NORDIC CLIMATE FACILITY

Nordic Development Fund • Nordic Environment Finance Corporation

Final Report

Efficiency Enhancement and Entrepreneurship Development in Sustainable Biomass Charcoaling, Ghana

Grantee: Pöyry Management Consulting Oy

Local Partners: African Plantations for Sustainable Development (APSD), Nature and Development Foundation (NDF), The Paramount Chiefs of the Traditional Councils of the Stools in the Atebubu and Sene districts (Traditional Council)

Project start date: 01*/01/2013*

Project end date*: 30/06/2016*

05.09.2016

Tuomo.utriainen@poyry.com Tuomo Utriainen
+358 50 5780 746 Senior Adviser

TABLE OF CONTENTS

ANNEXES

1. EXECUTIVE SUMMARY

The main objective of the project was to increase the efficiency and sustainability of charcoal production in the targeted regions of Ghana. The objective was met by providing sustainable sources of raw wood material to be charcoaled and to fuel efficient charcoal production kilns, decreasing deforestation and providing employment to the local communities simultaneously.

The project provides employment to both skilled bricklayers and unskilled workers and encourages the replication and further development of sustainable charcoal production business. The project brings together entrepreneurs of both the charcoal production plants and tree plantations in an entrepreneurial cooperative that aids in minimizing needed transportation and maximizing benefits to the local entrepreneurs. This method of production allows village entrepreneurs to retain more of the profits of charcoal sales that are otherwise lost in poor production methods and outsourcing transportation and distribution to the local markets.

1.1 Summary

NEFCO and Pöyry Management Consulting Oy signed a project contract "Efficiency Enhancement and Entrepreneurship Development in Sustainable Biomass Charcoaling in Ghana", March 8th 2013. This Nordic Climate Facility (NCF) project is financed by the Nordic Development Fund (NDF) and implemented jointly with the Nordic Environment Finance Corporation (NEFCO).

By the end of the project 30th June 2016 the main activities have been implemented as follows:

1. All seven charcoal plants constructed and in operation
2. By the end of the grant period the project had produced 301 tons of combined charcoal and biochar. This volume is approximately 70% of the production objective of 439 tons.
3. All energy wood plantations (210 hectares) had been established by the end of the grant period.
4. Instructions to manage plantations and to supply suitable wood raw material for charcoal making provided
5. Final instructions to kiln operation provided
6. Final instructions to wood plantation operations provided
7. Mass and energy balances calculated
8. CO2 emission estimates calculated
9. Project handover agreement signed
10. Final reporting completed

1.2 Overall project objectives and achieved results

The project consists of the construction and implementation of seven charcoal production plants (chamber wood retort of 4 integrated kilns, made of local brick) that are efficient, environmentally friendly, affordable to local entrepreneurs and easy to operate and maintain. This retort system consists of four integrated chambers and product gases are utilized to dry raw material.

Three separate plantations of fast-growing trees, approximately 10 hectares (ha) each, were established to source raw wood material for each charcoal production plant. The wood from the plantations became available three years after the plantation establishment, providing the raw material for the charcoal production. The other partner, African Plantations for Sustainable Development (APSD) has established commercial plantations throughout Ghana and has been responsible for overseeing the successful establishment of these plantations. 210 ha of energy wood plantations have been established over the course of the project and have been handed over to the local entrepreneurs. The Traditional Council Chiefs and village decision making bodies conceded less fertile land areas that are not suitable for food production that was planted with fast growing acacia to meet the foreseen feedstock demand of the charcoal manufacturers, located in the vicinity of the energy wood production area. All feedstock supply for charcoal manufacturing is based on sustainably managed energy wood plantations owned and managed by the villages themselves. Monitoring principles to secure the use of sustainable feedstock sources, taking into account also the various needs of local inhabitants, have been developed during the project with the knowledge and experience of the parties involved: NDF[1], Paramount Chiefs, APSD and Pöyry. Sustainable development means that new trees will be planted as old ones are cut. The project has adapted new working methods in order to find the most efficient and reasonable / motivated working environment for local people to manage the plantations.

Plantation development started by clearing and collecting wood from these areas, chopping it to suitable sizes and piling the chopped wood for air drying. This wood serves as the initial feed stock for the charcoal production plants while the first rotation of acacia is growing. This way, the charcoal kilns are able to begin producing charcoal right away, before the first rotation of the plantation wood is harvested.

Throughout the project duration (testing and first 2 to 3 years of supervised operations), raw material originating from land clearing has been used. Therefore, the wood specifications for raw material from land-clearing will differ from the specifications of wood originating from acacia plantations.

[1] NDF = Nature and Development Foundation

Once the plantation wood is ready to be harvested after 3 years' time, wood dimensions and properties will be redefined to suit the feedstock.

The main outputs of the project are:

1. Construction and implementation of seven improved, efficient charcoal production plants. Production of 301 tons of combined charcoal and biochar;
2. The establishment of 21 energy wood plantations of approximately 10 ha each of acacia to feed the 7 charcoal production plants. The plantations are located in close proximity to each corresponding kiln. Each production plant has a corresponding plantation in close proximity from which to source the raw wood material for the charcoal production;
3. The instruction and training of local entrepreneurs in managing the plantations and operating and managing the charcoal production at the kiln site; and,
4. A workshop hosted on entrepreneurship in the charcoal production economy that includes the charcoal production actors and local authorities, villagers and women

The main objective of the project was to increase the efficiency and sustainability of charcoal production in the targeted regions of Ghana. The objective has been met by providing sustainable sources of raw wood material to be charcoaled and to fuel efficient charcoal production kilns, decreasing deforestation and providing employment to the local communities simultaneously. A larger objective of APSD is to also create jobs in the villages to increase the standard of living for the locals in places in which APSD is active. With better standards of living and legally available raw material, a safer investment environment exists for APSD to continue establishing commercial wood plantations and wood processing industries.

The project provides employment to both skilled bricklayers and unskilled workers and encourages the replication and further development of sustainable charcoal production business. The project brings together entrepreneurs of both the charcoal production plants and tree plantations in an entrepreneurial cooperative that aids in minimizing needed transportation and maximizing benefits to the local entrepreneurs. This method of production allows village entrepreneurs to retain more of the profits of charcoal sales that are otherwise lost in poor production methods and outsourcing transportation and distribution to the local markets.

1.3 Summary of the sites / villages hosting charcoal plants

The principles applied in production site selection are described in the first Milestone report.

The role of the Energy Commission in this project was established during these meetings, in which the Energy Commission reinforced the socio-economic and environmental attributes of the project to the project beneficiaries. The Energy

Commission involvement was also important as they were interested in observing the kilns for possible replication and educational purposes.

The role of the NDF (former WWF) at this stage was to ensure that environmental concerns were taken into account, such as possible smoke emanating from the kilns, as well as any other potential negative effects on the watershed and ecosystems were prevented.

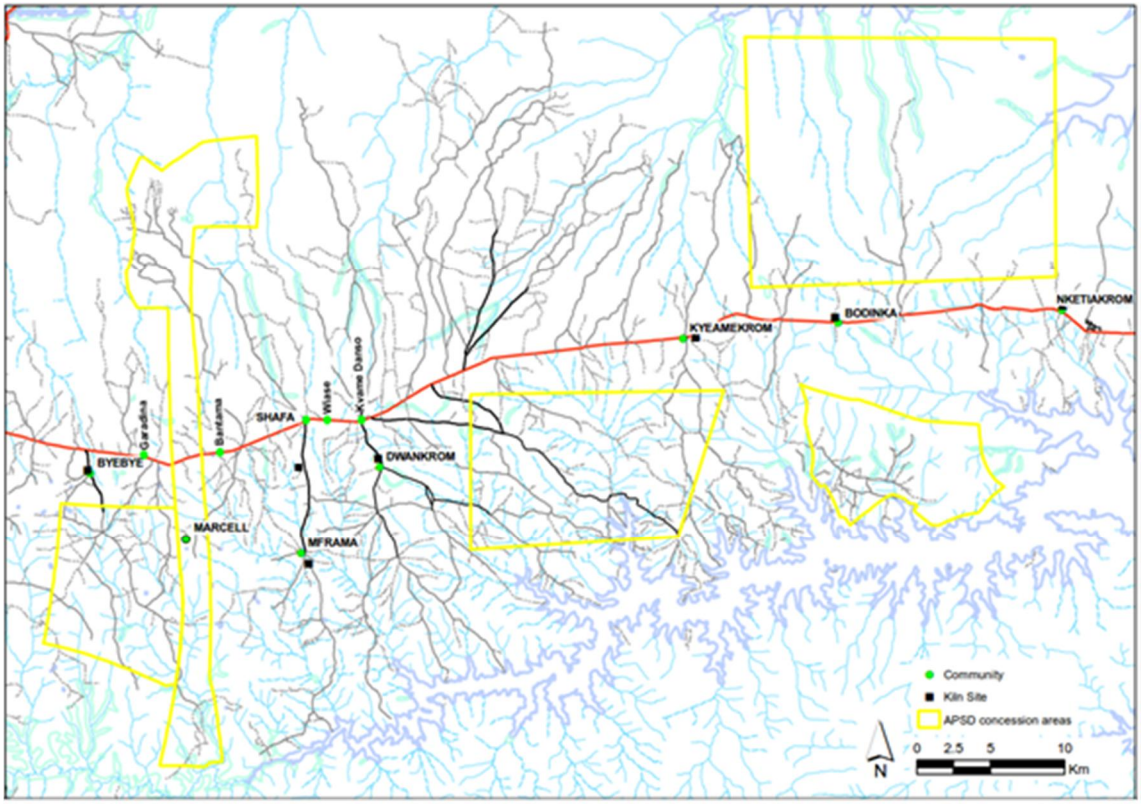


Figure 1 Map of selected kiln sites

1.4 Conclusions

Generally speaking the project was successful. Biggest challenges were met in:

- organising planting of seedlings to take place at a time horizon between dry and wet seasons,
- organising village people to help in land clearing, planting and forest management and
- identifying local, English speaking and vacant potential charcoal plant operators that were willing to make a long term commitment to operate & maintain the plant. The only plant that so far has a committed operator is in Byebye village.

2. ASSESSMENT OF IMPLEMENTATION OF THE PROJECT

2.1 Implementation of Activities

Activity 1: Stakeholder consultation and consent / Confirmation of land to locate plantations and kilns
A meeting was held with interested parties on the APSD plantations. A significant amount of time was spent discussing the charcoal project.

Activity 2: Confirmation of land to locate plantations and kilns
Initial visits had been paid to proposed communities by the Poyry team and APSD staff. NDF's first engagement on the project was during the consultation phase of the siting of plantations and kilns. Environmental, social and other considerations such as proximity to community dwelling and site suitability were assessed. This visit also tested the acceptability of the communities to the project.

Activity 3: Charcoal kiln construction and structures, contracting and purchasing
First a kiln constructor, Joe Nsiah, was selected for the work and final design of the kilns. During this period, several local contractors were contacted. Joe Nsiah was the only available contractor with experience in using bricks that could withstand high heat. Some debate was held about the thickness of the walls and the reinforcement of the structures with iron framing, due to the project coordinator's concerns about the added cost to each structure. Finally it was agreed to use the iron framing in order to ensure the long-term durability of the kilns and not take any risks that might reduce the usefulness of these structures.

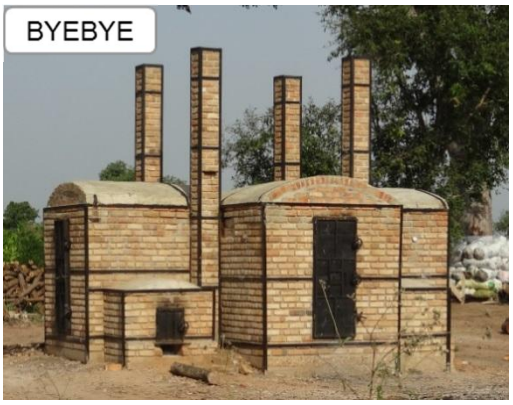
Joe Nsiah was able to discuss and agree with locals in each village the availability of local ingredients for cement manufacturing, water supply to be used in concrete manufacturing and in charcoal production (cooling) and local workforce though long-distance truck hauling of materials (heat resistant bricks and metal parts) still became necessary.

All charcoal production plants are constructed and in operation. Active operation time of the charcoal kilns vary from village to village due to several reasons including e.g. commitment of the operator, availability and quality of the raw material used, work day / holiday and operators other activities / availability to produce charcoal. Training and instructions regarding charcoal kiln operation, plant maintenance and safety training were provided.

All energy wood plantations (7 x 3 x 10 ha = 210 ha) have been established and forest management training provided.

Table 1 Kiln completion schedule

	Construction ready	Commissioning test done and plant entered into commercial operation
Baibai	25.10.2013	12/2013
Mframa	10.12.2014	3/2015
Dwankrom	20.12.2014	3/2015
Bodinka	15.1.2015	3/2015
Kyeamekrom	20.2.2015	3/2015
Nketiakrom	25.2.2015	3/2015
Shafa	1.11.2015	12/2015



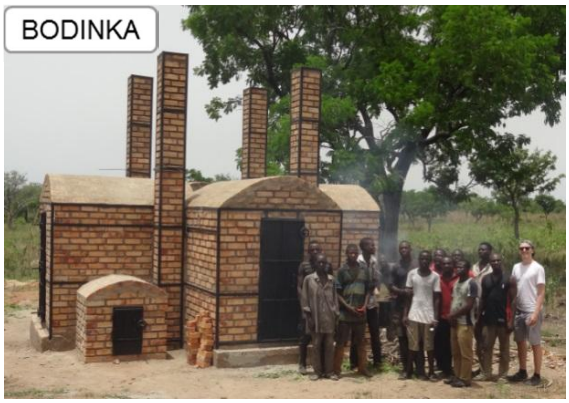


Figure 2 Images of kilns

All plants were constructed by Joe Nsiah's construction company. The brick size used is 230mm x110mm x76mm (9"x4½"x3").

There are differences in the wall thicknesses of the kilns as shown in the following table.

Table 2 Construction order of the charcoal production plants and wall thicknesses

		Thickness of the kiln walls	
Construction order	Community	Inch	cm
1	Baibai	15	38
2	Mframa	11	28
3	Dwankrom	11	28
4	Bodinka	11	28
5	Kymeamekrom	9	23
6	Nketiakrom	10	25
7 *)	Shafa (kilns 1&2)	9	22.9
	Shafa (kilns 3&4)	4.5	11.4

*) See next figure of the Shafa kiln wall thicknesses

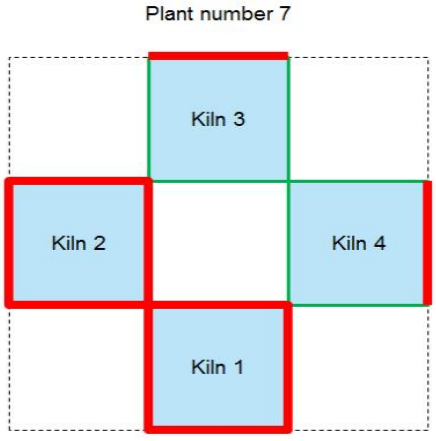


Figure 3 Thicknesses of the kiln walls in Shaffa community (red walls: 23cm and green walls 12cm including mortar)

The different wall thicknesses have direct impact to the cooling time of the kiln before the door can be opened without the risk of self-ignition of the charcoal. Naturally wall thickness has an effect on construction costs as well as to the durability of the kiln structures against cracks. As a general rule of thumb it has been noted by the kiln operators that kiln wall thickness has influenced the required cooling time. However, the project could not arrange suitable testing circumstances to verify the differences in the cooling time between the kilns.

The overall kiln *construction costs* of the seven plants, including contractor's 20-30% management fee, was 350 750 GHS or 50 107 GHS per plant. With currency conversion rate of 3.371 GHS/EUR (Jan 2015) the average construction cost was 14 864 EUR/plant and with 4.2 GHS/EUR (Jan 2016) conversion rate 11 930 EUR/plant. The last kiln in Shaffa, having thinnest wall structures, was the cheapest to construct with an estimated construction cost of approximately 10 000 EUR.

APSD's environmental officer, Samuel Okai, has been working during the project grant period and will continue to work also after the project in close cooperation with all seven communities which have a charcoal production plant. Samuel provides assistance to all villages in solving operational problems, oversees firewood procurement from APSD's land clearing areas, coordinates the management of the energy wood plantations and helps communities to procure charcoal sacks as well as coordinates the gathering of the ready charcoal sacks by trucks to be delivered to end-user markets.

Samuel Okai also prepared the Annual Environmental Report for the year 2015. This report is presented in Annex 1.

Activity 4: Training on plant operation, maintenance, safety and security
Operation and safety guidelines have been prepared and presented to the plant operators in every production site. Operation Guidelines are presented in Annex 2 and Safety Instruction in Annex 3. Plant maintenance guidelines were prepared and presented to the plant operators in every production site. Maintenance Guidelines are presented in Annex 4.

On-the-job training related to charcoal production, production safety and plant maintenance was provided by Pöyry experts, APSD (Samuel Okai) and partly also by Joe Nsiah.

Major hands-on training took place in November 2013, March 2014, March 2015 and November 2015. Many village people, including plant operators and their assistants, participated the training, which covered charcoal production, safety procedures and maintenance guidelines.

Training to solve potential charcoal production and charcoal quality problems was always an integral part of the on-the-job training. All challenges the production team faced were related to raw material quality (moisture content, particle size,

round wood logs surrounded with bark), charcoal production process (temperature levels, production time, cooling time, maximising charcoal production instead of biochar, sealing excess air holes) and to plant maintenance (cleaning of the door frames before closing the doors, fixing small cracks).

Activity 5: Land clearing and plantation management training
The sites for the plantations that had been previously selected with the villagers were cleared and the team dedicated to planting and maintenance were trained in best practices. For example, planting should be coordinated with the rain, while fire-belt preparation, needed to prevent the spread of forest fire from affecting the plantation areas, should be done just before the dry season each year. The weeding and maintenance team are instructed on weeding twice a year.

The land was cleared of existing trees and shrubs and the land clearing team was instructed on cutting the debris to sizes useful for charcoal production in the first stages, before the plantation is planted and the seedlings have matured. Most trained labour was devoted to the process and understood the instructions. Some problems with cutting the debris and logs to the best size for the kilns were experienced. Perhaps in the future, some exact guideline for measurement would be included.

APSD's nursery produced all acacia seedlings for the energy wood plantations. APSD continues to produce acacia seedlings to cover future replanting needs. The Acacia plantation establishment covers 30 hectares in each community. The area was sub plotted into 3, 10-hectare woodlots, each within the same area.

The involvement of the local people was mainly in lining and pegging, planting and weed control. They were also involved in plantation management, including fire prevention. APSD has largely been involved in providing seedlings, all transport arrangements, planting logistics, land clearing, initial weed control, overall supervision among other things. All of these services and seedlings have been provided free of charge to the communities. One local representative was appointed from each community, who was trained on the concept of plantation management. The training revolves around lining and pegging, seedling handling, planting, weed control, fire prevention and other activities related to the plantation establishment and management. This training was usually done afield, as the practicality of the activities demands demonstrations. All communities involved begun plantation development and had representatives who participated the training. These trainings were largely informal and very inconsistent. They were usually offered on an ad hoc basis.

Activity 6: Seedling production and plantation establishment
All seedlings were produced in Bantama at APSD's nursery. Plantation establishment was delayed in some villages due to lack of rains as seen in table 3.

Table 3 Plantation observations and learning opportunities

Location	Developmental status	Identified challenges	General comments
Nketiakrom	Land clearing completed. All plantations completed by end of April 2016.	Rains ended too quickly	Consider providing boreholes at the kiln sites to ensure continuous production
Bodinka	Partly planted in September 2015 by APSD with the help of the community; Trees are looking well. About 2 hectares burnt; land clearing for unplanted area completed; waiting for rains to resume planting. Planting completed 4/2016.	Fire -belt completed	There is need to ensure that in sourcing for wood to feed the kiln, the objective of the project of avoiding deforestation is not compromised
Kyeamekrom	Land preparation done and plantations completed 4/2016		
Dwankrom	Plantation completed 4/2016		
Shafa	Land preparation and plantations implemented 4/2016	Community yet to be fully engaged	Leaders of the town have been informed and fully involved so far
Mframa	All 30 ha established and growing well;		
Baibai	All 30 ha established and growing well; partly burnt	Heavy undergrowth	Operator is able to produce about 8 bags on average.

By the end of April 2016 all energy wood plantations (210 ha) on acacia had been established.

Table 4 Status of Acacia energy wood plantations

Community	Plantation target	Date plantation fully completed
	Ha	
Baibai	30	11/2013
Mframa [1)]	30	11/2014, 4/2016
Shafa	30	4/2016
Dwankrom	30	4/2016
Kyeamekrom	30	4/2016
Bodinka	30	4/2016
Nketiakrom	30	4/2016
	210	

1) Approximately 15 ha were planted in Mframa in autumn 2014. However, almost all of these plantations were burned by wildfire in January 2015. Replanting was finalised in April 2016.

Figure 4 Acacia plantation in Mframa after being burned by wildfire (March 2015)

Figure 5 One and half year old energy wood plantation in the background of the Baibai plant

Activity 7: Charcoal production

As of February 2016, all seven kilns had been successfully constructed. In a few of these, small problems were encountered as described in table 5.

Table 5 Kiln observations and learning opportunities

Location	Identified challenges			
	Labour	Kilns	Raw materials for charcoal production (wood stock)	Others
Nketiakrom	No identified problem with labour	Cracks observed in three kilns Two thermometers missing One kiln locker not closing, needs replacement	Wood not available for charcoal production	Water for charcoal quenching
Bodinka	No permanent person responsible for management of kiln	No problems observed so far	Wood from prepared land to be used for initial production	
Kyeamekrom	No labour challenges	No problems observed so far	Raw materials available	Water for charcoal quenching; community is yet to be fully involved
Dwankrom	No labour challenges	Cracked kilns 1 cracked thermometer	Raw materials available	Wood available
Shafa	No labour challenges	One chamber has cracks but filled with mud during operation; lighter rake may be required	Raw materials available	Supporting bricks inside kiln needs reinforcement; No PPEs (no boots); water to quench charcoal
Mframa	No labour problems	Cracks in kilns	Raw materials available	
Baibai	Operator needs assistant	Cracks	Raw materials available	No PPEs; water to quench charcoal, drums for water

Charcoal production volumes (as of May 2016)
Commercial operation started in the first plant 1/2013, in the five next plants in 5/2015 and in the last plant (Shaffa) in 12/2015.

The project has produced 301 tons of charcoal consisting of approximately 253 tons of lump size charcoal and 48 tons of smaller particle size biochar during the grant period. This is approximately 70% of the original production objective of 439 tons. However, verified sales of charcoal based on the money saved to the community accounts show that realised charcoal sales totalled to approximately 95,120 kg, whilst the rest of the production has not yet been sold or has been lost due to careless handling of charcoal after unloading it from the kiln. However, this is typical, especially during the charcoal production testing phase and always when a new / unexperienced plant operator starts production. The main reasons why the production objective could not be met are:

- The learning curve to produce charcoal has not been as fast as expected
    - Today the project has used approximately 1,364 tons of wood for the production of 301 tons of combined charcoal and biochar. Production efficiency has increased from 16% to 29% during the learning period. Production efficiency is expected to continue increasing.
    - With 1,364 tons of raw wood input, the charcoal and biochar production volume would have amounted to 487 tons according to the production efficiency rates of 35%, as experienced in production tests.
        - Delayed construction time of the kilns due to prolonged process with some villages to find consensus and to get the Environmental Permits.
        - Occasional lack of wood raw material to be processed to charcoal
        - Lack of suitable quality wood raw material from land clearing areas
    - Low quality wood has led to long processing times, low quality charcoal and excess volumes of ash. Low quality raw material refers here to: high moisture content, large particle sizes, and wood in the form of round wood that has a thick layer of bark all over the wood. Sometimes the wood species was not ideal for charcoal manufacturing, resulting in high ash volumes.
- The trained kiln operators were usually not committed enough to the charcoal production. New operators were not familiarized with the plant operation, frequently resulting the overheating of the kiln and excessive ash production
- Lack of long-term hands-on training of the kiln operators
- Charcoal kilns' cooling time proved to be much longer than anticipated (due to unnecessarily thick kiln walls). The long cooling time has hampered and complicated the charcoal production.
- Unaccounted for charcoal production
    - This may be due to collection of charcoal by local villagers for their own use. Some charcoal has been given to the truck drivers to test the quality on behalf of the buying company.

The charcoal and biochar production volume estimate is based on APSD's information about wood raw material delivery volumes, charcoal sack delivery and sales volumes, as well as on the kiln operators' and village chief's own estimations.

A summary of the realised charcoal and biochar production by the end of May 2016 volumes are presented in table 6.

Table 6 Cumulative charcoal and biochar production volumes (1000 kg)

	Charcoal	Biochar	Total
Sacked and sold in sacks (money saved to community bank accounts)	95,12	6	101,12
Stored in sacks or as a loose matter next to the kilns to be sold later or used as a soil improvement material	41	22	63
Collected by local village people to be used in their homes as cooking fuel	20		20
Sacked & donated to the truck drivers and perhaps to some other stakeholders for testing purpose	10		10
Charcoal that has been lost (perhaps stolen)	30		30
Total	196,12	28	224,12
Burned to ashes (inside the kiln if the kiln door has been left open) or the charocal has been left unguarded on the ground after unloading the kiln	57	20	77
Total	57	20	77
Grand total	253,12	48	301,12

By far the highest charcoal production volumes (70 tons) and sales income (13 418 GHS) have been met in Baibai village, as the plant was the first one to enter into production and reinforced with the most dedicated and skilled plant operator of all the plants. Baibai has produced approximately 70% of the total charcoal volume that has been sold so far.

Table 7 Charcoal sales incomes and estimated charcoal production volumes by processing plant

Community	Sacks of charcoal (Small)	Sacks of charcoal (Large)	Total Cash Received (GHS)	Total Cash Spent (GHS)	Cash Available (GHS)	Charcoal volume sold, ton
Baibai	1 473	521	13 418	8 774	4 644	70,24
Mframa	143	57	1 565	1 205	360	7,14
Shaffa		99	1 188	868	320	4,95
Dwankrom	143	149	2 478	1 222	1 256	11,74
Kyeamekrom		9	-	-	0	0,45
Bodinka			-	-	0	0
Nketiakrom		12	110	110	0	0,6
TOTAL	1 759	847	18 759	12 179	6 580	95,12

Activity 8: Training provided on charcoal sales and marketing

After several discussions with the parties involved, a consensus was found that all communities will sell charcoal and biochar sacks from the production site of each kiln.

APSD, together with the community representatives and paramount chiefs, identified suitable entrepreneurs that will come to pick up the charcoal sacks with a truck from the production sites at request. The truck driver counts the number of

charcoal sacks to be transported from each community and arranges the payment to the community account in question. The pricing of charcoal is based on sacks. The current price of one sack is 12 GHS/sack).

This arrangement is transparent and prevents community members (possibly involved in charcoal transportation and sales) from participating in illegal transactions.

Each community has a 5-member project committee which oversees all project transactions. 3 out of the 5 are signatories to the community account. When charcoal is sold, the buyer pays the accrued amount directly into the community account. Cash is withdrawn by the community to pay for workers on monthly basis. Only those 3 community members who are signatories to the account have the mandate to thumbprint and withdraw money for any activity.

Activity 9: Wood production instructions
Currently, no wood has originated from the energy wood plantations as they are not ready yet.

All charcoaling wood so far is sourced from land clearing areas within APSD concession. APSD has hired an operator to crosscut wood for transport to the charcoal kiln sites. These are trees that have been felled to make way for APSD plantation establishment. APSD releases a tractor as needed to load and transport the wood to the kiln sites. The operator has been instructed to select as good charcoaling wood as possible and available with reasonable diameters so as to skip splitting operations in the forest or at the production site.

Figure 6 Wood deliveries to Baibai plant from APSD's land clearing areas

Activity 10: Test production to measure mass- and energy balances
A detailed test production to measure the mass and energy balances was done in Baibai in March 2014. The test results are presented in Annex 5.

The test production of charcoal was done by measuring:
- The weight and moisture content of wood used in charcoaling and wood used as a fuel
- The weight of ready charcoal, biochar as well as wood not processed to charcoal

Based on this data and the approximate energy content of dry wood (19.5 MJ/kg, 5.42 MWh/t) it was possible to calculate the mass and energy balances. The result of the test production revealed that mass and energy balances varied a lot depending on the wood quality (species, particle sizes used, moisture content of wood) and production pattern (temperatures, overall processing time etc.) used. The best batch achieved a very high mass balance of 35% and 78% energy balance when both charcoal and biochar were included.

For the testing and comparison purpose, also a traditional earth mound kiln was constructed in the vicinity of the TU retort.

Activity 11: Project handover
Project handover agreement between project developers (Pöyry Management Consulting Oy and African Plantations for Sustainable Development, Ghana), and

project beneficiaries (Traditional Council Chiefs of Atebubu, Wiase, Dwan and Bassa and Sub-Chiefs representing villages of Byebye, Shafa, Mframa, Dwankrom, Kyeamekrom, Bodinka and Nketiakrom) has been signed and is presented in Annex 6.

2.2 Deviations from the Planned Activities

2.4.1 Charcoal production volumes and quality

The only deviation from the planned activities is related to the lower production volumes of lump size charcoal. The cumulative production volume of charcoal during the project grant period is 301 tons, compared to the 439 tons set forth in the objective. Approximately 8% of the charcoal produced is small size biochar, which has limitations regarding market access in Ghana. Part of the biochar has been recycled back to the forest while the rest is stored by the production plants in sacks or as loose matter piled on the ground. In the future, biochar could be processed into cooking briquettes. In the future, a bigger share of biochar could be recycled back into the forest, after APSD gains first-hand experience of the effects of biochar on the tree growth.

The main reasons why the production objective could not be met are:

- The learning curve to produce charcoal has not been as fast as expected
- Delayed construction time of the kilns due to prolonged process with some villages to reach a consensus and to get the Environmental Permits
- Occasional lack of wood raw material to be processed to charcoal
- Lack of suitable quality wood raw material from land clearing areas. Low quality wood has led to long processing times, low quality charcoal and excess volumes of ash. Low quality raw material refers here to: high moisture content, large particle sizes, and round wood with a thick layer of bark. Sometimes the wood species was not ideal for charcoal manufacturing, resulting in high volumes of ash
- The trained kiln operators were usually not committed enough to charcoal production. New operators were not familiarized with the plant operation resulting in frequent overheating of the kiln and excessive ash production
- Lack of long-term hands-on training of the kiln operators
- Charcoal kilns' cooling time proved out to be much longer than anticipated (due to unnecessarily thick kiln walls). Long cooling time has hindered and complicated charcoal production.

- Part of the production has been unaccounted for (e.g. stolen or used within the community). Additionally, some charcoal has been given to the truck drivers to test the quality on behalf of the buying company.

2.3 Achievement of Outputs and Objectives

Table 8 Achievement of the objectives and outputs

Planned Objectives and Outputs	Indicator(s):	Achievement of the objectives and outputs:
Construction of 7 charcoal plants	Number of kilns in operation	7 plants constructed, commissioned and in operation
All kilns are producing charcoal. Production objective 439 tons charcoal.	Volume of charcoal produced	301 tons charcoal produced from seven kilns.
Find committed plant operators	Operator turnover	Trained operators have not been committed enough. Charcoal production volumes have not been as high as expected and frequent production failures
Provide on-the-job training to operate and maintain the plant in an efficient and safe manner	Fairly high production volumes	Kilns are run in an efficient manner. No accidents recorded. Kilns have been too often idle due to weekends, holidays, crop harvest season, night time
Provide local employment	Number of permanent and temporary jobs created	The project exceeded its estimation of 120 new jobs, with a total of 247 created, 119 of which are permanent jobs. Of these, women obtained 37 of the permanent jobs and 24 of the seasonal jobs.

3. CLIMATE CHANGE

Emissions / emission reduction

Verifying emissions released from the chimney during the production process by taking and analysing gas samples was not possible because of the continuous gas flow during approximately 15-20 hours' time and the constant change of the gas composition during the whole processing period. CO_2 equivalent emissions have been calculated based on wood combustion and gasification theory.

The objective was to achieve an emission reduction of 5 061 tCO_2 based on a 439 t charcoal production volume target. The project achieved a 3 540 t CO_2 reduction based on a charcoal production volume of 301 t. This is approximately 70% of the objective. The GHG emission reduction calculation is shown in table 9.

Table 9 Calculated GHG emission reductions

Charcoal production with 7 plants	**300,8**	t/a
Wood consumption for fuelling -TTU Retort	42	t/a
Wood consumption for charcoaling –TTU Retort	811	t/a
Wood consumption for fuelling -Earth mound kiln	249	t/a
Wood consumption for charcoaling -Earth mound kiln	3 292	t/a
Wood moisture content, as received	30 %	%
Charcoal calorific value [1]	7,859	Kcal/g
Conversion coefficient	4,18	KJ/Kcal
Charcoal NCV [1]	32,85	TJ/t
Fixed Carbon in charcoal [1]	70,06	%
Emission reduction (CDM, Small-scale methodology) [2]	798	tCO_2
Efficiency increase (TU-retort vs. earth mound kiln) [3]	4,15	
Total emission reduction	**3 313**	tCO_2
Emission of methane: Earth mound kiln [4]	299	$tCO_{2\ eq}$
Emission of methane: TU-retort [4]	72	$tCO_{2\ eq}$
Emission reduction of methane (IPCC guidelines) [4]	**227**	$tCO_{2\ eq}$
Total emission savings	**3 540**	**tCO_2**

[1] *Laboratory analysis charcoal made with acacia in a Pöyry retort in Kenya in 2012 (annex)*

[2] *UN/CDM, AMS-III.BG, Small-scale Methodology Emission reduction through sustainable charcoal production and consumption, Version 02.0. Note: This methodology does not take into account the CH_4 emission reductions nor efficiency increase.* http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ref3.pdf

[3] Overall wood consumption in earth mound kiln / wood consumption in TU-retort (3 541 t / 853 t = 4,15)

[4] *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ref3.pdf (default value: 1000 kg CH_4/TJ charcoal produced).*

4. DEVELOPMENT IMPACTS AND CROSS-CUTTING ISSUES

Throughout the duration of the project, with partners WWF WAFPO / NDF, the Environmental, social and other considerations such as proximity to community dwelling and site suitability were assessed and deemed to meet project objectives, as presented in Annex 9.

Environmental sustainability was the main objective of this project, as the project consists of the construction and implementation of seven charcoal production plants (chamber wood retort of 4 integrated kilns, made of local brick) that are efficient, environmentally friendly, affordable to local entrepreneurs and easy to operate and maintain.

Promotion of human rights takes the form of the greater respect for communal assets by diverting the source of raw material for charcoal production from the illegal harvesting that has historically been the norm, to utilizing sustainable raw material from sustainably managed fast-growing tree plantations. Quality of life improvements were assessed through measuring impacts of the project on the social lives of the people, which proved to be a reiterative process, needing ample stakeholder consultations and discussions between community members and project developers.

In general, job creation was a secondary objective of this project, providing 247 temporary and permanent jobs. The jobs included kiln operator, security personnel, planting, fire belt preparation, weeding and maintenance, land preparation and water transference, as seen in table 10.

The promotion of women's rights has taken the form of including additional women into the work force, finding ways to employ women to be engaged in this communal work. The project has found employment for 37 women in full time jobs and 24 women in part time jobs seasonally throughout the year. Descriptions of the full and part time jobs created can be seen in table 11.

Table 10 Jobs created at each project site

Community	Job description													
	Kiln operator		Security/ Focal personnel		Planting team		Fire belt preparation team		Weeding/ maintenance team		Land & wood prep.		Water fetching	
Male / Female	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Baibai	2	-	1	-	5	17	15	-	12	3	5	-	-	10
Shafa	3	-	1	-			5	-	-	-	5	6	4	-
Mframa	4	-	1	-			5	-	12	4	5	-	-	8
Dwankrom	4	-	1	-			5	-	15	-	5	-	-	5
Kyeamekrom	4	-	1	-			5	-	-	-	6	-	5	-
Bodinka	4	-	1	-			5	-	15	-	6	-	-	-
Nketiakrom	5	-	1				5	-	-	-	6		2	8
Total	26		7		5	17	45		54	7	38	6	11	31

Table 11 Tasks and number of weeks of employment

Job type	Number of weeks engaged per year	Remarks
Kiln operator	52	Subject to the availability of wood and the condition of kiln
Security/focal Personnel	52	Engaged to assist in carrying out various tasks in connection with woodlot establishment and maintenance.
Planting team	12	Normally done with the rains, and ends when the 30 hectares of woodlot is established.
Fire belt preparation team	2	Done just before the dry season each year
Weeding/ maintenance team	10	Done twice in a year to keep the woodlot free from weeds competition
Land prep/ wood prep	52	This activity is continuous as wood making sets the stage for the manufacture of charcoal. Land preparation, however, stops with the completion of planting.
Water fetching	52	Water is needed when controlling weeds with herbicides and in the offloading of charcoal

Additionally, the WWF WAFPO/NDF undertook at least 10 field trips involving at least two staff, Mustapha Seidu (Director), Glen Asomaning (Operations Director), Margaret Appiah (Project Officer) and Emmanuel Agbodza (Driver). On every field trip, a visit was paid to the Baibai kiln and community due to its status of operation (first to become functional) and proximity to the APSD operational site. At least five visits were paid to all the other six sites of the project. This is part of a larger undertaking to understand the strengths and weaknesses of the project implementation and to discover the scaling-up potential of the project.

The foreseen development impacts of the scaling up of this type of project can be estimated to be significant, as 15 - 20 full time jobs and 20 – 40 part time jobs can be created from each implemented kiln and plantation site combination.

Interactions with communities participating in the project have given clear indications of the threat to the availability of raw materials for charcoal production

as well as the potential threat to agricultural production. Coupled with the presence of the APSD plantations, the project's own plantations have demonstrated that it is possible to set up small community plantations for charcoal production. Impacts on deforestation reduction are also considered to be significant, as the use of the adjacent fast-growing tree plantations for the sourcing of raw wood material will decrease pressure on natural forests as the demand for charcoal increases. According to the Nature and Development Foundation, the lessons learned in plantation establishment and other cultural practices such as fire-belt preparation, coupled with the continual increase in demand for charcoal will foster more individual plantations to be established for the purposes of charcoal production. The deliberate establishment of plantations will, in the long term, foster a sense of responsibility towards the conservation of natural stands.

In terms of development implications on a larger scale, it is apparent that through scaling up and increasing know-how, there are great market opportunities to benefit from the sales of sustainably produced charcoal. Operators in Baibai produce an average of eight mini bags per kiln. The other kilns mostly produce much lower bags per kiln. Therefore, it can be concluded that with constant practice and on-the-job training, the other sites will also raise their outputs. Once the few identified challenges are properly addressed, this model of charcoal production will be in a position supply the charcoal needs of not just Ghana, but the international market as well.

5. ASSESSMENT OF THE RESULTS AND IMPACTS OF THE PROJECT

5.1 Relevance

Project has high priority to the villages hosting the kilns as the project has created job opportunities and steady income flow to people involved. If and when the project will gain profits, these would be utilised to common purposes e.g. to pay school fees and other activities in order to revitalize life in the villages.

Paramount Chiefs are happy that livelihood in the villages is getting better. However, Chiefs have low interest to promote charcoal production as it does not bring direct benefits to them.

APSD's cooperation with all stakeholders has improved during the project. Later on, villages may also become customers of APSD when purchasing seedlings. They may also potentially act as a consultancy to maintain and develop the charcoaling business.

5.2 Effectiveness

Production efficiency (performance) during the first months of charcoal manufacturing was very low due to high volumes of lost charcoal due to production failures, which resulted in the charcoal burning to ashes. In the beginning of the charcoal production, the estimated efficiency or overall mass balance was 16% (= wood raw material input, t / charcoal output, t). The overall cumulated mass balance as of today (end of May 2016) is approximately 22%. Once kilns start to utilize wood from their own energy wood plantations, the efficiency is expected to increase further to 30% - 35%.

The plant operating times in all plants other than in Baibai have been very low. The reason for this can be explained by the non-committal attitudes of the plant operators as well as the occasional lack of suitable quality feedstock to be utilised in the charcoal manufacturing.

Sustainability

Charcoal manufacturing has been sustainable as the kilns have utilized only wood raw material originating from APSD's land clearing areas when preparing the land for wood plantations. All raw materials to be used later in charcoal manufacturing will originate from their own sustainably managed energy wood plantations.

Charcoal sales

In the beginning of the project, once the charcoal production volumes have been fairly low, the communities and other project stake holders decided to sell charcoal sacks directly (ex-mill) from the production plants to a middleman who organized the charcoal transportation to Kumasi (or Accra) and related retail sales. Again, once

the charcoal production volumes and sales incomes increase, project stakeholders will be interested in discussing the possibilities to purchase or hire their own truck to transport the charcoal themselves to the end-users.

5.3 Efficiency

So far plant operation time in all kilns has been very low leading to low overall production volumes, which affects the efficiency indicators to be used. Charcoal production volumes are expected to increase considerably once plant operators start to utilise the homogenous raw material from their own energy wood plantations and the plant operators will commit at full to charcoal production.

Following indicators have been used to measure the efficiency of the project by the end of the grant period:

a) Cost of emission reduction

72 EUR/tCO_2 = 500 000 EUR (grant financing) / 6 954 tCO_2 (total emission reduction)

b) Cost of charcoal produced

1 661 EUR/t charcoal = 500 000 EUR (grant financing) / 301 t charcoal production volume

c) Cost of charcoal sold (ex mill)

5 256 EUR/t charcoal = 500 000 EUR (grant financing) / 95.12 t (charcoal sold)

All indicators used show that the efficiency of the project has not been as high as could have been expected.

On the long run these indicators will be improved as the charcoal production volumes increase.

5.4 Impact

New jobs and other activities have been developed due to the charcoal production and wood plantation management activities. In small villages, the project is a common discussion topic, thus creating a joint fellowship amongst the village people. Several families also utilize the oven to prepare their food i.e. jams under the surveillance and instructions of the kiln operator.

Through word-of-mouth, potential benefits of these charcoal kilns made of local construction materials, having high production efficiency and low emissions combined with the utilisation of owned wood plantations to provide wood for charcoal manufacturing have spread widely in Ghana, as well as in financing

institutions seeking renewable energy projects. APSD and Pöyry have been contacted by several project developers interested to know more about the project and its up-scaling opportunities. Several experts from abroad have also visited the project site to get acquainted with the new charcoal production technology.

5.5 Innovativeness and learning

Learning opportunities

- With the demonstration completed, future projects should consider setting a time gap between plantation establishment and kiln establishment
- There is a need to assess the adopted model and investigate other models that will consider multiple ownership structures
- Future projects should consider providing boreholes on site to aid in the watering of plants and ensure continuous charcoal production especially during the long dry season.
- There is need for further working (exchange) visits between kiln sites to share lessons and experiences.
- Due to the constant complaint received from operators of the kiln concerning the levels of heat during removal of charcoal from the kiln, we propose a further redesign of the kiln to cool charcoal completely before removal.

Insurance of the production plants

- APSD had an overall insurance that covered among other things also charcoal plants during the project grant period. From now on the plant owner's (village chiefs) must decide themselves if they want to try to negotiate an insurance that covers only the charcoal plants. Challenge is that local insurance companies are not willing to insure the plants (at affordable costs) as they have not experience nor idea what this plant is like, how they have been constructed, what construction materials have been used and what are the risks related to their existence. On the other hand villagers don't want to have insurance as they don't understand why the plants should be insured. Village will take care of the plant maintenance at their own cost.

6. SUSTAINABILITY AND POTENTIAL FOR SCALING UP AND FOLLOW-UP INVESTMENTS

The project has gained a lot positive interest from all who have visited the production site in Ghana or who have heard about the project. E.g. IFC has expressed their interest to support the development and loan financing of a very large scaling-up project consisting of construction of 80 – 100 charcoal kilns and establishment of 2 000 – 3 000 ha energy wood plantations in Ghana. APSD and Pöyry are trying to identify suitable project developer to deal with this project as APSD can't take the lead in the scaling-up project development and Pöyry is not interested in developing this project further, as it does not fit into Pöyry's strategic project portfolio. This size scaling-up project would need also further grant financing to facilitate the initial investments related to plantation establishment and kiln construction.

APSD will ensure that the sustainability principles will be met by observing where the raw material to be charcoaled will be purchased from. Besides, APSD will visit the production sites regularly to help communities manage the charcoaling business and the energy wood plantations.

7. FINANCIAL REPORTING

General

The financial reporting covers all activities undertaken during the project grant period, as detailed in the invoices by each project partner. The invoices itemize costs incurred by project partners, in time spent (salaries), equipment, supplies, travel and other expenses.

Costs and funding

The project budget was EUR 848 000 and the realized overall costs were EUR 922 322 leading to budget overspend of EUR 74 322. The biggest deviation is seen in personnel costs.

Table 12 Summary of project expenditure by grantee and partners and budgeted costs

	Costs, in EUR (€)						
Item	Pöyry (Grantee)	APSD	NDF/ WWF	Traditional Council	CUM COSTS	Cumulative costs	Budgeted costs
1. Personnel	**362 176**	**69 977**	**49 871**	**48 966**	**530 990**	**530 990**	**484 000**
1.1. Salaries/time, International Staff	335 025	20 000			**355 025**	355 025	**287 000**
Technical	335 025	20 000					**287 000**
Admin./support staff							**0**
1.2. Salaries/time at Eligible Country		42 144	43 956	48 020	**134 120**	**134 120**	**157 349**
Technical		42 144	43 956	41 420			**150 199**
Admin./support staff				6 600			**7 150**
1.3. Travel Expenses	27 151	7 833	5 915	946	**41 845**	**41 845**	**39 650**
Staff assigned, related costs	4 216						**0**
International flights	11 211		60				**12 470**
Local transportation costs + accommodation	11 724	7 833	5 855	946			**27 180**
1.4. Equipment, supplies	**2 454**	**382 900**			**385 354**	**385 354**	**354 000**
Thermometers	724						**640**
Car rent	1 712						**4 360**
Wood harvesting equipment	0	41 970					**3 000**
Plant construction (work + materials)	18	117 930					**136 000**
Plantation establishment	0	223 000					**210 000**
2. Office Costs							
Office supplies							
Office rent							
Other, pls. specify							
3. Other Costs	**5 979**				**5 979**	**5 979**	**10 000**
Auditing costs	5 979						**7 000**
Training services & meetings							**3 000**
TOTALS	**370 608**	**452 877**	**49 871**	**48 966**	**922 322**	**922 322**	**848 000**

The budget overspend was EUR 74 322, consisting predominantly of the EUR 43 454 spent in personnel costs (covered by Pöyry's in-kind services) and EUR 26 970 in equipment costs (covered by ASPD).

The biggest single cost item (EUR 223 000) was the establishment of energy wood plantations, the cost of which was covered by APSD as in kind services.

Sources of financing of the project costs are presented in tables 13 and 14.

Table 13 Itemized project budget during reporting period

	Costs and financing, in EUR (€)								
	Costs				Financing				
Item	Pöyry (Grantee)	APSD	NDF/WWF	Traditional Council	Pöyry (Grantee)	APSD	NDF/(WWF	Traditional Council	NCF
1. Personnel	**362 176**	**69 977**	**49 871**	**48 966**					
1.1. Salaries/time, International Staff	335 025	20 000			43 454	20 000			291 571
Technical	335 025	20 000							
1.2. Salaries/time at Eligible Country		42 144	43 956	48 020					
Technical		42 144	43 956	41 420		42 144	9 957	41 420	33 999
Admin./support staff				6 600				6 600	
1.3. Travel Expenses	27 151	7 833	5 915	946					
Staff assigned, related costs	4 216								4 216
International flights	11 211		60						11 271
Local transportation costs + accommodation	11 724	7 833	5 855	946		7 833		946	17 579
1.4. Equipment, supplies	**2 454**	**382 900**							
Thermometers	724								724
Car rent	1 712								1 712
Wood harvesting equipment		41 970				**26 970**			**15 000**
Plant construction (work + materials)	18	117 930							117 948
Plantation establishment		223 000				223 000			
2. Office Costs									
Office supplies									
Office rent									
Other, pls. specify									
3. Other Costs	**5 979**								
Auditing costs	5 979								5 979
Training services & meetings									
TOTALS	370 608	452 877	49 871	48 966	43 454	319 947	9 957	48 966	500 000
TOTALS	922 322				922 322				

Table 14 Sources of funding, EUR

	Amounts, cumulative	% of total	Budgeted funding
1. NCF	500 000	53,9 %	500 000
2. Grantee's financial contribution	43 454	4,7 %	0
3. Contribution from other organizations			
APSD, Ghana	319 947	34,5 %	308 158
NDF (former WWF)	9 957	1,1 %	10 000
Traditional Council Chiefs	48 966	5,3 %	30 000
TOTAL CONTRIBUTIONS	**922 322**	**99,5 %**	**848 158**
Other sources of funding			
Direct revenue from the Project (charcoal sales) *)	4 466	0,5 %	
Interests from pre-financing	0		0
Other sources	0		0
GRAND TOTAL	**926 788**	**100,0 %**	**848 158**
Filled by: Tuomo Utriainen			
Approved by: Anne Leskinen			

*) Sales income as per end of May 2015, 18 759 GHS, 4 466 EUR (4,2 GHS/EUR)

In summary, the project costs were financed by NDF EUR 500 000 (53,9% of total costs), APSD EUR 319 947 (34,5%), Traditional council EUR 48 966 (5%), Pöyry EUR 43 454 (4,7%) and NDF/WWF EUR 9 957 (1,1%).

8. CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

- Communication with village people is important for acceptance and overall cohesion of the project partners and participants.
- Long term conditions and timeline are essential for the project to secure full adaptation of the project by local beneficiaries.
- A team of village people should be involved from the very beginning.
- Salary payment to people involved in wood supply and charcoal production should be agreed in the beginning of the project. Financing should be available to support salary payments during the training and ramp-up phase, before project financing (charcoal sales income) will be sufficient to cover the costs.
- It is difficult to find suitable skilled charcoal operators ready to make a long term operation commitment, from the villages (also capable to read and write in English.)

Recommendations

- There should be a pilot kiln for training.
- Walls of the kiln were too thick, resulting in the high production costs of the kilns as well as long cooling periods for the charcoal.
- The next project should be long term (> 5 years) to secure that plantation wood will be used and charcoal production ramp up will take place
- Perhaps the next project should start with the construction of one demonstrative kiln that would be used to train operators, test different raw material types and to benchmark production volumes.