker (LPG)
Annual fuel consumption	920 kg firewood	168 kg LPG
Annual fuel costs (EUR)	39	221
Device cost per year (EUR)	1	17
Total annual cooking costs (EUR)	40	238

Based on the assumption that a household can cook all dishes with a 'one-burner' gas cooker and that a continuous supply of LPG is assured in the rural areas - which in reality would not be the case, the calculated total annual costs of cooking with an LPG cooker amount to 238 EUR per household. This is approximately 600% of the total annual costs of cooking with the Rocket Lorena stove (40 EUR).

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Moreover, the majority of the households in the districts of Bushenyi and Rakai cannot afford to purchase LPG cookers and the required accessory devices, entailing costs of 90.55 EUR per unit.

The use of the Rocket Lorena stove is the only and best alternative for the households to reduce the burden of energy costs as well as the burden of disease due to indoor air pollution caused by the open fire.

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