SOLID BIOFUELS OPTIONS AND SUSTAINABILITY: TaTEDO EXPERIENCE

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ABSTRACT

Biomass energy (firewood and charcoal) are the main source of energy in Tanzania due to poverty, affordability and unavailability of alternatives. Biomass energy accounts for 90% of the overall energy consumption. The projections indicate that the contribution of solid biofuels will decrease, but the total use will increase during the coming decades due to population increase. Efficiencies of production and use of solid biofuels are usually low, with serious negative consequences. Charcoal demand has doubled over the past ten years as a result of rapid urbanization and high relative prices of or scarcity of energy substitutes, the projections show that the demand for charcoal, without appropriate interventions, will double by 2030, from approximately 2.3 million tons in 2012. The national biomass energy vision is to ensure that Tanzania and her people benefit from sustainable biomass energy management for sustainable development. In the efforts of enabling access to sustainable energy, TaTEDO has been promoting efficient cooking stoves and sustainable charcoal production. This paper discusses various alternative kiln technologies which were developed by TaTEDO for efficient use of biomass energy. The commonly used stoves (from the less to the most efficient) are provided. Various interventions for sustainable charcoal production are given. Among the recommendations provided for giving and maintaining biofuel options and sustainability include; improved resource management, improved regulations and governance and designing an enabling framework, enhanced affordability, and improved awareness on cooking technologies.

Keywords: Solid Biofuels, Options and Sustainability, TaTEDO Experience

Introduction

The total forested land in Mainland Tanzania is 48.1 million ha, which provides the national per capita area of 1.1ha. The forest area is equivalent to 54.4% of the total land area of 88.3 million ha (URT, 2015a). Around 28 million ha of the total forest area are protected where harvesting is not allowed; and the remaining 20.1 million ha are production forests where regulated harvesting of forest products including charcoal production is legally allowed. The average volume of wood is 37.9 m^3 per ha across all forest land cover types (URT, 2015a). Illegal and unsustainable harvesting of forest products, particularly charcoal is widespread in both productive and protective forests, leading to deforestation and environmental degradation. The estimated forest cover loss amounts to 372,816 ha per year (URT, 2015a). Tanzania is estimated to consume 62.3 million m^3 annually, which exceeds the annual allowable cut of 42.8 million m^3. The wood deficit from legal sources is around 19.5 million m^3 per year, which is met by overharvesting in the accessible forests and illegal harvesting in the protected forests.

Biomass Energy Sector

In Tanzania, wood energy demand accounts for approximately 90% of Tanzania's overall energy supply and demand. Almost 90% of that demand comes from the household sector, with the remainder coming from household enterprises (often referred to as cottage industries), commercial, institutional and industrial demand (CAMCO, 2015).

The use of firewood as the source of energy for cooking is still predominant in Tanzania Mainland as 71.2% of households use firewood as the major source of energy for cooking, followed by charcoal (37.0%) and kerosene (5.0%). The use of firewood is more dominant to rural households (92.0%) compared to urban households (28.4%). On the other hand, only 1% of households use modern sources of energy for cooking (electricity, bio and industrial gas, and solar) (URT, 2017).

In the urban areas, approximately 79% of the households use charcoal as their primary source of energy for cooking. Dar es Salaam city is the major consumer (50-70 % of the national consumption) of charcoal with 88.2% of households using it as the major source of energy. Until recently (2012), non-household demand for charcoal in Dar es Salaam was equivalent to approximately 15% of urban household consumption, and which amounted to 300,000 tons. The demand for charcoal has been driven by rapid urbanization and high relative prices or scarcity of energy substitutes, particularly kerosene, electricity, biogas, biomass briquettes, and Liquid Petroleum Gas (LPG). Projections show that the demand for charcoal, without supply- and demand-side interventions, will double by 2030, from approximately 2.3 million tons of charcoal in 2012 (URT, 2015b).

Unsustainable resource management and harvesting practices, low quality and inefficient energy technologies affect biomass energy conversion and utilization. The energy efficiency of charcoal production technology which is used is poor, with conversion efficiencies of 15% or less. In most instances, charcoal production is done using traditional earth or pit kilns, where wood is cut and stacked before being covered in earth and carbonized. This is a highly inefficient process, with a conversion efficiency of around 8% to 12% **(Fig. 1).**

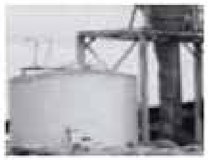
Characteristics	Traditional Kilns	Improved Kilns	Semi-industrial Kilns	Industrial Kilns
Conversion Technology				
Efficiency	8-12%	12-18%	18-24%	>24%
Emissions (in g per kg charcoal produced)	CO_2: 450 - 550 CH_4: ~700 CO: 450 - 650	→	→	CO_2: ~400 CH_4: ~50 CO: ~160

Figure 1: Efficiency of various charcoal production and Kiln Technologies

Source: World Bank, 2009.

According to World Bank (2010), charcoal production caused an annual loss of forest cover of 100,000 - 125,000 ha. For each tonne of charcoal produced in Tanzania, an estimated 9.1 tons of CO_2 are emitted (ESD, 2008) contributing to global warming and adverse climate change.

The cooking appliance which is used by the majority of rural population is a three stone stove which is estimated to have a little thermal efficiency of between 10% and 15% (TaTEDO, 2011). Of not less concern are the adverse socio-economic consequences such as indoor pollution, health hazards, and time used for fuel (firewood) gathering. This makes the lack of access to improved cooking solutions as a poverty trap and a barrier to economic development. According to World Health Organization (WHO) on a global scale, nearly 28,000 deaths occurring annually are linked to respiratory and other diseases, which are attributable to indoor air pollution from solid fuel. The same cause is believed to represent close to 5% of the burden of disease in Tanzania. Figure 2 shows chronological development of cooking stoves which is taking place in Tanzania.

Characteristics	Traditional Phase	Transition Phase	Semi-Industrial Phase	Industrial Phase
Combustion Technology	3-Stone Fire 	Improved Stove (First generation) 	Improved Stove (Second generation) 	High Efficiency Stove 
Efficiency	8-12%	20-25%	25-35%	>35%

Figure 2: Commonly used stoves for fuelwood and charcoal combustion

Source: Sepp, 2008 cited in World Bank, 2009

TaTEDO Interventions to Address Deforestation

TaTEDO promotes various technologies for sustainable charcoal production, energy efficient firewood stoves, charcoal stoves and ovens; biogas, charcoal briquettes.

Sustainable charcoal production methods

Many projects have tried to overcome the challenge of low efficiency levels by promoting more efficient kilns for charcoal production. However, the adoption rates have been disappointing as a result of an informal and often illegal nature of charcoal production. Without secure and long-term access to wood resources, investments by producers in more efficient conversion methods are likely to be limited. Additional challenges that have been encountered when promoting improved conversion technology include:

- The cost of improved kilns, which may be prohibitive for small-scale producers with limited purchasing power and very little access to credit;
- The tendency of charcoal production being highly mobile, given that most charcoal is produced in the drylands where forest cover is low. Improved kilns tend to be stationary, which puts additional costs to producers for carrying wood from the point of harvest to the kiln. This can be an arduous and time-consuming task over rough ground.

In recognition of these potential challenges, TaTEDO advocates for three types of kilns. These include Improved Basic Earth mound Kiln (IBEK), Half Orange Charcoal Kiln (HOCK), and Retort Kiln.

Figure 3: Improved Basic Earth mound Kiln (IBEK)

Improved Basic Earth mound Kiln (IBEK)

TaTEDO has undertaken simple adaptations to traditional kiln designs and achieved significant savings at a low cost. The improvement include the introduction of a chimney and ensuring that the wood used in the kiln is adequately dried and cut into approximately similar sizes. The Improved Basic Earth mound Kiln

(IBEK) **(Fig. 3)** has conversion efficiency of 20 – 25% as compared to traditional Kilns which has less than 13% (TaTEDO, 2013). IBEK has the benefit of reducing the number of logs which burn to ashes (wood wastage) in the kiln as well as reducing carbonization cycle time from 8 to 4 days. IBEK is applicable to small scale/individual charcoal producers. TaTEDO has trained more than 1000 local charcoal producers on the construction and operation of Improved Basic Earth mound Kiln.

Half Orange Kiln (HOK)

This is an improved charcoal production kiln which is constructed using burnt bricks. It has efficiency of 25 – 35 %. Half Orange Kiln has the benefit of reducing wood wastage and hence increases the quantity of charcoal. HOK is applicable in fuel wood plantations and saw mill industries that use larger amounts of raw materials (wood) for carbonization **(Fig. 4).** TaTEDO has been promoting the construction and operation technology through capacity building to technicians in sawmills industries for recycling the wood leftovers and areas of large scale trees clearing.

Figure 4: Half Orange Brick Kiln

Briquettes Production - Retort Kiln

TaTEDO promotes the production of charcoal briquettes from agro-forestry residues. The agro-forestry residues such as maize cobs, rice husks, sawmill wastes, and charcoal dusts are carbonized by using retort kiln through process which is called pyrolysis to produce carbonized residue (bio-char) **(Fig. 5).** The carbonized residues are processed into briquettes. According to Hanne (2012), the net Green House Gas (GHG) emission reduction is 78–557 kg of CO_2eq MWh−1, or 42–84%, when replacing charcoal from Miombo woodlands with these charcoal briquettes, depending on whether or not the substituted charcoal can be considered carbon neutral. High-quality non-carbonized briquettes and firewood are more eco-efficient than charcoal. This means that their carbon footprint, in other words, the amount of GHG they emit is smaller and consumer costs are low.

Figure 4: Retort Kiln

Efficient Charcoal and Firewood stoves

TaTEDO promotes energy efficient firewood and charcoal stoves for cooking and baking in households, institutions, and business centres. Through adaptive research and development (R&D) activities, TaTEDO has improved efficiency of cooking stoves through the designing and selection of proper materials. TaTEDO has developed twelve prototypes of charcoal stoves and six types of ovens including, (Straight, Bell-bottom and Sazawa), Double Plates (Stand and Box), Meat Roasting Ovens (Teksawa and Nyama Choma), and Baking Ovens (Households and SMEs) **(Figs. 6a&b).** The energy efficient firewood stoves are of three types; the improved brick made firewood stoves, the low cost made of mud stove, and Kuni-mbili stoves. All these stoves and ovens have passed through different processes of development depending upon the requirements of users and technical specifications which are considered appropriate. Improved cooking-stoves are more efficient and significantly reduce cooking time and fuel consumption compared with unimproved traditional three stone fireplaces and metal charcoal stoves.

Figure 6a: Efficient charcoal and firewood stoves

Figure 6b: Prototypes of charcoal stoves and ovenstutional firewood stoves

In addition, well performing improved cooking stoves help significantly in reducing fine particle emissions. The thermal efficiency of these stoves and ovens compared with the traditional ones has been raised from 15% to a range of 30 to 40% (TaTEDO, 2011). Through the combining efforts of different stakeholders, in Dar es Salaam more than 10,000 stoves are produced per month. The efforts of improving cooking stoves have resulted in the reduction of the quantity of the charcoal consumed as well as time and money, because the amount of charcoal and the time used in cooking have been reduced by 50%, leading to the reduction of deforestation.

Biogas

Tanzania has over 44 million of cattle units that could contribute to biogas production to intensify availability of clean energy to the community and contribute to the attainment of Sustainable development goals. Domestic biogas installations provide benefits in the fields of energy, agriculture, health, environment, natural resource, sanitation, education, gender, and the environment for enhancing the improvement of community livelihood and poverty eradication.

TaTEDO has been promoting biogas for cooking and lighting in households and institutions. Biogas is well suited for households and commercial farms where sufficient animal manure can be collected on a daily basis, or in communities that produce substantial agricultural waste. Digesters can be built on a variety of scales, from household to commercial, and is fairly efficient for use in stoves, providing instant heat upon ignition, and which can be regulated in most burners. Biogas provides a sustainable opportunity for individual households with livestock to reduce dependency on firewood and fossil fuels and benefits from modern and clean energy as well as potent organic fertilizers. Consequently, socio-economic living conditions, employment rates and environmental sustainability are considerably boosted, while reducing emissions and contributing to mitigation of climate change. With respect to biogas, some of the envisaged benefits of biogas use to the national economy include the reduction of CO_2 emissions. If biogas displaces kerosene, at least between 357 – 60,952 tons of CO_2 per annum would be avoided.

Challenges and Opportunities in Biomass Energy Sector

The National Five Year Development Plan (2016/2017 – 2020/2021) proposes the reduction in charcoal consumption in urban areas by 60% in 2020/2021 and by 30% in 2025/2026. The Biomass Energy Strategy (BEST) of 2014 suggests:-

- The implementation of an Improved Cooking Stove (ICS) programme prioritising urban households and commercial and institutional consumers, with an indicative target of reducing urban charcoal demand by 50% in 2030.
- Commercially mainstreaming of biomass alternatives (in particular biomass briquettes and biogas)

with the objective of reducing the demand for charcoal and commercial fuel wood by 5% by 2030;

- Making non-biomass charcoal and commercial fuel wood alternatives competitive on a non-subsidised basis in terms of availability and price with the target of reducing the demand for charcoal by 50% in 2020.

The Sustainable Energy for All (SE4ALL) Action Agenda (2015) projected the target of percentage of the population with access to modern cooking solutions of 75% of the population in the country by 2030. The challenges and opportunities which are associated with scaling up clean cooking solutions in the country are detailed below.

Improved Cooking Stoves

ICS sector is predominantly informal, largely donor driven and is operated between multiple development partners and networks, with weak coordination within ICS sub sector. Improved woodfuel stoves are disseminated by multi stakeholders through trained entrepreneurs, agents, and shops; and the stoves and fuels are not standardized. A GVEP study (2012) on ICS market assessment in Tanzania, estimated the penetration of improved stoves (mostly charcoal stoves) of about 1,000,000 households to urban areas. Low usage of improved cook stoves is attributed to low awareness and knowledge on the use of ICS, inadequate development of supply chain, existence of low quality stoves in the market due to inadequate quality control and failure to meet consumers' needs in some cases.

The adoption of ICS is determined by different factors such as usability, the costs involved in purchasing and maintaining the stove, the purchasing power of the people, portability, thermal efficiency, and emissions (in-door air cleanness). Consumer acceptance and preference for ICS is challenged by the prevalence of poor quality stoves due to lack of standardization and certification **(Table 1).** There is a need of demonstrating superior performance and cost savings to offer value for money for higher quality products. The introduction of subsidies or microfinance schemes may be combined with promotion initiatives to increase affordability.

Table 1: Market related barriers and opportunities – ICS

Cooking solution	Barriers	Market Opportunities
Improved Cooking Stoves	• Predominantly informal • Inadequate awareness on available quality technology options • Inadequate skilled producers for improved cook stoves • Weak coordination • Lack of high-level political buy-in. • Small scale initiatives with inadequate funding. • Existence of low quality stoves in the market	• Potential for local manufacture of stoves and local jobs creation • Growing international concerns for using ICS to alleviate respiratory health problems • Willingness of fund allocation from development partners, • Several local NGOs are willing to develop the ICS sector, • Huge potential market for ICSs and fuels in rural and urban areas

Charcoal Briquettes

Market uptake of charcoal briquettes is slow and the demand is still low. the supply of briquettes is facing challenges which are related to technical knowhow, competitive use of feedstock with other uses, low awareness and competition with firewood and charcoal **(Table 2).** Internationally, experience shows that progress often stops once international financial and technical support stops, and/or when the machinery supplied (presses, extruder, pelletizing tables) is worn out. For example, DANIDA supported the development of this technology during the 1980's, but discontinued the support in the beginning of 1990ies after several major failures.

Table 2: Market related barriers and opportunities for charcoal briquettes

Solution	Barriers	Market Opportunities
Charcoal Briquettes	• Production is still low and market is underdeveloped. • Capital intensive technology • Feedstock compete with other uses • Availability of binder is limited • Feedstock available at scattered nature. • Inadequate knowledge and skills of producing bio-char from bio-wastes • Lack of appropriate stoves, reducing in exhaust of fumes • Low investment in the briquette development • Few international success stories, particularly in comparable markets.	• Relatively simple technology • Potential of Innovation in appropriate stove production • No changes needed in people's cooking habits • Limited indoor air pollution (smokeless) compared to wood charcoal • Can be implemented at different scales • Good opportunities for women in production and sales • NGOs involved

Biogas

The biogas is used by both rural and urban households in Tanzania at an average of 0.1% and 0.4%, respectively (CAMCO, 2014). The main sources of feeding materials for biogas production in rural areas is livestock manure and human excreta (>20kg daily) (Tanzania Domestic Biogas Program, 2014). According to annual agricultural survey report by the Ministry of Agriculture Livestock and Food Security 2014/15, the number of cattle in the country was about 26 millions, where by one cattle is estimated to produce an average of 10kg of dung per day for zero grazing and 5kg for free range grazing. This is huge potential of biogas development in Tanzania. The low uptake of biogas is contributed among others by the capital intensiveness of the technology, affordability, low awareness on the potential of biogas, availability of biogas cooking appliances and close attention which is required for feeding the bio-digester (CAMCO, 2014). **Table 3** provides a list of some of the barriers and market opportunities for biogas in the country. Biogas plants represent a good synergy between energy and fertiliser, and the construction of biogas plants demands the training of new artisans and masons. Thus, despite the limited impact on wood fuel usage, the promotion of this clean, efficient, and employment creating technology is worth for further consideration.

Table 3: Market related barriers and opportunities for Biogas

Solution	Barriers	Market Opportunities
Biogas	• Inadequate awareness on biogas potential for cooking • Inadequate skilled biogas constructors/ installers • Inadequate knowledge by households to operate biogas plant • High upfront cost • The fermentation process needs a continuous supply of feedstock and water, which can be a problem in arid areas. • Feeding the digester, removing obstructions, and maintaining the mixture and equipment can be labour-intensive. • Limited availability of cooking appliances.	• Biogas if adopted can reduce use of wood fuels by households and institutions • Burns cleanly without producing smoke or ash, low emissions, clean cooking • Help to change waste into clean energy hence improve health, sanitation and the environment. • Slurry that remains after digestion is rich in nitrogen and phosphorus and can be used as a high quality organic fertilizer and increase crop productivity. • It is source of income and employment for biogas masons/ constructors • Multipurpose usage (cooking, lighting, etc.)

CONCLUSION

Several approaches may be applied to mitigate solid biofuel sustainability. This can be reached through improving regulation and sustainable management of biomass resources, promoting large scale use of efficient technologies, and encouraging people to switch to improved cooking fuels and technologies. These approaches are complementary, and a combination of all will be necessary to ensure lasting solutions to the problems.

RECOMMENDATIONS

The following recommendations are provided for sustainable use of solid biomass;

(i) Address inadequate awareness through demonstration programs, and subsidies on the available improved cooking technologies to promote behavioural change in the community;
- Promote large scale use of improved cook stoves in rural and urban areas.

(ii) Enhance affordability - address the barrier of low purchasing power through;
- Linking end-users with credit services providers (MFIs) to enable them to increase their income through establishing productive use of energy technologies; and
- Developing business models, sizes and solutions that are suitable for income levels of specific market segments.

(iii) Improved resource management - Reduce deforestation and encourage afforestation to increase biomass energy sustainability through;
- Developing harvesting plans for forest areas administered by the central or local governments;
- Encouraging large scale development of fast growing multi-purpose tree growing;
- Promoting fast growing Tree Woodlots and Urban Forests in high, medium, and low forest cover regions;
- Securing tenure for rural producers by scaling up community-based forest management in the urban catchment areas;

- Promoting sustainable wood resources management models (techniques and practices for sustainable harvesting of natural forest and Miombo woodlands (CBFM, JFM and PFM);
- Promoting the use of forest by-products such as pruning's, thinning, offcuts and sawdust's for energy purposes; and
- Increasing efficiency of converting wood to charcoal.

(iv) Improve regulations and governance and the enabling framework through;

- Addressing weaknesses in formulating and enforcing appropriate regulation;
- Developing biomass energy supportive policies;
- Capacity building for regulation development and enforcement and promote good governance
- Appropriate standards on cooking technologies (fuels and appliances);
- Active enforcement framework of enacted regulations and good governance;
- Overall national policy and strategy on the use of improved cooking energy solutions; and
- Harmonisation of different biomass related policies and legislations.

(v) Collaborating with Research and Development institutions in realization of biogas technologies that could be applied in the drought areas; and

(vi) Promoting gender participation in the whole biomass value chain.

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