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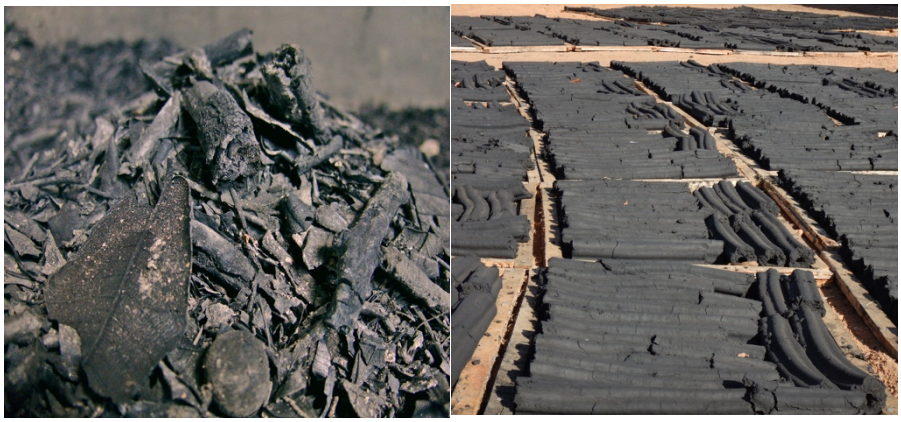
Final Report:

Waste Biomass to Charcoal Briquettes in Tanzania



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1. Summary

Charcoal is the most important energy source for urban areas in Tanzania - as in many other developing countries. The demand is satisfied through unsustainable production, leading to deforestation. At the same time, charcoal is a very important income for the rural population. It can be produced quickly with no specialized equipment, and there is always a market. To address this paradox, the goal of the project was to promote charcoal briquette production using waste biomass as a substitute for conventional (deforestation-causing) wood charcoal.

The project was located in the Southern Highlands of Tanzania. There were three main project phases with associated aims. Phase I aimed to establish rural char dust and briquette production to demonstrate operational proof of concept. This objective was met. A pre-commercial start-up enterprise was established in the village Magunguli (50 km from Makambako) training producers of charcoal dust (char dust). A pilot briquette facility was established to convert the char dust into charcoal briquettes. Necessary installations for drying and packing of briquettes was installed and a small amount was produced for testing purposes.

In Phase II, the project aimed to upscale and optimize briquette production and market these in large volumes to demonstrate economic proof of concept. Capacity of char dust and briquette production was expanded during this phase, and ca. 100 tons of char dust were produced. A team of youths of the surrounding villages (MTM) took over responsibility of production. A tracking system for biomass verification was developed using a combination of GPS measurements of crop/forestry plot sizes and expected biomass yields. MTM developed a market outlet in Makambako and spent almost a year marketing briquettes, with youths rotating between rural production and urban marketing. Unfortunately, the marketing effort did not reach expected volumes by the project end. This, combined with high production costs relative to the local charcoal price, meant that economic proof of concept was not achieved.

Phase III aimed at a prospective impact assessment of upscaling to capture available regional biomass. In partnership with the University of Bern (CDE), a biomass supply model was developed and scenarios constructed to explore impacts of using biomass for briquette production. The results demonstrated the potential to meet up to half the local demand for conventional charcoal using *only* waste biomass from crops and forestry. At the same time, this would create additional income for tens of thousands of local farmers (through selling biomass contracts or char dust) and hundreds of well-paying, legal jobs in briquette production. A business plan was developed based on these findings by project partner FARIP.

Due to the failure to market the briquettes by end of Phase III, an extension phase for 2019 was granted. In this phase, marketing efforts shifted away from retailing briquettes at local markets to selling by truck load. These briquettes were marketed through appearance at agricultural fairs and branding of the product and resulted in the selling of 30 tons of briquettes to a charcoal retailer in Dodoma, the capital city of Tanzania. The appearance of competing companies at the fairs and in the media prove that the market for briquettes is expanding.

2. Starting Point

Charcoal is the most important energy source for urban populations in Tanzania. Over 90% of households in Dar es Salaam use charcoal for cooking, 60% across other cities (Zah and Ehrensperger 2014). This demand is largely satisfied through unsustainable production (Mwampamba 2007), resulting in deforestation of both native forests and Miombo woodlands (responsible for the loss of ca. 91'000 ha of forest annually; Felix and Gheewala 2011). There is an urgent need to reduce pressure on native forests whilst simultaneously meeting energy needs, particularly of the poorest urban households who are disproportionately reliant on charcoal for fuel, and of rural households who depend on conventional charcoal production as an important source of income. Reducing the environmental impacts of charcoal production and use is thus a key priority for improving the sustainability of Tanzania's energy supply (Kituyi 2004).

Figure 1: Traditional cooking stove used with charcoal briquettes (Photo: EFCO)

The Mufindi District is economically dependent on small-scale agriculture (mainly livestock grazing, maize, rice and tea), tea plantations, and private/state-owned forestry operations, including plantations of mainly exotic conifers and eucalyptus species. Currently, agriculture in the region involves extensive burning of residues (maize stalks, rice straw etc.), bushy regrowth, and savannah grasses for field clearance before cultivation, resulting in a great wildfire hazard. In the forestry sector, waste from logging and timber processing (branches, tree-crowns, off-cuts, sawdust etc.) is generally abandoned to rot or is burned. Such waste is therefore freely available as a resource. Technology and procedures that can use these residues for charcoal production will improve local resource efficiency whilst generating additional income and jobs, reduce deforestation and reduce damaging emissions.

Figure 2: Briquette production for the brand «Mkaa Mkombozi» at ARTI / CBTL in the Daressalaam area (Photo: Tatjana Erpen)

Within Tanzania, there are a number of small green charcoal projects and associated stakeholders, but no major initiatives in our target region. To benefit from existing Tanzanian expertise, we engaged the assistance of the Appropriate Rural Technology Institute of Tanzania (ARTI-TZ). ARTI has established community-based green charcoal enterprises in the Bagamoyo and Kibaha District, Pwani Region[1], and in suburbs of Dar es Salaam (www.arti-africa.org). ARTI-TZ is a non-profit development organization that produces efficient charcoal kiln and briquette press technology for research and commercial sale through their commercial daughter company Charcoal Briquettes Tanzania Ltd (CBTL), which has successfully introduced charcoal briquettes in the Dar es Salaam market. ARTI-TZ also participates in the "Harvest Fuel Initiative", a joint project of the Massachusetts Institute of Technology (MIT) and the US-based charity "The Charcoal Project" (www.harvestfuel.org).

A final backdrop is the expanding logging of plantations in the Makungu area, due to the enlargement of the Udzungwa National Park Escarpment Forest. Monoculture exotic plantations within the enlargement zone are sequentially being cleared and replaced with mixed native forest. The logging is estimated to yield up to 10'000 m^3 of roundwood per year for two years. The roundwood is being processed by mobile sawmills directly in the forest plots, creating a massive amount of harvest and milling waste (roughly equal to the final timber output). Logging operations finally began in 2018 after a 2-year-delay.

Figure 3: Logging operations in the Magunguli area in September 2018 (Photo: Tatjana Erpen)

[1]http://arti-africa.org/projects/scaling-up-of-charcoal-briquette-production-in-tanzania/

3. Objectives

The overall goal of the project is to promote charcoal production based on waste agricultural and forestry biomass as a substitute for deforestation-based (conventional) wood charcoal. The project is split into three project Phases (I-III), with respective objectives:

- **Objective 1**: Demonstrate proof of operational concept for small enterprises in rural Tanzania who can produce green char dust that is sent to briquette manufacturers in Dar es Salaam.
- **Objective 2**: Demonstrate proof of economic concept of the production and marketing of a viable amount of green charcoal briquettes and develop business plans and investment proposals for expansion.
- **Objective 3**: Conduct an impact assessment of the potential positive and negative environmental and socio-economic impacts of this operation and its scaling up in the case study region. Prepare a business plan to be distributed to potential donors and investors.

4. Project Review

4.1 Project Implementation

The project "Waste Biomass to Charcoal Briquettes in Tanzania" launched in September 2016. The project review is presented according to project phase and respective objective(s). The project review text below is adapted from the three interim project reports submitted during the project, along with the associated biomass model report (Bär and Curran 2019) and business model (FARIP 2019) submitted alongside this final report.

Phase 1: Operational proof of concept (first 6 months).
Detailed objective: 1.1) Establish a pre-commercial start-up enterprise and begin production of charcoal dust (char dust) using available technology; 1.2) Process char dust into charcoal briquettes with project partners ARTI (Appropriate Rural Technology Institute; http://arti-africa.org/) and their commercial spin-off CBTL (Charcoal Briquettes Tanzania Ltd.); and 1.3) bring a sample of these briquettes to market to test consumer perceptions.

Implementation: Objective 1.1 was successfully reached, with the setting up of char dust production and training of 9 village youths in charcoal dust production. Initial project partners ARTI-TZ (Appropriate Rural Technology Institute Tanzania) were successfully integrated in this step. A local production chain of mobile charcoal kilns and trained youths was established and the "Kon-Tiki" pyrolysis method was taught with successful uptake. With practice and training, productivity was tripled within the teams to allow a single producer to operate 3 kilns and earn a daily wage exceeding that of local agricultural labour.

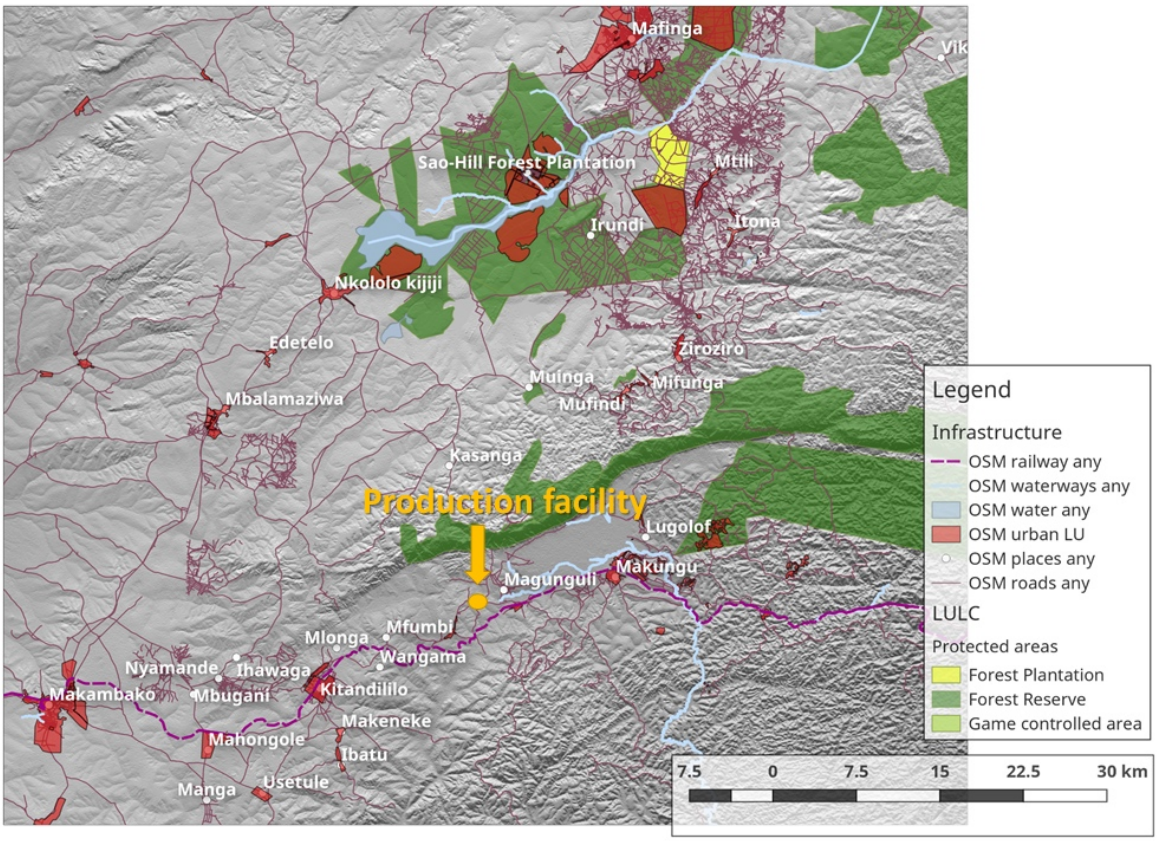

Figure 4. Case study region showing production facility and main target urban market (Makambako).

For objective 2, we deviated from the planned activity of transporting char dust to Dar es Salaam for briquette production by partner CBTL (Charcoal Briquette Tanzania Ltd.; a commercial subsidiary of ARTI-TZ). Discussions with CBTL illustrated the high cost of transport over such large distances and resulting uneconomic production costs. We therefore decided to invest resources in a medium-term solution using the funds assigned to transport and batch processing by CBTL. We built up local capacity for briquette production at our facility in Magunguli using a small-scale briquette machine from CBTL and further modified this to boost productivity 10-fold to a maximum daily capacity of 350 kg of briquettes. As a result of this shift in direction, the original Objective 1.2 of 10 tons of char dust produced and processed was not achieved on time (we achieved only ca. 3.8 tons of char dust and 300 kg of briquettes). The Objective was met with a few months delay. At the end of Phase I, a fully integrated production facility was established (differing from the original project objective but considered an overall success).

For Objective 1.3, marketing briquettes was not achieved due to the additional efforts and innovation required in Objective 1.2 (i.e. investing in briquette production locally rather than batch transport dust to Dar es Salaam). Effort was concentrated in building up a stock of char dust and briquettes before going to market in the nearby urban centre of Makambako. This required drying and packaging capacity, which was constructed over Phases 1 and 2.

Overall, Phase I was a deciding phase in the project, because it shifted orientation away from servicing the established Dar es Salaam market via CBTL to the challenging task of building an integrated and independent local production facility that serviced *local* urban markets (Makambako, with potential to reach Mufindi and Njombe; section 5.2.1). While production and marketing of briquettes ended behind target, we clearly demonstrated proof of operational concept starting from char dust production to final briquette pressing.

Figure 5-8: (top) A shift during project work from char dust production in portable kilns (left) to the flame curtain method (right); and (bottom) from the ARTI-supplied extruder to the EFCO-developed hydraulic extruder.

Phase 2: Demonstrating proof of economic concept (months 6 to 30).

Detailed objective: 2.1) Enlarge production teams for char dust to 6 teams (18 producers); 2.2) Produce 100 tons of char dust and establish relationships with biomass owners; 2.3) Develop a tracking and certification system with project partners TruTrade Ltd based on their "Transaction Security System"; and 2.4) Market 60 tons of briquettes.

Implementation: Phase II was successful in expanding char dust production and team training (Objective 2.1 and 2.2). In Magunguli and the surrounding villages, a network of char dust producers is ready to produce several tons of char dust per week on demand during the dry season. This network demonstrated this by easily producing 100 tons in 12 months. A group

Figure 9-12: Marketing activities on local and regional markets: (left and top middle) Outlet for local produce (briquettes, beans, potatoes) in the market town Makambako, (bottom middle and right) stand at regional trade fairs in Mafinga and Iringa, presenting the briquettes to district officials (Photos: MTM)

of young villagers took over responsibility of the briquette production facility and formed a locally registered enterprise under the brand MTM (Mkaa Tunza Mazingira = Charcoal which saves the environment). We developed a tracking system for biomass verification using a combination of GPS measurement of crop/forestry plot sizes and modelled biomass densities (Objective 2.3). This involved sending a "forest steward" from MTM to a plot previous to biomass purchase. The plot was measured with a GPS and then area was multiplied by the expected biomass availability based on field measurements conducted for the biomass assessment report (Bär and Curran 2019). This gave MTM reference values for potential biomass availability for any single source, allowing amounts of delivered char dust from the suppliers to be compared to the expected value and deviations to be detected (e.g. mixing in char dust from outside the plot). The tracking system was tested in the field (written contracts developed, processes developed) and three youths were trained in GPS usage. However, it was not used in practice because char dust purchases from producers stopped after an initial stock of ca. 100 tons was achieved.

Finally, MTM developed a market outlet in Makambako and spent almost a year marketing briquettes, with youths rotating between rural production and urban marketing. Overall, the number of marketed briquettes was modest (ca. 3 tons sold at the end of 2018 of a total of 20 tons produced). Feedback from consumers was collected, which was both positive (e.g. no smoke) and negative (e.g. slow ignition). Feedback largely conformed to existing experience from consumer studies by "The Charcoal Project" in Dar es Salaam (Kamil and Suzuki 2014), with briquettes essentially requiring a different cooking technique and thus marketing concept. Success in marketing was never fully realized due to a combination of lacking marketing skills and resources and demand factors that made briquette sales challenging. The latter related to a high availability of high-quality alternative fuels (wood and charcoal) and low price of charcoal on the local market. In contrast, where ARTI-TZ/CBTL has been successful

Figure 13-17: Evolution of the briquetting technology applied during the project (from top): hand operated meat grinder (supplied by ARTI), electric meat grinder (ARTI), boosted meat grinder (tuned by Hüsler Mobile Werkstatt), hydraulic press (developed by Hüsler), planned for scaling up: industrial scale briquetting extruder at ARTI / CBTL (Photos: EFCO, Claudia Bucher).

in marketing briquettes in Dar es Salaam, the price is double that of Makambako (ca. TSH 2000 per kg instead of TSH 1000) due to very high demand for cooking fuels in Dar. Thus, while the local briquette company tried for many months to stimulate sales in Makambako, this ultimately failed to shift them in large quantities.

Economically speaking, briquettes were sold at just above the local charcoal price, and the environmental benefit of briquettes was emphasized to consumers. However, this price was still about half of the total briquette production costs (including all fixed and variable production costs). While the price could cover direct labour and material costs, it could not cover machine purchase and infrastructure costs. This was due to very poor productivity of the pilot production facility. Actual productivity of the basic briquette machine provided by ARTI-TZ in Phase I was much lower than expected and led to rapid degradation of the press cylinder and frequent breakdowns. The machine was replaced in Phase II with a custom-built Swiss model using a wood splitter hydraulic press and petrol generator. The machine was built in a partnership with an Emmental-based engineering company that is active in Magunguli with capacity development and technology transfer (agricultural machines and services). This simple, prototype machine reached productivity of 200 kg briquettes per day under optimal conditions but was still much lower than the anticipated production of 1.6 tons per day by transporting char dust to CBTL's industrial facility in Dar es Salaam.

We investigated several efficiency-boosting measures for briquette production. A second extruder head for the existing press was considered but was not possible in the heat of the case study facility, and threatened overheating of the hydraulic fluid. Several local farmers showed interest in planting cassava to build up a local

binder supply chain (via contract-farming), but the timescale was too long, due to sub-optimal climate conditions requiring 2 years to maturity. We did successfully connect to Sustainable Agriculture Tanzania (SAT), a local implementing partner of Biovision. In November 2017, we exchanged presentation and project ideas with the Director, Alex Wostry, and followed this up with meetings in Switzerland and a second field visit in late 2018. A proposal for developing char dust and briquette production in the Morogoro region is currently being developed cooperatively by SAT and EFCO. However, the time horizon for project realization is 1-2 years away.

During this field trip in late 2018, ARTI's briquette production site in the Daressalaam area was also visited. During a guided tour, EFCO representatives and local partners could see the equipment in action. For scaling up the operations, this equipment should be taken into closer consideration. An ARTI project manager communicated the necessary investment costs for installing the equipment. ARTI is interested in a cooperation, because they are not able to meet the demand. In early 2019, samples have been delivered from MTM to ARTI to inquire if ARTI would purchase a truck load of briquettes from MTM. Negotiations have been taken up, but have not led to any agreement on cooperation by the end of 2019.

In summary, while three of the four objectives for Phase II were met, the production and sale of briquettes stalled and did not reach expected levels by the end of 2018. While a large stock of char dust exists in the production facility, the economic proof of concept could not be reached. Therefore an extension was applied for by the project team and granted by REPIC.

Phase 3: Environmental/socioeconomic impact assessment and business plan development (months 18 to 30)

Detailed objective: 3.1) Produce 200 tons of char dust; 3.2) Market 130 tons of briquettes; 3.3) Model and assess the environmental impacts (e.g. regional availability of waste biomass and benefits of substitution for charcoal) and socioeconomic impacts of upscaling (e.g. potential income effects for rural youths and farmers); and 3.4) Consolidate findings into a business plan to be disseminated to investors, donors and entrepreneurs to multiply the project impacts.

Implementation: As discussed above, char dust production was halted at ca. 100 tons to focus energy and resource on briquette sales (falling short of Objective 3.1). However, the marketing effort largely failed to generate substantial local demand for briquettes for various reasons (failing to meet Objective 3.2). As stated above, marketing of briquettes continues in 2019 through local partners MTM, TBM and Elisema based on the Transaction Security Services (TSS) until the remaining stock of char dust has been processed and sold

Regarding Objective 3.3, the biomass assessment in partnership with the University of Bern (Centre for Development and Environment) was highly successful and completed within the planned timeframe. Details of this modelling effort and associated environmental and

socioeconomic impact assessment results are presented in section 4.3 and in a separate report (Bär and Curran 2019).

The key results of this assessment is that waste biomass on cropland and forestry plantations alone could supply almost 20’000 tons of briquettes per year if fully exploited. This is equal to about half the charcoal demand of the three major urban markets close to the case study region (Makambako, Mafinga and Njombe). In addition, this would create over 500 full-time equivalent jobs paying higher wages than the local reference wage, with job creation mainly in rural areas. Much of the overall benefit would be income increases for farmers producing char dust. With full utilization of biomass, over 130’000 farmers could benefit from additional income of TSH 187’500 (CHF 80) per year for marginal additional work when clearing fields.

Finally, for Objective 3.4, the project completed a business plan to be disseminated to investors. This document was written by FARIP (Fund for African Rural Innovation Promotion), co-applicant to the project (FARIP 2019). The business plan was developed using the production data collected in the field combined with data from project partners ARTI-TZ/CBTL. This enables us to model production costs and income from briquette production under a range of assumptions (e.g. on briquette press technology, input prices, transport distances for inputs and to sales points, worker productivity).

Figure 18: Different biomass types: a) pine needles, b) harvest waste from forestry, c) collected harvest waste from a potato field and d) harvest waste from maize being weighted by field assistants. (Photos: EFCO, CDE)

Using this business plan, there are plans to develop follow-up projects in cooperation with Sustainable Agriculture Tanzania (SAT), a Morogoro-based NGO collaborating with smallholders in several areas of the country. See also paragraphs 4.3, 5.3 and 5.4 on business development and sustainability impacts.

Extension Phase (2019): Marketing, publication, sales, funding follow-up (months 30 to 42)

Detailed objective: E.1) Processing the stock of 100 tons of char dust; E.2) Market 100 tons of briquettes; E.3) Publish study results of the regional supply potential modelling to disseminate the findings E.4) Prepare and submit project proposal for follow-up

Implementation: REPIC agreed to extend the project duration by 12 months. In 2019, marketing efforts were shifted away from retail to selling truck loads to institutional customers and retailers. Marketing efforts included the appearance at the renowned national agricultural fair «Nanenane's» Highland edition in Mbeya which was backed by the follow-up of contacts made at this and previous occasions and the branding of the product.

Environmentally friendly charcoal briquettes as an alternative to deforestation causing traditional fuels are in demand, especially with a conscious public aware of environmental threats like it can be found among government officials and institutions. The government has been continuously increasing the push towards increased sustainability of energy supply, which also sets incentives to use briquettes. Competing companies like ARTI or Mkaa endelevu have been able to conclude deals with institutions such as the Tanzanian military[2]. These are signs of an expanding market and create confidence in the potential of our venture.

Finally, this led to the production total of 30 tons which were sold by the end of the year to a retailer in Dodoma, who supplies different selling points in the city. Quantitative objectives (E.1, E.2) were missed again, but being able to market a significant amount of the produce. Up to present (January 2020) there has not been any feedback from retail customers.

Throughout the year, EFCO and CDE proceeded with the preparation of a scientific publication based on the results of the study conducted on the supply potential of the crop and forestry residues in the area of the production facility at Magunguli. By the end of the year the paper has been nearly ready to be sent out for review (E.3). A project proposal for a follow-up funding including knowledge transfer from the MTM team to the crew at SAT's farmer training centre in the Morogoro area has been prepared but failed to receive funding (E.4).

Figure 19-21: Drying briquettes at the production facility, branded bags with the MTM logo and contact information, packed bags ready for transport at the production facility (Photos: MTM)

[2] https://www.thecitizen.co.tz/news/business/Maker-inks-deal-with-army-unit-over-charcoal/1840414-5089064-7a5h44/index.html

4.2 Achievements of Objectives and Results

For all project Phases, objectives were defined (identical to Milestones defined in the contract with REPIC for project funding). These are shown in Table 2 with description of their level of achievement.

Achievement of Phase 1 Objectives: Of the three designated objectives, two were achieved relating to training local farmers in pyrolysis and upscaling char dust production (O1.1, O1.2). One objective was redefined (O1.3) during a change of the project plan, and a new objective was achieved. Not all objectives were achieved within the planned schedule, but overall the Phase was successful, with targets exceeded.

Achievement of Phase 2 Objectives: Of the four designated objectives, three were achieved in upscaling char dust production (O2.1, O2.2) establishing and optimizing briquette production, and developing a tracing system for biomass (O2.3). Yet briquette production and sales volumes were below target for one objective (O2.4) and were not achieved by project end. Only 20 tons of briquettes were produced (from a target of 60) and only 3 tons were successfully marketed due to challenging market conditions (very low price of conventional charcoal not covering briquette production costs and an underestimation of the marketing effort required for market penetration).

The identified optimization measures could not all be realized because of challenging local conditions (see project review above). However, looking at other charcoal briquette producers like ARTI-TZ/CBTL in Dar es Salaam it seems possible to create a market for sustainably produced charcoal briquettes in Tanzania.

Achievement of Phase 3 Objectives: Of the four defined objectives, two were achieved regarding impact assessment of upscaling scenarios of briquette production and sales (O3.3, O3.4). We developed a quantitative economic model of briquette production and developed upscaling scenarios, which were compared to modelled biomass densities. We assessed the potential impact on forests, greenhouse-gas emissions and socio-economic benefits of these upscaling scenarios (O3.3). In addition, we identified the conditions for profitability under current market conditions via optimizing the basic economic model regarding choice of briquette machine technology (O3.4) using the quantitative economic model assuming decentralized briquette production in costlier rural facilities versus centralized briquette production in urban market centres. Details are presented in section 4.3 and in a separate project report (Bär and Curran 2019).

Achievement of Extension Phase Objectives: Of the four defined objectives, the two regarding processing and selling of briquettes (OE.1, OE.2) were not achieved quantitatively. However, qualitatively they have been met by selling a substantial ammount of briquettes. The third objective was achieved by making a publication of the biomass potential study results ready for publishing (OE.3). A project proposal for a follow-up project was prepared and submitted but did not receive funding (OE.4).

Table 1. Project milestones and modifications

Objective/Milestone	Description	Modification / Report	Status (31/12/2018)
O1.1	Train 3 teams of char dust producers and establish production facility	6 teams trained, production was established decentralised, ergonomic efficiency of char dust production was increased significantly through introduction of *Kon-tiki* method	✓Achieved (31/12/2016)
O1.2	Produce and send 10 tons of char dust for CBTL	Transport of char dust to Dar-es-Salaam did not meet the interest of partner CBTL due to high transport costs. New objective was modified to establish a briquetting facility at RAPP building in Magunguli. Due to unsuitable equipment provided by local project partner ARTI, a new briquetting machine was developed in Switzerland by Hüsler Landmaschinen GmbH, Heimisbach and shipped to Magunguli.	✓ Achieved (31/12/2017)
O1.3	Marketing of produced briquettes in Dar es Salaam via TruTrade "Transaction Security System" (TSS) network	Objective has been changed to marketing at Makambako. An outlet store for charcoal briquettes in Mak was not successful, due to lacking marketing skills of local partners. Cooperation with TSS is established.	✶ Alternative objective achieved
O2.1	Increase char dust production to 6 teams (18 workers) using refined process and kiln design	Achieved; 64 char dust producers trained, 4 full-time staff working in briquette facility, 3 support staff and 1 sales representative	✓ Achieved (31/7/2017)
O2.2	Produce 100 tonnes of char dust with relations established with biomass owners	100 tonnes produced and stocked at RAPP building. Ready for briquette production, biomass contracts established with numerous landowners (have not been put into action, because purchase of char dust is halted until the stock is processed)	✓ Achieved (31/12/2017)
O2.3	Develop tracking system based on TruTrade "Transaction Security System" (TSS) network	Concept and framework developed and tested, based on trained "forest stewards" (biomass sourcing agents) who verify each biomass contract using GPS tracking and model data.	✓ Achieved (31/12/2017)
O2.4	Market 60 tonnes of briquettes through TSS network	20 tonnes of briquettes produced, 3 tonnes marketed through B2B and outlet in Makambako, sales activities ongoing to market 100 tons	✶ Partially achieved
O3.1	Produce additional 200 tonnes of char dust	Not started, but possible to achieve when marketing successful	O Failed
O3.2	Market additional 130 tonnes of briquettes	Not started, but possible to achieve when marketing successful	O Failed
O3.3	Conduct socio-economic and environmental impact assessment	Report on the regional supply potential and the impacts of the use of these resources has been completed (Bär & Curran 2019)	✓ Achieved (31/12/18)
O3.4	Develop business plan and investment proposal	A scaling-up strategy was developed, based on the modelled regional supply potential (Beer & Curran 2019), the quantitative business model and the inventory of the biomass production facility. Written proposals to venture in on the scaling-up process are available (FARIP 2019).	✓ Achieved (31/12/18)
OE.1	Process 100 tons of char dust	30 tons achieved by the end of 2019	✶ Partially achieved
OE.2	Selling 100 tons of briquettes	30 tons sold to retailer in Dodoma	✶ Partially achieved
OE.3	Preparing data from biomass potential study for publication	Draft paper is ready to be submitted for review	✓ Achieved (31/12/19)
OE.4	Develop follow-up project	Project proposal developed with SAT, first attempt at funding failed	✶ Partially achieved

4.3 Multiplication / Replication Preparation

Modelling of regional biomass supply potential

Based on a classification of different land cover types and sampling of available biomass on different plots in the area around the briquette production facility, the potential for production of char dust for briquetting was modelled in cooperation with the Centre for Development and Environment (CDE) of the University of Berne.

The results show, where sufficient amount of biomass is available for establishing a profitable briquette production with viable transportation efforts for collecting the produced char dust. Possible locations of future briquetting facilities have been identified in two scenarios (see below). Only biomass burned in the current land use practice has been taken into account for the biomass potential. These are mainly crop residues like maize stalks and leftovers from pruning, logging or processing timber.

We considered crop fields and forest plantations as potential supply areas excluding privately or state-owned large-scale forest plantations and protected areas. Biomass supply from crop field is dominant in the East and notably in the Makambako Township Authority district and Wanging'ombe district. Forest plantations are dominant in the Northeast of the case study areas and in the Njombe district in the south of the case study area. The Northwest and Southeast of the case study area, in contrast, show little potential to supply biomass.

Business model for processing char dust into briquettes

During the project, we developed a pilot enterprise for briquette production. This facility was designed to achieve technical proof of concept and identify the conditions for economic profitability in briquette production. Based on the observed production processes, we developed a baseline "observed" production scenario (i.e. business model including all costs and income of the enterprise). We then developed as "optimized" scenario encompassing potential improvements of the facility within the bounds of the chosen technology (custom-built briquette press) and local constraints (lacking electricity, water facilities, transport costs, binder availability etc.).

However, for developing the regional scenarios of upscaling production across the region, the pilot enterprise did not reflect efficient production at scale with optimal access to infrastructure (water, electricity, transport etc.). Therefore, we developed two additional and separate scenarios of biomass collection and briquette production using upscaled production methods. We assumed a "decentralized" briquette production model and a "centralized" model.

1. *Decentralized upscaled production*: In this scenario, briquette production facilities were placed in suitable areas in the landscape to harvest the most available biomass (see below for criteria). 20 facilities were hypothetically placed in the landscape with at least a 5 km buffer distance around each facility. Char dust is assumed to be purchased locally and briquettes are sent to market.
2. *Centralized upscaled production*: In this scenario, briquette pressing was assumed to be centralized with biomass collected in larger amounts by truck, purchased of rural producers of char dust. We assume that all biomass is available for harvest within 5 km of a tertiary or larger road. Briquette pressing occurs in the urban market and the product is sold directly to consumers.

For both upscaling scenarios, we combined data observed in the field (i.e. in biomass conversion efficiencies, char dust weight and conversion factors, local wages etc.) with additional data from larger-scale producers (ARTI Tanzania, pers. comm.). Thus, these hypothetical models are anchored in realistic assumptions and parameters.

The business model gives us the possibility to contact investors for scaling up the charcoal venture. A proposal has been developed by FARIP based on the decentralized model (FARIP 2019) thought to have the largest effect on rural incomes.

Cooperation with partner organisations

In 2018 a cooperation with the Morogoro-based **Sustainable Agriculture Tanzania (SAT)** (www.kilimo.org) has been established. SAT addresses social and environmental problems caused by environmentally destructive and unsustainable farming practices. which lead to food insecurity, poverty and malnutrition resulting from environmental degradation through loss of topsoil, water supplies and forests. SAT teaches agroecological farming practices to farmer groups in their villages and at the SAT Farmer Training Centre in the vicinity of Morogoro. Knowledge is also distributed with the monthly farming magazine Mkulima Mbunifu. Published in Swahili, it offers practical and easy understandable information about agroecological farming methods. Social media outlets keep SAT networks abreast of current projects and news.

SAT is engaged in the whole value chain of agroecological food production. SAT is actively involved in agricultural production, processing, packaging, marketing, as well as awareness raising among consumers about organic food. Far-reaching efforts are undertaken within the field of agroecology. SAT collaborates with farmers and universities to create demand-driven research and to produce knowledge in agroecological practices.

The cooperation between SAT and EFCO was elaborated in a project proposal to link the production of char dust briquettes to agroforestry systems and to the voluntary carbon offset market in industrialised countries (based on avoided deforestation and terminal carbon sequestration in soils through use of char dust as soil amendment «biochar»). Second, farmer groups will be trained by the MTM team how to produce char dust and briquettes. Finally, a marketing cooperation is planned, based on the TSS-system of project partner TBM. The proposal was then submitted to a development funding organisation in Austria in April 2019 but unfortunately was not considered. Further efforts are scheduled for 2020.

The cooperation with Dar es Salaam based **Appropriate Rural Technology Institute Tanzania (ARTI)** has been established from the very beginning of this project. Even though production process had to be adapted to the context in the Southern Highlands, we have gained a lot of insight and have profited greatly from ARTI's experience with the production of char dust and the processing to briquettes.

Marketing is the next phase of cooperation with ARTI. ARTI produces annually around 2000 to of briquettes, based on char dust from around 1000 smallholders. Briquettes are marketed under the brand Mkaa Mkombozi to retailers but also to institutional buyers such as hospitals, schools and UNHCR (UN Refugee Agency). At the end of 2018, we supplied ARTI with sample briquettes out of the production of MTM in order to establish a regular delivery. Negotiations are still ongoing.

4.4 Impact / Sustainability

The use of residual biomass in fields and forest proved to be a feasible way to create income for the rural population in the Southern Highlands of Tanzania. The residual biomass proved to be available and rural population was eager to transform it into char dust. Using the biomass on fields that would be burned anyway, proved to be highly efficient, because it means little additional work for a good income.

Environmentally it seems highly efficient to use biomass that would otherwise be burned. This means that there is no competition between composting and recycling carbon (and other nutrients) back into the soil or diverting to energetic use via pyrolysis and briquette production. For future research on this topic, there is urgent need for a holistic assessment of the relative advantages and disadvantages of various biomass pathways relative to the current situation of burning (i.e. comparing the environmental/social costs and benefits of composting biomass versus char dust production for biochar fertilizer or energy briquettes).

An estimation of the overall impacts on employment and avoided environmental impacts is presented in section 6.2.

In the following table, quantitative aspects of the concluded project are summed up:

Table 2. Quantitative aspects of the concluded project

Ecological	**Unit**	**At the REPIC Project's Completion**
Installed renewable energy capacity	[kW]	-
Renewable energy produced	[kWh]/year	30 tons of charcoal briquettes = 30'000*9.7kWh=ca. 300'000 kWh. Capacity installed 120 tons = 1'200'000 kWh
Amount of fossil fuel energy saved	[kWh]/year	None, but the substitution of charcoal out of illegal deforestation helps improve the ecological sustainability of human activity
Greenhouse gas reduction	[t CO_2-eq]/year	Avoided emission caused by pyrolysis of cut-down forest trees: Produced 30 tons (C) * 4 (weight of CO2) * 2 (ratio of Carbon loss through pyrolysis of wood) = 240 t Capacity installed 120t = 960 t
Newly collected and separated waste	[t]	
Newly recycled waste	[t]	
Economic		
Energy costs (LCOE)	[Rp/kWh]	current 77 Rp / kWh, estimated reduction to 22 Rp / kWh
Triggered third-party funding/investments	[CHF]	50'000 CHF
Local private income generated	[CHF]	15'000 CHF (sale of 30 tons)
Social		
Number of beneficiaries	[Number]	
Number of new jobs	[Number]	7 briquetting facility operators
Number of trained personnel	[Number]	64 char dust producers, 7 facility operators

5. Outlook / Further Actions

5.1 Multiplication / Replication

Currently, briquette production by the MTM team in Magunguli has taken up momentum through the sale of 30 tons to a buyer in Dodoma. For 3 months into 2020, briquette production can continue based on the income achieved. However, due to the inability to dry briquettes during rainy periods, production will be taken up by the beginning of the dry season.

Through the donation of the equipment and the stock of 100 tons of char dust through EFCO to MTM at the end of 2018, our local partners are now in control of the whole value chain. Further action is necessary, to make the operations a steady business.

Marketing ist managed by Tanzania Biashara Mapema (TBM), the company of Bahat Tweve. Financial flow is organised with the TSS system which makes sure to fairly distribute profit among the whole value chain from farmers over processing up to traders and retailers. FARIP foundations continues to support TBM and MTM with consultancy and funding.

The cooperation with SAT in Morogoro region offers the possibility to transfer the knowledge to the innovative farmer's training centre (FTC). Since the FTC is visited by nearly 1000 farmers a year, there lies a huge multiplication potential in this cooperation. Financing for a knowledge transfer from MTM is sought for in 2020. The aim is to have the MTM team hold a course for interested farmers at the FTC in Vianzi near Morogoro.

The following hurdles need to be overcome in order to have successful multiplication / replication:

- Optimizing and scaling-up of briquette production facility to reduce production costs and achieve profitability.
- Successful marketing of briquettes to large-scale institutional buyers in light of the difficulties in competing with conventional charcoal with final, small-scale consumers (individuals and households).
- Development of entrepreneurial spirit and skills of project partners.
- Funding of initial investments (in production, marketing etc.).
- Funding of a follow-up project for multiplication of the knowledge, followed by the creation of additional briquetting facilities throughout the country.

5.2 Impact / Sustainability

Based on the upscaling scenarios developed (see section 4.3), we estimated the total production of briquettes based on available waste biomass. Using information from our business models of each facility, we could predict the total number of regional jobs that would be created (split into rural and urban jobs). These figures are shown in Table 2. In all scenarios, we could achieve the reference agricultural salary of TSH 10'000 per day. In the case of centralized scenario, transport costs for char dust to a centralized urban facility were much lower than for finished briquettes because of ease of handling. Thus, a wage of TSH 15'000 was possible (which is generally appropriate to the urban production setting of the centralized scenario).

Table 3. Production statistics, employment of upscaling scenarios

Scenario	Biomass harvest (t)	Char dust production (t)	Briquette production (t)	Total employment (FTE)	Rural jobs (%)	Urban jobs (%)
Decentralized	35'710	8'927	8'182	239	100%	0%
Centralized 25%	22'694	5'674	5'200	152	71%	29%
Centralized 50%	45'389	11'347	10'400	303	71%	29%
Centralized 75%	68'083	17'021	15'600	455	71%	29%
Centralized 100%	90'778	22'694	20'800	607	71%	29%
Combination 65%	59'005	14'751	13'520	394	89%	11%
Combination 100%	81'700	20'425	18'720	546	79%	21%

5.2.1 Meeting charcoal demand

In total, our scenarios resulted in an estimated 8'000 – 20'000 tons of briquettes being produced per year in the surveyed area. This figure is based on pyrolysis conversion efficiency of 25% (i.e. dry weight into dry weight out). This is the lower estimate from field trials of pyrolysis with the "flame curtain" method. Putting this in context to potential demand in the three main urban markets (Njombe, Mafinga and Makambako) shows that the regional production of briquettes could meet between 14% and 55% of regional charcoal demand.

Table 4. Charcoal consumption estimated in the urban markets. Consumption data from Mwampamba (2007)

Charcoal markets	Makambako	Mafinga	Njombe	Total
Population (ca. 2012)	93'800	51'900	130200	275'900
National average urban charcoal consumption (kg)	138	138	138	138
Total consumption (t)	12'944	7'162	17'968	38'074

5.2.2 Avoided environmental impacts

To gauge the degree of environmental benefits that could emerge from a substitution of conventional charcoal with waste-based charcoal briquettes, we took estimates of deforestation caused by charcoal production from the literature (Mwampamba 2007, Felix and Gheewala 2011). We combined this with estimates of carbon density in Tanzanian forest (Harris et al. 2012). The results suggest that the average scenario of regional upscaling of briquettes production could substitute for 13'203 tons of conventional charcoal. Assuming charcoal production is the main driver of deforestation in the region, this translates to a potential avoided forest loss of 4'251 ha. Substituting for conventional charcoal could thus potentially prevent the emission of over 208 thousand tons of carbon caused by forest degradation and conversion. In comparison to national emissions levels (in the year 2014), this amounts to a reduction of almost 0.1 percent. This is a sizeable contribution given that our model only covers a small region in Tanzania. Upscaled to the entire country, where suitable waste-biomass exists and would otherwise be burned, the overall contribution to climate change mitigation could be very substantial.

Table 5. Potential for avoided deforestation and carbon emissions of charcoal briquettes (assuming full substitution of conventional charcoal)

Char briquette potential environmental impacts	**Production (t)**	**Source**
Average scenario production	13'203	This study
National forest loss due to charcoal, middle estimate (ha y-1), ca. 2002	241'500	Mwampamba et al. (2007)
National charcoal consumption (t), ca. 2000	750'000	Felix and Gheewala (2011)
Forest loss per unit charcoal consumption (ha y-1/t)	0.322	
Average avoided forest loss (ha y-1)	4'251	
Carbon density of forest (t C ha-1)	49	Harris et al. 2012
Avoided carbon emissions (t C y-1)	**208'318**	
National emissions in 2014 (t C y-1)	286'490'000	www.climatelinks.org
Potential contribution to national emissions reductions	**0.073%**	

6. Lessons Learned / Conclusions

In conclusion, Phase I demonstrated that the operational concept of briquette production from waste biomass is viable.

- Local farmers and youths rapidly adopt the practice of char dust production, given a modest economic incentive, showing that there is a perceived socio-economic benefit.
- Pyrolysis trials and field experience further demonstrated that the “flame-curtain” method (Kon-tiki) is very appropriate for rural areas, illustrating that a “no-tech” approach is a viable strategy, because it decreases logistics and input costs. Requiring only a shovel, there are no maintenance costs, nearly no investment costs and simply logistics.
- Similarly, simple technology for briquette production (i.e. modified meat grinder and generator, both available locally) can be used for production, but the volumes are low and production costs high. Thus, low-tech briquette production is not commercially suited, but rather is geared for subsistence use.

Phase II illustrated that while small-scale production is technically feasible, it is unlikely to be economically viable without considerable investment in large-scale briquette production (or continued donor support to subsidize production in order to meet the reference price of conventional charcoal).

- While consumers valued the briquettes, their burning characteristics were different to conventional charcoal, requiring a change in cooking habits. Thus, more effort must be expended in communication to customers about the specific qualities and correct handling of the product to meet their expectations and increase the likelihood of char dust briquettes entering the household/institutional energy mix.
- In larger cities such as Dar es Salaam, where biomass fuels are scarce/expensive, briquettes are more likely to penetrate the energy market (as shown by ARTI). In small rural towns in areas with extensive forest cover (as in our case study region), the competition with cheap, high quality charcoal and other fuels likely increased consumer resistance to embrace char dust briquettes.

Phase III illustrated that scaling up will lead to large benefits where crop and forest residues (waste biomass) are abundant and otherwise have no alternative use (i.e. burnt or left to rot).

- Assuming residues have no alternative use, and that charcoal production is responsible for local forest loss, then briquettes could complement efforts to combat illegal harvesting of timber and strengthen natural resource protection.
- Investing in larger-scale briquette production technology could achieve profitability even under current market conditions in rural areas (based on our case study region), leading to multiple benefits to rural and urban livelihoods.

- Where waste biomass is not burned, but rather grazed or composted, then the potential impacts of briquette production need to be researched and compared to alternative uses of biomass before char dust briquettes are promoted on environmental grounds.

Extension Phase showed that it is possible to find buyers by truck loads.

- Interesting buyers are retailers supplying several selling points in an urban area, especially serving customers with high environmental consciousness, e.g. staff of government agencies
- Retailers are not ready to take a risk of a poor-quality product, so proof of the product quality through hands-on demonstration can provide important arguments.
- Appearance at agricultural fairs is a viable method to get in touch with institutions and retail buyers ready to buy large quantities of the product. This needs to be followed by close contact with the buyer to be able to enter business.
- The increasing number of comparable enterprises points out the increasing demand for environmentally sustainable charcoal.

For continuing this project or starting similar projects elsewhere concerning char dust briquettes, our experience leads to the following recommendations:

- The choice of technology along the production process is key to economic success and there is no single high/low tech correct choice. Technology choice is bound to the target user of the product and should take into account existing local systems of production and exchange.
- For char dust production, logistics and infrastructure are key considerations. Biomass can be transported to a central pyrolysis location, or pyrolysis can be conducted on the field and char dust transported. Both options have benefits and drawbacks which should be considered (e.g. transport mode and cost, amount of transported material, kiln and equipment needs, access to water to stop the pyrolysis process at the desired time, labour availability, etc.).
- Experiment with different options rather than fixing on a particular technology (e.g. kiln design). Let local experience, dynamics and preferences determine the outcome. In our case, initial plans for mobile TLUD kilns were shelved after the unexpected success and rapid dissemination of the flame-curtain technique for decentralised pyrolysis on field.
- Design of briquettes affects the burning qualities and therefore directly the handling while cooking. Gain experience by using the briquettes in the project itself and offer a demonstration of the handling to interested customers.
- Consider marketing by truckloads rather than to the end user of the product. Find opportunities to interact with large customers and continously follow up on these contacts through well trained project personnel (i.e. sales persons).

- Consider entrepreneurial skills (accounting, business development) of local partners from the outset. Do not assume this capacity will automatically develop with experience. Do not underestimate the effort required to build such capacity (e.g. rural actors may need to be educated in basic maths and accounting principles before even beginning to tackle business development and oversight).
- Analyse local actors' capabilities and needs simultaneously. Prioritize local partnerships based on a strong need (e.g. financial) for engagement in the project and a clear personal benefit to seeing the business succeed. Such partners will likely prove more motivated and hard-working than those who may have better capacities and education, but no personal or financial incentive.

7. References

Bär, R., and M. Curran. 2019. Waste Biomass to Charcoal Briquettes in Tanzania Regional Supply Potential – REPIC Project Report. Page 56. Centre for Development and Environment (CDE) of the University of Bern and Emmental Forest Cooperation (EFCO), Bern.

FARIP. 2019. Business Case for Production and Marketing of Charcoal Dust Briquettes in Tanzania. Page 5. Fund for African Rural Innovation Promotion, Bern, Switzerland.

Felix, M., and S. H. Gheewala. 2011. A Review of Biomass Energy Dependency in Tanzania. Energy Procedia 9:338–343.

Harris, N. L., S. Brown, S. C. Hagen, S. S. Saatchi, S. Petrova, W. Salas, M. C. Hansen, P. V. Potapov, and A. Lotsch. 2012. Baseline Map of Carbon Emissions from Deforestation in Tropical Regions. Science 336:1573–1576.

Kamil, A., and E. Suzuki. 2014. The Charcoal Project Market Research Report. The Charcoal Project and ARTI-TZ, Dar es Salaam.

Kituyi, E. 2004. Towards sustainable production and use of charcoal in Kenya: exploring the potential in life cycle management approach. Journal of Cleaner Production 12:1047–1057.

Mwampamba, T. H. 2007. Has the woodfuel crisis returned? Urban charcoal consumption in Tanzania and its implications to present and future forest availability. Energy Policy 35:4221–4234.

Zah, R., and A. Ehrensperger. 2014. Coordinated Advocacy for biomass friendly governance of the energy sector in Tanzania. Mandate 1: Potentials, limiations and impacts of biomass energy in Tanzania. Report V Synthesis. Report submitted to the Swiss Agency for Development Cooperation (SDC), SDC Tanzania Coordination Office, Dar es Salam.

8. Abbreviations

ARTI-TZ	Appropriate Rural Technology Institute Tanzania (Daressalaam-based NGO)
CBTL	Charcoal Briquettes Tanzania Ltd. (Commercial branch of ARTI-TZ)
CDE	Center for Development and Environment, University of Berne
EFCO	Emmental Forest Cooperation (Trubschachen-based NGO)
CHF	Swiss Francs (currency)
GPS	Global Positioning System
FARIP	Fund for African Rural Innovation Promotion (Swiss foundation)
MTM	Mkaa Tunza Mazingira (Charcoal that saves the environment, Magunguli-based charcoal briquette brand and production company)
REPIC	Renewable Energy, Energy- & Resource Efficiency Promotion in International Cooperation (Funding program of the Swiss government)
SAT	Sustainable Agriculture Tanzania (Morogoro-based NGO)
TBM	Tanzania Biashara Mapema (Magunguli-based support company for rural business)
TLUD	Top-lit up-draft (Pyrolysis method)
TSH	Tanzanian Shilling (currency)
TSS	Transaction Security Services (Program for facilitating trade of agricultural products)