Costs and benefits of efficient institutional cook stoves in Malawi

Economic evaluation of the component "Promotion of efficient institutional cook stoves" of the Programme for Biomass Energy Conservation (ProBEC) in Malawi in the years 2004 to 2007

by
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Contents

Abbreviations

CBA	cost-benefit analysis
cbm	cubic metres
CEA	cost-effectiveness analysis
CH_4	methane
CO_2	carbon dioxide
EU	European Union
EUA	EU allowance
EUR	euro
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH
GTZ/BEP	GTZ Basic Education Programme
HERA	GTZ Household Energy Programme
IFSP	Centre for Food and Fuel Security Promotion
kg	kilograms
LPG	liquefied petroleum gas
MJ	mega joules
MWK	Malawi Kwacha
NPV	net present value
p. a.	per annum
ProBEC	Programme for Biomass Energy Conservation in Southern Africa
RS	institutional Rocket Stove
SADC	Southern African Development Community
t	metric tons; tonnes
UNICEF	United Nations International Children's Emergency Fund
US$	US dollar (United States of America dollar)
WFP	World Food Programme
WHO	World Health Organization

Currency Conversion: 1 US dollar = 140 Malawi Kwacha
(Average exchange rate during 5/2006 – 12/2007)

Foreword

In 1999, the Southern African Development Community (SADC) started the regional Programme for Biomass Energy Conservation in Southern Africa (ProBEC). The Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH has been commissioned to implement ProBEC. The programme is focussing on the promotion of commercial supply and demand systems for efficient biomass-using technologies for three target groups: low-income households, social institutions and small and medium-size enterprises (SMEs). To achieve this, ProBECs main activities are concept development, product development, capacity development and market development.

In Malawi, ProBEC initiated the establishment of an Information Centre for Food and Fuel Security Promotion (IFSP) as a regional training centre for stakeholders interested in participating in energy conservation activities. In 2004, ProBEC started to adjust the Rocket Stove concept of the Aprovecho Institute (USA) to the conditions (materials, skills, etc.) available in Malawi. User records have shown that the use of the technology reduces firewood consumption by 70% to 90% compared to baseline technologies (e.g. open fire). In the same year, ProBEC also started to build up commercial production and marketing structures for the commercial promotion of large-scale institutional cook stoves. All activities of ProBEC in Malawi have taken place in cooperation with the Department of Energy in the Ministry of Energy and Mines, Government of Malawi.

The programme component “Promotion of efficient institutional cook stoves” of ProBEC Malawi is financed jointly by the Dutch Directorate-General for International Cooperation (DGIS) and the Federal Ministry for Economic Cooperation and Development (BMZ) of Germany.

Between October 2004 and December 2007, four commercial stove producers produced 4,200 Rocket Stoves for institutional kitchens and sold them to a large number of institutions in Malawi, mainly in the framework of donor-financed school feeding programmes (3,304 stoves). Between 2005 and 2007, tea estates constructed 66 large-scale Rocket Stoves.

Energy-efficient stove promotion programmes promote not only the production, marketing and use of fuel-saving stoves, but also the application of health-protecting and energy-saving-related techniques through the cooks when using the improved stoves. They also envisage other advantages for the local population, such as income- and employment-generating effects, the acquisition of new skills and knowledge, the improvement of the working conditions and health status of the cooks, the preservation of forest cover, including the protection of water, flora and fauna and maintaining the biodiversity.

This study presents the results of the economic evaluation of the programme component "Promotion of efficient institutional cook stoves" of ProBEC Malawi. The economic analyses assessed the economic benefits for the users of the institutional Rocket Stoves and the economic benefits derived from environmental impacts due to the use of these stoves on national and global level. It assessed the economic efficiency of the “stove promotion” from an overall economic view as well as that of the Rocket Stove’s use for individual institutions.

In Chapter 9 the reader will find a summary of the key results of the economic evaluation in the form of tables and the conclusion. The Executive Summary provides the main results, key assumptions and main base data of the economic evaluation.

The positive results of the economic evaluation show that the ProBEC Malawi programme component “Promotion of efficient institutional cook stoves” was successful. They also prove that energy-efficient institutional cook stove promotion projects yield promising returns compared with the expenses for these programmes.

Executive Summary

Method, assumptions and base data of the economic evaluation

The aim of this study was to evaluate the economic efficiency of the programme component "Promotion of efficient institutional cook stoves" of ProBEC Malawi. The economic efficiency is favourable from an overall economic view:

The investment of one US$ gives a return of 5.16 US$ when the economic benefits due to avoided fuel costs, preserved forest reserves and greenhouse gas reduction are considered (based on a period of 10 years and a discount rate of 3%).

The economic evaluation comprised a cost-benefit analysis (CBA), a cost-effectiveness analysis (CEA), the calculation of other macroeconomic criteria and analyses revealing the economic benefits of firewood savings due to the Rocket Stove's use for seven typical institutional stove users.

The CBA and the CEA were conducted on a period of 10 years (2005 – 2014) with a discount rate of 3%. This discount rate is generally recommended for the economic evaluation of projects that include highly valued social and environmental aims. Alternative calculations were carried out for periods of 5 and 20 years, with a discount rate of 10% and lower EUA prices for one tonne of CO_2.

The CBA and CEA considered the costs and benefits of the number of Rocket Stoves installed between 2004 and 2007 (4,200 purchased and 66 self-constructed Rocket Stoves). It was assumed that the values of all parameters remain constant in future years (from 2008) and that the Rocket Stoves are replaced after their life span, with the exception of the stoves purchased by the GTZ Basic Education Programme and by prisons (altogether 10% of the total stove number). The assumed average life span of the Rocket Stove is 4 years except for the stoves used in prisons (1 year).

The total expenses for the programme component "Promotion of efficient institutional cook stoves" of ProBEC Malawi came to 403,116 US$ (accumulative, 2004 to 2007). These costs include international and national staff, short-term experts, travel, transport, materials as well as administration and overhead costs. The average price of the Rocket Stove per type size was 120 US$ (30-80 l), 180 US$ (81-170 l) and 275 US$ (171-250 l). We applied minimum firewood saving rates per stove size that are achieved by all users on average compared to traditional-stove use: 60% (30-80 l), 70% (81-170 l) and 75% (171-250 l).

Since the institutions use the stove to very different extents during the year, ten user groups were formed to determine the annual amount of fuelwood savings. The number of cooking days p.a. ranged between 110 and 365; the utilization rate of the Rocket Stove compared to the traditional stove varied from 42% to 100% and the number of meals per cooking day was 1 or 2. The World Food Programme (WFP) installed most of the Rocket Stoves (2,332 stoves, or 55% of the total number) and used them 185 days p.a. (one meal daily) at an average utilization rate of 81%.

The CBA quantified and considered only the benefits due to avoided fuel costs, preservation of forest reserves and greenhouse gas reduction (CO_2 and CH_4): The firewood savings were valued with the trade price for fuelwood (0.0286 US$/kg). It was assumed that 30% of the firewood savings preserved forest reserves, and that their economic value equals the derived afforestation costs of 0.0521 US$ per kg firewood. For the economic value of one tonne of CO_2 avoided due to reduced firewood-burning, the author assigned one of the lowest prices of the EUA (EU Allowance) traded for one tonne of CO_2 in 2006 (7US$/EUA). For methane emissions, she assumed a 20 times higher price than for carbon dioxide emissions derived from the 20 times higher potency of methane as a greenhouse gas compared with carbon dioxide.

The amount of firewood saved and the economic benefits considered in the CBA for the year 2008 are presented in the following:

CBA-year:	Total firewood savings in tonnes	Economic benefits due to fuel savings, In US$	Economic benefits due to preservation of forest reserves, in US$	Economic benefits due to CO_2 and CH_4 reduction, in US$ (7 US$/EUA)	Total economic benefits in US$
2008	23,135	661,665	361,602	255,874	1,279,141

Main results of the economic evaluation

The CBA and CEA, based on a period of 10 years and a discount rate of 3%, produced the following main results:

The present value of the costs (sum of discounted annual stoves and ProBEC institutional stove promotion costs) comes to 1,584,442 US$.

The present values of the economic benefits (sum of discounted annual benefits) in monetary terms and as a share of the total economic benefits are as follows:

Period of 10 years; discount rate: 3%	Benefits due to fuel savings	Benefits due to preservation of forest reserves	Benefits due to greenhouse gas reduction (7 US$/EUA)	Present value of economic benefits – Total
Present value in US$	4,230,704	2,312,094	1,636,069	8,178,867
Percentage of total benefits	52%	28%	20%	100%

The net present value (present values of the benefits minus present value of the costs) comes to the significant amount of 6.6 million US$. Considering only the benefits due to avoided fuel costs, the net present value amounts to 2.6 million US$.

The comparison of the present value of the benefits with the present value of the costs (benefit-cost ratio) showed that the investment of one US$ gives a return of 5.16 US$. It yields a return of 2.67 US$ when only the benefits due to avoided fuel costs are taken into account. The result of the CEA was that the expenditure of one US$ results in firewood savings of 93 kg.

The results are still favourable even if a period of only 5 years is considered (2005-2009). The net present value comes to 2.5 million US$. Considering only the benefits due to avoided fuel costs, the net present value is approx. 0.9 million US$. The benefit-cost ratios are 3.82 US$ return per one US$

invested and 1.97 US$ when only benefits due to avoided fuel costs are considered. The cost-effectiveness is 69 kg/1 US$.

Even if a discount rate of 10% and the average EUA price of one tonne of CO_2 of 2007 (1 US$) are applied and a 5-year period is considered (most pessimistic scenario of the CBA and CEA), the net present value is still positive and indicates that the "stove promotion" is worthwhile from an overall economic view: The net present value comes to 1.4 million US$ and 0.6 million US$ (only benefits due to avoided fuel costs). The benefit-cost ratio is 2.82 and 1.76 (only benefits due to avoided fuel costs). The expenditure of one US$ results in firewood savings of 61 kg.

The results of the CBA and CEA show that the economic efficiency of the ProBEC Malawi programme component "Promotion of efficient institutional cook stoves" is very favourable.

In order to assess the economic profitability of the Rocket Stove's use for the individual institution, four economic criteria were calculated for seven typical institutional stove users, based on the use of one Rocket Stove. The payback period of the stove is the amount of time it takes for cumulative savings in the firewood expenses of the institution to offset the initial costs of the stove. The payback periods range between 89 and 280 cooking days. The 200 litre stove, which is used every day to prepare two meals, has the shortest payback period (2.8 months). The net benefit during the 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 net benefits are between 309 US$ (50 litre stove, one meal per day, 250 cooking days p.a.; used e.g. in a nursery) and 4,235 US$ (200 litre stove, two meals per day and 365 cooking days p.a.; used e.g. in an orphanage). The rate of return indicates by what factor the net benefit during the stove's life exceeds the expenses for the stove. For example, during the 4-year life of a 200 litre Rocket Stove, an orphanage having a net benefit of 4,235 US$ will have a rate of return of 1,540%, i.e. the avoided costs due to firewood savings minus the cost of the Rocket Stove will be 15 times higher than the costs spent for the stove. For the other institutional users, the rate of return ranges between 284% and 1,540%.

Fuel savings due to the Rocket Stove's use were economically significant for the institutions, as shown by the calculated ratios of avoided firewood costs to the catering budget of the seven typical institutions. Avoided fuel costs due to the Rocket Stove's use represent 12% to 38% of the catering budget (food and fuelwood expenses when the traditional stove was used) and definitely improve the financial conditions of institutional kitchens. The values of the other three economic criteria also prove that the Rocket Stove's use is profitable for each of the individual institutions.

In order to emphasize the favourable environmental impacts of the institutional Rocket Stoves' use in Malawi, the author wishes to present another result of the economic evaluation:

Assuming that 30% of the firewood savings preserved forest resources and these firewood savings are converted into woodland, approx. 689 ha of natural forest cover can be preserved in 2008 (achieved only by using the institutional Rocket Stoves that were installed by the end of 2007). The firewood savings of institutions and tea estates using plantation wood as fuel (11,167 tonnes in 2008) will be equivalent to an area of about 447 ha of eucalyptus plantation in 2008.

1 Introduction

Around 90% of the institutional kitchens in Malawi depend on biomass for cooking. Charcoal is seldom used. For institutions, expenditure on energy lies between 20-50% of the food budgets. Around 40% of institutions surveyed in the study ”SME and institutional cooking in Malawi” (P.M.J. Mushamba, 2002) use the three-stone fireplace and 60% use pots which are inbuilt with bricks. Both these cooking technologies are highly inefficient.

In 2004, the Programme for Biomass Energy Conservation in Southern Africa (ProBEC), in cooperation with the Department of Energy in the Ministry of Energy and Mines of Malawi, initiated the “Promotion of efficient institutional cook stoves” in Malawi. ProBEC has been promoting the production, installation and use of the Rocket Stoves in institutional kitchens, in particular those of schools. Emphasis was given to the promotion of Rocket Stoves through school feeding programmes of organizations like World Food Programme (WFP), Basic Education Programme (GTZ/BEP), Mary’s Meal and UNICEF. The Rocket Stoves are produced and sold on a self-sustaining basis, i.e. producers sell at true cost and derive profit from meeting market demand.

Between October 2004 and December 2007 4,200 Rocket Stoves for institutional kitchens were produced by four certified commercial stove producers and sold to a large number of different institutions in Malawi, namely in the framework of three donor-financed school feeding programmes: WFP, GTZ/BEP and Mary’s Meal (3,304 stoves). UNICEF purchased 499 Rocket Stoves. The other 397 Rocket Stoves were ordered by prisons, hospitals, secondary and boarding schools, orphanages, nurseries and a number of enterprises’ canteens. Tea estates constructed and used another 66 Rocket Stoves by the end of 2007.

The economic evaluation comprises the following components:
1) a cost-benefit analysis (CBA),
2) a cost-effectiveness analysis (CEA),
3) the calculation of other macroeconomic criteria, such as the areas of forest cover preserved through firewood savings and firewood savings valued at the LPG-shadow price for fuelwood,
4) the calculation of economic criteria revealing the economic benefits of firewood savings for typical users of institutional stoves.

The methods applied in the economic analyses have been described in “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 institutional Rocket Stoves installed by the end of 2007 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 to 2007. On the other hand, it assessed the relation between the economic benefits and the costs (“promotion project” and stove costs) over a longer period, including future years (periods of 5, 10 and 20 years were considered).

The CBA considered economic benefits derived from three main impacts of the programme component “Promotion of efficient institutional cook stoves” of ProBEC Malawi:

- Avoided fuel costs due to firewood savings,
- National and global impacts derived from firewood savings, i.e. the preservation of forest reserves and greenhouse gas reduction (avoided emissions of CO_2 and CH_4).

Aside from these benefits, the use of the institutional Rocket Stoves and the practise of efficient cooking and firing techniques generate further advantages that were not considered in the economic analyses, because convincing and quantifiable data were not available, in particular:

- Improvement of the working conditions and health status of the cooks
- Less pain and physical stress caused by smoke, intense heat, burns and accidents
- Reduced cooking time
- Improved nutrition of pupils, small children and adults due to more and better meals.

Important positive effects of the “promotion of efficient institutional cook stoves” 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
- Prevented declines in soil fertility due to preserved trees and woodlots
- Protection of water, flora and fauna and maintaining the biodiversity due to preserved forest cover
- Reduction of other emissions due to avoided combustion of fuelwood
- Creating and raising the level of environmental awareness
- The project’s experience will set an example for future projects in the region.

Sound, quantifiable data to derive economic benefits for these impacts were also not available.

All data, estimates and assumptions used in the economic analyses were based on ProBEC project data, data collection of the stove producers, data and information from the stove users, statistical documentations of the tea estates and impact or evaluation studies conducted in Malawi.

In particular, the “ProBEC Study on the Impact of the Institutional Rocket Stoves in School Kitchens” by Joseph DeGabriele and Amulike Msukwa (see References) provided reliable statistical data for deriving several important base data applied in this economic evaluation study.

The author wishes to thank the Regional ProBEC Coordinator for Malawi, Christa Roth and the Regional ProBEC Technical Adviser for Malawi, Andreas Michel, 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 possible to obtain realistic and precise base data. Thanks also to the GTZ staff Verena Brinkmann, Lisa Feldmann and Dr. Marlis Kees as well as the consultants Elmar Dimpl, Dr. Agnes Klingshirn and Dr. Andre Seidel for their comments on the draft of this study. Particular thanks go to the Regional ProBEC Coordinator for Malawi, Tanzania and Zambia, Dr. Christoph Messinger, for comments and constructive suggestions to the draft of this study.

2 General base data

This chapter presents general base data and assumptions used in the economic analyses. Specific base data and average values applied only in the CBA and CEA are presented in Chapter 3. The cost of the programme component “Promotion of efficient institutional cook stoves” of ProBEC Malawi and the stove costs can be found in Chapter 3.5.

All prices and average values applied in the study were derived from 2007 prices with the exception of the retail price for firewood and the price of the EU Allowance for one tonne of CO_2 (see Chapter 3.6.1 and 3.6.3).

2.1 User groups and their utilization rate of the Rocket Stoves

Due to the various activities of the institutions that have acquired Rocket Stoves, the institutions use the stove to very different extents during the year and therefore achieved varying annual firewood savings. Three parameters were applied to assess the use of the Rocket Stove and the firewood savings achieved: the number of cooking days per year, the number of meals cooked per day and the utilization rate of the institutional Rocket Stove (RS). In order to distinguish the institutions according to these parameters, the author formed ten different user groups, which are enumerated in the following table with their parameter values and the respective number of Rocket Stoves purchased by December 2007.

User groups and their utilization rate of the Rocket Stoves:

User group	Number of cooking days p. a.	Number of meals cooked per day	Utilization rate of the RS per user group	Number of RS purchased by December 2007
WFP	185	1	81%	2,332
Mary’s Meal	220	1	94%	606
GTZ/BEP	110	1	42%	366
UNICEF	365	1	84%	499
Prison	365	2	100%	80
Hospital, Orphanage	365	2	84%	49
Boarding School	185	2	84%	62
School	185	1	84%	121
Canteen, Nursery	250	1	84%	78
Tea Estate	300	2	100%	7+ 66 constructed in tea estates

The utilization rate of the Rocket Stoves per user group expresses the percentage of Rocket Stoves being used after delivery and during their life span. It also considers the extent to which the traditional stove may still be in use as well. Reasons for giving up the Rocket Stove or not using it in most of the known cases were the fact that cooks had not been taught sufficiently how to use the stove or not at the time when the Rocket Stove was installed. (The latter was reported especially by the GTZ/BEP user group.)

In order to be more pessimistic than optimistic in our assumptions, we applied as a utilization rate the percentage figure of Rocket Stoves still in use, as observed in the ProBEC Impact Study (DeGabriele, Msukwa, 2007): 81% for WFP (World Food Programme), 94% for Mary's Meal and 42% for GTZ/BEP (GTZ Basic Education Programme).

Since the field research for the Impact Study commenced at the end of the academic school year (when some schools no longer offer meals) and also in a period when the school feeding programme of GTZ/BEP was not active (this programme only targets schools during the hunger months, November through March), the percentage of Rocket Stoves in use in schools of the user groups WPF, GTZ/BEP and Mary's Meal as determined in the Impact Study was probably lower than it had been in other school months.

Additionally, the very low utilization rate for the GTZ/BEP user group can be explained by the fact that the Rocket Stove was often abandoned, because the cooks had to prepare food in a number of pots at the same time, but had only one Rocket Stove and therefore continued to use the traditional stoves.

For the other user groups, we applied as a utilization rate the average percentage of stoves still in use as assessed in the ProBEC Impact Study (84%), with the exception of the prisons and tea estates which gave up the traditional stoves altogether when the Rocket Stove was introduced.

The number of cooking days per year depends on the social or economic activity of the respective institutions. The number of warm meals per day per user group was based on a conservative assumption. We did not consider the fact that often during a cooking session two pots are used in meal preparation, one after the other. Nor did we include weekend cooking sessions which took place in some schools, too.

2.2 Average size and fuelwood savings of the Rocket Stoves

The size of the institutional Rocket Stoves varies widely. They are built for pot sizes ranging from 30 to 250 litres. Although most of the Rocket Stoves produced are for 110 litre pots, for the economic analyses we formed three average size groups for the Rocket Stove (50, 100 and 200 litres) in order to determine more accurately the average price as well as the average firewood consumption per stove and in total.

If correctly installed and especially if properly used, the Rocket Stove can save 70% to 90% of the firewood that would be consumed by the three-stone fire. Not all users of the Rocket Stoves achieve these fuelwood savings. It must be pointed out that the firewood savings achieved with the use of the Rocket Stove are always the result of the stove's use and a wide range of energy-saving tips as well as kitchen management techniques (using a lid for the pots, dried firewood, smaller pieces of wood, not completely burnt firewood for further cooking; soaking beans before cooking, etc.)

The average firewood saving rate per stove size applied in the economic evaluation reflects the fact that the firing technique, the preparation of firewood as well as other kitchen techniques were sometimes inefficient. It is the minimum saving rate which can in any case be achieved by all users, and also in cases where the Rocket Stove replaced an inefficient traditional stove and not the three-stone fire.

Besides the firing and kitchen management techniques, numerous other factors influence the firewood consumption per cooking process in the institutional kitchen, such as the dish prepared, the moisture content of the wood and the varieties of wood used. Nevertheless, we were able to derive for each size group of the Rocket Stove the average firewood consumption per cooking process and its firewood saving rate compared to the traditional stove.

The following table shows the firewood consumption per average size of the Rocket Stove and the respective minimum firewood saving rate compared with the traditional stove, as well as the firewood savings per cooking process.

Firewood consumption and savings per average Rocket Stove:

Average Rocket Stove (three type sizes)	Firewood consumed by the RS per cooking process	Minimum firewood saving rate	Firewood saved per cooking process due to the RS
50 litre (including 30 to 80 litre)	10 kg	60%	15 kg
100 litre (including 81 to 170 litre)	14 kg	70%	32.67 kg
200 litre (including 171 to 250 litre)	18 kg	75%	54 kg

The minimum firewood saving rate of Rocket Stoves is also influenced by the production quality of the product (the stove). ProBEC has introduced and implemented jointly with the Department of Energy in Malawi a quality control system for Institutional Rocket Stoves which includes a certification of qualified producers.

3 Scope of the CBA and CEA

3.1 Time horizon and discount rate

The cost-benefit analysis (CBA) as well as the cost-effectiveness analysis (CEA) were conducted over a period of 10 years (2005 to the end of 2014). Alternative calculations were carried out for periods of 5 and 20 years.

All benefits and costs were discounted to the beginning of 2005, or, as the case may be,to the end of 2004, the year in which the ProBEC Malawi programme component “Promotion of efficient institutional cook stoves” started and a very small number of Rocket Stoves had been installed. The author counted 2005 as the first year of the periods considered in the CBA and CEA, i.e. as the year in which the first benefits deriving from the use of the Rocket Stoves were assumed to emerge.

A discount rate of 3% p.a. was applied. This interest rate is generally recommended for the discount rate used in the economic evaluation of “efficient stove promotion programmes”, which always include highly valued social and environmental aims and are in the interest of the public and the respective government (Hutton and others, 2006; Habermehl, 2006). The discount rate of 3% also reflects the rate of return of long-term public securities, such as government bonds of West European countries.

Alternative calculations with a discount rate of 10% (reflecting the rate of return of risk government bonds) were carried out for the 5-year period.

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 (i.e. purchased by the end of 2007), the fuel prices, the fuel savings per average stove size and the utilization rate of the Rocket Stoves remain constant in future years (from 2008), and that the stoves are replaced after their average life spans, with the exception of the stoves purchased by prisons and GTZ/BEP.

In reality, the certified stove producers will probably sell a steadily growing number of Rocket Stoves, so that the number of Rocket Stoves in use will surely be much higher in the future than the number of stoves assumed to be in use in the CBA and CEA. The major supporting donors indicated budget provisions for the purchase of about 3,000 Rocket Stoves in 2008 (around 50% more than in 2007).

We assumed a life span of four years for the Rocket Stove. This assumption is based on the results of a study conducted in 2007 (DeGabriele, Msukwa, 2007) as well as on technical considerations.

Since the GTZ Basic Education Programme has been discontinued, we assumed that the 366 GTZ/BEP Rocket Stoves will be used by other school kitchens to the same small extent as they were used in the framework of GTZ/BEP (as reported to ProBEC) and that they will not be replaced after the end of their life span.

The other two school feeding programmes, WFP and Mary's Meal, will be continued in the coming years. Mary's Meal has no time limit. WFP is expected to run until 2012 in any case and is actually also open-ended, because in all probability it will be continued in the years after 2012 as well.

The Rocket Stoves in the prison kitchens were used very intensively (several pots of food were cooked, one after the other, on the Rocket Stove for the preparation of one meal) and the cooks did not take much care of them. We therefore assumed an average life span of only one year for the Rocket Stoves used in the prisons. In reality, the Rocket Stoves are still being used in the prison kitchen with a lower firewood saving rate (because of the stove damages). It is not known whether or when the Rocket Stoves in prisons will be replaced. Therefore, we conservatively assumed in the CBA and CEA that the Rocket Stoves used in the prisons are not replaced after the end of their assumed life span of one year.

3.3 Total number of Rocket Stoves considered

The Rocket Stove is ordered and installed throughout the year, but for calculation purposes, we assumed that all stoves delivered between June and December were installed and put into use in January of the following year, and that all stoves delivered between January and May were installed and put into use in January of the same year.

With the exception of the four donors (WFP, Mary's Meal, GTZ/ BEP, UNICEF), the institutions of each user group purchased Rocket Stoves of all three average type sizes (50 l, 100 l, 200 l; Chapter 2.2). The CBA and CEA considered the corresponding, different firewood savings per stove for each user group.

The following two tables present the number of Rocket Stoves considered in the CBA and CEA for the years 2005 to 2010 onwards. The first table shows the number of stoves installed by WFP, Mary's Meal and GTZ/BEP in the framework of school feeding programmes as well as by UNICEF and by prisons. It also indicates the reduced number of GTZ/BEP stoves for the years 2010 and 2011 and the number of stoves used in prisons (2005-2008) according to the above-mentioned assumptions (see Chapter 3.2). The second table presents the total number of Rocket Stoves considered per typical stove size for all the other user groups. The third table shows the total number of Rocket Stoves produced commercially and considered in the respective years of the CBA and CEA.

Number of Rocket Stoves considered in the CBA and CEA per year for the user groups "WFP, Mary's Meal, GTZ/BEP, UNICEF, Prison" (produced by commercial stove producers) (It was assumed that all stoves delivered between June and December were put into use in January of the following year and that all stoves delivered between January and May were put into use in January of the same year.)							
User group and size of the stove	2005 (delivered 6/2004-5/2005)	2006 (delivered 6/2004-5/2006)	2007 (delivered 6/2004-5/2007)	**2008** (delivered 6/2004-1/2008)	2009 (total of 2008)	2010 (total of 2009 minus GTZ/BEP-RS not replaced)	**2011 onwards** (total of 2010 minus GTZ/BEP-RS not replaced)
WFP, 110 l	181	518	653	2,332	2,332	2,332	2,332
Mary's Meal, 110 l	7	196	538	606	606	606	606
GTZ/BEP, 110 l	0	165	366	366	366	201	0
UNICEF, 50 l	0	0	499	499	499	499	499
Prison, mostly 200 l (life span:1 year, RS not replaced	17	22	21	20	0	0	0

Total number of Rocket Stoves produced by commercial stove producers and considered in the CBA and CEA per year for the user groups "Hospital, orphanage, boarding school, school, canteen, nursery and tea estate" (It was assumed that all stoves delivered between June and December were put into use in January of the following year and that all stoves delivered between January and May were put into use in January of the same year.)				
Average type size of the RS	2005	2006	2007	**2008 onwards**
50 litre	11	50	79	99
100 litre	6	48	106	163
200 litre	25	46	54	55

Total Number of Rocket Stoves produced by commercial stove producers and considered in the CBA and CEA per year (It was assumed that all stoves delivered between June and December were put into use in January of the following year and that all stoves delivered between January and May were put into use in January of the same year.)							
All user groups and stove sizes	2005 (delivered 6/2004-5/2005)	2006 (delivered 6/2004-5/2006)	2007 (delivered 6/2004-5/2007)	**2008** (delivered 6/2004-1/2008)	2009 (total of 2008)	2010 (total of 2009 minus GTZ/BEP-RS not replaced)	**2011 onwards** (total of 2010 minus GTZ/BEP-RS not replaced)
	247	1,045	2,316	**4,140**	4,120	3,955	**3,754**

The total number of Rocket Stoves produced by the four commercial stove producers and considered in the economic analyses amounts to 4,140 in 2008 and 3,754 in 2011.

Makandi and Eastern Produce tea estates constructed 66 Rocket Stoves (200 l), which were also considered in the CBA and CEA (26 stoves used in 2006, 56 in 2007 and 66 from 2008 onwards; see Chapter 3.4).

3.4 Fuelwood savings due to the Rocket Stoves considered in the CBA and CEA

The following table presents the annual firewood savings due to the use of the institutional Rocket Stoves for the years 2005 to 2011 onwards, not including the firewood savings of the tea estates Makandi and Eastern Produce, which are presented in the third table.

The fourth column of the following table ("Other institutions") includes the firewood savings of the prisons, which are presented separately in the second table.

With the exception of schools included in the school feeding programmes of WFP and GTZ/BEP, all institutions using Rocket Stoves buy their firewood (see Chapter 3.6.1). The third column of the next table shows the total amount of the firewood purchased by the institutions.

Annual firewood savings in tonnes due to the use of the Rocket Stove (not including savings of the tea estates):

Year	Total firewood savings (not including tea estates)	Firewood purchased by institutions	Other institutions (including prisons)	UNICEF	WFP (no firewood purchased)	GTZ/BEP (no firewood purchased)	Mary's Meal
2005	2,270.44	1,384.43	1,337.14	0.00	886.01	0.00	47.29
2006	6,663.22	3,878.54	2,554.47	0.00	2,535.66	249.02	1,324.07
2007	12,739.94	8,991.07	3,061.73	2,294.90	3,196.50	552.37	3,634.44
2008	21,871.13	9,903.39	3,514.67	2,294.90	11,415.37	552.37	4,093.81
2009	21,082.73	9,114.99	2,726.27	2,294.90	11,415.37	552.37	4,093.81
2010	20,833.71	9,114.99	2,726.27	2,294.90	11,415.37	303.35	4,093.81
2011 onwards	20,530.36	9,114.99	2,726.27	2,294.90	11,415.37	0	4,093.81

Annual firewood savings due to the use of the Rocket Stove in prisons:

Year	In tonnes
2005	654.57
2006	820.52
2007	643.62
2008	788.40
2009 onwards	0

Annual firewood savings due to the use of the Rocket Stove in the tea estates Makandi and Eastern Produce:

Year	in tonnes
2005	0
2006	624.00
2007	1,104.00
2008 onwards	1,264.00

Between November 2005 and January 2006 the Makandi tea estates constructed and installed 26 Rocket Stoves for 200 l pots which were used in their canteens. Since the conventional kitchen stoves had been entirely replaced by the Rocket Stoves, they could calculate the consumption with and without the Rocket Stoves. The expected wood usage would have been 2,013 cbm p.a. of blue gum trees with conventional stoves, but amounted to only 762 cbm with the Rocket Stoves. Annual firewood savings due to the Rocket Stoves were 62.17% (1,251 cbm). Assuming a wood weight of 500 kg per cbm of blue gum (data of Makandi tea estate), the amount of annual firewood savings per Rocket Stove was approximately 24 tonnes.

The tea estates of Eastern Produce did not have comparable figures on the firewood consumption with and without the Rocket Stoves. According to the reduced use of the firewood stoves in these estates (they also use steampowered stoves for several months per year), we assumed that one Rocket Stove used in the canteens of Eastern Produce achieves on average 66.67% of the annual firewood savings of one Rocket Stove of Makandi tea estate, i.e. 16 tonnes p.a. per Rocket Stove. In 2007, Eastern Produce used 30 self-constructed Rocket Stoves that had been built in 2006. Another 10 Rocket Stoves were constructed during 2007. This means that the number of Rocket Stoves used in the tea estates of Eastern Produce from January 2008 on amounts to 40, resulting in firewood savings p.a. of 640 tonnes.

The annual firewood savings achieved with the use of all institutional Rocket Stoves considered in the CBA and CEA are as follows:

Total annual firewood savings due to the use of the Rocket Stove:

Year	Total firewood savings in tonnes
2005	2,270.44
2006	7,287.22
2007	13,843.94
2008	**23,135.13**
2009	22,346.73
2010	22,097.71
2011 onwards	21,794.36

The firewood savings achieved with the use of all institutional Rocket Stoves in 2008 amounts to 23,135 tonnes.

3.5 Costs considered in the CBA and CEA

3.5.1 Costs of the stoves

The average price of the Rocket Stove per type size was:
50 l: 120 US$
100 l: 180 US$
200 l: 275 US$

These prices also include normally the transport costs. In the case of the school feeding programmes (approx. 80% of all Rocket Stoves purchased) the stove producers deliver the stoves to a central depot of the respective organisation. These stoves are transported to the schools together with the food for the school feeding programmes; i.e. no additional transport costs arise (information from the stove users). In all the other cases, either the stove producer delivers the stove to the stove buyer or the stove is picked up personally by the buyer.

No other costs, e.g. maintenance or repair costs, had to be taken into account. The average life span of the stove is 4 years and 1 year for the Rocket Stoves installed in prisons (see Chapter 3.2).

For the 66 self-constructed Rocket Stoves (200 l) in the tea estates, we assumed an average cost of 275 US$ per stove and a life span of 4 years.

A number of institutions were in the process of renovating their kitchens, or had to replace the traditional stove. Nevertheless, the economic analyses do not consider any replacement cost of the traditional stove, i.e. do not reduce the cost of the Rocket Stove by the cost which would have been incurred to acquire a new traditional stove.

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 applied (3% or 10%).

The following table shows the number of Rocket Stoves considered in the CBA and CEA per type size having a life span of four years and their total annual costs based on a discount rate of 3%.

Number of Rocket Stoves per type size having a life span of 4 years and their total annual costs:

Year	50 l stove (life span: 4 years)	100 l stove (life span: 4 years)	200 l stove (life span: 4 years)	Costs of RS with a life span of 4 years, in US$ (annuities; discount rate: 3%)
2005	11	194	25	11,261
2006	50	927	46+ 26	50,321
2007	578	1,663	54+56	104,202
2008	598	3,467	55+66	190,433
2009	598	3,467	55+66	190,433
2010	598	3,302	55+66	182,676
2011 onwards	598	3,101	55+66	173,226

The second figure in the fourth column (200 l stove) is the number of Rocket Stoves constructed and used in the tea estates.

The next table shows the number of Rocket Stoves installed in prisons and considered in the CBA and CEA per type size having a life span of one year, and their total annual costs between 2005 and 2008.

Number of Rocket Stoves installed in prisons per type size (life span: 1 year) and their total annual costs:

Year	50 l stove (life span: 1 years)	100 l stove (life span: 1 years)	200 l stove (life span: 1 years)	Costs of RS with a life span of 1 years, in US$
2005	0	1	16	4,580
2006	0	3	19	5,765
2007	1	10	10	4,670
2008	0	0	20	5,500
2009 onwards	0	0	0	0

3.5.2 Costs of the ProBEC programme component “Promotion of efficient institutional cook stoves”

The annual expenses for the ProBEC component “Promotion of efficient institutional cook stoves” in Malawi amounted to the following annual sums from 2004 to 2007 in euros:

2004: 56,560 EUR
2005: 119,840 EUR
2006: 78,960 EUR
2007: 62,160 EUR

The total expenses for the ProBEC Malawi programme component “Promotion of efficient institutional cook stoves” were 317,520 EUR (accumulative, 2004 to 2007).

These expenses included costs for the international and national staff, short-term experts, administration and overhead costs, travel and transport costs, as well as material costs for the following activities of the efficient institutional cook stoves’ promotion: research (stove development and adjustment of the “Rocket Stove concept” to the conditions in Malawi), training of the stove producers, quality control of the stoves, marketing activities (demonstration, exhibitions, trade fairs, public relations, etc.), monitoring, evaluation and impact studies.

We wish to emphasize that these costs represent the estimated expenses for one ProBEC programme component (“Promotion of efficient institutional cook stoves”) in Malawi and only proportionate overhead costs. A so-called “stand-alone institutional Rocket Stove programme” would require substantially higher financial means.

The author converted the annual expenses into US dollars by using average exchange rates of 1.25 US$ for 1 EUR for the years 2004 to 2006 and 1.35 US$ for 2007. The respective amounts in US$ were as follows:

2004: 70,700 US$
2005: 149,800 US$
2006: 98,700 US$
2007: 83,916 US$

The total expenses for the ProBEC Malawi programme component “Promotion of efficient institutional cook stoves” were 403,116 US$ (accumulative, 2004 to 2007).

3.6 Economic benefits considered in the CBA

3.6.1 Avoided fuel costs

The CBA considers the avoided fuel costs (firewood savings) derived from the use of the Rocket Stoves as economic benefits. These economic benefits are outlined in the following and in the CBA “Benefits due to fuel savings”.

With the exception of the school feeding programmes of WFP and GTZ/BEP, all institutional Rocket Stove user groups buy their firewood.

In the case of WFP and GTZ/BEP, schools have to supply the fuelwood, which means that the community provides it through collection or purchases. The percentages at which this firewood is collected or purchased are unknown. Based on observations of the "Rocket Stove promotion project" and the conclusions in studies carried out to date (Paul Mushamba, 2003; Joy Hecht, 2006), it can be assumed that the collected firewood is very often harvested from indigenous trees, i.e. it comes from the felling of these trees. The proportion of firewood that is purchased must be bought at retail prices.

Institutions can buy firewood in large amounts and therefore at a trade price. They often obtain it from the forestry authority. Mary's Meal purchased its firewood at a trade price of 2,000 MK for the cbm blue gum (eucalyptus) or pine wood in 2007. Assuming a wood weight of 500 kg per cbm of blue gum as well as for pine wood (data of Makandi tea estate and average value calculated by the author from different sources), the trade price of one kilogram of firewood came to 0.0286 US$ in 2007, based on the exchange rate of 140 MWK for 1 US$.

According to ProBEC Malawi and several other local sources, it was concluded that this trade price for fuelwood could be generalized for all the other institutions. They also had to pay at least this trade price on average.

The author also applied the trade price of 0.0286 US$/kg as an economic value for the firewood used by schools in the framework of the WFP and GTZ/BEP, based on the following considerations.

The proportion of firewood provided by the community from the felling of indigenous trees could be valued at afforestation cost, i.e. at a cost of 0.0521 US$/kg (see Chapter 3.6.2). The share of firewood that is purchased must be bought at retail prices. The average retail price of firewood on the markets in Blantyre, based on the survey by ProBEC in October 2006, amounted to 12.24 MK or 0.0874 US$ per kilogram.

Under the hypothesis that 60% of the community firewood is collected and 40% is purchased at a price of 0.0874 US$/kg, the average economic value of one kilogram of fuelwood would be 0.0506 US$, if we assume that 50% of the collected firewood comes from the felling of indigenous trees (valued at the above-mentioned afforestation costs) and the other 50% from dead wood (not valued, because it is free of charge and we would also not apply a firewood-collection shadow price for it).

Assuming that 80% of the firewood was collected (50% free of charge and not valued with a firewood-collection shadow price, and again 30%, coming from the felling of trees, valued at afforestation costs) and 20% purchased (0.0874US$/kg), the average economic value would be 0.0331 US$/kg.

In view of these rough calculation results and considering that the fuelwood collection time should be valued as well, at least with firewood-collection shadow prices, it can be said that the economic value of the firewood saved with the Rocket Stoves used by WPF and GTZ/BEP would in any case have been no lower than 0.0331 US$/kg.

The tea estates use firewood from their own blue gum plantations. Since the tea estates also sell fuelwood, we assumed that their total amount of firewood savings is sold at the trade price of 0.0286 US$/kg.

The following table presents the total economic benefits due to fuel savings achieved in the years 2005 to 2010:

Year	**Economic benefits in US$ due to fuel savings**
2005	64,935
2006	208,415
2007	395,937
2008	**661,665**
2009	639,116
2010	631,994
2011 onwards	623,319

3.6.2 Benefits due to preservation of forest reserves

The benefits due to preservation of forest resources were determined based on the following considerations and assumptions.

1.) 30% of the firewood savings preserve forest resources.
The author derived this figure based on the following hypotheses:
30% of the firewood supplied by communities in the framework of WFP and GTZ/BEP comes from the felling of indigenous forest trees.
The reduction of firewood (60-75%) in all the other Rocket Stove user groups, which obtain their fuelwood from blue gum (eucalyptus) or pine wood forest plantation, increases the supply of plantation fuelwood for other firewood consumers in Malawi by 60-75%. This leads to a reduction in the use of indigenous forest trees for firewood purposes, which was assumed to be 30% of the firewood savings of all the other Rocket Stove user groups.

2.) Afforestation costs for a natural forest are not available in Malawi (Joy Hecht, 2006). The author therefore calculated the surface of natural forest cover that is preserved through the reduced felling of indigenous trees due to the firewood savings of the Rocket Stoves as discussed above. She assumed that this surface could at least be planted with blue gum trees in order to regain a stock of trees. Then she calculated the value of forest reserves (ha of natural forest preserved) based on afforestation costs for blue gum.

Base data for this calculation were derived from several local sources as well as the Mulanje Mountain study (Joy Hecht, 2006) and can be summed up as follows.

An average stock density of 18 cubic metres per hectare of natural forest cover and an average wood weight of 800 per solid cubic metre were assumed. Losses derived from unmarketable wood species, overly thick trunks or destruction from fire were not taken into account.

Afforestation costs for blue gum amounted to 1,500 US$/ha, in cases where old coffee plantatation surfaces had been replanted with blue gum (data from Eastern Produce). The maintenance of tree stocks and replanting new trees after eight years in the blue gum plantation of Makandi tea estate entailed costs of around 352 US$/ha. We assumed that replanting an indigenous forest surface cleared of trees with blue gum would cost at least 750 US$/ha.

Based on the above-mentioned hypotheses the afforestation costs for one kg firewood saved (coming from the felling of indigenous trees) amount to 0.0521 US$/kg.

The economic benefits of natural forest cover preserved by annual firewood savings due to the use of the Rocket Stoves result in the following values:

Year	**Economic benefits in US$ of forest cover preserved**
2005	35,487
2006	113,899
2007	216,381
2008	**361,602**
2009	349,279
2010	345,387
2011 onwards	340,646

3.6.3 Benefits due to greenhouse gas reduction

One global environmental impact of firewood savings due to the use of the Rocket Stoves is the reduction of greenhouse gas emissions. In the CBA we assigned a monetary value to the amount of emissions 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.

For example, the firewood savings in 2008 (23,135 tonnes) result in reduced emissions of approx. 34,703 tonnes of CO_2 and 93 tonnes of CH_4. The average Rocket Stove with the typical size of 100 litres saves 32.67 kg firewood per cooking process compared to the traditional stove, reducing the CO_2 emissions by 49 kg and CH_4 emissions by 0.1307 kg per cooking process.

We assumed that the economic value of one tonne of CO_2 avoided is the price of the traded EUA (EU Allowance) for one tonne of CO_2. The volatility of the traded EUA is extremely high. Very low prices in 2007 and high prices in 2006, as well as high prices expected for 2008, make it more difficult to arrive at an average value. The author applied 7 US$ and 1 US$ per tonne of CO_2 in the economic calculations. The 7 US$ figure corresponds to the price of one EUA (about 5 EUR) applied in another study (Habermehl, 2007) and was one of the lowest prices for one tonne of CO_2 on the EUA spot market in 2006. The 1 US$ figure is approximately the average price on the spot market in 2007. The EUA spot market price was very low in 2007, because, amongst other reasons, the first period of the EU Emissions Trading Scheme (from 2005-2007) ended in 2007.

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 as a greenhouse gas compared with carbon dioxide. The corresponding values were 140 US$ and 20 US$ per tonne of CH_4.

The annual benefits from CO_2 and CH_4 emission reduction due to the use of the improved household stoves, valued at prices for EUA for one tonne of CO_2 (7 and 1 US$), were as follows:

Year	**Economic benefits in US$ (greenhouse gas reduction) price of EUA: 7 US$**	**Economic benefits in US$ (greenhouse gas reduction) price of EUA: 1 US$**
2005	25,111	3,587
2006	80,597	11,514
2007	153,114	21,873
2008	**255,874**	**36,553**
2009	247,155	35,308
2010	244,401	34,914
2011 onwards	241,046	34,435

A sensitivity analysis showed that, at a price of 0.1 US$ per tonne of CO_2 (price often traded on the spot market in October and November 2007), the benefits due to greenhouse gas reduction had a negligible influence on the main results of the CBA, as one can see from the following table.

Main results of the CBA assuming an EUA price of 0.1 US$ Applied discount rate: 3%	In US$
Share of benefits due to CO_2 and CH_4 reduction as part of total benefits	0.36%
US$ return per 1 US$ invested (Total benefits) – period of 5 years	3.06
US$ return per 1 US$ invested (Total benefits without CO_2 and CH_4 reduction) –period of 5 years	3.05
US$ return per 1 US$ invested (Total benefits) – period of 10 years	4.14
US$ return per 1 US$ invested (Total benefits without CO_2 and CH_4 reduction) –period of 10 years	4.13
US$ return per 1 US$ invested (Total benefits) – period of 20 years	4.73
US$ return per 1 US$ invested (Total benefits without CO_2 and CH_4 reduction) –period of 20 years	4.72

Moreover, at a price of 1 US$ for the EUA, the share of economic benefits due to greenhouse gas reduction amounts to only 3.5% of the total economic benefits and has hardly any influence on the results of the CBA compared with the economic benefits due to fuel savings and the preservation of natural forest cover (see Chapter 4).

3.6.4 Total economic benefits

The following two tables give an overview of the economic benefits considered in the CBA.

Economic benefits considered in the CBA (EUA price: 7 US$):

Year	Economic benefits due to fuel savings in US$ (see Chapter 3.6.1)	Economic benefits due to preserved forest cover In US$ (see Chapter 3.6.2)	Economic benefits due to CO_2 and CH_4 reduction in US$ (see Chapter 3.6.3) **EUA price: 7 US$**	Total economic benefits in US$ **EUA price: 7 US$**
2005	64,935	35,487	25,111	125,533
2006	208,415	113,899	80,597	402,911
2007	395,936	216,381	153,114	765,431
2008	**661,665**	**361,602**	**255,874**	**1,279,141**
2009	639,116	349,279	247,155	1,235,550
2010	631,994	345,387	244,401	1,221,782
2011 onwards	623,319	340,646	241,045	1,205,010

Total economic benefits in US$ without and with benefits due to CO_2 and CH_4 reduction (EUA price: 1 US$):

Year	Total economic benefits in US$ without benefits due to CO_2 and CH_4 reduction	Economic benefits due to CO_2 and CH_4 reduction in US$ (see Chapter 3.6.3) EUA price: 1 US$	Total economic benefits in US$ EUA price: 1 US$
2005	100,422	3,587	104,009
2006	322,314	11,514	333,828
2007	612,317	21,873	634,191
2008	**1,023,267**	**36,553**	**1,059,820**
2009	988,396	35,308	1,023,704
2010	977,382	34,914	1,012,296
2011 onwards	963,964	34,435	998,400

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

4.1 Key model calculations (considering a period of 10 years)

In Chapters 4.2 to 4.4, we present the main results of three key model calculations, which were carried out in the framework of the CBA. The key model calculations were based on a period of 10 years. This means that the key model calculations considered the benefits and costs derived from the "Rocket Stove promotion project" (i.e. the use of the Rocket Stoves) over a period of 10 years.

The three key model calculations based on a discount rate of 3% were as follows:
Model 1: Considering the total economic benefits and assuming an EUA price of 7 US$ (Case 1)
Model 2: Considering the total economic benefits and assuming an EUA price of 1 US$ (Case 2)
Model 3: Considering only the economic benefits due to fuel savings (Case 3)

In order to show that the "ProBEC stove promotion" was still effective even under more pessimistic assumptions, Chapter 4.5.1 and Chapter 4.5.2 presents the results for a period of 5 years, based on a discount rate of 10% and 3%, respectively.

Chapter 4.5.3 presents the results for a period of 20 years based on the same cases (1-3) and the discount rate of 3%.

Chapter 9 provides a summary of the key results and the conclusions.

4.2 Net present value of the "stove promotion" and present value of economic benefits (period considered: 10 years)

If we analyse the promotion of institutional Rocket Stoves in the concept of 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 project over a 10-year period and discounted to the year of the project's start (2005). The net present value was calculated by discounting the annual cash flows (annual benefits minus annual costs) to the beginning of the year 2005.

We assumed for the economic calculations that the first Rocket Stoves were installed and used in 2005 (Chapter 3.3). The costs of the ProBEC Malawi programme component "Promotion of efficient institutional cook stoves" for the year 2004 were considered as an initial investment in the CBA and CEA.

Three net present values (NPV) are shown in the following table, corresponding to the key model calculations 1 to 3 (discount rate of 3%):

NPV 1: Considering the total economic benefits and assuming an EUA price of 7 US$ (Case 1)

NPV 2: Considering the total economic benefits and assuming an EUA price of 1 US$ (Case 2)

NPV 3: Considering only the economic benefits due to fuel savings (Case 3)

Net present values in US$:

NPV 1	NPV 2	NPV 3
6,594,425	5,192,080	2,646,261

The present values for the different economic benefits (as described in Chapter 3.6) were also calculated and the share of each economic benefit as a percentage of the total economic benefits determined:

Present values of economic benefits in million US$:

Period of 10 years; discount rate: 3%	Benefits due to fuel savings	Benefits due to preservation of forest reserves	Benefits due to greenhouse gas reduction 7 US$/EUA	Total benefits 7 US$/EUA	Benefits due to greenhouse gas reduction 1 US$/EUA	Total benefits 1 US$/EUA
Present value (million US$)	4.231	2.312	1.636	8.179	0.234	6.777
Percentage of total benefits	51.73%	28.27%	20%	100%	3.45%	100%

4.3 Benefit-cost ratio (period considered: 10 years)

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 3%: 1,584,442

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

Benefit-cost ratios:

Model 1	Model 2	Model 3
5.16 US$	4.28 US$	2.67 US$

The benefit-cost ratio of Model 1 indicates that the investment of one US$ gives a return of 5.16 US$, when all economic benefits are considered and an EUA price of 7 US$ is applied.

The benefit-cost ratio of Model 2 indicates that the investment of one US$ gives a return of 4.28 US$, when all economic benefits are considered and an EUA price of 1 US$ is applied.

The benefit-cost ratio of Model 3 indicates that the investment of one US$ gives a return of 2.67 US$, when only the benefits due to fuel savings are considered.

4.4 Internal rate of return (period considered: 10 years)

The internal rate of return is the rate of interest earned on the capital (cost of the “stove promotion”) tied up in the project during the period under consideration. The costs of the stoves were considered as recurrent annual costs.

Internal rates of return:

Model 1	Model 2	Model 3
180%	148%	87%

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 4, 5 and 6, considering a period of 5 years and a discount rate of 10%.

Model 4: Considering the total economic benefits and assuming an EUA price of 7 US$ (Case 1)
Model 5: Considering the total economic benefits and assuming an EUA price of 1 US$ (Case 2)
Model 6: Considering only the economic benefits due to fuel savings (Case 3)

Net present values in US$:

Discount rate	NPV 4	NPV 5	NPV 6
10%	1,879,825	1,423,222	594.305

Present values of economic benefits in million US$:

Period of 5 years; discount rate: 10%	Benefits due to fuel savings	Benefits due to preservation of forest reserves	Benefits due to greenhouse gas reduction 7 US$/EUA	Total benefits 7 US$/EUA	Benefits due to greenhouse gas reduction 1 US$/EUA	Total benefits 1 US$/EUA
Present value (million US$)	1.378	0.753	0.533	2.663	0.076	2.206
Percentage of total benefits	51.73%	28.27%	20%	100%	3.45%	100%

Benefit-cost ratios:

Model 4	Model 5	Model 6
3.40 US$	2.82 US$	1.76 US$

Internal rates of return:

Model 4	Model 5	Model 6
173%	140%	74%

4.5.2 Considering a period of 5 years and a discount rate of 3%

The following are the main results of the CBA for the model calculations 4 and 5, considering a period of 5 years and a discount rate of 3%.

Model 7: Considering the total economic benefits and assuming an EUA price of 7 US$ (Case 1)
Model 8: Considering the total economic benefits and assuming an EUA price of 1 US$ (Case 2)
Model 9: Considering only the economic benefits due to fuel savings (Case 3)

Net present values in US$:

Discount rate	NPV 7	NPV 8	NPV 9
3%	2,512,234	1,928,511	868,820

Present values of economic benefits in million US$:

Period of 5 years; discount rate: 10%	Benefits due to fuel savings	Benefits due to preservation of forest reserves	Benefits due to greenhouse gas reduction 7 US$/EUA	Total benefits 7 US$/EUA	Benefits due to greenhouse gas reduction 1 US$/EUA	Total benefits 1 US$/EUA
Present value (million US$)	1,761	0.962	0.681	3,404	0.097	2,821
Percentage of total benefits	51.73%	28.27%	20%	100%	%3.45%	100%

Benefit-cost ratios:

Model 7	Model 8	Model 9
3.82 US$	3.16 US$	1.97US$

Internal rates of return:

Model 7	Model 8	Model 9
176%	143%	77%

4.5.3 Considering a period of 20 years and a discount rate of 3%

The following are the main results of the CBA for the model calculations 10, 11 and 12, considering a period of 5 years and a discount rate of 3%.

Model 10: Considering the total economic benefits and assuming an EUA price of 7 US$ (Case 1)
Model 11: Considering the total economic benefits and assuming an EUA price of 1 US$ (Case 2)
Model 12: Considering only the economic benefits due to fuel savings (Case 3)

Net present values in US$:

Discount rate	NPV 10	NPV 11	NPV 12
3%	13,143,439	10,429,681	5,503,122

Present values of economic benefits in million US$:

Period of 20 years; discount rate: 3%	Benefits due to fuel savings	Benefits due to preservation of forest reserves	Benefits due to greenhouse gas reduction 7 US$/EUA	Total benefits 7 US$/EUA	Benefits due to greenhouse gas reduction 1 US$/EUA	Total benefits 1 US$/EUA
Present value (million US$)	8.187	4.474	3.166	15.827	0.452	13.114
Percentage of total benefits	51.73%%	28.27%	20%	100%	3.45%	100%

Benefit-cost ratios:

Model 10	Model 11	Model 12
5.90 US$	4.89 US$	3.05 US$

Internal rates of return:

Model 10	Model 11	Model 12
180%	148%	88%

5 Results of the cost-effectiveness analysis

The CEA values the benefits in natural units. It determines the efficiency of the “stove promotion project” as a function of lowest costs. The author assessed the cost-effectiveness of the “stove promotion” in terms of firewood saved.

In other words, the amount of firewood saved in kg per 1 US$ invested in “stove promotion” and stove investment is a direct indication of the efficiency. A high kg-value indicates a high efficiency. Dividing the amount of firewood saved (kg) by 1 US$ results in the costs of one kilogram of fuelwood that is saved through the use of Rocket Stoves (result of the “investment in stoves and in stove promotion”). This makes it more understandable why efficiency is defined in the CEA as a function of lowest costs.

The dynamic cost-effectiveness was calculated by dividing the sum of discounted annual amounts of firewood savings by the sum of discounted annual costs.

The costs included the costs for the stoves as well as the costs of the “stove promotion”.

The cost-effectiveness ratios of the “stove promotion”, considering periods of 5, 10 and 20 years and discount rates of 3% and 10%, are presented in the following table.

Cost-effectiveness in kg/1 US$:

Period considered	Discount rate: 10%	Discount rate: 3%
5 years	61	69
10 years	81	93
20 years	122	181

The cost effectiveness in a period of 10 years amounts to 93 kg/1 US$ based on the discount rate of 3%. This ratio shows that the capital outlays (or expenditure) of one US$ result in firewood savings of 93 kg.

Based on the discount rate of 10% the expenditure of 1 US$ results in firewood savings of 81 kg.

The costs of one kilogram of fuelwood that is saved through the use of Rocket Stoves can also be calculated:
Based on the cost-effectiveness of 93 kg/1 US$ (period of 10 years and a discount rate of 3%), the costs of one kilogram of fuelwood that is saved through the use of Rocket Stoves amount to only 0.0108 US$. The trade price of firewood is 0.0286 US$/kg. A comparison between these two figures shows again that it is advantageous to replace the traditional stove or the open fireplace with the Rocket Stove.

6 Comparing areas of forest cover with firewood savings

6.1 Area of forest cover preserved in 2008 through firewood savings

The annual firewood savings achieved through the use of institutional Rocket Stoves amount to 23,135 tonnes in 2008 (see Chapter 3.4).

Since 30% of the firewood consumed came from the felling of natural forest cover, it was assumed that 30% of the firewood savings preserved forest resources (see Chapter 3.6.2). Converting firewood savings into woodland, the 23,135 tonnes fuelwood saved preserve 689 ha of natural forest cover in 2008.

This calculation is based on the following hypotheses:

1. The average stock density per ha of forest cover is 18 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 800 kg/m^3.

6.2 Area of blue gum plantation equivalent to the firewood savings in 2008 of institutions using blue gum as fuel

The amount of firewood saved by Rocket Stoves used in the framework of WFP and GTZ/BEP amounts to 11,968 tonnes in 2008. The firewood savings in 2008 of all the other user groups of the Rocket Stove using blue gum and pine wood from plantations as firewood total 9,903 tonnes. Tea estates using the Rocket Stove saved 1,264 tonnes of blue gum in 2008.

From data of Makandi tea estate, we derived that the average stock density per ha of blue gum is 50 cubic metres per hectare. The average wood weight was 500 m^3/kg.

The firewood savings of institutions and tea estates using blue gum as fuel (11,167 tonnes) were equivalent to an area of 447 ha of blue gum plantation in 2008.

6.3 Area of forest/plantation cover equivalent to the total firewood savings

In order to illustrate the extent of the fuelwood savings achieved through the use of Rocket Stoves installed by WFP and GTZ/BEP, the fuelwood savings of 11,968 tonnes in 2008 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 6.1, it was estimated that only 30% of the firewood savings applied to indigenous trees cut down exclusively for fuel.

Based on the three hypotheses presented in Chapter 6.1, the stock volume of a natural forest cover of 1,187 ha would have been equal to the total amount of fuelwood saved in 2008.

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.

With this in mind, it can be said that in 2008 the total amount of firewood savings was equivalent to 1,187 ha of natural forest cover and 447 ha of blue gum plantation.

7 Firewood savings valued at the LPG-shadow price 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 that express scarcity aspects.

The market price of fuelwood, and also the trade price of firewood, does not reflect the economic value of the firewood. Despite the shortage of fuelwood and the high ecological value of forest resources, woodlands and tree stands, fuelwood is treated almost like a so-called “free” good which is available in random supply.

The shadow price for the fuelwood was calculated based on the market price of the substitution product LPG. 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.

The higher heating value of LPG and the higher cooking efficiency of an appropriate LPG cooker were 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 presumed for the three-stone fire and 60% for the LPG cooker.

The retail price of LPG came to 495 MWK (3.54 US$) per kilogram in December 2007. The price for the LPG-cooker and accessory devices were not taken into account. They were negligible compared with the total fuel costs. The firewood savings valued at the LPG-shadow price for fuelwood amount to 6,720,287 US$ in 2008.

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

The substitution cost for one kilogram firewood based on the LPG-shadow price amounts to 0.2905 US$ and can be compared with the costs of one kilogram of fuelwood that is saved through the use of Rocket Stoves of 0.0108 US$, based on a discount rate of 3% and a period of 10 years (see Chapter 6). It can also be compared with the trade price for one kilogram firewood (0.0286 US$) applied in the CBA (see Chapter 3.6.1) and with the afforestation cost of 0.0521 US$ per kg firewood (see Chapter 3.6.2), which could also be regarded as a shadow price for fuelwood.

Such a comparison, however, amounts to a rough economic calculation, since it did not include costs for the LPG-cooker and the applied market price for LPG was not adjusted by taxes, duties or subsidies.

8 Results of the economic analyses for seven typical institutional stove users

8.1 Economic criteria at institutional level

Savings in fuelwood expenditure are definitely a tangible benefit from the use of improved stoves. However, savings in fuelwood expenditure cannot convey how relevant this benefit is for the institution itself, nor whether the use of the Rocket Stove is indeed economical. In order to evaluate the profitability of using this firewood-saving stove for the institution, the following four economic criteria were calculated:

- payback period,
- net benefit during the life of the stove,
- rate of return during the life of the stove,
- avoided fuel costs and annual net benefit as a share of the catering budget.

The economic analysis was performed for seven different institutional Rocket Stove user groups:
- Mary’s Meal – school feeding programme for primary schools, using 100 l stoves,
- WFP (school feeding programme) or School, Secondary School, using 100 l stoves,
- Boarding School, using 100 l stoves,
- Canteen or Nursery, using 50 l stoves,
- Orphanage or Hospital, using 100 l stoves,
- Orphanage or Hospital, using 200 l stoves,
- Prison, using 200 l stoves.

Economic criteria were calculated for one institutional stove of each of the seven user groups mentioned above.

8.2 Base data

The general base data for the economic analyses were presented in Chapters 2.1 and 2.2. Furthermore, in the economic analyses at institutional level the author used the same life spans and costs of the Rocket Stoves (see Chapter 3.2 and 3.5.1), as well as the same fuelwood price (see Chapter 3.6.1), as applied in the CBA.

The fuelwood price is a trade price and amounts to 0.0286 US$/kg. The Rocket Stove has a life span of 4 years with the exception of the Rocket Stoves used in the prisons (1 year).

The following two tables show the other base data as well as annual firewood savings p.a. and annual avoided fuel costs due to the use of Rocket Stove, per stove and institution.

Base data of the average Rocket Stove per type size:

Average Rocket Stove (three type sizes)	Average price of the stove in US$	Firewood consumed by the RS per cooking process	Minimum firewood saving rate	Firewood saved per cooking process due to the RS
50 litre (including 30 to 80 litre)	120	10 kg	60%	15 kg
100 litre (including 81 to 170 litre)	180	14 kg	70%	32.67 kg
200 litre (including 171 to 250 litres)	275	18 kg	75%	54 kg

User groups and their utilization rate of the Rocket Stove, annual firewood savings and avoided fuel costs per stove:

User group	Number of cooking days p. a.	Number of meals cooked per day	Size of stove considered	Firewood savings in kg p.a. due to the use of one RS	Avoided fuel costs in US$ p.a. per stove
Mary's Meal (primary school)	220	1	100 l	7,187	205.54
WFP or School	185	1	100 l	6,043	172.84
Boarding School	185	2	100 l	12,087	345.68
Canteen or Nursery	250	1	50 l	3,750	107.25
Hospital or Orphanage	365	2	100 l	23,847	682.01
Hospital or Orphanage	365	2	200 l	39,420	1,127.41
Prison	365	2	200 l	39,420	1,127.41

8.3 Payback period

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

The relationship between the payback period and the life of the stove (4 years; 1 year in the case of prisons) is also a rough indication of the profitability of the investment in the stove.

The results for the seven institutional stove types are as follows:

User group	**Payback period in cooking days**
Mary's Meal (primary school)	193
WFP or School	193
Boarding School	97
Canteen or Nursery	280
Hospital or Orphanage, 100 l	97
Hospital or Orphanage 200 l	89
Prison	89

The calculated payoff times are average values. In reality, the payback periods can be longer or shorter. The period of amortization for the 200 l Rocket Stove used for two meals a day (hospital, orphanage, prison) is the shortest.

For all Rocket Stoves used in schools, it must be borne in mind that in reality the payoff times of the stove are longer, depending on the number of school days per month, holiday periods and the date on which the Rocket Stove was installed.

8.4 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.

The calculations were based on a static return on investment analysis, i.e. the values of avoided fuel costs of the second, third and fourth year were not discounted to the first year of the stove's use. The static method is often applied in financial analyses covering short periods. It is easier to understand for the non-economist reader than the dynamic method, which introduced a discount rate in order to value future incomes and outlays to the present.

The results for the seven institutional stove types are as follows:

User group	**Net benefit during stove's life in US$**	**Rate of return during stove's life**
Mary's Meal (primary school)	642	357%
WFP or School	511	284%
Boarding School	1,203	668%
Canteen or Nursery	309	258%
Hospital or Orphanage, 100 l	2,548	1,416%
Hospital or Orphanage 200 l	4,235	1,540%
Prison (life span: 1 year)	852	310%

The results can be interpreted as follows. During the 4-year life of the Rocket Stove, an orphanage, for example, using a 100 l Rocket Stove will have a net benefit of 2,548 US$. The avoided costs due to firewood savings minus the total cost of the Rocket Stove will be 14 times higher than the costs incurred for the stove.

8.5 Ratio of net benefit or fuel savings to the catering budget of the institution

The economic importance of the net benefit or fuel savings for the institution can be determined if the net benefit or fuel savings are compared with the total expenses of the catering budget of the institution.

Two different ratios of firewood expenditure to the catering budget (also called food budget) were considered: 20% and 50% (when using the traditional stove).

Based on the annual fuelwood consumption of one traditional stove, the annual amount of food-budget expenditure by the different institutions was calculated per stove. The net benefit per year and the annual fuelwood savings from the use of one Rocket Stove were compared to this amount and their share in relation to the food-budget expenses determined. The result of this calculation was the percentage to which the total expenses of the catering budget were reduced by the use of the Rocket Stove. It was assumed that the expenditure for the Rocket Stove had to be paid from the catering budget.

The following table shows the results per stove, assuming that 20% of the catering budget was being allocated to firewood purchases before introducing the Rocket Stove.

Ratio of net benefit and fuel savings to the catering budget of the institution (20%-firewood expenditure ratio):

User group (fuel = 20% of food budget)	Net benefit of the first year in US$	As % of the food budget	Annual firewood savings in US$	As % of the food budget
Mary's Meal (primary school)	25.54	2%	205.54	14%
WFP or School	- 7.16	-1%	172.84	14%
Boarding School	165.68	7%	345.68	14%
Canteen or Nursery	-12.75	-1%	107.25	12%
Hospital or Orphanage, 100 l	502.01	10%	682.01	14%
Hospital or Orphanage 200 l	852.41	11%	1,127.41	15%
Prison (life span: 1 year)	852.41	11%	1,127.41	15%

The net benefit of the first year is the amount of avoided firewood costs due to the use of the Rocket Stove minus the expenditure for the Rocket Stove.

Since, as of the second year, the institution does not have to spend any money on the stove (assuming that repair and maintenance costs do not occur), the net benefit of the second year of the Rocket Stove's use equals the annual amount of avoided fuel costs due to firewood savings.

For the user groups "WFP or Schools" and "Canteen or Nursery", the net benefit of the first year of the stove's use is negative, because the expenditure for the Rocket Stove exceeds the avoided firewood expenses. The net benefit of the second year of the Rocket Stove's use is therefore lower than the annual amount of avoided fuel costs. It amounts to 165.68 US$ (WFP or Schools") and 94.50 US$ (Canteen or Nursery).

The "minus" ratio of the net benefit to the expenditure of the catering budget indicates that the institution's catering budget expenses are higher in the first year of the stove's use than before, because the expenditure for the Rocket Stove exceeds the reduction in the catering budget expenses due to fuelwood savings in the first year. The percentage to which the catering budget is higher than it was before the Rocket Stove's use is, however, very small in both cases.

The following table presents the results per Rocket Stove, assuming that 50% of the catering budget was being allocated to firewood purchases before introducing the Rocket Stove.

Ratio of net benefit and fuel savings to the catering budget of the institution (50%-firewood expenditure ratio):

User group (fuel =50% of food budget)	Net benefit of the first year in US$	As % of the food budget	Annual firewood savings in US$	As % of the food budget
Mary's Meal (primary school)	25.54	4%	205.54	35%
WFP or School	- 7.16	-1%	172.84	35%
Boarding School	165.68	17%	345.68	35%
Canteen or Nursery	-12.75	-4%	107.25	30%
Hospital or Orphanage, 100 l	502.01	26%	682.01	35%
Hospital or Orphanage 200 l	852.41	28%	1,127.41	38%
Prison (life span: 1 year)	852.41	28%	1,127.41	38%

The ratios of net benefit (or avoided fuel costs) to the catering budget expenses show the degree to which the use of the Rocket Stoves improves the financial conditions of institutional kitchens in terms of quantifiable data.

The values of the economic criteria at institutional level prove that the Rocket Stove's use is profitable for each of the individual institutions.

9 Economic evaluation of the promotion of efficient institutional cook stoves: Summary of key results and conclusions

9.1 Benefits included in the CBA and impacts not considered

The CBA assessed three main impacts of the ProBEC Malawi programme component “Promotion of efficient institutional cook stoves”:

- the avoided fuel costs due to firewood savings,
- the preservation of forest reserves derived from firewood savings, and
- the greenhouse gas reduction (avoided emissions of CO_2 and CH_4 caused by the avoided combustion of fuelwood due to firewood savings).

These impacts were valued in monetary terms and considered in the CBA as economic benefits.

Aside from these impacts, the use of the institutional Rocket Stoves and the practise of efficient cooking and firing techniques generate further impacts that were not included in the economic analyses, because sound, quantifiable data were not available. In particular, the following impacts could not be included as economic benefits in the CBA:

- the improved nutrition of pupils, small children and adults due to more and better meals achieved through the use of the institutional Rocket Stoves,
- the improvement of health status and working conditions of the cooks,
- the reduced cooking time,
- income- and employment-generating effects due to stove production,
- the reduction in emissions of other greenhouse gases, and
- the prevented declines in soil fertility due to preserved trees and woodlots.

These impacts--had they been considered as benefits in the CBA--would have contributed to a higher economic efficiency for the ProBEC Malawi “stove promotion”.

Chapter 9.2 to 9.6 presents the key results of the economic evaluation in the form of tables and main conclusions.

9.2 Number of Rocket Stoves, firewood savings, costs and economic benefits considered in the CBA and CEA

The following table presents the annual amounts of firewood saved due to the use of institutional Rocket Stoves and improved firing and cooking techniques as well as the annual economic benefits derived from these firewood savings:

Firewood savings and economic benefits due to the use of institutional Rocket Stoves:

Year	Total firewood savings in tonnes	Economic benefits due to fuel savings In US$	Economic benefits due to forest cover preserved in US$	Economic benefits due to CO_2 and CH_4 reduction in US$ (7 US$/EUA)	Total economic benefits in US$ (7 US$/EUA)
2005	2,270	64,935	35,487	25,111	125,533
2006	7,287	208,415	113,899	80,597	402,911
2007	13,844	395,936	216,381	153,114	765,431
2008	**23,135**	**661,665**	**361,602**	**255,874**	**1,279,141**
2009	22,347	639,116	349,279	247,155	1,235,550
2010	22,098	631,994	345,387	244,401	1,221,782
2011 onwards	21,794	623,319	340,646	241,045	1,205,010

The next table shows the number of institutional Rocket Stoves considered in the CBA and CEA per year and their total annual costs as well as the ProBEC "stove promotion" costs, the total annual benefits and the annual surplus amounts (total benefits minus total costs).

Number of institutional Rocket Stoves considered, annual stoves and "stove promotion" costs, benefits and surplus :

Year	Number of RS considered in the CBA and CEA (including RS of the tea estates)	Costs of RS in US$ (annuities; discount rate: 3%)	ProBEC "stove promotion" costs In US$	Total costs in US$ (Stoves and promotion costs)	Total economic benefits in US$ (7 US$/EUA)	Total annual benefits minus total annual costs in US$
2004	0	0	70,700.00	70,700.00	0	-70,700
2005	247	15,841	149,800.00	165,641	125,533	-40,108
2006	1,071	56,086	98,700.00	154,786	402,911	248,125
2007	2,372	108,872	83,916.00	192,788	765,431	572,643
2008	**4,206**	**195,933**		**195,933**	**1,279,141**	**1,083,208**
2009	4,186	190,433		190,433	1,235,550	1,045,117
2010	4,021	182,676		182,676	1,221,782	1,039,106
2011 onwards	3,820	173,226		173,226	1,205,010	1,031,784

Chapter 3.1 to 3.6 provides detailed information on the figures in the above two tables and explains how these figures were derived.

The total expenses for the ProBEC Malawi programme component “Promotion of efficient institutional cook stoves” amounted to 403,116 US$ (accumulative, 2004 to 2007).

The last column in the above table contains the total annual benefits minus the total annual costs (annual surplus). The reader can see that the annual economic benefits already exceed the annual costs (stoves and “stove promotion” costs) in 2006. The sum of benefits in the years 2005 and 2006 (528,444 US$) exceed the total costs of 2004, 2005 and 2006 (391,127US$). From 2008 onwards, the annual surplus amounts to approx. one million US$. These are obviously good results, but in terms of economic criteria they do not determine the profitability of the “stove promotion”, nor can they be compared with the results of economic calculations carried out for other “stove promotion or development projects”. Therefore, the values of four economic criteria describing the economic efficiency of public investment projects had to be determined (see next chapter).

9.3 Results of the CBA and CEA

9.3.1 General remarks

Stove promotion projects are characterized by high expenses in the beginning (the first years) and high returns (valued impacts) in future years due to the steadily growing number of efficient stoves in use.

In order to assess the economic efficiency of the ProBEC “stove promotion” for a longer period of time, four “dynamic” economic criteria were calculated based on a period of 10 years and a discount rate of 3% (see Chapter 4):
- Net present value,
- Benefit-cost ratio,
- Internal rate of return,
- Cost-effectiveness.

“Dynamic” economic analyses (like the CBA and CEA) introduce the “time factor” into the calculations, i.e. they consider the different times at which benefits or costs arise. It is assumed that future benefits or costs have a lower economic value than present benefits and costs. The present value of future values is calculated by discounting natural or monetary values to the present point in time, which is normally the year in which the first benefits are assumed to emerge, or the first year of the period considered. For the ProBEC Malawi “stove promotion”, this year was 2005. A discount rate of 3% is generally recommended in the case of projects which include highly valued social and environmental aims, reflecting the rate of return of long-term public securities, such as government bonds of West European countries.

9.3.2 Net present values and benefit-cost ratios (key results)

The present values of the three economic benefits considered (based on the discount rate of 3%) were as follows:

Present values of economic benefits:

Period of 10 years; discount rate: 3%	Benefits due to fuel savings	Benefits due to preservation of forest reserves	Benefits due to greenhouse gas reduction (7 US$/EUA)	Total benefits (7 US$/EUA)
Present value (million US$)	4.231	2.312	1.636	8.179
Percentage of total benefits	52%	28%	20%	100%

The present value of the costs came to 1.584 million US$ (including stoves and ProBEC "stove promotion" costs).

The net present value (present values of the benefits minus present value of the costs) of the 10-year period amounted to 6.595 million US$. This is an important economic value, representing high gains for the country's economy and social welfare. Considering only the benefits due to avoided fuel costs, the net present value was 2.6 million US$.

The economic efficiency of the "institutional stove promotion" is favourable from an overall economic view. The ProBEC "stove promotion" yields good returns compared with its expenses. The comparison of the present value of the benefits with the present value of the costs (benefit-cost ratio) showed that the investment of one US$ gives a return of 5.16 US$, and still yields a return of 2.67 US$ even if only the benefits due to avoided fuel costs are taken into account.

The results are favourable even if a period of only 5 years is considered (2005-2009). The net present value came to 2.5 million US$. Considering only the benefits due to avoided fuel costs, the net present value was still positive at around 0.9 million US$. A positive net present value indicates that the "stove promotion" is worthwhile from an overall economic view as well as from the social welfare viewpoint. The return per one US$ invested came to 3.82 US$, and to 1.97 US$ when only benefits due to avoided fuel costs were considered

The most pessimistic scenario calculated in the CBA and CEA was based on the following assumptions:

- a period of 5 years,
- discount rate of 10% (rate of return of risk government bonds),
- average EUA price of 1 US$ for one tonne of CO_2 on the spot market in 2007 (end of the first period of the EU Emissions Trading Scheme).

Even under these pessimistic assumptions, the benefits still exceeded the costs and proved that the expenses of the “stove promotion project” and for efficient Rocket Stoves were still worthwhile from an overall economic view. The net present value came to 1.4 million US$ and the benefit-cost ratio was 2.82. Considering only benefits due to avoided fuel costs, the net present value came to 0.6 million US$ and the benefit-cost ratio to 1.76 US$ return per one US$ invested.

Considering a period of 20 years, the net present value of the “stove promotion” came to 13 million US$ and represents a significant economic value for the country’s economy. It is approximately double the amount of the net present value of the 10-year period (6.6 million US$). The net benefit increases steadily with the length of the periods considered. That means the longer the Rocket Stoves are used and replaced in the future, the higher the “profit” (i.e. the welfare gain) of the “stove promotion project”.

The comparison of the benefit-cost ratios for the 20-year period (5.90 US$) with the 10-year period (5.16 US$) shows that the expenses for the “stove promotion project” (incurred from 2004 to 2007) have a negligible influence on the difference in economic efficiency when longer periods are concerned. This is not the case if longer periods are compared with shorter periods. The benefit-cost ratio of the 5-year period, at 3.82 US$, is significantly lower than the benefit-cost ratio for the 10-year period (5.16 US$).

These results are not surprising, since the relation between the annual costs of the Rocket Stoves and the annual economic benefits derived from the use of these stoves remains constant over the years; whereas, the annual costs of the ProBEC “stove promotion project” only arise in the years 2004 to 2007. If we consider only the costs of the Rocket Stoves and no costs of the ProBEC Malawi programme component “Promotion of efficient institutional cook stoves”, the benefit-cost ratios of the 5-, 10- and 20-year periods would come to the same value of 7 US$ return per one US$ invested. (These benefit-cost ratios amounted to 6.73 US$ for 5 years, 6.82 US$ for 10 years and 6.89 US$ for 20 years. There is a minimal difference between these ratios because the annual number of stoves per individual user group considered in the CBA varies from 2005 to 2011 and does not remain constant until the year 2011.)

The following table provides an overview of the above-discussed net present values and benefit-cost ratios of the calculations considering the total economic benefits.

Net present value and benefit-cost ratios (key results):

Period considered	5 years	10 years	20 years	5 years
Discount rate applied	3%	3%	3%	10%
EUA price per one tonne of CO_2	7 US$	7 US$	7 US$	1 US$
Net present value (million US$)	2,5	6,6	13,1	1,4
Benefit-cost ratios (US$ return per one US$ invested)	3.82	5.16	5.90	2.82

9.3.3 Internal rate of return (key results)

The economic internal rate of return is the rate of interest earned on the capital (cost of the "stove promotion project"/initial investment) tied up in the "stove project" during the period under consideration. The costs of the Rocket Stoves were considered as recurrent annual costs. The internal rates of return are very high, further evidence that the ProBEC "stove promotion" has a good economic efficiency:

Internal rates of return (Discount rate of 3%):

5-year period	10-year period	20-year period
176%	180%	180%

The results show that the internal rates for the 10-year and 20-year period are the same. This is due to the fact that the recurrent annual costs (annuities of the stoves costs) and the annual benefits are the same in both of these periods, and that the initial investment (cost of the "stove promotion project") is very low compared to the sum of the total annual stove costs over 10 or 20 years.

The total annual benefits of the 5-year period cannot offset the initial investment to the same degree as those in the 10-year and 20-year periods; this results in a lower internal rate of return for the 5-year period.

9.3.4 Cost-effectiveness

The cost-effectiveness compares the sum of the discounted annual amounts of firewood savings with the sum of discounted annual stoves and "stove promotion" costs (see Chapter 5). The cost-effectiveness ratios based on the discount rate of 3% were as follows:

Cost-effectiveness in kg/1 US$:

Period considered	**Discount rate: 3%**
5 years	69
10 years	**93**
20 years	181

The cost-effectiveness of the 10-year period amounted to 93 kg/1 US$ and as much as 181 kg/1 US$ for the 20-year period. It shows that the expenditure of one US$ results in firewood savings of 93 kg or 181 kg (for the 20-year period). These results prove that the efficiency of the ProBEC "stove promotion" assessed in natural units (firewood saved in kg) is good.

Based on the cost-effectiveness of 93 kg/1 US$, the costs of one kilogram of fuelwood saved can be calculated. They amounted to 0.0108 US$ from an overall economic view. The trade price of firewood was 0.0286 US$/kg. A comparison between these two figures again shows that it is advantageous to replace the traditional stove with the Rocket Stove.

9.4 Areas of forests cover preserved and firewood savings valued at LPG-shadow price

Two other macroeconomic criteria were calculated in order to illustrate the positive impact of the Rocket Stoves' use for the environment in Malawi and to assess the economic value of the firewood savings for the national economy from another economic point of view.

Assuming that 30% of the firewood savings preserved forest resources and these firewood savings are converted into woodland, 689 ha of natural forest cover can be preserved in 2008. The firewood savings of institutions and tea estates using plantation wood as fuel (11,167 tonnes in 2008) are equivalent to an area of 447 ha of eucalyptus plantation in 2008. (See Chapter 6)

If we assume that the market or trade price of fuelwood does not reflect the economic value of firewood from the viewpoint of the country's economy, we can introduce so-called "shadow prices" for fuelwood in order to assess the "true" economic value of firewood saved for the country.

A shadow price for the fuelwood was calculated based on the market price (3.54US$/kg) of the substitution product LPG (see Chapter 7), not considering the cost for LPG stoves. Firewood savings valued at the LPG-shadow price amounted to 6,720,287 US$ for the year 2008 and represent a significant economic value for the country's economy.

This economic value roughly represents so-called "opportunity costs" of the fuelwood, i.e. the costs that arise if the amount of firewood saved through the use of the Rocket Stoves had been saved through the use of LPG stoves. These “opportunity costs”, adjusted for customs, taxes and subsidies, would also represent savings in foreign currency for the country’s economy, if we assumed that LPG cookers and LPG had to be imported and used instead of the production and use of the Rocket Stoves.

The substitution cost for one kilogram firewood based on the LPG-shadow price was 0.2905 US$. It can be compared with the costs of one kilogram of fuelwood that is saved through the use of Rocket Stoves (0.0108 US$). This comparison shows that the investment in Rocket Stoves is extremely efficient and cost-effective compared with the purely “theoretical alternative” of investing in LPG cookers instead of Rocket Stoves. In practise, LPG cannot substitute firewood as cooking fuel, because it is not sufficiently available in rural and semi-urban areas of Malawi. Furthermore, the institutional kitchens cannot afford to pay the high prices for this fuel as well as the LPG cooker and the required accessory devices.

9.5 Considerations concerning a comparison with other stove promotion projects

The calculation of all the above-presented economic criteria showed that the economic efficiency of the ProBEC Malawi programme component “Promotion of efficient institutional cook stoves” is very favourable from an overall economic view.

Nevertheless, in this context it should be borne in mind that, in most cases, the institutional Rocket Stoves of Malawi were used in school feeding programmes and therefore for only about six months of the year, and for one meal per day. Household stoves are normally used 365 days per year (2 to 3 times daily).

The average utilization rates of the Rocket Stoves (compared to the traditional stove’s use) which were applied in the economic analyses were low compared to household stove projects (which often have a utilization rate of 90%). They were based on very conservative assumptions and ranged from 42% to 100%. For the 2,332 Rocket Stoves of the WFP, for example, a utilization rate of only 81% was assumed.

Chapter 2.1 provides detailed information about the above-mentioned circumstances and a table showing the varying values of the parameters that influence the total amount of firewood savings per Rocket Stove user group.

9.6 Economic criteria at institutional level

The economic evaluation of a “stove promotion project” should also assess the profitability of the stove’s use for the individual user of the promoted stove. Four economic criteria were calculated for seven typical institutional stoves in order to assess the economic profitability of the Rocket Stove‘s use for the individual institution (see Chapter 8):

- payback period,
- net benefit during the life of the stove,
- rate of return during the life of the stove,
- avoided fuel costs and annual net benefit as a share of the catering budget.

The main results, based on the use of one Rocket Stove, are presented in the following table.

Price and size of the Rocket Stove, annual firewood savings, avoided fuel costs and values of three economic criteria:

User group	Average size of the stove	Average price of the RS in US$	Firewood savings in kg p.a. per RS	Avoided fuel costs in US$ p.a. per RS	Payback period in cooking days	Net benefit during stove’s life in US$	Rate of return during stove’s life
Mary’s Meal (primary school)	100 l	180	7,187	205.54	193	642	357%
WFP or School	100 l	180	6,043	172.84	193	511	284%
Boarding School	100 l	180	12,087	345.68	97	1,203	668%
Canteen or Nursery	50 l	120	3,750	107.25	280	309	258%
Hospital or Orphanage	100 l	180	23,847	682.01	97	2,548	1,416%
Hospital or Orphanage	200 l	275	39,420	1,127.41	89	4,235	1,540%
Prison	200 l	275	39,420	1,127.41	89	852	310%

The payback periods ranged between 89 and 280 cooking days. In addition to the price of the stove and the firewood, the length of the payback periods depends on the number of meals prepared per day, the cooking periods during the year and the size of the stove (or its firewood savings rate compared to the traditional stove). For the Rocket Stoves used in school kitchens, it must be borne in mind that the real payoff times depend on the number of school days per month, holiday periods as well as the date on which the stove was installed. The payback periods can be relatively long.

The 200 litre stove, which is used every day to prepare two meals, had the shortest payback period (2.8 months).

The net benefit during the stove’s life is the sum of the avoided fuelwood costs during this period minus the costs incurred for the stove. The net benefits represent a significant amount for each individual institution, ranging from 309 US$ to 4,235 US$ per stove. The net benefits exceed the expenses for the stove by 284% to 1,540% (rate of return), i.e. the net benefits will be 3 to 15 times higher than the expenditure for the stove.

As one might expect, the 200 l stove that is used to cook two meals a day, 365 days of the year, had the highest rate of return. For example, during the 4-year life of a 200 litre Rocket Stove, an orphanage with a net benefit of 4,235 US$ from stove use will have a rate of return of 1,540%, i.e. the avoided costs due to firewood savings minus the cost of the Rocket Stove will be 15 times higher than the costs incurred for the stove. On the other hand, the same 200 l stove used in the prisons for two meals 365 days p.a. has only a net benefit of 852 US$ and a 310% rate of return, because its life span is only 1 year instead of 4.

Fuel savings due to the Rocket Stove's use were important for the institutions, as shown by the ratios of avoided fuel costs to the catering budget of the seven typical institutions. In a study including 80 different institutions it was found that the expenditure on firewood ranged between 20% and 50% of the catering budget when the traditional stove was used. Based on these data, it was derived that avoided fuel costs due to the Rocket Stove's use represent 12% to 38% of the catering budget of the seven typical institutional stove users. The net benefit of the stove's use in the first year (avoided fuel costs of the first year minus stove's costs) is positive for five Rocket Stoves user groups, ranging from 25.54 US$ to 852.41 US$. Their ratios for the first-year net benefit to catering budget range between 2% and 28% (see Chapter 8.5).

These ratios indicate that the Rocket Stove's use definitely improves the financial conditions of institutional kitchens.

The economic analyses at institutional level proved that the Rocket Stove's use is profitable for each of the individual institutions. The 200 l stove (4-year life span) which is used every day to prepare two meals (e.g. in hospitals and orphanages) has the highest profitability.

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In conclusion, the results of all economic analyses carried out in the context of the economic evaluation prove that the ProBEC Malawi programme component "Promotion of efficient institutional cook stoves" has a good economic efficiency.

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