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Charcoal's role in the energy supply of a modernizing African city

Dar es Salaam

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EXECUTIVE SUMMARY

The National Energy Policy seeks to replace biomass energy (firewood and charcoal) with electricity and fossil fuels (liquefied petroleum gas, kerosene and natural gas) as the primary sources of cooking energy. In 2018, in Dar es Salaam, LPG is used by 58% of households, kerosene by 28% and electricity is used by 12% of households for cooking. Natural gas distribution is being piloted. Most households use multiple fuels. Biomass energy remains the most widely used energy source, with 88% of households using charcoal and 25% using firewood. Within the debate around cooking energy, much of the attention has focused on charcoal. This report looks at the current status of the charcoal trade and options for achieving a more modern energy mix aligned with Tanzania's industrialisation agenda.

Change is happening. The proportion of households in Dar es Salaam who are using LPG is increasing rapidly. 32% of households are now using LPG as their main cooking fuel and 58% are using it as part of their energy mix. 96% of charcoal-using households are using more energy-efficient, ceramic-lined cook stoves.

At an average retail price of TZS 776 (US$0.34) / kg, the Dar es Salaam charcoal market is worth between TZS 621 billion – TZS 737 billion (US$ 272 million – US$ 326 million) per year. The inflation-adjusted price of charcoal appears to have declined by at least 15% between 2009 and 2018.

Between 145,000 – 176,000 people are regularly employed in producing, transporting and selling charcoal for the energy market in Dar es Salaam. Approximately, 70% of employment is in production, with the remainder being provided through transportation (10%) and wholesale / retail (20%). The value chain is characterised by a multitude of small-scale independent enterprises. Charcoal stove production generates additional employment.

As urban households in Tanzania become wealthier, they replace firewood with charcoal as their main fuel supplemented by one to three types of fossil fuel (LPG, kerosene) or electricity. Overall, the strongest trends are the positive relationships between wealth and a shift from firewood to charcoal use; and wealth and increased fuel stacking up the energy ladder. As stated by NBS (2017) '*Looking at Tanzania as a whole, charcoal is the preferred fuel for households in the highest wealth category where 83.7% use charcoal, compared with only 7.5% of households in the lowest wealth category*.'

Charcoal is the second cheapest fuel per unit of energy, followed by LPG. Firewood is the cheapest. Households are making economically rational decisions in selecting charcoal and LPG as the most commonly used cooking fuels. Charcoal and firewood gain a price advantage as domestic energy products with low production and transportation costs relative to imported fossil fuels (LPG and kerosene). Exemption from VAT and excise duty for LPG has contributed to its rapid adoption. In the case of briquettes and ethanol, higher taxes, poor performance and access constraints have impeded widespread adoption. Natural gas requires a distribution infrastructure which has only been piloted in two small areas, so far.

Non-compliance with Central Government revenue collection on charcoal has contributed to charcoal being cheaper than other energy sources. Central government revenues for charcoal are primarily collected through royalties. Compliance is checked at strategic natural resource checkpoints on the main roads coming into the city. However, many loopholes exist in this system. Low capture rate of royalties on charcoal, mean that the effective tax / royalty rate per joule of energy is significantly lower for charcoal, than for briquettes, electricity, ethanol and kerosene. This has contributed to charcoal being cheaper per joule of energy than other, more heavily taxed energy forms.

It is highly likely that the rate of capture of charcoal royalties, collected by the Tanzania Forest Services Agency, does not exceed 10%. Based on the estimated consumption figures for Dar es Salaam of between 800,000 – 950,000 tonnes and taking a royalty fee of TZS 250,000 / tonne[1] (US$ 110 / tonne), TFS revenues should be between TZS 200 billion – TZS 238 billion (US$ 88 – US$ 104 million) from charcoal royalties for Dar es Salaam alone. If Dar es Salaam comprises half of the national market then, at a national level, revenues should be closer to TZS 400 - 475 billion (US$ 176 million – US$ 208 million). Data from 2013 / 14 show national revenues from charcoal being closer to TZS 17 billion (US$ 7.5 million) which would be less than 5 % of the expected revenue.

No VAT is being collected on charcoal. Although charcoal is not exempt from VAT by law, in practice VAT is not collected from charcoal as TRA consider it to be an informal trade. At a national scale, the charcoal trade is worth at least US$ 600 million. Assuming the trade volumes outlined above, potential VAT revenues at 18% would be approximately US$ 108 million nationally. VAT collection on charcoal would help to level the playing field for other competing cooking fuels.

If the Government chose to focus its revenue collection from charcoal through VAT instead of royalties, revenue collection could take place at the point of sale; and would be managed by a specialised revenue collection agency i.e. TRA. By collecting revenues through VAT for electricity and the fuel levy for kerosene, revenue capture is more effective on other energy forms. A similar model could be applied to charcoal.

Effective VAT collection at 18% would increase the combined tax / royalty rate on charcoal from the current level of 30%[2] to 48%. If VAT alone were applied, it would reduce the tax rate from 30% to 18% but could lead to a higher effective tax rate assuming more efficient tax collection. If VAT were collected more effectively than the current royalty collection rate, this would have an effect on the price. If the price of charcoal increased by 18% it would cost on average TZS 100 (US$ 0.04) / MJ, closer to the price of LPG at TZS 123 (US$ 0.05) / MJ.

Any increase in the price of charcoal, will have a negative effect on poor urban households and those involved in the charcoal trade and would need to be managed carefully to mitigate negative social impacts. Recommendations regarding whether or not to collect VAT as well as, or instead of, royalties would require further research and consultation, particularly in identifying ways to mitigate potential negative effects poorer households.

Charcoal can be produced sustainably from well-managed natural woodlands generating multiple benefits in terms of reducing deforestation, rural development and good governance. Currently, charcoal production is poorly managed and is often a stepping stone towards farm clearance. Alternative production models are available based on well-established forest management principles. In Tanzania, the expansion of community-based forest management would be the most effective way to achieve this, as well as generating many additional benefits in terms of livelihoods, climate change adaptation and protection of ecosystem services.

To meet Dar es Salaam's current demand for charcoal, would require between 3 and 3.75 million hectares of woodland to come under sustainable production, approximately 16% of the remaining woodland on village land. This assumes that Dar's annual demand is between 800,000 tonnes - 950,000 tonnes. Nationally, approximately double this amount is needed requiring approximately 7 million ha or 32% of the

[1] Based on TZS 250 / kg x 1000 = 250,000 / tonne. Then multiplying 840,000 tonnes by TZS 250,000 = TZS 210 billion
[2] TZS 250 / kg at a current price of between TZS 740 – TZS 760 / kg

remaining woodland on village land. Based on a sustainable charcoal production model that has been successfully piloted in Morogoro Region, sustainable production at a competitive price is possible.

Charcoal sourced from fuelwood plantations would cost at least one third more than is supplied through existing value chains. Biomass from planted trees can only compete when the biomass production costs are covered by revenue from another product value chain such as tannin in the case of black wattle or transmission poles in the case of eucalyptus.

Developing a sustainable urban energy strategy for Dar es Salaam would provide a useful framework for stakeholders to work together to achieve a more economically, environmentally and socially sustainable energy mix for the city. We propose a target of improving household energy efficiency by 25% and a 2030 energy mix dominated by LPG (Table 1.). The targets reflect what is feasible in terms of infrastructure, fuel availability, consumer preferences and affordability. The targets closely follow energy targets proposed by a wide range of stakeholders consulted during the course of the study. The charcoal fuel target is based on the amount of charcoal that could be produced from half of the area of woodland that could realistically be brought under sustainable production by 2030, with the remainder of the area under sustainable production, supplying other urban areas.

Table 1. Proposed 2030 cooking energy targets for Dar es Salaam.

Fuel type	Proposed cooking energy target as a % of total domestic cooking energy required in Dar es Salaam in 2030	Petajoules of output energy required per year based on 2030 targets	Quantity of fuel required to meet output energy target per year
LPG	44%	5.69	210,692 tonnes
Electricity	20%	2.59	1,026 GW·h
Briquettes	16%	2.07	237,771 tonnes
Charcoal	13%	1.68	193,189 tonnes
Firewood	5%	0.65	417,059 tonnes
Ethanol	0.5%	0.06	N/A
Kerosene	0.5%	0.06	4 megalitres
Natural Gas	0.5%	0.06	N/A
Total	**100%**	**12.86**	

A biomass energy policy, supportive of sustainable charcoal production and briquettes, would provide an important foundation for achieving these changes. Implementation of the policy would require close cooperation between the Ministry of Energy, the Ministry of Natural Resources and Tourism and the President's Office for Regional Administration and Local Government (PO RALG). Establishing a biomass energy division within the Ministry of Energy would provide an institutional home for such a policy.

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ABBREVIATIONS

BAU	Business as usual
CBFM	Community-Based Forest Management
CCFAT	Clean Cookstoves and Fuels Alliance of Tanzania
CHAPOSA	Charcoal Potential in Southern Africa
DoE	Division of Environment
ESD	Energy for Sustainable Development
FAO	Food and Agriculture Organization
FBD	Forest and Beekeeping Division
FS	Fuel switch
GAI	Green Advocates International
GDP	Gross Domestic Product
GoT	Government of Tanzania
HH	Household
ICS	Improved cook stove
IK	Improved kiln
IS	Improved stove
JFM	Joint Forest Management
LPG	Liquefied Petroleum Gas
ME	Ministry of Energy
MEM	Ministry of Energy and Minerals
MJ	Megajoule
MJUMITA	Community Forestry Network of Tanzania (Mtandao wa Jamii wa Usimamizi wa Misitu Tanzania)
MNRT	Ministry of Natural Resources and Tourism
NCTF	National Charcoal Task Force
NGO	Nongovernmental organization
NRM	Natural Resources Management
PFM	Participatory Forest Management
PJ	Petajoule

PO-RALG	President's Office – Regional Administration and Local Government
PSMP	Power Sector Master Plan
REDD	Reducing Emissions from Deforestation and Forest Degradation
RPTES	Regional Program for the Traditional Energy Sector
RWEDP	Regional Wood Energy Development Programme
SNV	Netherlands Development Organisation
TANESCO	Tanzania Electric Supply Company
TANROADS	Tanzania National Roads Agency
TAREA	Tanzania Renewable Energy Association
TaTEDO	Tanzania Traditional Energy Development and Environment Organization
TEITI	Tanzania Extractive Industries Transparency Initiative
TFCG	Tanzania Forest Conservation Group
TFS	Tanzania Forest Services Agency
TOF	Trees outside forests
UDSM	University of Dar es Salaam
URT	United Republic of Tanzania
US	United States of America
USAID	United States Agency for International Development
VAT	Value Added Tax
VLFR	Village Land Forest Reserve
VPO	Vice President's Office
WB	World Bank

Unless otherwise stated, all dollars are US Dollars and all tons are metric tons. 1 US Dollar = TZS 2,280 (September, 2018)

Units of measurement

Area / Distance

ha hectare

km kilometre

m metre

m^2 square metre

Currency

TZS Tanzania Shillings

US$ United States Dollar

Energy

J joule

kW·h kilowatt hour

MJ megajoule (10^6 joules)

GJ gigajoule (10^9 joules)

TJ terajoule (10^{12} joules)

PJ petajoule (10^{15} joules)

MW megawatt (1,000 kilowatts)

Time

hr hour

yr year

Volume

l litre

m^3 cubic metre

Weight

kg kilogramme

t metric tonne (1,000 kg)

Conversion Rates

1 gigawatt hour = 0.0036 petajoules

1 kilowatt hour = 3.6 megajoules

US$ 1 = TZS 2280

Charcoal conversion rates (Source Camco, 2014)

0.7 t air-dry wood = 1 m^3 air-dry wood

1.43 m^3 = 1 t air-dry wood

19% = wood to charcoal conversion efficiency (tonne to tonne)

5.26 t of air-dry wood = 1 t of charcoal

7.52 m^3 of wood (air-dry) [5.26 t] required to make 1 t charcoal

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1. TRANSFORMING TANZANIA'S CHARCOAL TRADE: TAKING A FRESH LOOK AT AN OLD ISSUE

1.1 Background to the study: unpicking Dar's love-hate relationship with charcoal

Most residents of Dar es Salaam use charcoal as their main cooking fuel. Most policy-makers would like to see charcoal disappear from the urban energy mix. This contradiction has persisted for at least three decades. Understanding both of these perspectives is necessary in order to move towards a more sustainable energy mix for Dar es Salaam and other urban areas in Tanzania.

Charcoal's critics point to its negative environmental and health impacts. Charcoal production is frequently blamed for Tanzania's high deforestation rate, and attendant environmental (climate, soil, water, biodiversity) problems. However, empirical evidence for charcoal's contribution to deforestation is weak. Evidence of the primacy of agriculture in driving deforestation is stronger (Willcock et al. 2016, Hosonuma et al. 2012). Counter-intuitively, there is some evidence that sustainable charcoal production may incentivize forest owners to retain natural forests.

Charcoal use causes indoor air pollution and can trigger a range of respiratory diseases and neurological problems for users. Charcoal production and transportation also cause a range of health and safety hazards for those involved. Understanding these negative impacts, and distinguishing between real and perceived impacts, is important for rational decision-making. Debates around charcoal have tended to simplify the choice to a '*biomass bad, modern energy good*' dichotomy. The reality is more nuanced.

There are have been numerous previous studies about Dar es Salaam's charcoal trade. Many authors and committees have generated recommendations, plans and strategies about Dar's charcoal trade (see Section 7). That such studies have been repeated so regularly reflects the importance of the issue; the profound inertia in the system; and the persistent paucity of reliable data on the charcoal value chain. This will not be, and should not be, the last study. There remain significant knowledge gaps. In particular, more solutions-oriented experimentation is needed with broad stakeholder cooperation and support. End-users, many of whom are women, need to be proactively engaged in a transition to a more sustainable urban energy mix. Systematic data collection on the trade is needed.

Strategies are needed that capture the economic benefits of the trade while mitigating its negative environmental and health impacts. Marginalising charcoal from national policy risks excluding a homegrown product already generating widespread urban and rural employment. An open-minded reassessment of how charcoal could be aligned with national priorities on modernisation, industrialisation and revenue generation, could achieve significant win-wins across different sectors.

Responsibility for urban energy supply is divided between different parts of government, however, there is no clear coordination mechanism or well-defined strategy for the provision of cooking energy for Dar es Salaam. At national level, responsibility for urban energy, including biomass energy, is divided between the Ministry of Energy, the Ministry of Lands, Housing and Human Settlements Development, and the Ministry of Natural Resources and Tourism. In practice, the Ministry of Natural Resources and Tourism through the Tanzania Forest Services Agency (TFS) has the most day-to-day engagement in the charcoal trade through the collection of royalties and registration fees. The Ministry of Energy has minimal direct engagement with the charcoal market instead focusing on other forms of renewable energy, electricity and fossil fuels. At local level the City Council has responsibility for city-wide issues, although charcoal has not been a priority.

Municipal governments do not have a strategic responsibility regarding energy provision but play a role in licensing energy suppliers in their localities.

At a national level, the Ministry of Energy is implementing various strategies relevant to urban cooking energy supply. The Sustainable Energy for All (SE4ALL) Action Agenda and Investment Prospectus set targets regarding access to modern cooking solutions; and for increases in the contribution of renewable energy to the national energy supply (URT-MEM, 2015a)[3]. The SE4ALL targets are aligned with the targets and indicators for '*Sustainable Development Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all'*. Tanzania's targets for 2030 include:

- 75% of the population with access to modern cooking solutions;
- 10% renewable energy share in thermal (cooking and heating) (URT, 2015a).

SE4ALL consider biomass energy to be sustainable where it comes from '*demonstrably renewable biomass*'. Based on UNFCCC calculations, 4% of Tanzania's biomass production is classified as demonstrably renewable[4]. As such, charcoal has the potential to be considered renewable energy under SE4ALL provided that the forests from which the charcoal is produced meet one of three criteria:

(a) The land area remains a forest;

(b) Sustainable management practices are undertaken on these land areas to ensure, in particular, that the level of carbon stocks on these land areas does not systematically decrease over time (carbon stocks may temporarily decrease due to harvesting);

(c) Any national or regional forestry and nature conservation regulations are complied with (UNFCCC-CDM, 2012).

Provision of electricity is elaborated in the Power System Master Plan (URT - MEM, 2016), which includes a target of 100% of households in Dar es Salaam having electricity by 2025. The Ministry of Energy has also prepared the Natural Gas Utilization Plan 2017-2045 which was at the approval stage in October 2018.

The Ministry of Lands, Housing and Human Settlements Development has developed a Master Plan for Dar es Salaam. The plan has been under development since 2011 and a draft was finalised in 2018. However, the plan has not yet been adopted[5]. In terms of household energy, the draft plan exclusively focuses on electricity. According to Kasala (2015), most previous master plans for Dar es Salaam have not been effectively implemented for a variety of economic and political reasons. In 2007, the Urban Planning Act was passed which adopts a master planning approach. There is no requirement for a sustainable urban energy supply plan in the Urban Planning Act.

Municipal councils interviewed as part of this study stated that energy planning was outside their remit. They considered that planning for the provision of electricity and gas are the responsibility of the Ministry of Energy; and charcoal and firewood are the responsibility of the Ministry of Natural Resources and Tourism.

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[3] The National Energy Policy 2015 defines renewable energy as '*energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, water, tides, waves and geothermal heat*.' (URT, 2015). In the context of electricity generation, the National Energy Policy defines non-hydro renewable energies as including biomass.

[4] The SE4ALL Action Agenda follows UNFCCC 2012 EB67 Report Annex 22 (http://cdm.unfccc.int) in which the fraction of non-renewable biomass is calculated at 96%. From this, SE4ALL calculate that 4% of the biomass used is 'demonstrably renewable'.

[5] https://www.ippmedia.com/en/news/19trn-draft-master-plan-dar-es-salaam-ready

None of the council representatives interviewed during the study, mentioned the Dar es Salaam Master Plan 2018 – 39.

1.2 Rationale for the study: thinking strategically about urban household cooking energy supply

Dar es Salaam's population is projected to double every 12.3 years, so too could demand for household cooking fuel. Population is a key determinant of overall household cooking energy demand. Dar es Salaam's population grew by 5.6% per year in the intercensal period from 2,487,288 in 2002 to 4,364,541 in 2012 (NBS, 2016). At this rate, the population will double every 12 years (URT-NBS 2016). At the 2002/12 growth rate of 5.6% p.a., the population of Dar es Salaam reached 5.96 million in 2018 and will reach 11.4 million people by 2030. Household size and incomes, food preferences and cooking behaviour will also affect urban energy demand.

If we assume that every resident of Dar es Salaam needs an average of 4.14 MJ of cooking energy per day[6], this is equivalent to 9 PJ / yr for a population of 5.96 million in 2018 and 17.2 PJ / yr for a population of 11.4 million in 2030. If all households only used charcoal, this would be equivalent to approximately 1 million tonnes per year in 2018 and 2 million tonnes per year in 2030 (assuming a 30% energy efficiency stove). Similarly, if all households only used LPG, this would be equivalent to 333,792 tonnes / yr in 2018 and 638,460 tonnes / yr in 2030. The values for other fuels are presented in Table 2.

Table 2. Amount of fuel required to meet the total annual domestic cooking energy demand in Dar.

Energy form	Unit	2018	2030
Charcoal	tonnes	1,035,905	1,981,429
LPG	tonnes	333,792	638,460
Firewood (air dried)	tonnes	5,814,433	11,121,567
Electricity	GW·h	3,576	6,841
Kerosene	Megalitres	621	1,187

Thinking strategically about how much of each energy type is needed, can provide a common target for supply-side and demand-side planning. By considering the pros and cons of different future energy-mix scenarios, policy makers can think more strategically about the most desirable and sustainable energy future. From there plans can be set in place to ensure that the investment environment and infrastructure are in place to achieve those targets.

Charcoal consumption in Dar es Salaam has aroused concern amongst policy-makers and other stakeholders. Concerns are expressed around charcoal's role in: deforestation and forest degradation; climate change; indoor air pollution; and governance. Despite three decades of attempts to reduce charcoal consumption in the city, it has remained persistently popular. Tanzania's National Energy Policy 2015 aims for a transition from traditional biomass energy to electricity, fossil fuels and renewable energy (largely excluding biomass). 85% of the energy used in Tanzania currently comes from biomass (URT, 2015). Household energy consumption, mainly for cooking and heating, comprises 72.5 % of the national energy

[6] Kilahama 2004 and Malimbwi and Zahabu 2008 found that households use 2 kg charcoal per day. HH size at that time was on average 4.2 people therefore per capita charcoal consumption was 0.4762 kg / person / day. This is converted to MJ at a rate of 29 MJ/kg (Camco 2014) to give 13.81 MJ input energy / person / day. With an end use efficiency rate of 0.3 for ceramic-lined charcoal stoves, this is equivalent to 4.14 MJ / person / day of energy delivered to the pot.

consumption (URT, 2015). With 24.8% of all Tanzanian households using charcoal in 2012 (Camco, 2014), we can deduce that approximately 17.8% of the total national energy supply was provided by charcoal in 2012. That is more than the 13.8% contributed by electricity and petroleum products combined including all energy uses (URT, 2015). This highlights the scale of the National Energy Policy's ambition in transforming Tanzania's energy mix away from biomass.

Although focused in Dar es Salam, the report's findings have wider relevance in an increasingly urbanised Tanzania. Tanzania is becoming increasingly urbanised. The proportion of the population living in urban areas increased from 6.4% in 1967 to 26% in 2012. By 2030, it is projected that 32% of the population will live in urban areas. Dar es Salaam comprised 37.4% of the urban population in 2012. Whilst the Government's decision to move many government offices to Dodoma from 2016 may slow Dar's growth, it remains the commercial capital. The analysis and recommendations presented in this report have relevance to other urban areas in Tanzania.

2. OBJECTIVES AND METHODS

2.1 Study objectives

The objective of this study is to provide a thorough characterization of the conditions of the Dar es Salaam charcoal value chain in 2018, and to propose a pathway towards a sustainable and economically feasible energy mix with lower environmental and human impacts. The study covers six key areas:

1. Demand and consumption - An assessment of current charcoal use with a critical analysis of alternatives and sustainable use initiatives, focusing on Dar es Salaam. Chapter 3.
2. Supply - An assessment of current charcoal value chains supplying Dar es Salaam. Chapter 4.
3. Supply-side alternatives: A comparative analysis of sustainable charcoal production options and initiatives including sustainable natural woodland management and biomass production through plantations and woodlots. Chapter 5.
4. A description of the impacts of the production, transportation and consumption of charcoal. Chapter 6.
5. Knowledge gaps and analytical agenda moving forward. Chapter 7.
6. Recommendations. Chapter 8.
7. Future energy scenarios for Dar es Salaam. Chapter 9.

2.3 Methods

Literature review

The literature consulted in the course of the study is listed in the reference section. Literature that was consulted include official statistics and reports from the National Bureau of Statistics, national policies and related policy tools (laws, regulations, strategies), scientific publications and technical reports.

Stakeholder interviews and consultation

A stakeholder consultation workshop involving representatives from government, academia, civil society organisations, private sector and development partners was held at the outset of the study. Participants' contributions and recommendations are reflected in the design and content of the report. A list of participants is provided in Annex 2. This was followed by interviews with 19 stakeholders from Central Government, Local Government and the private sector (Annex 3). Interviews included questions on the role of respondents' institutions in the charcoal value chain, and their perceptions of an optimal energy mix for Dar es Salaam. Results were presented at a stakeholder meeting in December 2018.

Survey of charcoal producers, transporters, wholesalers and retailers

In collaboration with Sokoine University of Agriculture, a survey of 35 producers and 36 transporters supplying the Dar es Salaam market, was conducted. Working with enumerators from the University of Dar es Salaam, interviews were also carried out with 26 retailers and 6 wholesalers. Questions covered volume, type and source of charcoal traded; charcoal prices and business costs; regulatory compliance; and trend perceptions. The weight of different charcoal units on sale, were measured to generate data on price.

Survey of household energy users in Dar es Salaam

In collaboration with the University of Dar es Salaam, household surveys on domestic energy use were carried out in 100 randomly selected households across Dar's five municipalities. This gives a confidence interval of 9.8 at a 95% confidence level. The surveys included questions about: household fuel use; reasons for using / not using each fuel type; types of food cooked with each fuel; energy saving techniques; amount of each fuel used; and expenditure on each fuel.

Timing of the survey

The field work and report-preparation were carried out between October and November 2018. The report was then circulated for stakeholder comments and was finalised in February 2019.

2.4 About Dar es Salaam

Dar es Salaam is a rapidly expanding city that has played a central role in Tanzania's trading and commercial development.

Brief history: In the 19th Century, Sultan Majid bin Said of Zanzibar began the construction of Dar es Salaam. After his death, the German East Africa Company established a trading post in Dar es Salaam in 1887. The city expanded further with the construction of the Central Railway Line in the early 20th Century. Dar remained Tanzania's capital city until 1974 when it was decided to make Dodoma the capital. Relocation of many Central Government offices took place between 2016 – 18 under the 5th Phase Government.

Administration: Dar es Salaam has a Regional Administration headed by the Regional Commissioner; a city council headed by the City Mayor; and 5 municipalities: Ilala, Kigamboni, Kinondoni, Temeke and Ubungo. The City Council is responsible for coordination between the municipal councils and for cross-cutting issues including transportation and fire services. The municipal councils are responsible for maintaining peace and order in their municipalities; promoting the social welfare and economic well-being of their residents; and, in accordance with approved development plans, promoting social and economic development.

Population: The population in 2012 was 4.3 million with 32% of the population under 15 years. There is a bulge in the population pyramid for the 15 – 34-year age category reflecting, in part, in-migration of youth. This is greatest amongst women. There were 1,083,381 private households in 2012 in Dar es Salaam. The average household size was 3.9 persons (NBS, 2016).

Economic activities / employment: 51.8 % of the population aged 10 years and above[7] are employed, of whom 48.1% are self-employed and 42.7% are employees. 6.7% are unemployed and 17.7% are engaged in home-making. Of those people who are in employment, 19.5% are service workers or shop and stall workers and 14.2% are street vendors and related workers[8] (NBS, 2016). The manufacturing sector provides the largest proportion of jobs (12.3%) followed by trade and commerce (11.7%) and trade in raw foods (11.2%).

Wealth and home ownership: the majority of households (52%) rent their homes privately whilst 37.1% of households own their home. Most households have iron sheet roofs (96%); cement floors (88.9%) and cement brick walls (95%). 89.5% of households own mobile phones (NBS 2016).

[7] Note that the age categories are taken from NBS 2016. Although the Employment and Labour Relations Act No. 6 of 2004, prohibits employment of children under 14 years of age, many children under 14 years remain in employment. Nationally, 34.5% of 5 to 17-year olds are involved in economic activities including 22.1% of 5 to 11-year olds. Dar es Salaam has one of the lowest rates of child employment with 3.9% of 5 – 17-year olds involved in economic activities (NBS-ILO 2016).

[8] The report follows the categories published in NBS 2016.

3. WHAT MAKES CHARCOAL THE NUMBER 1 COOKING FUEL IN DAR ES SALAAM?

3.1 Cooking energy options for consumers in Dar es Salaam

The results of our 2018 survey indicate that there is already a decline in the proportion of households using charcoal as their main cooking fuel and a rapid uptake of LPG. According to surveys by the National Bureau of Statistics, 88.2 % of households in Dar es Salaam were using charcoal in 2016 (NBS, 2017), and 74% of households described charcoal as their main cooking fuel in 2012[9] (NBS, 2016). If we just consider the 74% of households who were using charcoal as their main cooking fuel in 2012, and we assume that they were using approximately 2 kg per day, this would have been equivalent to at least 804,000 tonnes[10] of charcoal per year for domestic use. Had demand increased in line with urban population growth at 5.6% p.a., the volume being consumed in 2018 should have been at least 1.1 million tonnes. Household surveys suggest that the actual consumption rate is significantly less.

Charcoal has remained the cooking fuel of choice for households in Dar es Salaam because it is affordable and available. Alternatives are also available and are used alongside charcoal in most households. However, they are more expensive per unit of energy, and so are mainly adopted for situations where time efficiency and convenience override energy cost, such as preparing the morning meal. LPG is rapidly gaining in popularity primarily due to its convenience. Complete substitution of charcoal with other fuels is rare except in the poorest households where fire wood is used. Understanding patterns of domestic fuel use, and the reasons behind those patterns, is needed in order to promote demand-side change.

Charcoal is the most popular household cooking energy but there is evidence of increasingly widespread adoption of LPG. Consumers choose one, or a combination of more than one, energy type. Comparing 2016 and 2018 energy use, there are signs of increased energy diversification, with a doubling in the proportion of households using LPG and firewood, plus an increase in electricity use (Table 3, Figure 1).

Table 3. Proportion of households in Dar es Salaam using different types of cooking fuel either individually or in combination.

	2016 NBS Energy Access Situation Report	**2016 NBS Energy Access Situation Report**	**2018 Current study**
Energy type	**% of households nationally using each fuel**	**% of households in Dar es Salaam using each fuel**	**% of households in Dar es Salaam using each fuel**
Charcoal	37.0	88.2	88
LPG	7.2	26.7	58
Kerosene	5.0	22.1	28
Firewood	71.2	14.3	25
Electricity	1.0	1.3	12
Other	0.2	0.3	0
Solar	0.0	0	0
Wood/crop	0.1	0	0
Briquettes	N/A	N/A	0
Ethanol	N/A	N/A	0

[9] NBS 2016. P. 89 Basic Demographic and Socio-Economic Profile for Dar es Salaam based on 2012 census data.
[10] Total population 4.3 million / 3.9 persons per household = 1.1 million households use 2 kg / day for 365 days / yr.

Source of 2016 data: NBS 2017. 2016 Energy Access Situation Report. Source of 2018 data: Current Field Study.

Table 4. Changes in the main household cooking fuel between 2000 and 2018 in Dar es Salaam.

Fuel type	2000/01 HBS	2007 HBS	20011/12 HBS	2012 Population and Housing Census *	2018 Current Study
	% of surveyed respondents in Dar es Salaam who stated that this was their main fuel type				
Charcoal	46.1	74.9	76.5	73.5	56
LPG	0.4	0.9	4.8	3.9	32
Firewood	4.6	8.0	2.5	6.6	9
Kerosene	43.0	12.4	9.4	6.7	3
Electricity	4.8	2.2	1.2	7.2	0
Other	1.1	1.6	5.6	0.1	0
Total	**100.0**	**100.0**	**100.0**	**98.0**	**100.0**

*As reported in NBS 2016. Energy Access Situation Report p. 79 as NBS 2016. PHC 2012 results for Dar es Salaam Region combined the data for LPG and Electricity.

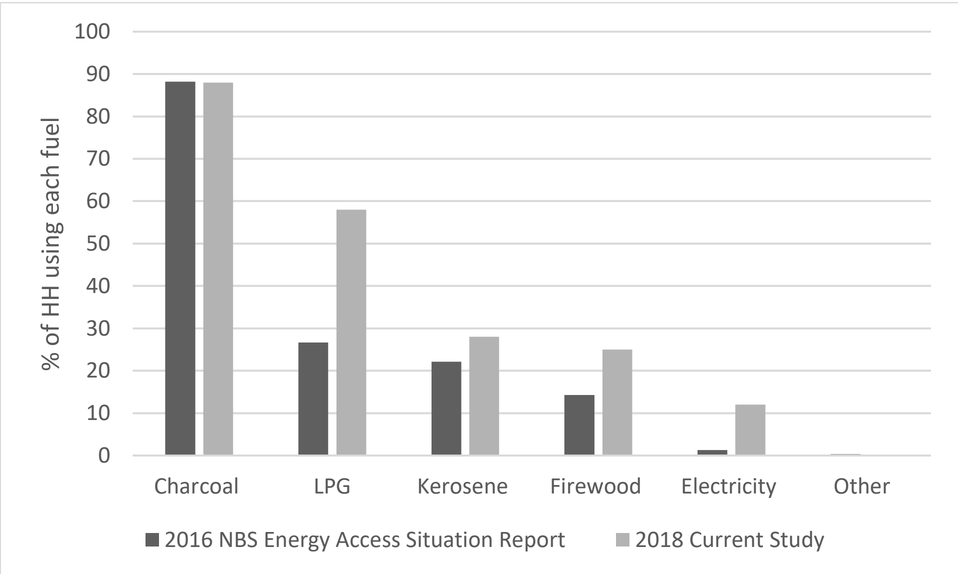


Figure 1. Changes in household cooking fuel use (reflecting all cooking fuels used in multi-cooking fuel households) in Dar es Salaam between 2016 and 2018.

National surveys such as the Household Budget Surveys and Population and Housing Survey collect data on the main cooking fuel only. These data sets show that the proportion of households using charcoal as their main cooking fuel appears to have declined from around three-quarters of households in 2007 – 12 to just over half of households in 2018 (Table 4). Similarly, there are declines in kerosene and electricity as the main fuel type, with LPG popularity increasing from less than 5% in 2012 to over 30% in 2018. The dramatic decline in the popularity of kerosene came at the same time as the liberalisation of the downstream petroleum trade in 2000 and an eight-fold increase in excise duty introduced in 2011. It would appear that the declining popularity for kerosene was mirrored by an increase in popularity for charcoal between 2000 and 2012.

Most households in Dar es Salaam use more than one fuel-type for cooking. Data that considers the mix of cooking fuels used by households provides a more accurate picture of the status and dynamics of household energy demand. Fuel stacking is where households use multiple forms of cooking fuel. Data from the National Panel Survey of 2008 - 2013 (NBS, 2014 c + d) show that 21% and 12% of households purchased two and three cooking fuel types respectively in 2012/13 and that this practice is most common in wealthier households (Choumert *et al*, 2017). Fuel stacking is not new and was also detected in 88% of Dar es Salaam households surveyed by the CHAPOSA project in 2001 (CHAPOSA, 2002). Our survey found that 80% of households in Dar es Salaam use two to four different fuels for cooking (Table 5). Most (52%) use two fuels. The most common combination, found in 25% of surveyed households, is a mix of charcoal and LPG. No households use only electricity or kerosene. This data shows that, although charcoal as a primary fuel has been in decline, it remains highly prevalent as a supplementary fuel.

Table 5. Percentage of surveyed households using different cooking energy combinations in Dar es Salaam in 2018.

Fuel combination	% of surveyed households in 2018
One-fuel households	
Charcoal only	13%
LPG only	5%
Electricity only	0%
Kerosene only	0%
Firewood only	2%
Sub-total	**20%**
Two-fuel households	
Charcoal and LPG	25%
Charcoal and kerosene	16%
Charcoal and firewood	0%
LPG and electricity	6%
LPG and kerosene	4%
Other two-fuel combinations	0%
Sub-total	**52%**
Three-fuel households	
Charcoal, LPG and kerosene	3%
Charcoal, LPG and electricity	6%
Charcoal, firewood and LPG	11%
Charcoal, firewood and kerosene	3%
Charcoal, kerosene and electricity	2%
Other three-fuel combinations	0%
Sub-total	**25%**
Four-fuel households	
Charcoal, firewood, LPG and kerosene	3%
Other four-fuel combinations	0%
Sub-total	**3%**
Total	**100%**

Most households were not familiar with either ethanol or briquettes. When we asked why households were not using ethanol or briquettes, the majority of households stated that they had not heard of them

(69% for ethanol, 76% for briquettes) and / or they did not know how to cook with them (34% for ethanol, 31 % for briquettes).

The relationship between increasing wealth and cooking energy choice is complex. There is evidence in some countries that, as households become wealthier, they climb an 'energy ladder' moving from traditional fuel (firewood, animal residues) to transition fuels (charcoal) to modern fuels (fossil fuels, electricity). In Tanzania, the biggest shift in fuel use is a shift from firewood, the dominant fuel in the poorest 67% of households, to charcoal, the dominant fuel in the wealthiest 33%. This shift also reflects a rural (firewood) to urban (charcoal) transition. There is some evidence that wealthier households in Dar es Salaam are more likely to shift to LPG. For example, we found that only 16% of households in the poorer, high density areas use LPG as their main cooking fuel, compared with 40 % of households using LPG as their main cooking fuel, in all other areas. Among households in low to medium density areas, 49% of surveyed households with larger houses (> 100 m^2) use LPG as their main fuel compared with 24% of households with smaller houses (≤ 100 m^2). Lower use rates in high density areas may also be affected by safety concerns given higher risks of use in high density areas. 31% of those households who do not use LPG cited fear of explosions as one reason as to why they do not use it. We classified households based on the density of housing in their neighbourhood and the size of the building where the survey was conducted. We assume that households in small houses in high density areas are likely to be poorer than households living in large buildings in low-density areas.

Education also affects fuel choices, particularly tertiary education. Households where the head of household has completed tertiary education are more likely to adopt modern fuels and overall, the combined educational attainment of a married couple is positively correlated with the adoption of modern fuels alongside charcoal (CHAPOSA, 2002).

There are differences in fuel use patterns between the municipalities. The proportion of households using charcoal as their main cooking fuel was highest in Temeke (77% of Temeke households) and lowest in Kinondoni (30% of Kinondoni households), based on our 2018 survey. Conversely, LPG use as the main HH cooking fuel was lowest in Temeke (19%) and highest in Kinondoni (52%). Ubungo had the highest rate of firewood use (16%), while 0% of households in Temeke and Kigamboni were using firewood as their main cooking fuel. Understanding the spatial differences within the city can help target interventions.

There is interest from policy-makers in the factors that influence household cooking energy choices. It is assumed that if we understand the household decision-making process, policies can be tailored to influence those choices. In particular, policy-makers in Tanzania have been interested in how to influence households to stop using charcoal. Fuel price, fuel availability (delivery infrastructure, distance to supplier), stove / equipment cost, availability of the fuel in low cost units, convenience, flavouring of the food and safety have all been linked with decision-making (CHAPOSA, 2002). An experimental study providing LPG stoves to 293 households in Dar es Salaam resulted in a 27% decrease in charcoal use after 15 months (Alem *et al*. 2017) i.e. overcoming the barrier of stove ownership triggered fuel-stacking although it did not result in the elimination of charcoal from the energy mix. This is important as it demonstrates that the adoption of LPG by a household does not automatically lead to a significant reduction in charcoal consumption. In some case, it may have no impact on charcoal consumption where LPG simply replaces another fuel type e.g. kerosene.

Households choose to use a mix of fuels for multiple reasons. The preference for fuel stacking has been linked with cultural preferences for charcoal and as a strategy to mitigate risks associated with unreliable supply, irregular incomes and price fluctuations particularly in fossil fuels and electricity (Choumert *et al*, 2017, Ruiz-Mercado and Masera, 2015).

The most commonly cited criterion for selecting the main household cooking fuel was availability in small, affordable quantities. In the current study, we asked households to select the most important reason for choosing their **main** cooking fuel. Overall, affordability and flexibility / convenience were the two most frequently cited reasons. Affordability was the reason most frequently cited by households using charcoal as their main cooking fuel; whilst convenience was the main reason cited by households using LPG (Table 6). The taste of the food is also an important factor and accounted for 10% of households selecting charcoal as their main cooking fuel.

Table 6. Most important reasons for households to select their main fuel type.

Reason for selecting the households main cooking fuel	**% of household citing each selection criteria disaggregated by the main fuel type used by those households**				
	Charcoal	**LPG**	**Kerosene**	**Firewood**	**Total**
The fuel is available in small amounts that I can afford	32%	1%	2%	0%	**35%**
It can be turned on and off quickly if I just need to heat something for a short amount of time.	0%	21%	1%	0%	**22%**
The fuel is easily available near my home	4%	1%	0%	7%	**12%**
I like the way that food tastes when I cook with this fuel type	10%	1%	0%	0%	**11%**
The fuel is cheap	6%	1%	0%	2%	**9%**
I can afford the stove for this cooking fuel	2%	3%	0%	0%	**5%**
The stove is simple to use and maintain	1%	4%	0%	0%	**5%**
It is the only fuel that I know how to cook on	1%	0%	0%	0%	**1%**
Total					**100%**

Consumers apply multiple criteria in choosing their overall energy mix with affordability and convenience remaining the most important factors. We also asked consumers to cite all of the reasons why they use each fuel in their household energy mix (Table 7). Again, affordability is a strong determinant in households choosing charcoal and kerosene, while the convenience of being able to turn on and off LPG, kerosene and, to a lesser degree, electricity comes out as a selling-point for those fuel types. Environmental considerations also come into play with a quarter of LPG and electricity users citing environmental concerns about other fuels, as being influential. Firewood-users cite affordability and availability as the main reasons for use.

Table 7. Reasons that consumers choose different fuel types for use in their household energy mix.

Reasons for selecting this fuel for use either individually or in combination with other fuels	% of the households using each fuel type who mentioned each criterion as influencing their choice. Multiple responses were allowed.				
	Charcoal	Firewood	LPG	Kerosene	Electricity
It can be turned on and off quickly if I just need to heat something for a short amount of time.	14%	16%	95%	82%	42%
The fuel is easily available near my home	63%	68%	28%	39%	17%
The fuel is available in small amounts that I can afford	66%	52%	9%	79%	0%
The stove is simple to use and maintain	49%	16%	50%	46%	42%
I can afford the stove for this cooking fuel	61%	24%	22%	54%	25%
The fuel is cheap	47%	40%	14%	29%	0%
I like the way that food tastes when I cook with this fuel type	52%	4%	5%	0%	0%
It is better for the environment than other types of fuel	5%	0%	26%	0%	25%
It is the only fuel that I know how to cook on	2%	0%	2%	0%	8%

In terms of cultural preferences, cooking involves many different tasks with different requirements in terms of cooking times, temperatures and type and size of pan or pot used. Many traditional foods are associated with the use of specific fuels (Ruiz-Mercado and Masera, 2015). The links between fuel choices and cooking practices in the context of Dar es Salaam are poorly understood. Similarly, it is poorly understood whether fuel stacking involves simultaneous use of multiple stoves for different cooking tasks, or substitution of one fuel with another during times of shortage. In our 2018 survey we found that, in LPG / Charcoal 2-fuel households, charcoal was the fuel of choice for rice, beans and meat while LPG was preferred for breakfast porridge preparation. This suggests that there is a temporal difference in fuel use with a preference for LPG in preparing breakfast, while charcoal is used for lunch and dinner. For LPG- charcoal households, fuel type choices for different foods are summarised in Table 8. For this analysis we have just 'zoomed in' on those households using LPG and charcoal only, in order to understand consumer preferences between these two major fuel types.

Table 8. Fuel types used for different foods in 2-fuel LPG-charcoal households.

	% HH using fuel type per food item[11]		
Food type	Charcoal	LPG	Difference
More households use charcoal than LPG for the following foods:			
Beans	92%	8%	84%
Rice	72%	32%	40%
Roast Meat	48%	8%	40%
Stewed Meat	68%	28%	40%

[11] Note that some households stated that they used both LPG and charcoal for some food items hence the sum of the % of households using charcoal and / or LPG may be greater than 100% per food type.

Food type	% HH using fuel type per food item[11] Charcoal	LPG	Difference
More households use charcoal than LPG for the following foods:			
Potatoes	44%	20%	24%
Plantains	56%	32%	24%
Soup or Sauce	40%	20%	20%
Peas	48%	32%	16%
Ugali / thick maize porridge	68%	56%	12%
Boiling Water	56%	48%	8%
Chapati	36%	28%	8%
More households using LPG than charcoal for the following foods:			
Porridge	20%	48%	-28%
Leafy Greens	52%	72%	-20%
Eggs	28%	48%	-20%
Bread	8%	12%	-4%
Other	8%	12%	-4%

For most food types households do not consistently use one fuel type or another. In the LPG-Charcoal households, 43% of households interchange use of LPG and charcoal to prepare leafy greens and ugali. In contrast, the two fuels were rarely inter-changed when cooking beans and meat suggesting a strong preference for charcoal when cooking those items.

Charcoal has other domestic uses. In 16% of households, charcoal is used for other purposes apart from domestic cooking. Other uses include: ironing, poultry husbandry, and for commercial food-preparation.

Enhancing fuel efficiency is important in reducing overall urban fuel consumption. We asked households about some of the ways in which they improve fuel efficiency. Commonly cited measures included re-using charcoal between cooking events (78% of charcoal-using households); soaking beans in advance (35% of all households); turning off the stove as soon as the food is cooked (16% of all households); only using small amounts of firewood or charcoal, and cooking in bulk (~10% of households each). 10% of households stated that they sometimes use a pressure cooker.

Whilst the micro-economics of consumer choices is a key consideration, the macro-economic, strategic, social and environmental implications of different energy sources are also important. The National Energy Policy 2015 recognises that 85% of all energy consumed in Tanzania comes from biomass. However, biomass energy is largely excluded from the scope of the policy which is instead focused on fossil fuels, electricity and renewables (largely excluding biomass). The rationale for the focus on modern fuels, is that by developing modern energy supplies, biomass energy can be phased out of the energy mix, thereby avoiding the negative environmental and social impacts of charcoal and firewood. The disadvantage of this is that it has left a significant gap in Tanzania's energy policy, given continued dependency on biomass energy. Proposals to develop a biomass energy policy have been put forward by many stakeholders and a detailed biomass energy strategy was developed in 2014. To date, this has not been adopted.

3.2 Household cooking energy option profiles

Household cooking energy options in Dar es Salaam vary in terms of price, consumer preferences, availability, safety and strategic considerations. Comparing options is an important step in urban energy planning. This section presents profiles of the main energy options. Unless stated otherwise, data on prices, percentage of households using each fuel type, consumer perceptions, use patterns and availability are based on the household and retailer surveys conducted as part of this study in Dar es Salaam in 2018.

Charcoal is the cheapest fuel per unit of energy, followed by LPG. Households are making economically rational decisions in selecting charcoal and LPG as the most commonly used cooking fuels. Charcoal costs TZS 85.40 (US$ 0.04) per megajoule, compared with TZS 123 (US$ 0.05) / MJ for LPG and TZS 141 (US$ 0.06) / MJ for electricity (Table 9). This comparison does not include firewood as most households indicated that they collect firewood themselves rather than purchasing it. It would follow that, where firewood is available, it is the cheapest but is not readily available to households in more densely populated parts of the city.

Table 9. Prices of cooking fuels per unit of energy.

Fuel type	(a) Price TZS	(b) Unit	(c) Energy density (MJ per unit (a))[12]	(d) End use cooking efficiency[13]	Price TZS per MJ useful energy output
Charcoal	776	Per kg	29.0	0.30	89
LPG	3,333	Per kg	45.0	0.60	123
Electricity	356	Per kW·h	3.6	0.70	141
Kerosene	2,247	Per litre	36.3	0.40	154
Briquettes	1,500	Per kg	29.0	0.3	172
Ethanol	5,900	Per litre	23.0	0.65	395

[12] **Based on Camco 2014**
[13] **Based on Camco 2014**

3.2.1 Charcoal

Energy output cost	**TZS / MJ**	89	**US$ / MJ**	0.04
Retail price	**TZS / kg**	776[14] (Min: 385, Max: 1,500)	**US$ / kg**	0.34
Stove	**TZS**	10,000 – 14,000 for a typical metal, ceramic-lined stove	**US$**	4-6
Demand	**% of surveyed households using this option:** 88%		**% of surveyed households using this option as their main cooking fuel:** 56%	
Consumer perceptions and % of households citing these reasons	**Positive:** Available for sale in affordable quantities (66%) Fuel is readily available (63%) Stove is affordable (61%)		**Negative:** Takes longer to ignite and be ready than LPG.	
Use patterns	Preferred for slow-cook food items particularly beans, and for meat			
Supply	**Source:** Natural woodlands, mostly on village lands[15]. Some from tree crops including black wattle, mango and cashew nut trees.	**Fuel availability:** Easily available. 73% of households stated that they could buy charcoal within 0 - 10 minutes of their house. Sold in units varying in weight from 0.8 kg – 100 kg.	**Main suppliers:** Many retailers and transporters.	**Past or ongoing promotion initiatives:** Initiatives to produce charcoal sustainably include the TFCG / MJUMITA initiative in Morogoro Region. www.tfcg.org/what-we-do/develop/sustainable-charcoal/
Taxes, fees and other revenues:	Generates revenue for villages, local and central government. See Section 4.6 for further discussion on charcoal's contribution to tax revenues.			
Environmental impacts:	Sustainable production can reduce deforestation rates by incentivizing forest-owning communities to maintain woodland on village land. Unplanned production can result in forest degradation.			
Health and safety:	Exposure to biomass particulates and gases causes numerous cardiopulmonary and neurodegenerative diseases. Charcoal stoves are particularly associated with chronic carbon monoxide exposure which can cause a range of neurological problems. See Section 6.1.			
Macro-economic considerations:	Provides rural employment for producers; and urban employment for wholesalers, retailers and stove producers. See Section 6.2.1. Locally produced. Does not require imported fossil fuels. Generates around 33% of Central Government forestry royalties.			

[14] This is the price based on the retailer survey. The mean price based on the **retailer** survey was TZS 776.03, ranging from a minimum of TZS 385 / kg to a maximum of TZS 1,500 / kg. The mean price based on the **consumer** surveys was 743, ranging from TZS 526 – TZS 1,333 / kg. This provides a useful triangulation of the two surveys.

[15] Land in Tanzania falls into 3 categories: Village, General and Reserved land which comprise 70%, 2% and 28% of all land respectively. Village councils are responsible for the management of village lands.

3.2.2 Liquefied Petroleum Gas

<table>
<tr><td>Energy output cost</td><td>TZS / MJ</td><td>TZS 123 / MJ</td><td>US$ / MJ</td><td>0.05</td></tr>
<tr><td>Retail price</td><td>TZS / kg</td><td>TZS 3,333 (based on Oryx price for 6kg bottle = TZS 20,000)</td><td>US$ / kg</td><td>1.46</td></tr>
<tr><td>Stove</td><td>TZS</td><td>70,000 for one 6kg tank with burner and single-hob trivet.[16]</td><td>US$</td><td>31</td></tr>
<tr><td>Demand</td><td colspan="2">% of surveyed households using this option: 58%</td><td colspan="2">% of surveyed households using this option as their main cooking fuel: 32%</td></tr>
<tr><td>Consumer perceptions and % of households citing these reasons</td><td colspan="2">Positive: Convenient – can be turned off quickly and easily (94%).
Stove is easy to use (54%).
Good for the environment (28%).</td><td colspan="2">Negative:
Produces too much smoke (48%)
Too messy (41%)
Spoils the taste of the food (34%)</td></tr>
<tr><td>Use patterns</td><td colspan="4">In households using multiple fuels, LPG is commonly used for making tea and porridge for breakfast. It is also used to re-heat food. It is rarely used for slow-cook items such as beans. At a national level, LPG is most commonly used by the wealthiest households. 30.6% of households in the highest wealth category use LPG, whilst 0% of households in the poor and poorest wealth categories (the two lowest wealth quintiles in the 2016 NBS / REA survey) use LPG (NBS 2017).</td></tr>
<tr><td>Supply</td><td colspan="4"><table><tr><td>Source: Butane and propane are imported. They are not available for extraction in Tanzania in commercially viable quantities. LPG sold in Tanzania is usually an 80:20 Butane:Propane mix.</td><td>Fuel availability: Increasingly available. 80% of surveyed households using LPG state that it is available within 0 – 10 minutes of their house. For Oryx, the 6kg and 15kg cylinders are the most popular; for Lake Oil the 15kg and 38 kg are the most popular.</td><td>Main suppliers: Oryx Energies, Mihan Gas, Lake Gas Ltd</td><td>Past or ongoing promotion initiatives: LPG is actively promoted by the LPG Marketing Companies

Initiatives such as KopaGas (see below) are enabling poorer households to access LPG in some parts Dar es Salaam.</td></tr></table></td></tr>
<tr><td>KopaGas</td><td colspan="4">KopaGas have designed a smart meter for gas cylinders and deployed a Pay-as-you-Cook™ service in Dar es Salaam, in partnership with Oryx Energies. The service uses machine-to-machine (M2M) connectivity to monitor and control gas usage and customers use mobile money to purchase gas in affordable quantities for clean cooking. Source: GSMA, 2018. KoPa gas has the potential to provide a smart purchasing mechanism accessible to poorer households but is not yet widely available.</td></tr>
<tr><td>Taxes, fees and other revenues:</td><td colspan="4">LPG and LPG cylinders are exempted from Value Added Tax (URT, 2009). LPG is exempted from the fuel and petroleum levies[17]. Other taxes, duties and levies paid by LPG companies include Corporate Income Tax, Railway Development Levy (1.5% of CIF), Government Laboratory Agency fees and payroll levies. Fees are also paid to the Tanzania Ports Authority and to the Tanzania Bureau of Standards.</td></tr>
<tr><td>Environmental impacts:</td><td colspan="4">LPG is a fossil fuel. Burning LPG releases carbon, previously stored beneath oceans or land, into the atmosphere thereby contributing to climate change. See Section 6.</td></tr>
</table>

[16] Fuel cylinders for domestic use are available in different sizes e.g. 3 kg, 6 kg, 10 kg, 15 kg & 38 kg from Oryx and Lake Oil. For institutions such as schools and military camps, fuel is available in tanks of 250 kg, 500 kg, 1000 kg and / or 2000 kg. A simple double-hob stove with 6 kg cylinder and 1 metre pipe costs TZS 123,000

[17] In 2002, the Tanzania Association of Oil Marketing Companies (LPG Committee) published an influential report, '*The True Cost of Charcoal: a rapid appraisal of the potential economic and environmental benefits of substituting LPG for charcoal as an urban fuel in Tanzania*'. The report argued that '*charcoal is effectively subsidised by ineffective collection of dues while LPG is penalised by high import duties*', and successfully argued the case for excise duties to be removed from LPG, a change that has been highly effective in contributing to its uptake.

Health and safety:	LPG produces less particulates than biomass fuels and is therefore better for human health. Other risks: Heavier than air and so LPG leaks pool on the ground, rather than dispersing. It is highly flammable. This combination means that there is a risk of explosions.
Macro-economic considerations:	LPG imports to Tanzania have almost quadrupled from 28,286 MT in 2011/12 to 107,083 MT in 2016/17 (EWURA 2012, 2018). Currently all LPG is imported. This creates a dependency on imports and vulnerability to price fluctuations in the global LPG market. However, LPG comes from multiple regions including the Middle East, Africa and Asia. This reduces the risk of localised supply disruptions affecting global supplies. Global trade in LPG has been steadily increasing.

3.2.3 Kerosene

<table>
<tr><td>Energy output cost</td><td>TZS / MJ</td><td colspan="2">155</td><td>US$ / MJ</td><td>0.07</td></tr>
<tr><td>Retail price</td><td>TZS / litre</td><td colspan="2">2,247 (EWURA DSM price cap Oct 2018)</td><td>US$ / litre</td><td>0.99</td></tr>
<tr><td>Stove</td><td>TZS</td><td colspan="2">TZS 18,000 – 22,000 for a wick stove type</td><td>US$</td><td>8- 10</td></tr>
<tr><td>Demand</td><td colspan="2">% of surveyed households using this option: 28%</td><td colspan="3">% of surveyed households using this option as their main cooking fuel: 3%</td></tr>
<tr><td>Consumer perceptions and % of households citing these reasons</td><td colspan="2">Positive: Convenient – can be turned off quickly and easily (82%).
- Available in affordable quantities (79%).
- Stove is affordable (54%).</td><td colspan="3">Negative: Produces too much smoke (48%)
- Too messy (41%)
- Spoils the taste of the food (34%)</td></tr>
<tr><td>Use patterns</td><td colspan="5">Kerosene is used primarily for cooking leafy green vegetables, maize porridge (uji and ugali) and for boiling water. It is almost never used for cooking beans.
Overall, use of kerosene as the main cooking fuel has declined over the last decade from 12.4% in 2007 (NBS, 2009) to 3% in 2018. It remains popular as a supplementary fuel.</td></tr>
<tr><td>Supply</td><td>Source: Imported.</td><td>Fuel availability: On average households using kerosene stated that it was available within 5 minutes of their houses.</td><td colspan="2">Main suppliers: Imported by the major fuel marketing companies and then sold to consumers at local shops.</td><td>Past or ongoing promotion initiatives: None identified.</td></tr>
<tr><td>Taxes, fees and other revenues:</td><td colspan="5">Kerosene is exempt from VAT. The petroleum levy is charged on kerosene at a rate of TZS 467 / litre. Corporate income tax and employment taxes are paid by kerosene marketing companies.</td></tr>
<tr><td>Environmental impacts:</td><td colspan="5">Kerosene is derived from petroleum oil. It is a fossil fuel. Burning kerosene releases carbon, previously stored beneath oceans or land, into the atmosphere thereby contributing to climate change. Pollutants from kerosene include particulate matter, carbon monoxide and nitrogen dioxide (Lam et al, 2012) See Chapter 6. Kerosene has a lower energy conversion rate than LPG. This contributes to higher CO_2 emissions per unit of useful energy output.</td></tr>
<tr><td>Health and safety:</td><td colspan="5">Swallowing kerosene is a common cause of childhood poisoning in many developing countries (Lam et al. 2012). Use of small plastic drink bottles to store kerosene increases the risk of children swallowing it. Ingestion is rarely fatal but can be fatal if simultaneously inhaled. There is some evidence that cooking with kerosene risks impaired lung function and increased infectious illness (including tuberculosis), asthma, and cancer risks (ibid). In general, more research has been recommended to understand the chronic health risks of cooking with kerosene (ibid). Kerosene is highly flammable. Tipping of stoves and stove malfunction can result in explosions leading to serious, sometimes fatal, burns (Peck et al. 2008).</td></tr>
<tr><td>Macro-economic considerations:</td><td colspan="5">All kerosene is imported. This creates a dependency on imports and vulnerability to price fluctuations in the global petroleum market. Historically, kerosene prices have significantly affected demand for charcoal. For example, in the 1990s when the Government reduced the relative price of kerosene, demand for charcoal fell (Camco, 2014 p.20). Conversely, increased kerosene prices in the 1970s have been linked to increased charcoal demand at that time (Camco 2014). In 2011, excise duty on kerosene was increased from TZS 52 (US$ 0.02)/ litre to TZS 400.3 (US$ 0.14) / litre in an attempt to stop traders mixing cheaper kerosene with more expensive diesel (UNIDO, 2015). Since then, imports of kerosene have fallen by one third, from 362 million litres in 2010/11 to 240 million litres in 2016/17 (EWURA 2011, 2017).</td></tr>
</table>

3.2.4 Firewood

<table>
<tr><td>Energy output cost</td><td colspan="4">Most (75%) households who use firewood, collect the fuel themselves. 17% use a mix of firewood that they had bought and collected while 8 % bought all of the firewood that they use. All of the households who bought firewood were also running food preparation businesses making snacks such as maandazi (doughnuts). For this reason, we have not put a price on firewood for household use.</td></tr>
<tr><td>Stove cost</td><td colspan="4">All households interviewed use a traditional 3-stone stove. Zero cost.</td></tr>
<tr><td>Demand</td><td colspan="2">% of surveyed households using this option: 25%</td><td colspan="2">% of surveyed households using this option as their main cooking fuel: 9%</td></tr>
<tr><td>Consumer perceptions and % of households citing these reasons</td><td colspan="2">Positive: Easily available (68%).
Available in affordable quantities (52%).
Cheap or free (40%).</td><td colspan="2">Negative: Generates a lot of smoke;
Inconvenient;</td></tr>
<tr><td>Use patterns</td><td colspan="4">Firewood is often used for cooking beans, ugali and rice; and for boiling water. It is not favoured for cooking chapatis or meat.
At a national level firewood is used by 71.2 % of households as the main cooking fuel (EAS NBS 2017). Whilst it is most popular in rural areas (92% of rural HH use firewood), it is also the second most frequently used fuel in urban areas (28.4%) (ibid).
</td></tr>
<tr><td>Supply</td><td>Source: 46% of households who use firewood collect wood from trees that they own or have planted themselves.</td><td>Fuel availability: On average, firewood was available within 10 minutes of user households. The time to the firewood collection point ranged from 0 minutes to 60 minutes.</td><td>Main suppliers: 75% of households using firewood, collect the fuel themselves. For those who purchase the firewood, they do so from small-scale traders.</td><td>Past or ongoing promotion initiatives: Tree planting is promoted by Municipalities, particularly on National Tree Planting Day. This is primarily for improving urban aesthetics, air quality and shade provision rather than for firewood production.</td></tr>
<tr><td>Taxes, fees and other revenues:</td><td colspan="4">The Forest (Amendment) Regulations, 2015 set a royalty of TZS 5,900 (US $2.59) / per stacked cubic metre from dead branches and off cuts. However, this royalty is not collected for those gathering fuelwood for their own domestic use.</td></tr>
<tr><td>Environmental impacts:</td><td colspan="4">Smoke from burning biomass contributes to indoor and outdoor air pollution. Firewood-use may contribute to tree-planting in and around urban areas.</td></tr>
<tr><td>Health and safety:</td><td colspan="4">Firewood produces particulate matter that can trigger a range of cardiopulmonary health problems. Compared with charcoal, firewood and crop residues produce more fine particulate matter resulting in a higher risk of a range of cardiopulmonary and neurodegenerative diseases (Das et al. 2017). Many of the households interviewed, cook outside. This helps to reduce exposure to the smoke and gases produced by the fire. Firewood is time-consuming and labour intensive to collect and adds to the work load of women and children, with an opportunity cost in terms of time spent away from other tasks / education / leisure.</td></tr>
<tr><td>Macro-economic considerations:</td><td colspan="4">Firewood is essential for the livelihoods of poorer households.</td></tr>
</table>

3.2.5 Briquettes

Energy output cost	**TZS / MJ**	172	**US$ / MJ**	0.08
Retail price	**TZS / kg**	1,500[18]	**US$ / kg**	0.66
Stove	**TZS**	10,000 – 14,000 for a ceramic-lined metal stove	**US$**	4-6
Demand	**% of surveyed households using this option:** 0%. There is some demand in Dar es Salaam for briquettes however it was too low to be detected in the current survey.		**% of surveyed households using this option as their main cooking fuel:** 0%	
Consumer perceptions and % of households citing these reasons	Reasons for not using briquettes: i. unheard of (77%); ii. no knowledge on how to use briquettes (30%); and iii. unavailable near to the household (4%). The quality of briquettes varies significantly depending on their material content and manufacturing method. Poor quality briquettes that are difficult to light, crumble easily and produce a low heat have created a negative perception amongst some consumers in Tanzania.			
Supply	**Source:** Briquettes can be made from many different types of biomass. In Tanzania, most briquettes are made of agricultural residues and by-products of wood industries (Camco, 2014).	**Main suppliers / availability / ongoing promotion initiatives: Commercial suppliers to Dar es Salaam include Mkaa Endelevu and ARTI energy. There are also small-scale producers.** Mkaa Endelevu manufacture their briquettes in Iringa Region using pine saw dust from saw mills serving Iringa's pine and eucalyptus plantations. The saw dust is dried, pyrolysed and combined with starch from maize, rice or potatoes as binding agents. This material is then compressed using a screw extruder machine to produce the briquettes. The briquettes are sold in 2 kg or 6 kg bags to household consumers. Sales to household users have been limited due to low demand. Instead, the company has focused on large institutional consumers such as universities and government institutions particularly those concerned to substitute charcoal with an alternative, due to charcoal's bad environmental reputation. Mkaa Mkombozi[19] briquettes are produced by ARTI Energy Limited from agricultural residues, charcoal dust and other dry biomass. They are available in 4 kg and 25 kg bags. ARTI Energy also produce modern fuel-efficient stoves.		
Taxes, fees and other revenues:	VAT, corporate income tax, employment taxes, TFS licence fees and TFS transit pass fees are paid by briquette manufacturing companies. Along with ethanol-based fuels, they currently face the highest tax burden of any of the urban cooking energy fuels. This contributes to their being more expensive per unit of energy than other fuels and has made them uncompetitive relative to charcoal for household consumption.			
Environmental impacts:	Air pollution due to particulate matter.			
Health and safety:	Risks include particulate matter and carbon monoxide indoor air pollution.			
Macro-economic considerations:	Briquettes can be manufactured in Tanzania using locally available materials and creating employment opportunities. Modern manufacturing techniques such as those used by Mkaa Endelevu address the quality issues that typified many briquettes promoted previously. It is estimated that there is sufficient saw dust and timber by-products available in the Southern Highlands to produce ½ million tonnes of briquettes per year[20], approximately half of Dar's current charcoal consumption. Although the availability of raw materials does not guarantee a market, it is one important piece in the development of a viable value chain. Reducing the tax burden on briquette companies or stemming the revenue leakage on charcoal, would create a more level playing field for briquettes.			

[18] Price is based on a 2 kg packet of Mkaa Endelevu briquettes from retailers in Dar es Salaam. The wholesale price is less at TZS 1,000 / kg. Prices to consumer can reach TZS 1,600 / kg depending on the outlet.
[19] http://arti-africa.org/2013/08/mkaa-mkombozi-sustainable-charcoal-briquettes/
[20] Mkaa Endelevu. Pers. Comm.

3.2.6 Electricity

<table>
<tr><td>Energy output cost</td><td>TZS / MJ</td><td>141</td><td>US$ / MJ</td><td>0.06</td></tr>
<tr><td>Retail price</td><td>TZS / kW·h</td><td>356</td><td>US$ / kW·h</td><td>0.16</td></tr>
<tr><td>Stove</td><td>TZS</td><td>70,000 for a single hotplate.</td><td>US$</td><td>31</td></tr>
<tr><td>Demand</td><td colspan="2">% of surveyed households using this option: 12%</td><td colspan="2">% of surveyed households using this option as their main cooking fuel: 0%</td></tr>
<tr><td>Consumer perceptions and % of households citing these reasons</td><td colspan="2">Positive: - Convenient – can be turned off / on quickly and easily (42%).
- Stove is easy to use and maintain (42%).
- Better for the environment (25%).</td><td colspan="2">Negative: - The fuel is too expensive (93%)
- The stove is too expensive (49%)
- It is not available in affordable quantities (32%)</td></tr>
<tr><td>Use patterns</td><td colspan="4">Electricity is mainly used for boiling water and rice, including using electric rice cookers. It is also used for baking bread and cooking potatoes and plantains. 2% of households only use electricity in emergencies when their gas runs out. Half of the households who use electricity do so as part of a charcoal / LPG / electricity mix. 0.9% of households in Tanzania owned an electric stove in 2016 (NBS, 2017). Despite increased access, electricity remains unpopular as a source of cooking energy. Cost seems to be the main barrier to uptake. Camco (2014) report that hundreds of stakeholders consulted during the BEST Tanzania Project, stated that they would use electricity for cooking if it was cheaper. The price of electricity has not changed since 2016 despite TANESCO requests to raise tariffs. Use of electricity as an urban household’s main cooking fuel is low in many African countries e.g. 7% in Uganda and 4.6% in Ghana (Scott et al. 2018).</td></tr>
<tr><td>Supply</td><td>Source: Electricity in Tanzania is generated from natural gas (59%), hydropower (34%), liquid fuel (6%) and biomass (0.3%) (EWURA, 2017).</td><td colspan="2">Fuel availability / Past or ongoing promotion initiatives: 92% of the households who use electricity for cooking, pay through mobile payment services using their phones (2018 Current Study). Electricity access in Dar es Salaam has increased significantly. In 2016, 75.2% of households in Dar es Salaam were connected to an electricity supply of whom 99.3% were connected to the grid and 0.7 % had access to solar-powered electricity (NBS, 2017). This is a significant increase from 68.1% of households in Dar es Salaam with access to electricity in 2011/12 (NBS, 2014).</td><td>Main suppliers: 99% of electricity supplied to Dar es Salaam is provided through the grid. The Tanzania Electric Supply Company (TANESCO) is the main supplier of electricity to the grid.</td></tr>
<tr><td>Taxes, fees and other revenues:</td><td colspan="4">Taxes: Consumers pay the following taxes on their electricity:
Value Added Tax: 18%
Energy and Water Utilities Regulatory Authority levy: 1%
Rural Energy Agency Levy: 3%</td></tr>
<tr><td>Environmental impacts:</td><td colspan="4">Varies depending on the energy type. Electricity generated using fossil fuels (natural gas, oil, coal) contribute to climate change and air pollution. Hydropower dams result in natural habitat loss, often in ecologically sensitive areas, and disruption of hydrological patterns.</td></tr>
<tr><td>Health and safety:</td><td colspan="4">The cleanest fuel available in terms of indoor air pollution.</td></tr>
<tr><td>Macro-economic considerations:</td><td colspan="4">Electricity generation involves power plant and transmission infrastructure construction, generation and transmission infrastructure operating and maintenance, and fuel costs. The Power Sector Master Plan proposes infrastructure investments in generation, transmission and sub-stations worth US$ 11.6 billion in the period 2016 – 20. This compares with an annual GDP of US$ 52 billion. Based on current investments, the plan predicts that TANESCO will start to make a profit in 2021 and that profits will have covered the 2016 – 20 losses by 2040 (URT-MEM 2016). The Power Sector Master Plan (PSMP) predicts that residential sector demand for electricity will increase by 11% p.a. from 2015 to 2040 and that ‘the share of wood and charcoal in final energy consumption will decrease up to 49% in 2040[21]’ (URT-MEM, 2016). The PSMP is based on an estimated total residential demand of 46.33 PJ (12,870 GW·h) by 2030 (URT-MEM, 2016). This compares with an estimated household cooking energy demand for</td></tr>
</table>

[21] It is assumed that this should be interpreted as a target to reduce biomass energy to no more than 49% of the total energy mix nationally.

	Dar es Salaam of 17.2 PJ /yr[22] for a population of 11.4 million in 2030, equivalent to 37% of the total allocated residential energy. Even if electricity becomes affordable for the majority of households, the projected supply is insufficient for electricity to become the main cooking energy for the majority of urban households. If all Dar es Salaam households switched to electricity for cooking in 2018, it would require 3,576 GW·h[23] per annum, equivalent to 40% of the total national projected electricity demand of 9,196 GW·h for 2018 (URT-MEM, 2016). This would leave insufficient electrical power for industry, business and other domestic appliances. It would also cause a large spike in daily electrical demand at peak cooking times, such as early evening, requiring additional infrastructure.

[22] See Table 1.

[23] See Table 1 on how this is calculated. Note that this is the input energy, taking into consideration a 0.7 efficiency conversion factor.

3.2.7 Ethanol

<table>
<tr><td>Energy output cost</td><td>TZS / MJ</td><td>395</td><td>US$ / MJ</td><td>0.17</td></tr>
<tr><td>Retail price</td><td>TZS / litre</td><td>5,900 (2018 Dar es Salaam price for 1 litre of Moto Poa ethanol-based fuel gel).</td><td>US$ / litre</td><td>2.59</td></tr>
<tr><td>Stove</td><td>TZS</td><td>40,000</td><td>US$</td><td>17.5</td></tr>
<tr><td>Demand</td><td colspan="4">There is some demand in Dar es Salaam for ethanol and methanol (methyl alcohol) however it was too low to be detected in the current survey. No households in the current survey mentioned ethanol or methanol.</td></tr>
<tr><td>Consumer perceptions and % of households citing these reasons</td><td colspan="4">Positive: Most consumers are unaware of this fuel type. In our survey, 68% of households stated that they had never heard of ethanol as a cooking fuel; 35% stated that they did not know how to cook with it while 7% stated that it was not available near them. One respondent had tried it in the past but said that it produced an unpleasant smell and smoke 'Hutoa moshi na harufu mbaya'.</td></tr>
<tr><td>Supply</td><td>Fuel availability: Not widely available. Available in a few supermarkets in Dar es Salaam, in some of which it is displayed alongside camping supplies.</td><td>Source / Main suppliers: Moto Poa fuel gel and stoves are imported from South Africa Hotpack is imported from United Arab Emirates.</td><td colspan="2">Past or ongoing promotion initiatives: Moto Poa have promoted their ethanol-based cooking fuels in Dar es Salaam and Arusha. Since 2016, UNIDO have been promoting bio-ethanol in Dar es Salaam as a clean alternative energy. In August 2018, UNIDO announced a plan to distribute 110,000 ethanol stoves to households in Dar es Salaam over the next 5 years[24]. Between 2014 – 15, UNIDO worked with Project Gaia to pilot ethanol production and use in Zanzibar using sugar cane as the feedstock. UNIDO (2015) identified sweet sorghum, cassava and sugarcane a having the greatest potential for ethanol production in Tanzania.</td></tr>
<tr><td>Taxes, fees and other revenues:</td><td colspan="4">VAT, corporate income tax and payroll taxes.</td></tr>
<tr><td>Environmental impacts:</td><td colspan="4">In 2010, Guidelines for Sustainable Liquid Biofuels Development were adopted. These sought to mitigate risks of negative environmental and social impacts caused by biofuel developments. Although reducing deforestation from charcoal production is cited as a rationale for bio-ethanol adoption, it is not clear that widespread adoption would achieve that goal. Given that bioethanol would require additional crop land and given that conversion of forests to agriculture is the main deforestation driver in Tanzania, it could increase conversion of forests to crop land were it to be scaled up without proper safeguards. Environmental safeguards on bioethanol production could mitigate this risk if implemented.</td></tr>
<tr><td>Health and safety:</td><td colspan="4">Methanol fuel gels are toxic and highly flammable and therefore pose health risks in terms of poisoning and burns.</td></tr>
<tr><td>Macro-economic considerations:</td><td colspan="4">If produced locally, could reduce dependence on imported fossil fuels and create employment.</td></tr>
</table>

3.2.8 Natural Gas

Natural gas dominates cooking in many industrialised countries. Tanzania has abundant reserves of natural gas. Tanzania's Natural Gas Utilisation Plan includes the strategic objective, '*promoting the use of natural gas as alternative fuel to liquid fuel, charcoal and wood for domestic use*.' The plan goes on to state that '*the importance of supply of gas as an alternative energy to biomass (mainly charcoal and firewood) makes it necessary for the Government to strategically intervene and promote its implementation through appropriate policies in order to save the fast depleting natural forests*.' The plan assumes that '*10% of households in the country will be supplied with natural gas for cooking by 2045… a total demand of 0.5*

[24] https://www.ippmedia.com/en/news/unido-bid-have-dar-residents-use-ethanol-opposed-charcoal

trillion cubic feet for 30 years (2015 – 2045)' (URT, 2016). The plan also outlines the investment costs required to ensure a reliable and safe supply of natural gas to domestic users. In terms of pricing, the plan suggests that, '*alternative fuel price methodology should be used for industries and domestic use. However, alternative fuel pricing methodology should have a price seal to ensure that natural gas price reflects investment costs incurred in the natural gas value chain*.'

The Tanzania Petroleum Development Corporation (TPDC) is piloting the provision of natural gas to households and industries in Kinondoni Municipality and Mkuranga District[25]. According to media reports[26], 70 households were using natural gas from southern Tanzania for heating and cooking by February 2018. The cost of installing natural gas delivery infrastructure is high. Whilst natural gas may become a significant part of the urban energy mix in future, there are no concrete plans on the table yet, to scale this up across the city. Media reports describe some of the technical challenges as including '*the poor plan of the city, which is causing difficulties in identifying routes for the construction of the distribution network and its associated facilities… water, underground electric lines, communications cable suppliers do not have drawings*.'[27] Media reports also refer to a US$ 1.6 million feasibility study by the TPDC for the distribution of natural gas to 30,000 households across the city (*ibid*).

3.2.9 Biogas

The 2000/1 household budget survey found that 0.1% of households were using biogas. Since then all national surveys have recorded its adoption at 0.0% (NBS, 2017). No households interviewed during the current survey were using biogas for cooking.

Biogas has been promoted in Tanzania since the 1980s. The Centre for Agricultural Mechanisation and Rural Technology (CAMARTEC), in collaboration with the Netherlands Development Organisation (SNV) and the Ministry of Energy are implementing the Tanzania Domestic Biogas Programme (TDBP) which aims to scale up adoption of biogas. Complexities of managing a biogas system make it more appropriate for institutional use than for domestic use.

3.3 Improved cook stoves and other energy-saving techniques

Improving energy efficiency is an important pillar in urban energy planning. There are many measures that households can take to increase energy efficiency.

3.3.1 Experience in Tanzania

Ceramic lined metal stoves have been widely adopted in Dar es Salaam and our surveys found that 96% of charcoal-using households were using ceramic lined stoves. Only 3% of households were using traditional metal-only stoves and 1% were using ceramic only stoves. Ceramic lined stoves are considered 'improved' relative to the single-walled metal charcoal stoves that were widely used before improved cook stove (ICS) promotion campaigns by TaTEDO, the ICS Task Force and others.

UNIDO (2015) cite research indicating that ceramic lined stoves improve efficiency from 15% up to 30 - 40% relative to metal only stoves. Other research suggest that the differences may be less (Grimsby *et al*.

[25] http://www.thecitizen.co.tz/News/-Mkuranga-receives-gas-project-boost/1840340-4753786-prp9dlz/index.html
[26] http://www.thecitizen.co.tz/News/Manufacturers-line-up-for-natural-gas/1840340-4291800-format-xhtml-1418ja4z/index.html
[27] https://www.theeastafrican.co.ke/business/Tanzania-completes-plan-to-distribute-gas-to-users/2560-2459696-12801pv/index.html

2016). As with fuel-use, the cook stove market is highly price sensitive. The success of recent ICS promotion campaigns reflects the success of various initiatives in supporting a commercially viable industry manufacturing competitively-priced stoves designed to meet local cooking practices (Rajabu, 2013).

Higher efficiency imported charcoal stoves have been promoted. For example, ARTI were promoting imported 'Envirofit' charcoal stoves with a thermal efficiency of 35.7%. By 2015 more than 45,000 had been sold (UNIDO, 2015).

3.3.2 International developments in improved cook stoves

The Clean Cooking Alliance is a global network of initiatives promoting cleaner cooking. The alliance promotes learning and partnership between initiatives. Tanzania has been engaging with the network through TaTEDO and TAREA. A Country Action Plan for Clean Cookstoves and Fuels was developed in 2014 by the National Improved Cook Stove Task Force and the Clean Cookstoves and Fuels Alliance of Tanzania (CCFAT). The action plan seeks to '*mobilize stakeholders, secure resources and champion the sector*,' (ICS Task Force, 2014).

There are many initiatives working on improved stoves. These include high efficiency biomass stoves such as the Enivrofit stoves promoted by Arti Energy. In neighbouring Kenya Envirofit, EcoZoom and BURN have between them sold well over 200,000 high performance charcoal stoves. Efficiency is only part of the appeal, and they are marketed as aspirational household durables. The potential exists in Tanzania for significantly higher uptake of products like this.

For electricity users, induction cookers can increase energy efficiency by 9.8% (US Department of Energy, 2014). An 80% efficient electric cooker would bring down the price per unit of energy to TZS 124 / MJ[28] i.e. the same price as LPG. Induction stoves require special induction compliant pots / pans. Single hob induction cookers are available from online sellers for TZS 95,000 in Dar es Salaam. This is comparable to the price of non-induction single hob electric cookers. With more awareness, induction cookers could help to make electricity a more attractive and affordable option.

3.3.3 Changing cooking behaviour

Actions such as soaking beans prior to cooking and using a pressure cooker can significantly reduce household energy consumption. We found that 34% of households regularly soak beans prior to cooking and 10% of households sometimes use a pressure cooker. Other strategies to save energy include cooking in bulk, careful fuel use and fuel-stacking. Although using a pressure cooker can halve the amount of cooking time, a good quality pressure cooker costs more than TZS 200,000 in Dar es Salaam. Strategies that encourage improved energy efficiency at household level can bring significant impact in reducing energy wastage and in helping households to save money.

[28] Normal electric stoves have a 70% end use efficiency (Camco, 2014). If this were increased by 9.8% to 79.8%, given a price per kW·h of TZS 356 and a mWh : MJ conversion factor or 3.6, this would work out at TZS 123.92 / MJ.

4. THE CHARCOAL TRADE: STATUS AND TRENDS

4.1 How much charcoal is consumed in Dar es Salaam each year?

4.1.1 Overall market volume

Our surveys suggest that between 800,000 – 950,000 tonnes of charcoal are consumed annually in Dar es Salaam. Non-household consumption is the area of greatest uncertainty. Our surveys found that, on average, households that use charcoal use 0.347 kg / person / day. This is an average and includes households for whom charcoal is their main or sole fuel; and those for whom it is a supplementary fuel alongside one to three other fuels. This is broadly representative of the current Dar domestic charcoal market. Our data and the NBS (2016) data show that 88% of households are using charcoal as part of their household cooking energy mix. If we calculate that 88% of the 5.96 million people living in Dar in 2018 is equal to 5.24 million people and multiply that by the per person daily demand of 0.347 kg, this gives us a daily consumption level of 1,820 tonnes and an annual rate of 664,355 tonnes for household use. This does not include use by institutions, hotels and food outlets, or industries. If we follow the WB, 2009 estimate that 31% of demand comes from non-household sources, then the overall demand is closer to 950,000 tonnes per year, exceeding the WB 2009 projections for 2018. Camco estimated that non-household demand for charcoal in urban areas was closer to 20% of household demand. If we follow Camco's estimate, then 2018 demand would be closer to 800,000 tonnes per year. Given the limitations of the available data, we can state confidently that annual demand for charcoal in Dar es Salaam is at least 800,000 tonnes, with an upper limit of 950,000 tonnes.

4.2 How much is the Dar es Salaam charcoal market worth?

At an average retail price of TZS 776 / kg, the Dar es Salaam household charcoal market is worth between TZS 621 billion – TZS 737 billion (US$ 272 million – US$ 323 million) per year. As outlined above, the area of greatest uncertainty relates to the value of the commercial trade.

4.3 How have prices and trade volume changed over the last decade?

It appears that the volume of trade has increased while the inflation-adjusted price has fallen over the last decade. The current market value of US$ 272 million – US$ 326 million is less than the market value estimated by the World Bank (WB) 2009 study[29]. Our 2018 study found a charcoal price of TZS 776 US$ 0.34)/kg (see 3.2.1 for details on how this is calculated). The WB 2009 study estimated the price to be US$0.70 /kg. This appears to reflect a fall in the inflation-adjusted price of charcoal. The inflation-adjusted price of charcoal increased from US$ 0.20 / kg in 2002 to US$ 0.65 / kg in 2006. The rapid price increase followed a two-week charcoal ban in 2006. After 2006, more traders entered the market and, by 2009, the price fell again to US$ 0.44 / kg[30] [31]. By 2013, there was an increase in price to TZS 750 / kg[32] equivalent to

[29] WB 2009 estimated that the 500,000 tonnes / yr (p. vi) coming into Dar es Salaam was worth US$ 350,000 (p.1). This works out at US$ 0.70 per kg. WB, 2009.

[30] Schaafsma et al. 2012 stated that one 60 kg bag in Dar es Salaam cost on average US$ 21 i.e. US$ 0.35/kg. This has been converted to 2018 prices.

[31] WB 2009 estimated a price of US$ 0.70 / kg however, it is likely that the earlier study over-estimated the price per kg primarily due to uncertainty around the sack sizes.

[32] Camco, 2014. P. 50

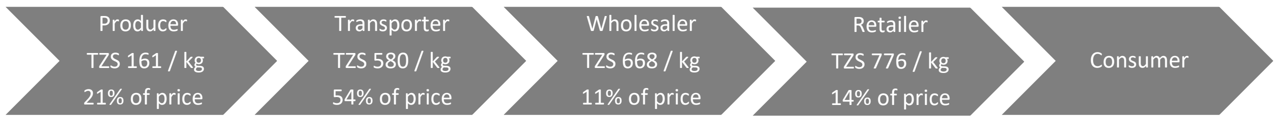
US$ 0.53 / kg (at 2018 prices). Since then it has fallen further to its current price of US$ 0.34 / kg in Dar es Salaam (based on our 2018 field surveys).

Prices are affected by seasonality, quality of the charcoal and charcoal bans. Retailers also highlighted that different buyers are willing to pay different prices and so they adapt accordingly. Scarcity of charcoal was also mentioned by 12% of retailers.

4.4 How is the current charcoal value chain structured and how has it changed over the last decade?

4.4.1 Pricing along the charcoal value chain

The price structure of the charcoal chain shows that 54% of the final price is incurred at the transportation stage; 21% during production; and 25% at the whole sale and retail end of the value chain.



The prices per unit weight and the weights of the sacks being sold, vary significantly at each stage of the value chain with the greatest variability at the production stage (Table 10). In general sack sizes decline along the value chain due to re-packing in preparation for sale to the end consumer.

Table 10. Prices and sack weights along the charcoal value chain in 2018.

	Average bag weight	Max weight	Min weight	Average price sold at	Max price	Min price
	kg	kg	kg	TZS / kg	TZS / kg	TZS / kg
Production	80	100	55	161.41	442.11	52.63
Transporter (lorry)	58	80	30	579.66	1,000.00	400
Transporter (motorcycle + tricycle)	67	100	50	622.85	900.00	400.00
Wholesalers	43	50	36	667.90	1,086.96	520.00
Retail price to consumer	Multiple units are used including sacks, small tins, large tins and plastic bags.			776.03	1,500.00	385.00

4.4.2 Production

Charcoal is made from most woodland tree species. Commonly used species include various species of Brachystegia, Julbernardia and Acacia. Charcoal is also made from planted trees including mango, cashew nut and black wattle (*Acacia mearnsii*) (Malimbwi and Zahabu, 2008). Many woodland trees species will readily regenerate after harvesting through coppicing, root suckers and, to a lesser degree, from seedlings (Malimbwi and Zahabu, 2008; Chidumayo, 1993).

Most charcoal is made from trees on village land. Some charcoal is produced illegally from trees in forest reserves. At least for the last decade, the charcoal supplying Dar es Salaam has been produced as far away as Tabora 830 km to the west, Mtwara 556 km to the south, and Tanga 354 km to the north (Malimbwi and Zahabu, 2008). All of the producers interviewed in the current survey stated that they make their charcoal from woodland trees on village land. No planted trees were used and they were not producing charcoal in forest reserves. The survey did not include producers in Iringa and Njombe, the main source of black wattle charcoal.

Between 35% - 50% of the charcoal that is produced, is produced by households for whom charcoal sales are the main source of income. Nationally, we estimate that there are approximately 60,054 households for whom charcoal sales are the main source of household income (NBS, 2017 and NBS 2018)[33]. Assuming that most of those households are involved in production, rather than retail or transportation, and based on an annual production rate per producer household of 11.29 tonnes[34], their cumulative annual production would be 677,000 tonnes. This is equivalent to 35% of our upper limit estimate of charcoal demand nationally (1.9 million tonnes) or 42% of our lower limit estimate (1.6 million tonnes) for total national charcoal production.

Most producers are farmers who engage in charcoal on a seasonal basis. 49% of the producers interviewed in the 2018 surveys, were primarily farmers while 34% stated that charcoal is their main economic activity. Others were involved in other economic activities such as driving motorbike taxis. Some farmers only engage in charcoal production occasionally when clearing new agricultural land or to meet an urgent cash need (Malimbwi and Zahabu, 2008). Most farmer/producers (> 65%) engage in charcoal production between August to November with less than 30% being active in other months. If we assume that part-time charcoal producers each produce 6.4 tonnes / yr[35] and that they produce between 0.9 million to 1.2 million tonnes of charcoal cumulatively (total production less the amount produced by full-time producers), we can estimate that there are between 144,000 – 191,000 part-time producers **nationally**, of whom we assume that half would be supplying the Dar market.

Most producers do not pay for the wood that they use. Their main cost is labour for cutting and transporting wood; managing the kiln; and packaging and transporting the charcoal sacks. 20% of respondents stated that they had paid the village council for the right to produce charcoal. One respondent stated that they had paid TFS; while another stated that they had paid the District Council.

Most charcoal is produced using basic earth kilns. All of the producers interviewed in 2018 were using the basic earth kilns. Depending on the size of the kiln, each kiln may generate 0.3 – 0.8 tonnes of charcoal, taking up to 14 days. Kilns are situated as close as possible to the trees being harvested. Producers use many different factors to select a production site including tree species availability and avoiding detection if

[33] NBS 2017 p.35-36 indicates that charcoal sales are the main source of household income for 0.6% of households across mainland Tanzania (0.6% of rural HH, 0.8% of urban HH). Taking the NBS 2018 population projections for 2017 of 50,045,131 people in Mainland Tanzania and an average HH size of 5 people / HH (NBS, 2014), this gives a total of 60,054 households for whom charcoal is the **main** source of household income. 67% of people live in rural areas in Tanzania based on https://data.worldbank.org/indicator/sp.rur.totl.zs

[34] This is based on the 2018 field surveys with producers in Morogoro and Coast Region. Van Beukering et al. 2007 estimated that full-time producers produce around 8 tonnes per year while part-time producers produce on average 5 tonnes per year. Their estimates are likely to be an under-estimate due to their under-estimating the weight of the bags which are stated to be 30 kg (p.6) at the kiln site (although elsewhere bags are stated to be 53 kg e.g. p 24). If we took their 53 kg / bag figure then their estimates would be 14 tonnes / full time producer / year or 9 tonnes / part-time producer / year.

[35] This is based on the 2018 field surveys with producers in Morogoro and Coast Region.

production is illegal. In many cases, charcoal is produced as a by-product of farm clearance, in which case, the suitability and availability of the land for agriculture may be a more important consideration than criteria related to charcoal production. The process of charcoal production is known as pyrolysis. The conversion efficiency of traditional kilns ranges from 10% - 30% (Malimbwi and Zahabu, 2008). Using improved basic earth kilns, the conversion efficiency can exceed 30%, and the pyrolysis rate is increased thereby reducing the number of days for the carbonisation from up to 14 days down to 4 days (Malimbwi and Zahabu, 2008). Whilst kiln type is important, producer skill is even more important. Full-time charcoal producers are, on average 30% more productive than part-time producers based on bags produced per day (van Beukering, 2007). Similarly, the TTCS project found that producer expertise is the most significant factor in determining kiln efficiency. This suggest that efficiency is more a matter of operator skill, and less about kiln type.

Most producers sell their charcoal at the kiln site. Only 3% of producers stated that they sell the charcoal outside of the village themselves. The other 97% of producers sold the charcoal at the kiln site (86% of producers) or in the village centre (11% of producers). Transporters reiterated this pattern whereby 86% of transporters stated that they collect charcoal at the production site, whilst 11% stated that they collect it from the centre of the village where the charcoal was produced. The means of transport, that producers stated was being used to remove their charcoal from the village, were motorcycles (74% of producers) and lorries (78% of producers). Private cars are also used to transport charcoal from the village or production site (6% of producers).

4.4.3 Transportation

Most charcoal is transported into Dar es Salaam on lorries and motorcycles. There has been a significant shift from bicycles to motorcycles over the last decade. Whilst Malimbwi and Zahabu (2008) indicated that 11% of charcoal was transported to Dar es Salaam by bicycle in 2007, by 2018 bicycles have been largely replaced by motorcycles and, to a lesser extent, motorised 3-wheel vehicles. This change may reflect the lifting of a previous ban on using motorcycles for charcoal transportation, as well as the increased availability of low-cost motorcycles in Tanzania during that time period[36].

Charcoal transportation is the main economic activity for the majority of charcoal transporters. In the 2018 surveys, 85% of the transporters stated that transporting charcoal was their main economic activity and only 20% stated that they transported other products on their return journeys. On average they had been involved in the charcoal trade for 6.4 years. Transporters using lorries had been involved for longer (on average 9.4 years) compared with those transporting charcoal by motorcycle (3.8 years). For those transporting charcoal by motorcycle, 100% stated that it was their main economic activity, whilst 26% of charcoal lorry drivers stated that transporting charcoal was not their main economic activity.

Most transporters are self-employed. The majority of transporters (79% of lorry transporters, 75% of motorcycle transporters) stated that they were not employed by anyone else to transport the charcoal. Ownership of the means of transportation by the driver, is higher among motorcycle transporters (60%) than among lorry transporters (32%). 50% of the lorry transporters stated that the owner of the lorry has more than three lorries involved in charcoal transportation suggesting that there are many small and medium sized enterprises involved in the charcoal trade. In some cases, transporters have well-established links with producing communities. For example, 44% of transporters stated that they usually purchase charcoal from

[36] The number of motorcycles in Tanzania increased from 308,412 in 2010 to 1,047,659 in 2016. https://www.thecitizen.co.tz/News/New-curriculum-for-training-motorcyclists-now-launched/1840340-3099526-75gnrf/index.html

the same village. However, there was no evidence that the supply is controlled by any single, or cluster of enterprises, rather there seem to be multiple entities operating independently.

On average lorries carry 6.78 tonnes of charcoal per trip and motorcycles carry 0.2 tonnes (four 50-kg sacks). Taking Malimbwi and Zahabu's 2008 estimate that 84% of charcoal is transported on commercial vehicles, we can estimate that between 270 – 320 lorries enter Dar es Salaam each day carrying charcoal.

4.4.4 Wholesale

Most wholesalers are small self-employed businesses focused on charcoal sales[37]. The mean age is 30 years and on average the respondents had been in the charcoal business for 4 years. 29% were women. Wholesalers generally sell charcoal by the sack, either directly to consumers or to retailers for re-packaging for sale in smaller quantities. On average wholesalers sold approximately 8 tonnes per month. Since only 7 wholesalers were interviewed, these figures are indicative only.

Wholesale charcoal is usually transported to the outlet in large lorries, and occasionally from motorcycles (14% of wholesalers buy from both lorries and motorcycles). A few wholesalers (28%) buy regularly from the same transporter but most buy from a range of different suppliers. Only one of the wholesalers exceeded the TZS 40 million TRA threshold in terms of turnover (see 4.6.7 for details on the implications of this threshold). None of the wholesalers provide Electronic Fiscal Device (EFD) receipts. 71% stated that they have some kind of permit, most frequently (80% of wholesalers) this was a trader's licence from TFS, while 60% stated that they have a business licence from the Municipality.

Most wholesalers (83%) stated that they are selling charcoal from black wattle coming from Njombe and Iringa. Only 43% of the wholesalers stated that they sell any charcoal from natural forests. Iringa and Njombe were the main sources of charcoal for wholesalers. Other source areas include Tanga, Rufiji, Bukoba and Kisarawe.

4.4.5 Retail

Most retailers are small self-employed businesses focused on charcoal sales[38]. The mean age is 36 years and on average the respondents had been in the charcoal business for 7.36 years. 36% were women. Retailers sell charcoal directly to consumers in a wide range of quantities from small plastic bags to sacks.

Most retailers buy their charcoal from transporters delivering directly to their shop (56% of retailers). Purchasing from wholesalers is also common (44% of retailers). In other cases, retailers buy from transporters at some other location, not their shops (16% of retailers) and 8% purchase directly from a production site (*shambani*). The charcoal is usually transported to the shop in small or large lorries. Cars, motorcycles, bicycles and wheel barrows are also used for this step in the journey. Some retailers (40%) buy regularly from the same trader.

The average annual turnover for a charcoal retailer is TZS 18 million. The turnover for 12% of retailers exceeded the TZS 40 million TRA threshold. None of the retailers provide Electronic Fiscal Device (EFD)

[37] In the WB 2018 field survey, 100% of wholesalers stated that charcoal was their main source of income. 57% stated that they were self-employed.
[38] In the WB 2018 field survey, 96% of retailers stated that charcoal was their main source of income. 72% stated that they were self-employed.

receipts. On average retailers sell 1.5 tonnes per month. This ranges from 0.3 tonnes / month to 10 tonnes / month.

Most retailers do not have business licences or trader permits. 28% of retailers stated that they had some kind of permit. Those retailers that had permits generally stated that they had two or three different permits. The permits that retailers mentioned most frequently were TFS charcoal trader permits (24%) and TRA certificates (20%). 16% stated that they had a business licence from the Municipality. Larger traders, and those in Temeke and Kinondoni, were more likely to have permits than the smaller traders and those in Ilala.

Charcoal from natural forests is sold by most retailers (72% of retailers). Wattle charcoal from Iringa and Njombe is also commonly sold (40% of retailers). The wattle charcoal is no cheaper than natural forest charcoal. Cashew nut tree and mango tree charcoal were also relatively common. While wattle charcoal seems to be sold more commonly through wholesalers, the value chain for the natural forest charcoal appears to flow more directly from transporter to retailer. Commonly cited source areas include Rufiji (36% of retailers), Tanga, Mkuranga, Kisarawe, Handeni and Morogoro. Approximately 5% of charcoal is lost to the value chain as dust during the retail / wholesale process. (Gmunder, 20140).

Most retailers stated that the situation was harder in October 2018 than in 2017 due to a decline in charcoal availability and customers. They also stated that the price of charcoal has increased.

4.5 Are consumers getting a fair deal?

There is high variability in the price that consumers pay per joule of energy for charcoal, with the poorest households paying the highest prices. Whilst we found an average retail price of TZS 776 / kg, this ranged from TZS 385 / kg to TZS 1,500 / kg. Given that the energy value of a piece of charcoal is proportionate to its weight, it is in consumers' interest to purchase by weight rather than volume. However, charcoal is currently sold by volume to consumers. We found that the weight of charcoal in a 10-litre bucket (a commonly used unit of sale) can vary from 2.8 kg to 4.2 kg, and that the price per kg can vary from TZS 385 / kg to TZS 1,071 / kg. If we convert this to megajoules, this would translate to a price range of TZS 44 / MJ to TZS 123 / MJ. The variability and the cost are greatest for the charcoal sold in small amounts in plastic bags. Households who buy charcoal in plastic bags are paying on average TZS 831 / kg, one third more than those purchasing by sack where the mean price is TZS 561 / kg. The highest prices, TZS 1,429 / kg, are being charged to the small-unit purchaser. Since it is generally the poorer households who buy in small quantities, it seems likely that the poor are paying the highest price for their charcoal (Table 11).

Table 11. Prices per kilogram of charcoal in retail outlets in Dar es Salaam.

Value	Unit	10 litre bucket n = 15 retailers	20 litre bucket n = 2 retailers	Sack n = 7 retailers	Plastic bag n = 17 retailers
Variability in the price per kg of charcoal sold per bucket / sack / plastic bag					
Average price per kg	TZS / kg	755	938	561	831
Maximum price per kg	TZS / kg	1,071	1,000	947	1,429
Minimum price per kg	TZS / kg	385	875	400	455
Range in price per kg	TZS / kg	687	125	547	974

Value	Unit	10 litre bucket n = 15 retailers	20 litre bucket n = 2 retailers	Sack n = 7 retailers	Plastic bag n = 17 retailers
Variability in price per bucket					
Average price per bucket	TZS / bucket	2,567	7,500		
Minimum price per bucket	TZS / bucket	1,000	7,000		
Maximum price per bucket	TZS / bucket	4,000	8,000		
Range	TZS / bucket	3,000	1,000		
Variability in weight of charcoal sold per container (bucket / sack / plastic bag)					
Mean weight per container	kg / container	3.44	8	73.04	1.5
Max weight per container	kg / container	4.2	8	100.0	2.6
Minimum weight per container	kg / container	2.8	8	47.5	0.7
Range	kg / container	1.4	-	52.50	1.9

4.6 Royalties and other government revenue from charcoal

4.6.1 Overview of revenue collection

Revenue collection has been designed to generate payments from actors at each stage of the value chain. Most revenue is generated at the transportation stage of the value chain. The Government generates revenue from charcoal primarily through collections from transporters / traders made by the Tanzania Forest Services Agency (TFS). District and village governments in producing areas also collect fees, while municipal governments in consumption areas collect business licence fees from those involved in retail and wholesale.

VAT is not collected from charcoal, although charcoal is not VAT-exempt. Although charcoal is not exempt from 18% VAT, TRA do not currently collect VAT from charcoal. One reason that TRA cite for not collecting VAT is that many enterprises involved in the trade are below their revenue thresholds.

Data on the overall contribution of charcoal to government revenues is not collected or published systematically. Each part of government charged with revenue collection mentioned challenges with the current system of revenue collection as discussed below.

4.6.2 Royalties and fees collected by the Tanzania Forest Services Agency

The Tanzania Forest Services Agency was established under the Executive Agencies Act Cap. 245 (R.E. 2009) on 30th July, 2010 through the Establishment Order that was published in the Government Notice No. 269. TFS core functions (URT, 2010) include:

- Establishing and managing central government natural forest and bee reserves;
- Establishing and managing central government forest plantations and apiaries;
- Managing forest and bee resources in general land;
- Enforcing Forest and Beekeeping legislation in areas of TFS jurisdiction;

- Collecting Forestry and Beekeeping revenue;

Revenue types collected by TFS from charcoal include:

Fees payable on non-plantation forest produce

Fees for a bag of charcoal (75 kg per bag) = TZS 16,600 or (TZS 240 /kg) (URT, 2015). This was increased to TZS 250 / kg in 2017 or TZS 12,500 / 50 kg bag (Dos Santos Consultation Interview, October 2018). Of this 95% or TZS 237.5 / kg goes to TFS and 5% or TZS 12.5 / kg goes to local government. These fees are also termed royalties. Charcoal sacks are required to be 50 kg however, this is only partially followed and enforced. Royalties are remitted to the treasury.

Licence fees for forest produce dealers and traders for each site per year

Licence fees to operate a forestry business are paid annually per site between July and September. The rate varies depending on the nature of the business. Currently rates are:

Charcoal Producers: TZS 270,000 (US$ 118) / yr (Dos Santos Consultation Interview, October 2018).

Charcoal Dealers: TZS 256,000 (US$ 112) / yr. Source: URT, 2015. The Forest (Amendment) Regulations.

Transit pass application fees Source: URT, 2015. The Forest (Amendment) Regulations.

Transit passes are required for the transportation of forest products. Transit passes are required for each trip from production site to point of sale and are usually valid for 1 – 7 days. The rate varies depending on the size of the vehicle as follows:

i) For a 7-tonne vehicle or below: TZS 7,500 This was increased to TZS 7,700 in 2017 (Dos Santos Consultation Interview, October 2018). These are usually paid to the TFS District Forest Managers.

ii) Above 7 tonnes: TZS 15,000. This was increased to TZS 15,400 in 2017 (ibid).

Compounding fees can also be collected in respect of illegally harvested natural forest produce. The Forest Act 2002 describes the process of compounding an offence as follows:

95.-(1) The Director or any officer specifically authorised by the Director by notice published in the Gazette may…., if he is satisfied that a person has committed an offence against this Act, compound such offence by accepting from such person a sum of money together with the forest produce, if any, in respect of which the offence has been committed.

Tanzania Forest Fund surcharge. The Tanzania Forest Fund (TFF) is a Conservation Trust Fund established by the Forest Act Cap. 323 [R.E. 2002] under Sections 79 – 83. The sources of funds for the Fund are a levy of 2% of every prescribed fee payable under the Forest Act; a levy of 3% of any royalty payable under the Act[39].

4.6.3 Value of royalties and fees collected by the Tanzania Forest Services Agency

Exact figures on revenues along the charcoal value chain are not available. The value of revenue collected from charcoal is not published by TFS. TFS annual implementation reports do not disaggregate charcoal revenue from other categories of non-plantation forest produce such as timber. No data on charcoal revenues was made available during the current study.

Overall, natural forest products (mainly timber and charcoal) generate 42% - 45% of TFS revenue with the remainder coming from plantation forests (URT 2012, 2013). Some district-level TFS revenue collection reports disaggregate revenue collection figures from different produce type. For example, Kibaha TFS District Forest Management reported charcoal royalties of TZS 186 million for 2017/18 including the 3% TFF levy

[39] http://www.forestfund.go.tz/about/category/overview

(TFS DFM – Kibaha October 2018). Similarly, some TFS zones have specific data on charcoal. The National Charcoal Task Force (NCTF) preliminary report cites cumulative charcoal revenues of TZS 422 million from Lindi, Mtwara and Ruvuma for 2017/18.

Most TFS revenue from natural forests, i.e. excluding plantation revenues, comes from charcoal. Previous studies have found that approximately 62% of royalty revenues from natural forests, come from charcoal, with timber contributing most of the other 38%. Similarly, URT (2010) stated that 44% of forestry revenues in 2006/07 were generated from charcoal. If natural forests contribute approximately 44% of TFS revenues and 62% of that comes from charcoal, we can deduce that approximately one third of TFS revenues comes from charcoal. In 2013/14 TFS collected TZS 26 billion from natural forest products, so we could expect that around two thirds of this is from charcoal, equivalent to TZS 17.3 billion (US$ 7.6 million).

Based on the estimated consumption figures for Dar es Salaam of 800,000 – 950,000 tonnes and taking a royalty fee of TZS 250,000 / tonne[40], TFS revenues should be TZS 200 billion – TZS 238 billion (US$ 88 million – US$ 104 million) from charcoal royalties for Dar es Salaam alone. This estimate excludes charcoal for other urban areas and revenues from other charcoal-related fees. If Dar es Salaam comprises half of the national market then, at a national level, revenues should be closer to TZS 400 - 476 billion (US$ 176 – US$ 208 million). Data from 2013/14 suggest that actual revenues (TZS 17.3 billion) are less than 10% of the amount due. Whilst some of the data that is needed to calculate the value of the revenue leakage is not available, it is clear that there is significant revenue leakage in the charcoal sector, probably in the order of 90%. This finding is similar to that of previous studies (e.g. van Beukering, 2007). Whilst corruption may cause some revenues to be collected but not remitted, the low price of charcoal suggests that there is widespread evasion of official and unofficial fees.

4.6.4 Challenges with TFS revenue collection from charcoal

During our stakeholder consultation, various challenges were mentioned by TFS and other stakeholders in relation to the current revenue structure and collection system. These are challenges, as perceived by stakeholders. In most cases, data is not available to determine the scale of these challenges. These are outlined below:

Compliance issues

Non-compliance with existing laws and regulations including the following:

Many charcoal dealers are not registered. Charcoal dealers and transporters are required to pay a registration fee per site per year (Forest (Amendment) Regulations, 2015). This costs TZS 256,000 / yr. Each dealer is supposed to have a defined area of operation and collection point (yard). In our interviews with transporters, 50% stated that they have a transporter licence. The rate of stated compliance was lower (35%) amongst motorbike and tricycle transporters than amongst those transporting charcoal by lorry (63%). The licence was not verified so the actual rate may be different. Non-compliance with this regulation was raised as an issue during consultation with TFS representatives.

Some charcoal is transported into the city at night making it difficult for revenues to be collected by TFS. The law requires that dealers transport charcoal during the daytime, however Municipal authorities deny entry to charcoal lorries during the daytime to reduce traffic congestion. This contributes to evasion of royalty payments.

[40] Based on TZS 250 / kg x 1000 = 250,000 / tonne. Then multiplying 840,000 tonnes by TZS 250,000 = TZS 210 billion

Some charcoal does not pass through the natural resource checkpoints. Transporters are aware of the location of the natural resources check points. Some avoid the check points by taking alternative routes into the city.

Only lorries are inspected at checkpoints. Many charcoal traders use motorcycles that evade revenue collection.

Under-stating charcoal loads. Some transporters under-state the quantity that they are transporting. They pay royalties for some but not all of the charcoal in their lorry.

Re-use of permits. In some cases, permit documents are re-used.

Other challenges that were raised by stakeholders include:

Corruption among staff involved in revenue collection including embezzlement of revenues.

Inadequate working tools, staff and resources to facilitate revenue collection in some areas, including electronic revenue collection tools.

Inconsistencies and weak cooperation between TFS District Forest Managers and the District Forest Officers.

Inconsistent packaging and charcoal bag sizes making it difficult to calculate accurately the revenue that is due on a charcoal load.

Inconsistency in enforcing licensing requirements for traders and producers. Enforcement of the requirement for traders and producers to be registered and to pay a license fee is not applied consistently. This is a source of frustration and mistrust in the system, particularly amongst traders.

Compliance rates

During the 2018 survey, producers and transporters were asked which fees they currently pay. Royalties and District cess are the fees most regularly paid (Table 12). Depending on who is financing the charcoal production process, and at which stage in the process the royalties are being paid, either the producer or the transporter may pay the royalties.

Table 12. Compliance rates based on producer and transporter interviews.

	Charcoal Producer Licence	Charcoal Transporter Licence	Royalties	Transit Permit	District Cess[41]	VAT
Transporters	N/A	50%	78%	47%	89%	0%
Producer	11%	N/A	17%	3%	17%	N/A

Structural issues with the royalty system

Inconsistency between revenues that are charged by kilogram and prices for consumers which are based on volume. The density of charcoal varies significantly, depending on the wood that was used to produce the charcoal. While traders are paying revenues on the basis of weight, charcoal is sold by volume. So, the

41 Cess is a tax that is charged by Local Government Authorities on agricultural produce. Cess rates are prescribed in Local Government by-laws.

price of a tin of charcoal weighing 4 kg might be the same as a tin weighing 2 kg, given wood density differences. The heavier charcoal would have paid double the royalties of the lighter charcoal but the price paid by the consumer would be the same. This is perceived to be unfair by traders.

Requirement to pay multiple fees to different authorities discourages some traders from continuing with the business. The requirement to pay multiple fees to TFS and local government comprises a transaction cost which makes compliance expensive both in terms of the fees, and the time and effort required to comply.

The current system of revenue collection embeds a disincentive for TFS to support sustainable charcoal production on village land. This undermines community-based forest management, the main policy tool available to address deforestation on village land and promote rural employment in the forestry sector. Approximately one third of TFS revenues come from charcoal. Most of the charcoal comes from village land for which TFS has no management mandate. If communities establish community-based forest management, the right to collect and retain revenues falls to the villages. This is based on the Section 78 (3) of the Forest Act 2002 which states that '*No royalties shall be required for the harvesting or extraction of forest produce within a village forest reserve or a community forest reserve by the resident of the village*.' TFS staff have expressed concern about the potential impact that the expansion of CBFM could have on their overall revenue. Some TFS staff would prefer to see TFS's mandate expanded to cover all forests given the expertise in forest management within agency. This systemic conflict of interest has stalled the expansion of CBFM. It could be avoided by re-setting TFS royalty targets only to reflect the potential revenues from forest produce from productive Central Government Forest Reserves while supporting local government to work with communities to establish and implement CBFM. Currently, TFS royalty targets are based on historical revenues, of which a majority are generated from forest produce harvested unsustainably from village land forests.

Charcoal is taxed lower than timber per unit of biomass. 1 kg of charcoal (equivalent to 0.00752 m^3 of wood (air-dry)) is charged royalties at TZS 240 / kg, this is equivalent to 1 m^3 of wood used for charcoal being charged at TZS 31,915. This compares with the fees charged for timber which range from TZS 264,960 / m^3 for Class IA down to TZS 88,320 / m^3 for Class IV (Other species not listed under Classes (I to III). This means that even for the lowest class of tree species, the charcoal tax is 2.5 times less per m^3 than for timber. The lower royalty rate per for charcoal may favour conversion of timber-grade wood to charcoal, rather than timber. GAI, 2014 estimated that, in the Southern Zone, charcoal royalties generate 10% of revenues but the volume of charcoal that generated these revenues represents 80% of trees harvested. The rationale for the lower rate for charcoal is that sawn timber is a high value product that can only be produced from mature trees while charcoal can be produced from much younger trees and a wider variety of species, so supply is more abundant and regrowth is faster. In addition, the proportion of a tree's biomass that is used for timber is likely to be far less than the proportion used for charcoal production. So, it seems reasonable that the charge should be lower per unit of volume for charcoal than timber as long as this doesn't create any perverse incentives to turn timber-grade trees into charcoal

Stakeholders are supportive of more transparency in the forestry sector as a whole. In a study by Green Advocates Initiatives (GAI, 2014), government and private sector expressed support for the forestry sector to be integrated in the Extractive Industries Transparency Initiatives, as a way of improving governance and adding value to the sector.

4.6.5 TFS initiatives to improve revenue collection

TFS recognises many of the challenges associated with revenue collection and is implementing measures to address these. Some changes that are being made include:

- Awareness raising on forestry regulations and compliance amongst actors along the value chain;
- Building a good rapport with other state and non-state actors involved in the charcoal value chain;
- Establishment of charcoal trading points;
- Stricter enforcement of trader licencing;
- Adoption of technological solutions to improve revenue collection, including integration of payments in the Government Electronic Payment Gateway System;
- Adoption of new product and revenue tracking technology along the charcoal value chain;
- Use of Electronic Fiscal Device machines and mobile payments;
- Research and consultation towards improved and standardised charcoal packaging;
- Research on the charcoal value chain through the National Charcoal Task Force.

4.6.6 Local government revenue collection

Local Government Cess: Based on the Local Government Act No. 9 of 1982, Local Government Authorities can charge a levy of 5% of the royalties charged by the central government. This is equivalent to TZS 12.5 / kg. In effect, TFS take 95% of the royalty while local government should be paid 5% of the revenues from products harvested in their respective district.

Local government tree planting levy: Districts can charge a tree planting levy worth 5% of the royalty i.e. TZS 12.5 (US$ 0.005) / kg. This is charged in addition to the TZS 250 (US$ 0.11) / kg royalty collected by TFS. These funds are retained by the district for use in tree planting. They can be collected by the TFS District Forest Manager on behalf of the District Forest Officer.

Local Government Charcoal bag fees – local government can establish by-laws requiring an additional fee on charcoal produced in their district. For example, Kibaha District charges TZS 1,600 (US$ 0.70) per 50 kg bag.

Business licences in the municipalities – in urban areas where charcoal is being sold and used, municipal councils collect business licence fees from traders.

4.6.7 The role of the Tanzania Revenue Authority in the charcoal trade

Value Added Tax is not collected on charcoal. Similarly, under the presumptive tax system of the Tanzania Revenue Authority, it is assumed that charcoal trader annual returns do not reach the TRA threshold of TZS 4 million (US$ 1,754) / yr for individual income tax. TRA consider most charcoal dealers as falling under the informal sector business category. TRA are currently working with relevant government authorities such as MNRT and TFS, in formalizing the business. This includes identifying charcoal dealers; providing them with necessary education and awareness on tax; and registering them. It is still at an early stage and has so far proved challenging due to the informality of the trade; the absence of permanent business premises; and the small scale of most operations. TRA's 2018/19 strategic plan places emphasis on training and capacity building for stakeholders on taxes and revenue streams (Source: Stakeholder Consultation with TRA, October 2018).

Under the current system enterprises are heavily penalised for growth and formalisation. The more formalised and larger a charcoal enterprise becomes, the higher the proportionate tax burden. For example, once a charcoal or other forestry sector enterprise exceeds TZS 40 million (US$ 17,544), it is required to pay a suite of additional taxes to TRA and NSSF including Corporate Income Tax, 'Pay As You Earn', the Skills and Development Levy and NSSF contributions (GAI, 2014). This can act as a barrier to formalisation, professionalisation, investment and growth. Provided enterprises keep below the TZS 40 million (US$ 17,544) threshold they can proceed to trade charcoal (or any other product) in a low-tax environment.

4.7 Government revenue from other urban household energy fuels

Taxes charged on other household fuels include Value Added Tax which is charged at 18% of the retail price on electricity and briquettes. A petroleum levy is charged when kerosene is imported. The rate for the petroleum levy rate is set annually. For 2018/19, it is TZS 465 (US$ 0.20) / litre, equivalent to 21% of the retail price. For electricity two additional levies are charged: 1% is paid towards the Energy and Water Utilities Regulatory Authority (EWURA) and 3% is paid towards the Rural Energy Agency. There are no direct charges on LPG. In Table 13, the direct revenue to the government per megajoule of energy to the consumer for each fuel type is compared. The highest rates are for ethanol and briquettes while LPG is exempt from these direct revenues. Charcoal, electricity and kerosene have comparable rates at TZS 30 – 32 / MJ.

Table 13. Direct taxes and fees paid on urban household energy fuels.

	VAT	EWURA (1%) + REA (3%)	Petroleum levy	Royalties*	End use cooking efficiency	Government revenue in TZS per MJ
Ethanol	18%	0%		0	14.95 MJ/litre	71.04
Briquettes	18%	0%		0	4.35 MJ/kg	66.21
Kerosene	0%	0%	TZS 465 / litre	0	14.5 MJ/litre	32.02
Electricity	18%	4%		0	2.52 MJ/kW·h	31.08
Charcoal	0%**	0%		TZS 262.5 / kg	8.7 MJ/kg	30.17
LPG	0%	0%		0	27 MJ/kg	0

*TZS 250 / kg. Of which 95% goes to TFS; 5% to LGAs. Plus TZS 12.5 / kg LGA tree planting levy
** As outlined previously, although charcoal is not exempt from VAT, it is not applied hence we consider it as 0%.

In addition to these direct levies, corporations pay 30 % corporate income tax on profits plus employment taxes on all salaries. Individual income tax is based on variable rates. For incomes above TZS 720,000 per month, it is 30 %. The Skills and Development Levy is an additional employment tax charged at 5% of the basic salary. Employers are also required to contribute to the National Social Security Fund at a rate of 10% of the basic salary. LPG, briquette and ethanol producers are all required to pay these levies and taxes while TANESCO pays employment taxes.

Charcoal producers and traders do not pay these income and payroll taxes. When taking these additional taxes into consideration, it is clear that the taxation structure generates significantly more money for the government per megajoule of energy from ethanol, briquettes, kerosene and electricity, than from charcoal. In the case of LPG, whilst it contributes less per MJ than kerosene, briquettes and ethanol, a more in-depth analysis would be needed to compare its corporate and employment tax contributions with the value of the direct fees on charcoal. The higher tax burden on briquettes, ethanol, electricity and kerosene contribute directly to their higher cost per unit of energy. The higher cost is partly linked to lower demand for these products. Reviewing the taxes and levies on different urban cooking fuels to make them more competitive with charcoal, would encourage more households to make more use of these fuels.

5. BIOMASS PRODUCTION FOR CHARCOAL: COMPARING OPTIONS

5.1 How much woody biomass is needed to supply charcoal to Dar es Salaam?

Between 4.2 - 5 million tonnes of dry biomass are needed annually to meet Dar's current charcoal demand. This assumes a 19% conversion rate of dry biomass to charcoal (Camco, 2014; CHAPOSA 2002), and based on a current demand estimate for charcoal in Dar es Salaam of between 800,000 tonnes and 950,000 tonnes. We have taken a moderately efficient conversion rate. With improved carbonisation procedures, the rate could increase up to 30% (CHAPOSA, 2002).

5.2 Current and potential sources of woody biomass for charcoal production

Natural woodland on village land has the highest potential for sustainable charcoal production based on current biomass stocks. There are three main categories of charcoal in the market currently: natural woodland charcoal; black wattle charcoal; and charcoal from agroforestry trees, particularly mango and cashew nut trees. Comparing the area of land currently existing under those three systems, natural woodlands on village land cover 21.9 million ha compared with 1.3 million ha agroforestry and 6,000 ha of black wattle (Table 14). This includes the woodlands that also supply firewood for rural households. The potential current charcoal yield is broadly reflective of the findings of the transporter and retailer surveys where natural forest charcoal was the main charcoal type being traded, with smaller amounts of black wattle, mango and cashew nut tree charcoal. Although the area of black wattle is 0.03% compared with the area of natural woodland, 40% of retailers and 83% of the wholesalers stated that they were selling black wattle charcoal. The amount of black wattle charcoal in the market appears to exceed the potential supply (~10,659 tonnes). This could be due to 'laundering' of charcoal from small natural woodland trees as black wattle to evade forestry royalties or an anomalous spike in the supply at the time of the surveys.

Disregarding the economics, just to provide the necessary biomass for agroforestry or black wattle to supply Dar's charcoal demand, they would need to be expanded four-fold for agroforestry or approximately 80 times, in the case of black wattle.

5.3 Can miombo woodlands be managed sustainably to supply charcoal?

There are many ways to define sustainability. When discussing sustainability, we follow the SE4ALL approach (Section 1.1). As SE4ALL follow the UNFCCC Clean Development Mechanism definition, this provides an internationally recognised reference point, as well as one already applied in Tanzania. This is based on three principles: the land remains as forest; sustainable management practices are undertaken to ensure no systematic decrease in carbon stock; and compliance with national and regional forestry regulations.

To supply Dar es Salaam, would require at least 3 million hectares of woodland to come under sustainable production, approximately 14% of the remaining woodland on village land. Assuming that Dar's demand is 50% of the national demand, to meet national demand would require at least 6 million ha or 28% of the remaining woodland on village land. There are already an estimated 1,233 villages practising CBFM with Village Land Forest Reserves (VLFR) covering 2.3 million hectares with an average VLFR area of 1,865 ha (URT-MNRT 2012). Assuming that 60% of that area (1.4 million ha) could be supported to integrate sustainable charcoal production, it would require an additional 4.6 million hectares, involving approximately 2,500 villages (assuming a mean VLFR area of 1,848 ha). If charcoal demand were reduced to 198,000 tonnes

/ yr for Dar es Salaam (368,000 tonnes nationally) by 2030 (see Section 8.2 Overall energy targets for Dar es Salaam), then only approximately 1,500 villages would need to be involved.

Table 14. Comparison of the area of woodland, black wattle and agroforestry areas that would be required to meet Dar es Salaam's demand for charcoal with current areas.

Biomass category	MAI in tonnes biomass / ha / yr a	Biomass to charcoal conversion efficiency rate [42] b	Annual charcoal yield in tonnes charcoal / ha / yr c (=a*b)	Area (ha) to produce 800,000 t of charcoal 800,000 t/c	Area (ha) to produce 950,000 t of charcoal 950,000 t /c	Current area Ha d	Potential charcoal yield based on current area t / yr d*c
Natural woodland on village land	1.40[43]	19%	0.27	2,962,963	3,518,519[44]	21,908,274[45]	5,915,234
Black wattle	9.35[46]	19%	1.78	449,438	533,708	6,000[47]	10,680
Agroforestry trees	0.75[48]	19%	0.14	4,714,286	6,785,714	1,373,000[49]	192,220

With 22 million ha of woodland on village land in 2018 and even assuming a constant annual deforestation rate of -1.3%, there would still be 18 million ha of woodland remaining on village land by 2030. If approximately 1.43 million hectares were managed for sustainable charcoal production, 16.57 million ha would remain available to meet other ecological, social and economic needs.

Managing woodlands sustainably for charcoal production is best understood for miombo woodlands. Charcoal can be produced without permanently deforesting or degrading a forested area, by protecting harvested areas from cultivation, intensive grazing, and fire, thus enabling natural regeneration. Miombo woodlands are a disturbance-tolerant ecosystem in which fire plays a complex and defining role. Miombo species readily regenerate from root / stump sucker shoots, or from coppice shoots from stumps and even branches. To a lesser degree, regeneration also occurs from seedlings present in the grass layer, and from seeds. Miombo woodland is remarkable in its capacity to tolerate disturbance, including tree cutting. Provided that stumps, roots, seedlings, and seed sources are retained, the woodland will naturally regenerate. Management practices can be fine-tuned to enhance the regeneration process.

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[42] Conversion rate used by Camco 2014 and 2002 CHAPOSA report. The conversion rate can range from 10% - 25% depending on a number of factors, particularly the skill of the producer.

[43] Equivalent to 1.65 m^3 / ha / yr assuming a volume : weight of 1 : 0.85 based on CHAPOSA 2002 report (p. 59). Chidumayo 1993 also estimated a mean annual increment of biomass in coppice woodland ranging from 1.2 to 3.4 tons ha–1yr–1. The MAIs may over-state the amount of wood available for charcoal, as some of the growth will be leaves, branches and stump, which will not be usable.

[44] This is comparable to the area estimated in the 2002 CHAPOSA report p. 59 estimated that to produce 471 000 tonnes. With a kiln conversion efficiency of 19%, 2 million tons of wood are required annually to produce this charcoal. This is equivalent to about 2,3 million m^3 of wood at a weight/volume ratio of 0,85. At a mean annual increment of about 2,4 m^3/ha/yr, it would take the growth of 1 million hectares to produce the wood needed annually. Note that we have taken a more conservative figure for the Mean Annual Increment

[45] URT MNRT 2015 NAFORMA Report. P.40 Table 4.7. Forest and Woodland on Village land = 21,908,274 hectares

[46] UNIQUE 2017. Give a MAI of 11.1 m3 / ha. We have converted this to tonnes at a ratio of volume : weight of 1 : 0.85 based on CHAPOSA 2002 report (p. 59).

[47] Based on UNIQUE 2017. P8 TANWAT Limited area of *Acacia mearnsii* plantation.

[48] URT MNRT 2015 NAFORMA Report. Page 46Table 4.9. Estimated increment per year m3 / ha. Agroforestry systems. Converted to tonnes at 0.85 ratio. See above.

[49] URT MNRT 2015 NAFORMA Report. Page 34 Table 4.3. Area of agroforestry system in hectares.

Table 15. Area of CBFM required to meet current and 2030 charcoal demand.

	Total area required million ha*	60% of the total area currently under CBFM[50] million ha	Additional area required under CBFM to meet 2030 demand million ha
2018 demand in Dar assuming 0.8 million tonnes of charcoal / yr	3	1.4	1.6
2018 demand nationally assuming 1.6 million tonnes of charcoal / yr	6	1.4	4.6
2030 demand in Dar assuming 0.19 million tonnes of charcoal / yr	0.72	1.4	0
2030 demand nationally assuming 0.38 million tonnes of charcoal / yr	1.43	1.4	0

*This is the area required for sustainable charcoal production (SCP). It is advisable for the village land forest reserves to be larger than the SCP area to allow for other management zones.

Miombo is found in Central, Southern and Western Tanzania. Estimates of the area of miombo woodland, in Tanzania, indicate that there were approximately 46.3 million ha of wet miombo, dry miombo and wet seasonal miombo in 1984. More recent forest assessments, have not distinguished miombo from other woodland types. The most detailed and recent assessment of woodland area is the National Forest Resources Monitoring and Assessment of Tanzania Mainland (NAFORMA) which recorded 44 million ha of woodland between 2009 – 2014. This includes miombo and other woodland types such as the northern Acacia - Commiphora woodlands. Accurate data on the area of miombo on village land is needed to fully understand the potential for scaling up sustainable charcoal. Further research, using the NAFORMA dataset, could generate an updated estimate of the area, distribution and tenure of Tanzania's remaining miombo woodlands. Miombo woodlands in Tabora, Singida and Kigoma Region are currently a deforestation hotspot due to rapid expansion of agriculture in these areas.

Sustainable charcoal production can reduce deforestation by providing an incentive for communities to retain and manage their forests. If scaled up, sustainable charcoal production could supply Dar es Salaam's charcoal needs whilst generating rural employment, providing finance for rural development projects, and safeguarding other forest products and ecosystem services. Two Tanzanian NGOs, the Tanzania Forest Conservation Group and the Community Forestry Network of Tanzania (MJUMITA) have successfully modelled a system of sustainable charcoal production in Morogoro Region (see Box 1). The authors of this report have been closely involved in this project.

[50] Assumes 40% of the current CBFM area is unsuitable for sustainable charcoal for ecological, economic or social reasons.

Box 1. Sustainable Charcoal Production in natural woodlands in Morogoro Region

Since 2012, the Tanzania Forest Conservation Group (TFCG) and the Community Forestry Network of Tanzania (MJUMITA) have been promoting sustainable charcoal production in Kilosa, Mvomero, and Morogoro Rural Districts. The sustainable charcoal model centres around the Forest Act, 2002, which allows for villages to take ownership over forests on their lands by establishing village land forest reserves (VLFRs).

Under the project model, villages can put up to 20% of their VLFR into forest management units (FMU) for sustainable charcoal production. FMUs for charcoal are divided into 50 x 50 metre harvesting blocks or coupes. The coupes are harvested in a chequerboard pattern over 24 years. The species targeted for charcoal harvesting all naturally regenerate from coppicing, root-suckers, and seedlings. Agriculture, livestock grazing, and burning are prohibited in the FMU to ensure that the harvested coupes will regenerate naturally over 24 years. Only trees larger than 15 cm diameter at breast height are to be cut for charcoal making. Other harvesting restrictions also apply to reduce environmental impact.

Harvesting is regulated by trained village natural resource committee members. Charcoal producers in the villages apply for the right to harvest a particular coupe and pay royalties to the village for each bag of charcoal they produce. They also pay per bag fees to the district council. Charcoal produced by villages adopting the model is sold into the mainstream charcoal market. Under the Forest Act, 2002, resources harvested from VLFRs are exempt from central government forest royalties. Thus, villages can charge their own royalties and still remain competitive in the market.

Villages decide how to spend revenue from sustainable charcoal harvesting in village assembly meetings. Most of the money gets spent on improving local health, water, and education infrastructure, while a smaller portion is spent on forest protection. Examples of projects funded by charcoal revenue since 2014 include building school class rooms, housing for teachers, purchasing school desks, building health clinics, housing for doctors, bringing piped water to parts of villages and adding hand water pumps to boreholes. Some villages have also chosen to spend charcoal revenue on health insurance for all village residents making it free for them to visit local health clinics.

While a comparatively low value forest product, sustainable charcoal can still be a good source of revenue for villages. Between June 2013 and December 2017, 13 village governments earned a combined total of US$ 203,000 from charcoal royalties. In addition to generating income for villages, the model is also helping to protect forests. As of December 2017, 27 villages adopting the sustainable charcoal model have put 109,540 ha of forests into village land forest reserves and deforestation has declined steadily since the introduction of the model (see section 6.3 for more details).

All sources of revenue contribute to the sustainability of community-based forest management (CBFM) and this encourages villages to put more forest into VLFRs. However, charcoal has some particular advantages. The market is local and relatively easy to access. Charcoal production is non-technical and requires little starting capital. Charcoal harvesting is easier to monitor and manage than timber harvesting. Sustainable charcoal harvesting can often be started within one year of starting the process of establishing CBFM. Thus, sustainable charcoal harvesting may be the easiest source of revenue for CBFM villages to develop and can play a very important role as an early source of revenue to depend on while villages develop other sources of revenue from CBFM.

Some stakeholders are sceptical of the potential for sustainable charcoal production to function independently of donor-financed support mechanisms. During our stakeholder consultation, we asked stakeholders for their opinions on the potential for sustainable charcoal production to operate in the context of community-based forest management. Several respondents were familiar with the TFCG / MJUMITA project in Morogoro Region. Some agreed that the basic model was good, however concerns were raised around: sustainability, governance, reduced incomes to TFS, conflict between communities and government over revenue collection, conflict and weak governance within communities that could undermine the sustainability of the management system, and short project timelines. This was the only model for sustainable lump charcoal production that was mentioned although many were also familiar with the *Mkaa Endelevu* briquette initiative. Many of the risks raised by stakeholders could be mitigated by bringing all production up to the standards modelled by the communities in the TFCG / MJUMITA project including enforcement of requirements for charcoal to be produced according to sustainable harvesting principles, increased compliance with payment of harvesting and other fees, and transparency around revenue collection. Donor investment in the project has established a model that can be scaled up.

5.4 The role of 'free' biomass in the current system

Under the current system, biomass-for-charcoal production costs need to be zero or close to zero, in order to be commercially competitive. Natural woodlands grow freely while, in the case of black wattle, mango and cashew nut trees, the woody biomass is a bi-product of another value chain i.e. tannin, mango fruits and cashew nuts. The cost of growing those trees is paid for from the income from the sale of the main product i.e. from the sales of the tannin, fruits and nuts. This is how these three categories of charcoal can compete. Similarly, this is the reason why tree plantations specifically for charcoal cannot compete commercially. The price of charcoal is too low to pay for biomass production, except through minimal input natural woodland management.

5.5 Is there a role for plantations specifically for charcoal production?

Plantations have a role to play in supplying biomass for charcoal production where the biomass is a bi-product of another value chain such as tannin or offcuts from the timber industry. Fuelwood plantations and woodlots intended solely to supply urban household cooking fuel have failed repeatedly over the last 60 years because the price of charcoal is too low to cover biomass production through a plantation or woodlot system and because there are other, more lucrative options for the same piece of land, either under forestry or under some other land use. Many authors have recommended tree planting as an alternative to natural forests as a source of biomass for charcoal production and firewood (Lusambo, 2016). Johnsen (1999) provides a history of 20th Century fuelwood plantation and woodlot projects going back to the 1960's. These projects and proposals have continued into the 21st century. During the stakeholder consultation, none of the stakeholders who were interviewed were aware of any successful plantations for lumpwood charcoal, although briquette production using the sawdust bi-product from sawmilling in the southern highlands was mentioned. Reasons that have been cited for the failure of fuelwood plantations include lack of motivation and lack of funds (Johnsen, 1999). These reasons reflect the reality that the price of charcoal is too low to cover biomass production through a plantation or woodlot system and that this reality has changed little since Tanzanian Independence.

The logic that has been used to promote fuelwood plantation and woodlot projects is simple. To stop deforestation from charcoal, an alternative supply of biomass is needed. This can be achieved through tree planting. Foresters have the technical capacity to do this, the species are known, and land can be made available. What is too often overlooked is the business model for these proposals. The question of whether the charcoal produced from these woodlots will be commercially viable, given the current market prices, is not considered. In their enthusiasm to promote tree planting, foresters and donors often pay insufficient attention to the tough realities of the charcoal market.

There are currently at least 325,828 ha of tree plantations in Tanzania (UNIQUE, 2017), of which 100,368 ha are owned by TFS; 51,327 ha by large scale private owners; and 174,374 by small-scale tree growers in the Southern Highlands (ibid). The area owned by small-scale tree growers is an under-estimate and there are additional small-scale tree grower areas in other parts of the country particularly serving the tobacco industry in Tabora.

85% of the total plantation area is for pine and eucalyptus (65% and 20% of the total plantation area respectively) (ibid). The remainder of the area is for other conifers (7%), teak (4%) and other broadleaves (4%) including black wattle. Charcoal from pine is of low density and quality, and the only major effort to produce it (at Sao Hill Industries) did not succeed.

Plantations serve five key markets: construction, furniture, paper, power transmission poles and pallets and boxes. If we take the two main plantation crops, pine and eucalyptus, the approximate cost of producing 1 m^3 of wood ranges from TZS 45,000 – TZS 120,000 based on the current price of standing trees i.e. to reach an equivalent stage to trees grown in natural forests (Table 16).

Table 16. Cost of producing plantation biomass.

Item	Unit	Pine	Eucalyptus
Stumpage prices private growers	TZS/m3 standing	80,000 – 120,000	45,000

From UNIQUE 2017. Table 11.

Trees grown in a plantation incur more costs than trees grown in natural woodland therefore biomass from a charcoal-specific plantation will cost more than biomass from natural woodland. We estimate that biomass from a charcoal plantation would cost at least 36% more than biomass from natural woodland. If biomass from plantations were to be converted into charcoal, assuming 1 m^3 biomass = 0.85 tonnes biomass and using a standard carbonisation efficiency of 19%, this would represent an additional cost of at least TZS 279 / kg of eucalyptus charcoal (or TZS 743 / kg of charcoal if we take the price of pine biomass), equivalent to approximately 36% of the current retail price of TZS 776 / kg of charcoal. If biomass losses during processing are considered, the cost is even higher. Assuming that all of the other costs of pyrolysis, transportation etc remain the same, the final price for the eucalyptus charcoal will be at least 36% higher than woodland charcoal. For this reason, charcoal plantations cannot compete with value chains in which the cost of the biomass input is close to zero cost. Whilst recognising that pine is inappropriate for charcoal, the analysis serves to show why plantations for charcoal have repeatedly failed to produce competitively priced charcoal.

6. THE CHARCOAL TRADE: ECONOMIC, SOCIAL AND ENVIRONMENTAL IMPACTS

6.1 Health and social impacts

6.1.1 Health and safety issues along the charcoal value chain

There are a number of health and safety impacts that affect people all along the charcoal value chain. The informal nature of the charcoal trade has meant that charcoal production has not been bound by occupational safety and health regulations and no data is available to determine the scale of the problem.

Charcoal producers

- Risk of accidents associated with tree-felling; lung disease associated with smoke inhalation (Obiebi *et al*. 2017); injuries caused by transporting logs and charcoal bags; disease (malaria, intestinal infections etc) exposure due to poor sanitation while camping close to the charcoal kilns; encounters with dangerous wildlife at, or on the way to, kiln sites; and violent conflict at kiln sites including conflict with pastoralists when cattle damage kilns.

Charcoal transporters

- Road accidents particularly associated with bicycles (Malimbwi and Zahabu, 2008), motorcycles and lorries overloaded with charcoal bags.
- HIV transmission.

Charcoal retailers

- Injuries while carrying bags.
- Exposure to charcoal dust during packaging, weighing and sieving of charcoal is associated with various chronic lung diseases (Hamatui, 2016).

Consumers

Cooking using firewood and charcoal is a major source of household air pollution. Household air pollution (HAP) caused 466,079 premature deaths in Africa in 2013 (Roy 2016). In Tanzania it is estimated that there were 22,729 premature deaths in 2013 equal to 1,053,072 years of life lost due to household air pollution compared with 23,919 premature deaths due to unsafe water (ibid). This highlights that household air pollution is comparable to water quality as a cause of premature death, despite HAP receiving far less attention than unsafe water. Firewood causes more morbidity than charcoal because more people in Tanzania use firewood (72% of households use firewood nationally compared with 25% using charcoal (Camco 2014)) and because cooking with firewood is more harmful than cooking with charcoal.

Biomass smoke includes particulate matter, carbon monoxide and carcinogens such as bonzo(a)pyrene. Micro-particulate matter less than 2.5 microns in diameter are particularly harmful as they can penetrate deep into the lung tissue (Bruce *et al*. 2000). Exposure to biomass smoke causes numerous cardiopulmonary diseases including acute respiratory infections, obstructive pulmonary disease, and various cancers (Bruce *et al*. 2000; Roy, 2016; Dherani *et al*. 2008). Household air pollution has also been linked to neurodegenerative diseases such as dementia, cataracts, low birth weights, increased infant and perinatal mortality, eye diseases, tuberculosis, ear infections and nutritional deficiencies (Das *et al*. 2017; Bruce *et al*. 2000). The primary cook in a household, often a woman, is at greatest risk. Where young children are carried on the back of the cook or spend prolonged periods in the cooking area, the children are also at high risk.

Efficient cookstoves reduce the amount of gas and particulate matter produced by charcoal combustion. Pipes and stacks, when installed, manage to transfer the pollutants outside the household, although this contributes to the more diffuse outdoor air pollution problem.

Comparative data on the proportion of deaths attributable to household air pollution in Tanzania caused by different cooking fuels is not available. Research in neighbouring Malawi found that charcoal stoves produce more carbon monoxide than wood stoves; while wood stoves generate more particulate matter including the micro-particulates that are particularly damaging to lungs (Das *et al*. 2017). Overall wood stoves were found to cause more health problems than charcoal. In comparison, other fuels such as electricity and LPG produce low (LPG) to zero (electricity) gaseous emissions. LPG produces no particulate matter (the most harmful of air pollutants), its combustion yields mostly CO_2, and to a lesser extent, CO and SO_2.

6.1.2 Gender

The gender balance of the charcoal value chain shifts from male-dominated production to female-dominated use. Charcoal production and transportation are mainly, but not exclusively, done by men. More women are involved at the wholesale / retail stage of the value chain, while women are the main users of charcoal particularly for domestic cooking use (Table 17). Nationally, charcoal is the main economic activity for 1.1% of female-headed households, compared with 0.5% of male-headed households (NBS, 2017).

Table 17. Gender of actors along the charcoal value chain based on 2018 survey data.

Role in the charcoal value chain	% women	% men	Sample size n
Producers	11	89	35
Wholesalers	29	71	7
Retailers	36	64	25
Main household cook	91	9	100

6.2 Economic impacts

6.2.1 Employment

Overall, we estimate that between 145,000 and 176,000 people are regularly employed along the Dar es Salaam charcoal value chain. Assuming a household size of 3.9 persons, this would suggest that between 0.57 – 0.69 million people depend on the Dar charcoal trade for their livelihood (see Annex 4).

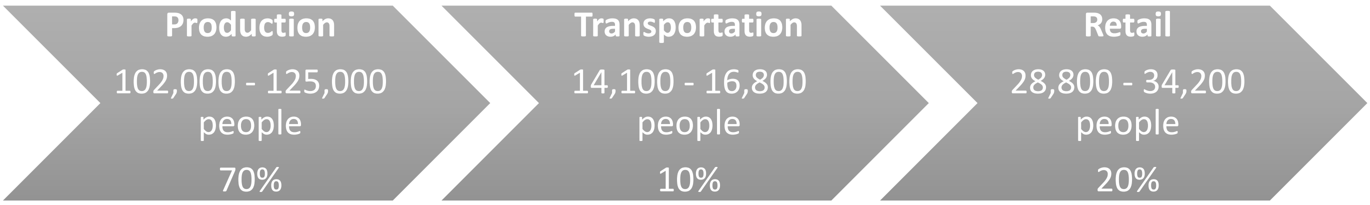


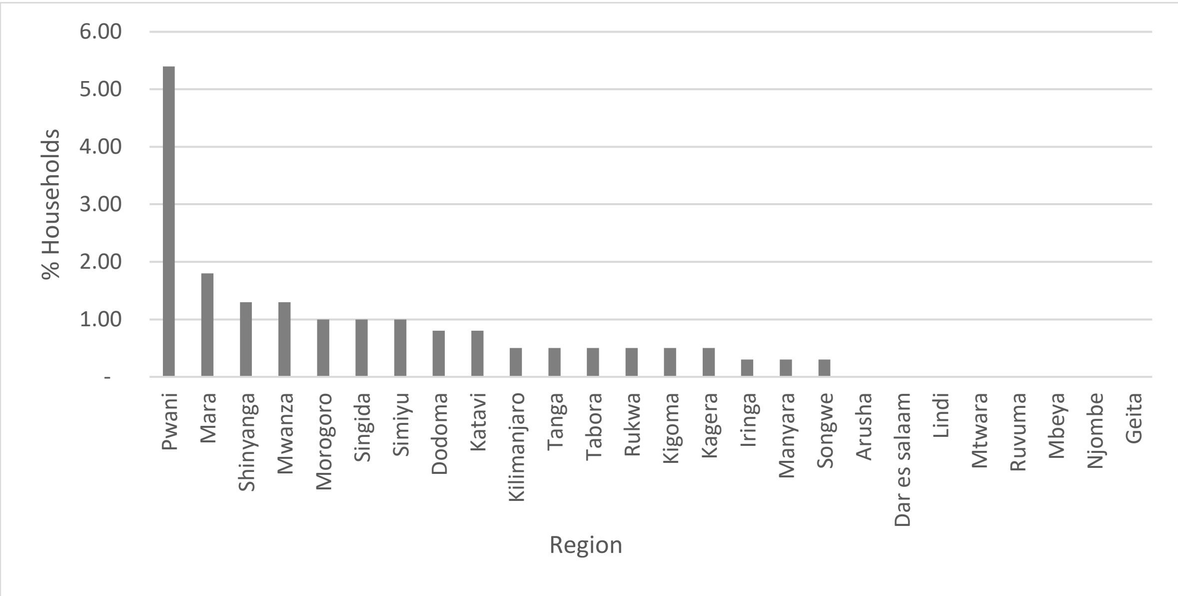
Figure 2. Contribution of each stage of the Dar es Salaam charcoal value chain to employment by number of people employed and as a percentage of the charcoal employment.

Between 102,000 to 125,000 people earn a regular income from charcoal production for Dar es Salaam. Estimates vary on the number of people employed in the charcoal sector. NBS 2017, found that the sale of charcoal was the main livelihood activity for 0.6% of households across the country (0.6% of rural households, 0.8% of urban households) in 2016[51]. Applying this to the 2017 population projections, this would be equivalent to approximately 60,054 households nationally (NBS, 2018). This compares with 51% of households involved in the sale of food and cash crops (NBS, 2017). If each of these households produce 11.29 tonnes per year[52], they can supply 677,738 tonnes per year. This leaves between 0.9 million – 1.2 million tonnes of the total national demand being produced by part-time producers. We found that part-time producers individually produce an average of 6.4 tonnes per year suggesting that another 144,000 – 191,000 people are involved in producing on a part-time basis. In the absence of official statistics on part-time employment in the charcoal sector, these estimates provide an indication of the range of employment figures from 204,000 people to 250,000 people in charcoal production, of whom approximately half (i.e. 102,000 – 125,000 people) would be producing charcoal for the market in Dar es Salaam. The figure would be higher if those producing charcoal irregularly, to meet occasional cash needs, were included. Overall, the production section of the value chain generates approximately 70% of the charcoal-related employment.

Agriculture is the primary economic activity for most part-time charcoal producers. Charcoal production is often a part-time seasonal activity used to supplement agricultural incomes, or to meet emergency cash needs.

Charcoal is the main source of income in > 1% of households in 4 regions: Coast, Mara, Shinyanga and Mwanza. As the main source of income for households, charcoal is most important in Coast Region where 5.4 % of households depend on charcoal sales as their main source of income (NBS, 2017). This is one of the main source regions for charcoal coming into Dar es Salaam.

Figure 3. Percentage of households for whom charcoal is the main source of income disaggregated by region.



Source: NBS 2017. Energy Access Situation Report, 2016.

[51] See Tables 3.21 and 3.22. Energy Access Situation Report, 2016. NBS 2017.
[52] See foot note 33.

Between 14,000 – 17,000 people are involved in transporting charcoal into Dar es Salaam. Taking our upper and lower estimates of charcoal trade volume, and assuming that 86% of charcoal is transported into Dar es Salaam by lorry, and 14% by motorcycle[53]; and that a motorcycle transporter does two trips per week, and a lorry transporter does two trips per month and employs one person to assist on the journey, we calculate that between 5 – 7,000 people are involved in transporting charcoal by motorcycle, and 9,000 – 10,000 are involved in transporting charcoal into the city by lorry. Overall, the transportation section of the value chain generates approximately 10% of the charcoal-related employment.

Between 28,800 – 34,000 people are involved in charcoal retail in Dar es Salaam. Taking our upper and lower estimates of charcoal trade volume, and assuming that each retailer sells an average of 30 tonnes per year and each retail outlet involves an average 1.08 people[54], this would mean that between 28,800 – 34,000 people are involved in retail. Overall, the retail section of the value chain generates approximately 20% of the charcoal-related employment.

Charcoal generates additional employment through stove production. With regular use, the metal, ceramic-lined stoves last 2 – 3 years. Assuming 810,000 households need to replace their charcoal stove every 3 years means that at least 270,000 new stoves are required each year. If each stove cost TZS 10,000, stove production annually comprises a TZS 2.7 billion (US$ 1.2 million) industry.

6.3 Landscape impacts

6.3.1 Charcoal, deforestation and forest degradation

Charcoal production contributes to both deforestation and forest degradation. Deforestation refers to the permanent conversion of forest to non-forest, whilst forest degradation occurs where there is a reduction in woody biomass and ecosystem services, but the land cover remains as forest. Charcoal production may be part of a deforestation trajectory where the land is then converted to another land use, usually agriculture. Where charcoal production occurs in isolation of other human activities, woodland or degraded forest will regenerate. For this reason, charcoal production in isolation of other activities, causes forest degradation but not deforestation. Based on a recent nationwide study, approximately 88% of deforestation and degradation events involved the conversion of forests to agricultural land (TFCG. In prep). This is broadly in line with patterns elsewhere in the tropics (Hosonuma *et al*. 2012). In 30% of these cases, there were signs of charcoal. Where charcoal production is not followed by agricultural production, natural vegetation will regenerate and can reach 3 metres (the official definition of forests according to the Forest Act 2002) within 4 – 5 years. Regeneration on the kiln scars takes longer.

Demand for land, not biomass, is the main driver of deforestation in Tanzania. The amount of deforestation that is caused by people cutting trees for charcoal, firewood and timber is frequently over-stated. In Tanzania, most woodland is cleared because people want land to plant crops. The trees are often just burned to clear the land and release nutrients as fertiliser for the crops.

The National Forest Resources Monitoring and Assessment report provides valuable data on the status of forests in Tanzania. However, there has been considerable confusion about its findings with regard to overall deforestation. The report states that the legally available biomass increment in Tanzania is 42.8 million m^3/

[53] This estimate is based on Malimbwi and Zahabu's 2008 lorry / bicycle estimates and our retailer survey where 16% of retailers stated that they receive charcoal from motorcycles.
[54] Based on the WB 2018 field surveys.

yr[55]. This means that every year, trees outside of protected areas, cumulatively grow by 42.8 million m^3. The NAFORMA study estimated that rural and urban biomass energy demand was approximately 45.3 million m^3/ yr[56]. So, this would mean a shortfall of 2.5 million m^3/ yr. This means that, if the legally available woody biomass was managed sustainably for biomass energy production, it could meet 94 % of Tanzania's biomass energy demand. As a percentage of the wood balance, the net shortfall of 2.5 million m^3 / yr that is attributable to biomass energy demand, only contributes 13% of the wood balance. So, what is causing the rest of the negative balance?

To understand deforestation, a key figure from the NAFORMA report is the 14.9 million m^3/ yr that is lost due to land cover / land use change ('LULC change analysis[57]'). This is the woody biomass that is often just burned or left to decay *in situ* as part of the process of converting forest land to agricultural land. This is equivalent to 76 % of the negative wood balance. In many cases this is a permanent loss of woody biomass as crop cultivation will prevent natural regeneration of forest.

Frequently, this technical, but important, point is overlooked. Instead, there has been a tendency to attribute the whole of the deficit of 19.5 million m^3 / yr to demand for biomass, and from that to conclude that more tree-planting is needed, or more electricity generation, or more LPG (e.g. URT 2016), without looking at the primary deforestation driver i.e. the need for more agricultural land for a growing population dependent on low productivity agriculture.

Degradation due to charcoal production causes irreversible damage in evergreen forests. Tanzania has many different kinds of forest and woodland. These vary in their sensitivity to disturbance. Forests with the highest biodiversity values, including the Eastern Arc Mountain and Coastal Forests, are most sensitive to disturbance. Many Coastal Forests have been irreversibly degraded due to charcoal production. The Coastal Forests close to Dar es Salaam have been harmed most intensively including Pugu, Kazimzumbwi and Ruvu South Central Government Forests Reserves, home to many unique, rare and threatened species including Critically Endangered species such as the Rondo galago. Despite their legal protection; their well-known global biodiversity importance; and their potential for providing recreation areas for Dar es Salaam residents, illegal charcoal production has been allowed to continue in these reserves for many years with the result that most of the evergreen forest has been degraded, and biodiversity values reduced.

6.3.2 Charcoal, community-based forest management and reduced deforestation

Sustainable charcoal production nested within community-based forest management can help to reduce deforestation in Tanzania. Establishing village land forest reserves (VLFRs) prevents village forests from being converted to agriculture. By providing village governments with a reliable and sustainable source of revenue, sustainable charcoal production makes establishing VLFRs more attractive to villages and provides them with the resources they need to pay for forest management.

This outcome has been observed by the Transforming Tanzania's Charcoal Sector (TTCS) Project in Kilosa District. As of December, 2017, TTCS project villages had put 109,540 ha into VLFRs. Gross deforestation rates for all forests in TTCS villages declined 28% between 2014 and 2017 at the same time that deforestation rates elsewhere in Kilosa District increased by 7% (Figure 4). Furthermore, the deforestation

[55] URT-MNRT 2015. Table 47. Table 4.10

[56] URT-MNRT 2015. Table 47. Table 4.10 Household wood demand (0.96 m3/capita). 43 million m^3 / yr Industrial and household wood demand (0.05 m3/capita. plus FAOSTAT 2014) 2.3 million m3 / yr

[57] URT-MNRT 2015. Table 47. Table 4.10 LULC change analysis (1995 vs 2010 maps) on FW: (-372816 ha/a * 40 m3/ ha; 0.33 m3/capita -14.9 million m^3/yr

rate for the TTCS VLFRs in 2017 was less than half of the rate in the rest of the district. Without the income from sustainable charcoal, villages would not have chosen to put so much forest area into VLFRs and would not have had resources to devote to forest protection. Supporting other communities to establish village land forest reserves that include sustainable charcoal production in their management plans would reduce deforestation; create employment opportunities and help communities to sustain access to multiple forest products and ecosystem services.

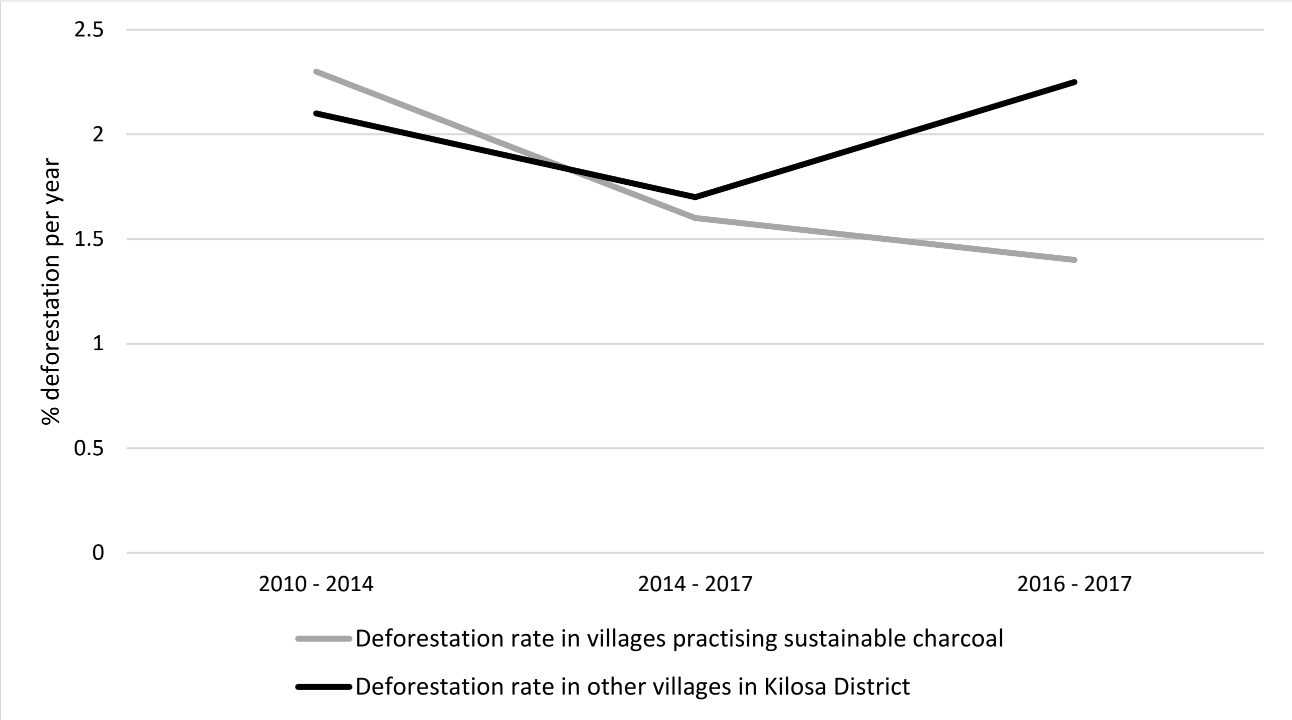


Figure 4. Deforestation rates from 2007 to 2017 in villages practicing and not practising sustainable charcoal production in Kilosa District.

6.4 Climate Change

6.4.1 Charcoal and its impact on climate change

Greenhouse gas emissions occur along the charcoal value chain with the majority being emitted during charcoal production. Charcoal results in emissions of carbon dioxide, methane and particulate matter including black carbon (LeFebvre 2016). More than 80% of emissions occur during the harvesting and production stage of the charcoal life cycle (Gmunder *et al*. 2014)[58]. Depending on the details of the value chain, emissions can vary from 0.39 kg CO_2eq/MJ at pot to 2.44 kg CO_2eq/MJ at pot in situations where vegetation regenerates after harvesting. If land use / land cover change is included in the calculations, the emissions can be as high as 22.9 kg CO_2eq/MJ at pot (ibid). Variables affecting the overall emissions include the post-harvesting land use; kiln efficiency; means of transportation; and stove efficiency. The most

[58] Note that carbon monoxide is also emitted during the pyrolysis and combustion stages however according to IPCC 'carbon monoxide (CO) does not absorb terrestrial infrared radiation strongly enough to be counted as a direct greenhouse gas'. https://www.ipcc.ch/ipccreports/tar/wg1/139.htm

significant factor is whether or not the land is converted to permanent agriculture, or whether regeneration is allowed to occur.

Land use / land cover change is the main source of greenhouse gas emissions in Tanzania. The annual emission level for 2002 – 13 from deforestation was calculated to be 43,552,305 ± 5,265,895 tCO2e/year (URT, 2017a). As outlined in Section 6.3.1, charcoal may be produced as part of the process of preparing agricultural land. Emissions from forest degradation have not been calculated officially (URT, 2017a). Charcoal has played a more significant role in emissions due to forest degradation.

The most important measure that can be taken to limit greenhouse gas emissions along charcoal value chains is to allow natural woodlands to regenerate after harvesting. Improved kiln and stove efficiencies and reducing loss of material through proper packaging and careful packing, can also reduce the greenhouse warming potential of the process. Where charcoal production is financing community-based forest management over an area exceeding the charcoal forest management units, the avoided emissions from the woodland outside the FMU, generate an additional climate change benefit that can balance the emissions from the charcoal value chain by avoiding deforestation. In this way, sustainable charcoal production could be used as a means to finance Reducing Emissions from Deforestation and forest Degradation (REDD).

6.4.2 Comparative life cycle analyses for charcoal and other cooking energy options

Aside from charcoal and fuelwood, emissions in the energy sector for commercial and residential use of LPG and kerosene were cumulatively estimated at 0.007664 Gg of methane, 185.34 Gg of carbon dioxide and 0.001528 Gg of Nitrous oxide (URT-VPO, 2014). Although results from life cycle analyses are difficult to compare given different assumptions and variables, several studies have found that LPG and kerosene have significantly lower emission rates than charcoal per unit of energy delivered to the pot (Gmunder *et al*. 2014, Bruce *et al*. 2017). However, many such analyses do not consider the transportation-related emissions of imported fossil fuels, nor the broader implications of releasing carbon from fossil fuels into the atmosphere. If these are taken into consideration then the climate change mitigation case for replacing biomass energy with fossil fuels, is weakened.

6.4.3 Charcoal production and its role in climate change resilience

Livelihood diversification is a key pillar in building resilience to climate change, particularly in agricultural communities. Charcoal production provides a valuable additional income source for many rural households which can help to mitigate shocks associated with agricultural losses linked to climate change.

Access to forests is also important in building climate change resilience. Communities' resilience to climate change may therefore be increased in areas where sustainable charcoal production has reduced deforestation.

7. KNOWLEDGE GAPS

7.1 Previous research on the charcoal value chain

Influential studies over the last 16 years include the CHAPOSA and NorConsult reports in 2002, the World Bank study in 2009 and the Biomass Energy Strategy document in 2014. With many of our findings, we are echoing the findings of previous studies. This highlights that many of the trends detectable in 2018 have been evident for the last two decades. The key findings from these reports are summarised below.

Table 18. Summary of previous studies on the Dar es Salaam charcoal market with their key findings.

Author	Year	Publication	Description	Key findings
CHAPOSA	2002	Charcoal Potential in Southern Africa Final Report for Tanzania	The objectives of the project were to investigate the trends in deforestation and forest depletion in areas supplying three urban centres in Sub-Saharan Africa: Lusaka in Zambia, Dar es Salaam in Tanzania, and Maputo in Mozambique. Additional objectives were to identify indicators of over-exploitation, and to increase the understanding of the reasons for charcoal production. The time scope was the last decade of the previous century.	**Woodland cover has been reduced during the study period**, partly due to charcoal production, **partly due to increased cultivation**. Cleared areas can regenerate into woodlands or continue to be degraded, depending on management regimes. Charcoal production has become one of the major income sources for rural people in areas where transportation to the big cities is possible. **Charcoal prices do not increase in real terms**, although inflation causes the current prices to increase. **The key to implementing changes to the system is to revise and enforce the licensing and fee system** for the charcoal trade.
Norconsult	2002	The True Cost of Charcoal: a rapid appraisal of the potential economic and environment al benefits of substituting LPG for charcoal as an urban	A report prepared by the consultancy firm Norconsult for the Tanzania Association of Oil Marketing Companies. The report set out to provide a clear, convincing and credible statement of the environmental benefits likely to accrue from increased consumption of liquefied petroleum gas (LPG) in Tanzania.	**LPG is easy to tax and charcoal difficult** because of the nature of the two businesses. Charcoal is effectively subsidised by ineffective collection of dues while LPG is penalised by high import duties. They recommended that Tanzania follow the example of Senegal where the Senegalese government '*actively promoted the use of liquefied petroleum gas (LPG), by adopting favourable fiscal, social and environmental policies and thereby succeeded in checking the pace of deforestation*'.

Author	Year	Publication	Description	Key findings
		fuel in Tanzania.		
World Bank	2009	Environmental crisis or sustainable development opportunity? Transforming the charcoal sector in Tanzania	At the request of the Government of Tanzania (GoT), the World Bank prepared a policy note summarizing the fundamental characteristics of charcoal use in the country and presenting policy options along the entire value chain of charcoal production and consumption.	The total annual revenue generated by the charcoal sector for Dar es Salaam alone is estimated at US$350 million, and generates employment and cash income for several hundred thousand people. Unregulated and unregistered activities in charcoal production and utilization lead to an estimated revenue loss of about US$100 million per year. From 2001 to 2007, the proportion of households in Dar es Salaam using charcoal as their primary energy source has increased from 47 percent to 71 percent. Total annual charcoal consumption in Tanzania is estimated at 1 million tons.
Camco Clean Energy (Tanzania) Limited	2014	Biomass Energy Strategy (BEST) Tanzania: Tanzania Biomass Energy Strategy and Action Plan	At the request of the Ministry of Energy and Minerals (MEM), the European Union Energy Initiative Partnership Dialogue Facility (EUEI PDF) supported the development of a Biomass Energy Strategy (BEST) in Tanzania. The document includes a detailed review of biomass energy policy, supply and demand. The document also proposes changes in: biomass energy policy, supply and demand; and the promotion of alternatives to biomass energy. The strategy has never been officially adopted.	Demand for wood energy has led to increasingly negative environmental, agricultural and other local and macro-impacts. Unsustainable biomass energy demand is accelerating year-on-year because of: - the **low priority that is accorded to biomass energy** by almost all key government agencies; - **The lack of a national policy framework for biomass energy**; - **Complicated, often contradictory and poorly-regulated governance of commercial biomass energy production and trade**;

7.2 Knowledge gaps – charcoal

7.2.1 Knowledge gaps – charcoal production and trade

Empirical studies on the role of charcoal production as a driver of deforestation. Whilst charcoal is often cited as a driver of deforestation, there is limited empirical evidence to support this. Empirical studies on the direct and indirect drivers of deforestation in Tanzania are needed. The results of a national study on deforestation drivers led by the Tanzania Forest Conservation Group is due to be published in 2019; and a study of charcoal's role in deforestation is underway led by the Tanzania Forest Services Agency. Both studies are likely to identify further research needs in relation to understanding deforestation drivers in Tanzania.

Empirical studies on employment along the charcoal value chain. The NBS Employment and Earning Surveys e.g. NBS 2012, lump forestry, agriculture and fisheries together. Many actors involved in the charcoal value chain do so on a part-time or seasonal basis. Understanding charcoal's contribution to employment is necessary if the effects of policy changes are to be properly anticipated. For example, who would be negatively impacted should the charcoal trade contract as a result of policy changes, and how can the negative impacts on employment be mitigated.

Charcoal trade flows. The spatial flow of the charcoal trade is poorly understood. Understanding the flow of charcoal would help to identify more efficient trading patterns; and reduce revenue leakage. Data on the volume of charcoal being illegally exported was also highlighted as an important knowledge gap by the Forestry and Beekeeping Division.

Information on charcoal value chains to other urban areas including Dodoma. With the growth in size and importance of Dodoma, more information is needed on the biomass energy value chains supplying Dodoma, and cooking energy options for the city. Similarly, data is needed for other large urban areas including Mwanza, Arusha and Morogoro.

Accurate data on the area of miombo on village land is needed to fully understand the potential for scaling up sustainable charcoal. Further research, using the NAFORMA dataset, could generate an updated estimate of the area, distribution and tenure of Tanzania's remaining miombo woodlands. By accurately mapping the distribution of miombo woodland in Tanzania, villages with potential for sustainable charcoal production could be identified and provided with support on CBFM and sustainable production. This information could be used as part of a strategy to scale up sustainable charcoal production.

Experiment with different miombo harvesting regimes for sustainable charcoal production. In Tanzania, the TTCS project adopted a 24-year harvesting rotation. This was a conservative choice given the innovative nature of the work. Some researchers recommend significantly shorter rotations.

The profile of the traders who employ the transporters requires further research. Our 2018 field surveys found that a quarter of transporters were employed by someone else to undertake their transportation work. Understanding the profile of these traders would be useful in order to engage them in a process of change.

7.2.2 Knowledge gaps - charcoal revenues

Data is needed on the value of charcoal revenues and the scale and sources of revenue leakage. Data on the value of revenues from charcoal harvesting fees, transport permits, fines, registration fees, cess, district fees and other levies is not readily available. The Tanzania Forest Service District Forest Managers code different revenue types. Local Government also collect revenue from cess and, in some cases, charcoal bag fees. Information on this may be available in some districts. Using this data, information about charcoal fees / royalties, transit permits and levies collected by TFS and local government could be extracted and published. This information is needed in order to understand the scale of the value chain and its contribution to the local and national economy. It is also needed to calculate accurately the level and sources of revenue leakage.

7.2.3 Knowledge gaps - charcoal use

More accurate data on annual consumption volumes is needed. There is no robust data on the scale of charcoal consumption in Dar es Salaam. Instead, most studies, including this one, have relied on estimates based on household consumption rates multiplied by the estimated number of user households using charcoal. This involves assumptions about consumption rates which may vary significantly, particularly given widespread fuel-stacking.

In-depth study of patterns of household energy use to identify 'easy wins' in terms of improving energy efficiency and reducing overall energy demand. Many cooks already adopt energy-saving strategies such as cooking in bulk, soaking beans, fuel stacking and avoiding fuel wastage. Documenting these behaviours and identifying the gains at household level and to society more widely, would be a valuable input to awareness raising campaigns designed to improve urban energy efficiency.

More in-depth understanding of fuel-stacking behaviour. Detailed studies of fuel use within the household, as have been done in other countries (e.g. Ruiz-Mercado and Masera 2015 for Mexico), would provide valuable insights into reasons for fuel stacking.

Add a question to the household budget survey to capture information on all cooking fuels used by a household, not just the main one. To understand household energy consumption, it is important to collect data on all fuels that a household uses for cooking, not just the main fuel. Surveys such as the household budget survey should consider adopting a question to capture information on all household cooking fuels.

More reliable data is needed on the efficiency gains of using ceramic-lined charcoal stoves in real-world settings. Whilst development partners and government have invested in the promotion of improved stoves, research on their efficiency gains in real-world scenarios is significantly incomplete.

Research on commercial and institutional cooking energy consumption. The current study has focused on domestic consumption as the largest market share. Data on the commercial use of charcoal is needed to give a more complete picture of the charcoal market in Dar es Salaam.

8. RECOMMENDATIONS

Overall, we recommend a strategic approach to sustainable energy planning for the city in which the pros and cons of the different energy options are balanced in the overall energy mix. We recommend that this be approached from the perspective of maximising advantages and mitigating risks to both rural and urban stakeholders. To achieve this requires a shift from the narrower focus on replacing charcoal with alternatives, that has tended to characterise discussions around Dar es Salaam's cooking energy. Embracing a mix of different fuels, including charcoal, has clear advantages in terms of rural development, employment, revenue generation and reducing deforestation. To achieve these changes, we need a vision of the cities' energy future that has broad support within different parts of government, among consumers and among those involved in different energy product value chains. This requires leadership, policies and plans, fiscal measures, institutional reform, investment measures, and behavioural measures. These are elaborated below.

8.1 Developing an urban energy strategy for Dar es Salaam

Developing a sustainable urban energy strategy for Dar es Salaam would provide a useful framework for stakeholders to work together to achieve a more economically, environmentally and socially sustainable energy mix for the city. Local level strategies can be effective policy tools for change. There is considerable experience in Asia in the development of such strategies (World Bank, 2012, Ostojic *et al*. 2013).

Guidelines on the development of Urban Energy and Emission plans are available and outline a stepwise approach to developing such plans. Responsibility for developing such a plan could be taken on by the City Council to link with the Dar es Salaam Master Plan with the participation of other key stakeholders within government, private sector and civil society.

Source: Ostojic et al. 2013

8.2 Overall energy targets for Dar es Salaam

A sustainable energy mix for Dar by 2030 is outlined in Table 19. This reflects stakeholder recommendations, current trends, and potential supply data.

Target for overall end-use cooking energy demand for the total population of Dar es Salaam in 2030: 12.86 PJ / yr[59]

This assumes a population of 11.4 million[60] people or 2.9 million households[61] by 2030; a per household annual target of 4,400 MJ; and a per household daily target of 12 MJ

Table 19. Proposed energy mix for Dar es Salaam.

Fuel type	Proposed Target %[62]	2030 Target PJ[63]	Amount[64]	Unit	Comment
LPG	44%	5.69	210,692	tonnes	Assumes fuel levy exemption, a stable world price and supportive policies for LPG investors.
Electricity	20%	2.59	1,026	GW·h	Assumes 6% of expected national residential supply can be allocated to household cooking energy in Dar at an affordable price for wealthier households.
Briquettes	16%	2.07	237,771	tonnes	Assumes continued improvement in briquette quality, and investor friendly policies.
Charcoal	13%	1.68	193,189	tonnes	To be sourced from sustainably managed woodlands under community-based forest management.
Firewood	5%	0.65	417,059	tonnes	Assumes that poorer households in peri-urban areas continue to use firewood.
Ethanol	0.5%	0.06	N/A		Assumes some use of this fuel type as part of a fuel-stacking arrangement. Aligned with UNIDO targets to supply ethanol stoves to 110,000 households = 0.4% of projected households in 2030.
Kerosene	0.5%	0.06	4	megalitres	Assumes some use of this fuel type as part of a fuel-stacking arrangement.
Natural Gas	0.5%	0.06	N/A		Assumes scaling up of pilot projects to supply natural gas to 14,600 households and that those households then adopt it as their sole cooking fuel.
Total	**100%**	**12.86**			

[59] This assumes a 25% increase in cooking efficiency. If no increase in efficiency, based on current consumption and with a population of 11.4 million, the combined demand would be 17.2 PJ / yr in 2030 an increase from 9 PJ /yr in 2018

[60] Assumes that the 2002-12 population growth rate for Dar es Salaam of 5.6 % remains constant. NBS 2016 p. 13

[61] Assumes a constant average HH size of 3.9 based on NBS 2016 p. 26.

[62] If 64% of energy were provided by electricity and LPG, these would bring Dar closer to the SE4All 2030 target of 75% of the population using modern energy for cooking

[63] This is the amount of the output energy requirement of 12.86 PJ, per fuel type, based on the proposed target %.

[64] This is the amount of fuel required to supply the target PJ per fuel type, taking into consideration the end use efficiency conversion factors outlined in Annex 1.

8.3 Policy Recommendations

A policy is needed to guide biomass energy supply given its primacy in the national energy mix. Charcoal is an energy product. Charcoal and other forms of biomass energy have been excluded from the National Energy Policy 2015 despite biomass energy being the source of 90% of national energy demand. Policy guidance is needed to ensure an economically and environmentally sustainable supply of energy for the majority of Tanzanians for whom biomass energy is an essential ingredient of everyday life.

There has been considerable discussion about how to bridge the gap between the Ministry of Natural Resources and Tourism, with its supply-side responsibility for forest management oversight, and the demand-side niche of the Ministry of Energy. Coordination between the two is needed. Over the last two decades, the policy focus on the supply-side and the presumption that the forestry sector can manage biomass energy effectively, has not resulted in a sustainable biomass energy supply that is commensurate with demand. For this reason, we would recommend that a Biomass Energy Division be established; that it be well-resourced; and that it focuses on how to manage the role of biomass energy in the national energy mix from both the supply and demand side. Whilst the Ministry of Energy is the most relevant ministry, a strong case could also be made for placing it in the Vice-President's Office, Division of Environment.

Align charcoal value chains with national priorities on industrialisation, modernisation, job creation and revenue collection. The availability of fast-regenerating natural woodlands gives Tanzania a competitive advantage in biomass energy production. With the right mindset this could be turned to Tanzania's advantage bringing rural employment, encouraging local industries and generating more revenue for communities, and for local and central government. Excluding charcoal in favour of imported fossil fuels is disadvantageous to local businesses. Leadership is needed to embrace biomass energy as a renewable, modern, domestically produced cooking fuel relevant to the 21st Century.

8.4 Fiscal measures

Use fiscal tools to incentivize a more sustainable urban energy mix. Given the price sensitivity of the urban cooking fuel market, tax exemptions, additional taxes or fees and increasing compliance along the value chain, can be used to guide demand towards a more strategic mix.

Increase revenue collection on charcoal by shifting the focus for Central Government revenue collection to the Tanzania Revenue Authority. In order to 'level the playing field' in the energy market, there needs to be a fair taxation system between energy types. The massive revenue leakages that have characterised the charcoal trade have contributed to it being the cheapest fuel available. The revenue leakages reflect the mis-match between the capacity of the forestry sector to collect revenues, and the scale of the trade. The Tanzania Revenue Authority have a much greater capacity to collect revenues in terms of their technical skills base, their technological infrastructure and their human resources. It is recommended that TRA engage actively in the charcoal sector. This could be implemented alongside a programme of support and professionalisation for charcoal transporters and traders. Capacity support was repeatedly requested by those in the charcoal retail sector. If VAT is added, careful consideration is needed with regard to the future of royalties to determine whether they should be removed altogether on charcoal, or set at a lower rate. Consideration also needs to be given as to how a revised system can incentivise sustainable production.

Continue to exempt LPG from the fuel levy until a more effective revenue collection system is in place for charcoal. LPG's exemption from VAT and the fuel levy has helped to make LPG competitive with charcoal.

Maintaining this exemption will make LPG affordable to more households. Exemption is justifiable given the low capture rate of charcoal fees. Exemption from VAT and the fuel levy on LPG should be reconsidered once a more effective fiscal structure is in place for charcoal. If other products such as briquettes are to compete, a more investor-friendly taxation system is needed.

Promote standardisation of the units that charcoal is sold in. Re-structuring and standardising the units that charcoal is sold in has been recommended by several stakeholders. Changes should be designed to align the traded unit with its energy content. For this reason, standardisation should focus on weight not volume. Selling charcoal by weight, rather than by volume, would be better for consumers, particularly poorer households. Poor households buying charcoal in small quantities are currently paying on average 30% more per unit of energy than households who purchase their charcoal by sack. Current proposals to re-structure royalties to be charged by standard volume sacks, rather than by standard weight sacks, are likely to work against consumers. Charging by volume rather than weight incentivizes traders to pack their sacks loosely, and to use cheaper, less energy-dense charcoal. Since the end product is energy, and energy is more directly correlated with weight than with volume, a weight-based system would be more favourable for consumers with less risk of perverse incentives.

8.5 Recommendations on behavioural measures and increasing energy efficiency

Implement strategies designed to reduce per household energy demand through the adoption of multiple household-level fuel saving techniques and technologies. Involve cooks, most of who are women, in designing these strategies. Promote the exchange of experience on fuel-saving strategies. Targeting fuel consumption is likely to be more effective in reducing overall energy demand, than strategies that focus on single solutions in isolation, such as the adoption of improved cook stoves or switching to LPG.

As part of holistic strategies on household energy use, promote cooking devices designed to improve efficiency, particularly for technology used to prepare food with high-energy demands such as beans and rice. Devices such as pressure cookers and electric rice cookers are already available in Tanzania. However, they are expensive to purchase and there is limited information available on the potential energy / cost savings that could benefit households. Widespread adoption of technology and behaviours designed to reduce energy consumption for the most energy-demanding cooking tasks, could halve household cooking times, and therefore demand. The private sector is crucial to the success of such strategies.

Programmes to promote LPG should place as much emphasis on use and adoption as on increasing stove ownership. Awareness raising campaigns, particularly campaigns that target household members primarily responsible for cooking, should promote use of LPG for more cooking tasks. Focusing on Kinondoni and Ilala Municipalities would achieve easier 'wins' given widespread stove ownership in these municipalities.

Promote increased electricity use as part of households' energy mix. If we assume that 6% of the electricity planned for residential use nationally, could be allocated to cooking energy in Dar es Salaam, this would be equivalent to 2.59 PJ. This would be sufficient to supply 20% of households as their sole fuel or 40% of households for half of their cooking needs.

Extrapolating the results of our 2018 surveys, in which 12% of households reported using electricity as one of their cooking fuels, this is equivalent to 183,000 households using electricity[65]. Increasing the number of

[65] Assumes a population of 5.96 million. Household size of 3.9 persons. Total number of households in Dar 1,528,205. 12% of the households = 183,384

households using electricity in an energy mix with LPG to 1.1 million (equivalent to 40% of households in 2030) could be achieved, particularly through promotion of appliances such as electric kettles for heating water, electric rice cookers and bread making devices, microwaves and induction cookers.

Encourage local enterprises in designing, manufacturing and trading technologies that improve cooking efficiency, particularly for high-demand cooking tasks. This could include pressure cookers, efficient stoves for food stalls, pressure type kerosene stoves and rice cookers. This could create local employment, raise awareness and improve overall urban energy efficiency.

Raise awareness on measures that households can take to reduce exposure to indoor air pollution. This should include information on the particular risks to children associated with chronic exposure to carbon monoxide and particulate matter. Include information on the risks of indoor air pollution in teaching in primary and secondary schools.

Table 20. Interventions to mitigate negative health impacts of cooking with biomass.

Intervention	Potential impact
Ventilation – encouraging a through-flow of air in an indoor cooking area	Cooking in a well-ventilated space can reduce exposure to pollutants thereby reducing mortality and morbidity due to household air pollution. Particulate matter can be reduced by 93 – 98% with good ventilation (Das, 2018).
Cooking outside can reduce respiratory disease in children of 0 – 1 yr by 13% (Langbein, 2017)	Cooking outside can reduce exposure to pollutants by 57 – 73% (Das 2018) thereby reducing mortality and morbidity due to household air pollution
Chimney use can remove pollutants from the cooking area	Using a chimney can reduce exposure to pollutants thereby reducing mortality and morbidity due to household air pollution
Use of improved stoves	Improved cook stoves can reduce exposure to carbon monoxide and particulate matter (Das, 2018).

8.6 Recommendations on charcoal production

Scale-up, support and improve sustainable charcoal production in forests under CBFM. Given that charcoal remains an important energy source for urban Tanzanians; and given its potential to contribute to rural development and reduce deforestation, it is recommended that sustainable production from natural woodlands be scaled up to replace current unsustainable practices.

Experiment and learn from different charcoal production models. Given the diversity of markets, forests, communities and forest-owners in Tanzania, it is unlikely that a 'one-size-fits-all' charcoal production model, can be found. There needs to be a willingness to support experimentation, and to build upon the lessons learned from previous models, and those adopted in other countries.

Identify skilled producers to train other producers in more time- and energy-efficient production techniques. A skilled charcoal producer can achieve double the production efficiency compared with a less skilful producer. Charcoal production requires a range of different skills. Skilled producers can achieve efficiency gains at each stage of the production process. Transferring those skills to other producers in a more formalised way could double the charcoal yield per unit of biomass, thereby significantly reducing the wood input for the same overall charcoal yield.

9. COMPARING ENERGY PATHWAY SCENARIOS FOR DAR ES SALAAM

In this section we outline two scenarios for the charcoal trade and Dar es Salaam's energy future for the period 2018 – 2030.

Scenario 1 is the business as usual scenario and assumes that there are no significant changes in policy or market conditions. No biomass energy policy or strategy is adopted. Biomass energy remains outside the remit of the Ministry of Energy and of marginal importance to the Ministry of Natural Resources and Tourism. There is no sustainable energy plan for Dar es Salaam or other urban areas.

Scenario 2 assumes that deliberate measures are taken to improve the economic and environmental sustainability of biomass energy in Tanzania at national and local level. These include:

- The adoption of a National Biomass Energy Policy by 2020 providing a clear framework for ensuring an environmentally and economically sustainable supply of biomass energy to support Tanzania's overall industrialisation and economic growth road map. Policy implementation tools such as laws, strategies and regulations are in place by 2023. The policy links biomass energy supply with demand.
- The establishment of a biomass energy division in the Ministry of Energy with responsibility for implementation of the biomass energy policy. Responsibilities include the promotion of sustainable biomass energy production, including firewood and charcoal.
- The development and implementation of a Sustainable Urban Energy Strategy for Dar es Salaam including a widely accepted vision of a sustainable urban cooking fuel mix; clear targets, coordination mechanisms and roles and responsibilities; promotion of energy efficient cooking techniques and support for private sector.
- A reform of the tax / revenue / royalties for charcoal with increased VAT collection.
- Payments to producers, districts, TFS and village authorities are made electronically using an easy-to-use combined payments system linked to the product-tracking system.
- Widespread support for and leadership on CBFM-based sustainable charcoal.
- Professionalisation of production through training for producers and village forest managers; establishment of sustainable charcoal associations; and well-established governance procedures.
- Biomass energy transportation is guided by a national biomass energy policy and strategy linking supply with demand; identifying charcoal source areas and efficient transportation systems.

Table 21. Outcomes for a business as usual scenario and a sustainable energy pathway scenario.

Value Chain Stage	Scenario 1 2018 - 2030. Business as Usual	Scenario 2 2018 - 2030. Sustainable Energy Pathway	Key Stakeholders
Adoption of energy efficient cooking techniques	Ceramic stoves continue to be widely used with little data or monitoring on efficiency gains. Efficient technologies such as pressure cookers, induction stoves are rarely used. Some households continue to use efficient cooking techniques such as soaking beans and careful stove management but mechanisms for exchanging experiences between households are limited.	Energy efficiency awareness campaigns, involving and designed by those responsible for household cooking result in 90% of households adopting two or more energy saving techniques. 50% of households are using pressure cookers by 2030 particularly for cooking beans. Local pressure cooker manufacturers generate employment. Widespread adoption of 'next generation', energy-efficient charcoal stoves. This results in A 25% decline in per household cooking energy use from 21.6 PJ/million households to 16.2 PJ / million households.	Consumers Local Government City Council Private sector suppliers of energy efficient technologies NGOs Researchers
Fiscal	Responsibility for revenue collection remains largely with TFS. Revenue collection rates remain at < 10%. A few, donor-supported communities succeed in capturing revenues from their village land forest reserves. District governments continue to collect cess at a low rate due to widespread evasion.	TRA generate > TZS 100 billion from VAT on Dar es Salaam charcoal sales by 2030. 7,200 villages are earning on average TZS 10 million per village per year from charcoal fees of TZS 120/kg for community development projects and CBFM costs. TFS earn TZS 0.4 billion from producer licences (assuming at least 1 licence per charcoal association / village in 7,200 villages). Local government earn TZS 5 million / producer village / yr from cess at TZS 50 / kg to cover costs of technical support to CBFM and other district development needs.	TRA Local Government Authorities Charcoal producers NGOs
Production	***Forest management and production levels*** Production continues to increase, including in ecologically sensitive areas and government forest reserves. Revenues from charcoal are not reinvested in forest management. Harvesting does not follow sustainable forest management principles. Forests on village land are cleared at a rate of -1.34% p.a. with many villages losing all woodlands in deforestation	***Forest management and production levels*** Total production declines to match the mean annual increment of woodlands in charcoal forest management units under CBFM. Production in government reserves and ecologically sensitive forests is reduced. Forests regenerate. 4,000 villages earn revenues from CBFM resulting in reduced deforestation; ecosystem services safeguarded; climate change resilience enhanced and community revenues available for social development.	Producers Village leaders Local government PO-RALG TFS FBD Training Institutes

Value Chain Stage	Scenario 1 2018 - 2030. Business as Usual	Scenario 2 2018 - 2030. Sustainable Energy Pathway	Key Stakeholders
	hotspots such as Tanga, Coast, Mwanza, Tabora, Shinyanga and Singida [66] CBFM is not scaled-up and fails to work effectively due to barriers to communities establishing forest-based enterprises to incentivise effective CBFM and lack of technical support. TFS remain unsupportive of CBFM in order to protect their right to collect charcoal royalties from village land and meet revenue targets. Communities lose access to forest resources vital to climate change adaptation; ecosystem services are degraded; biodiversity is lost. ***Production*** Production by thousands of unskilled producers continues using basic earth kilns, high GHG emissions, harvesting in ecologically sensitive areas, unsafe production practices, low incomes and insecure livelihoods. Most producers do not have licences. Per capita incomes remain constant in real terms.	***Production*** Increased revenues to TFS through higher compliance on producer licenses. Greater cooperation between producers, TFS and local government. Local government earn revenues from well-governed production and reinvest a portion in technical support to CBFM villages. GHG emissions are reduced through reduced deforestation and improved carbonisation.	Vice-President's Office DoE NGOs Development partners
Transportation	***Transport*** Transportation of charcoal increases to supply Dar es Salaam from unmanaged forests and woodlands in an expanding trading arc. Lorries and motorcycles continue to be used. Charcoal is untraceable. Payments are made in cash. Numbers of people employed increase. Per capita incomes remain constant in real terms. Accidents due to overloading and poorly maintained vehicles continue at the same rate.	***Transport*** Transportation declines to match an overall decline in the charcoal trade to bring it into line with sustainable limits. Transporters trade with well-governed charcoal associations supplying legal charcoal from CBFM areas. Charcoal is transported in sacks of uniform weight / energy content. Accident rates decline as a result of safety awareness. Employment rates decline but incomes per transporter increase. ***Revenue collection*** Charcoal is traceable using modern product-tracking technologies.	Transporters Producers Local Government Authorities PO-RALG TFS Ministry of Energy –

[66] URT 2016. FREL. Total annual deforestation = 469,000 ha. Annual deforestation in reserved areas = 97,101 ha. Annual deforestation in unreserved forests (this category includes all village land forests) = 379,899 ha (469,000 ha – 97,101 ha). Given a total forest area of 48,090,699 ha and a total forest area on central and local government reserved land as 19,717,932 ha (NAFORMA, 2016 p. 40), this leaves 28,372,767 ha of forest on unreserved land. The 379,899 ha of annual deforestation on unreserved forest land is equal to a rate of 1.34 % annual deforestation rate.

Value Chain Stage	Scenario 1 2018 - 2030. Business as Usual	Scenario 2 2018 - 2030. Sustainable Energy Pathway	Key Stakeholders
	Charcoal losses due to poor packing procedures continue. Charcoal is transported in sacks of varying weight and volume. ***Revenue collection during transportation*** Most charcoal evades royalties by by-passing checkpoints; under-stating loads; laundering natural forest charcoal as black wattle; re-using permits; and bribing checkpoint staff. Most transporters evade fee payment due to high transaction costs of compliance and ease of evasion. GoT continue to collect < TZS 50 bn from the charcoal trade. Per capita incomes remain constant in real terms.	Revenues to villages and districts increase. Revenue to TFS remains constant based on increased capture of transit fees, licence fees and fines for illegal charcoal.	Biomass Energy Division
Charcoal Retail / Wholesale	***Retail / wholesale*** Charcoal continues to be widely available. Employment in charcoal trade increases but at a lower rate than the overall urban population increase. Per capita incomes for charcoal sellers remain constant in real terms. Morbidity rates due to inhalation of charcoal dust and injuries due to unsafe un-loading practices remain constant. ***Revenue collection*** Traders do not pay VAT. TRA continues to generate TZS 0 from charcoal. 60% of sellers have municipal business licenses. 80% of sellers have TFS trader permits.	***Retail / wholesale*** Charcoal is less readily available in Ilala and Kinondoni Districts as more households adopt LPG. Availability rates decline more slowly in Temeke, Ubungo and Kigaomboni. Charcoal sellers are supported to diversify into sales of LPG and briquettes and are involved in awareness campaigns to promote alternatives and efficient cooking practices. Charcoal sellers are supported to professionalise through standardised weight-based / energy content-based packaging and use of EFD receipts. Charcoal sellers use safety equipment such as face masks when handling charcoal and remove charcoal dust from trading premises resulting in reduced morbidity. Charcoal sellers are trained on health and safety issues resulting in less injuries from the loading / unloading process. Charcoal is sold in standardised weight-based / energy content-based packages of varying sizes and specifying charcoal type. ***Revenue collection*** Charcoal sellers pay VAT on sales or equivalent for smaller traders.	Wholesalers Retailers Municipal Authorities City Council Consumers PO-RALG TRA Ministry of Energy – Biomass Energy Division TFS Vice-President's Office DoE

Value Chain Stage	Scenario 1 2018 - 2030. Business as Usual	Scenario 2 2018 - 2030. Sustainable Energy Pathway	Key Stakeholders
		GoT collections from VAT on charcoal increase steadily from TZS 30 billion to TZS 100 billion per year as compliance gradually increases. Charcoal sellers are supported to professionalise through use of EFD receipts; compliance with other TRA requirements; and establishment of trade networks. 90% of charcoal sellers have municipal business licences.	
Charcoal consumption	Charcoal consumption increases but at a slower rate than overall urban growth as more consumers adopt LPG. Most households continue to practice fuel-stacking with a preference for charcoal for slow-cooking foods such as beans. Charcoal prices increase in line with inflation. Mortality and morbidity rates due to indoor air pollution increase in proportion to use. Employment in stove production remains constant. Poorer households continue to pay more per unit of energy for their charcoal.	Overall charcoal consumption declines due to the increased price resulting, from VAT prompting increased fuel-switching and more efficient cooking practices. Efficient practices are adopted widely based on well-targeted campaigns led by those responsible for cooking. Mortality and morbidity rates due to indoor air pollution decline significantly, particularly among children, due to awareness raising campaigns and development / adoption of cleaner stoves. Employment in stove production increases as safer / more efficient stoves, designed and fabricated by local enterprises, are developed and sold. Consumers get a fairer deal due to accurate packaging by weight / energy content.	Consumers Local Government Ministry of Energy NGOs
Consumption of other household cooking fuels	***LPG*** Demand continues to increase both as a main cooking fuel and as a supplementary fuel in a fuel-stacking system. Real prices remain constant. ***Electricity*** Demand for electricity for cooking increases slowly particularly with the adoption of devices such as micro-waves, rice cookers and electric kettles by a growing middle class. Real prices remain constant. ***Briquettes***	***LPG*** Demand increases rapidly as a result of promotion campaigns, improved distribution networks, and a supportive business environment guided by the Sustainable Urban Energy Strategy (SUES). Demand increases most rapidly in Ilala and Kinondoni as a result of a campaign focus on these municipalities. By 2030, 80% of households in Ilala and Kinondoni are using LPG as their main fuel. ***Electricity*** Demand for electricity for cooking increases, particularly in Kinondoni and Ilala through adoption of induction cookers, electric kettles, microwaves and rice cookers by a growing middle-class and as a result	Suppliers of LPG, briquettes and ethanol. TANESCO Local Government Ministry of Energy Consumers NGOs

Value Chain Stage	Scenario 1 2018 - 2030. Business as Usual	Scenario 2 2018 - 2030. Sustainable Energy Pathway	Key Stakeholders
	Briquette sales to institutions increase slowly then stagnate. Briquettes remain commercially unviable for the domestic market due to unfavourable taxation relative to charcoal and LPG. Prices decline slightly as production is scaled up using more efficient modern processing technologies. ***Kerosene*** Kerosene demand continues to decline as a cooking fuel as more households choose LPG as their 'back-up' fuel. ***Firewood*** Firewood continues to be freely available to poorer households and those in city suburbs. ***Ethanol*** Adoption increases very slowly as a result of projects such as UNIDO. However, it remains unpopular and commercially unviable as a cooking fuel when competing with charcoal and LPG.	of awareness raising campaigns and marketing by appliance suppliers, guided by the SUES. ***Briquettes*** 25% of households are using briquettes as part of their energy mix by 2030 and they supply 15% of overall household energy demand. Briquettes become price-competitive with charcoal as a result of VAT on charcoal; economies of scale; and exemption from TFS transit permits. Product standards are established in consultation with users and manufacturers. Employment in briquette manufacturing increases. 15% of households are using briquettes by 2030. Charcoal sellers are linked with briquette suppliers thereby increasing the supply network. ***Firewood*** Firewood continues to be freely available to poorer households and those in city suburbs. Morbidity due to indoor air pollution declines as a result of awareness campaigns. ***Kerosene*** Continues to be used as a back-up fuel in some households with increased use of pressure-type kerosene stoves. ***Ethanol*** Remains available but of marginal significance in the urban energy mix.	
Climate change	Greenhouse gases due to deforestation and forest degradation increase.	Greenhouse gases due to deforestation and forest degradation stabilise as deforestation on village land declines with increased uptake of CBFM	

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Annex 1. Energy conversion factors and per capita cooking energy consumption records

Energy conversion factors used in the report

Energy form	Conversion		End use cooking efficiency conversion	Output efficiency	
Electricity	3.6	MJ/kW·h	0.7	2.52	MJ/kW·h
LPG	45	MJ/kg	0.6	27	MJ/kg
Kerosene	36.3	MJ/litres	0.4	14.52	MJ/litres
Charcoal	29	MJ / kg	0.3	8.7	MJ / kg
Briquettes	29	MJ / kg	0.3	8.7	MJ / kg
Firewood (air dried)	15.5	MJ / kg	0.3	4.65	MJ / kg

Source: Camco 2014.

Household daily energy consumption records

Energy per HH	HH size	Per capita	
2.8 kg / hh /day The average daily consumption of charcoal was found to be 1.5 tins (2.8 kg) per household.	4.3 people[67]	0.65 kg / person / day	CHAPOSA, 2002.
2 kg / hh / day Majority of the households sampled (56.4%) of sample reported cooking three meals daily in the city of Dar-es-Salaam and on average, are using 2 kg of charcoal day-1 or about 2 bags of charcoal month-1.	4.3 people[68]	0.47 kg / person / day	Kilahama, 2004.
2 kg / hh / day On average a household uses a tin of about 1 kg of charcoal sold at TShs 600 to prepare one hot meal, 2 times a day.	4.2 people	0.45 kg / person / day	Malimbwi and Zahabu , 2008.

[67] Based on the URT -NBS 1999 Reproductive and Child Health Survey 1999 p. 10
[68] Based on the URT -NBS 2004 Tanzania Demographic and Health Survey 2004 p. 11

Annex 2. List of participants in the inception workshop for the study.

Name of Participant	Office & Title
Kahana Lukumbuzya	NRM Consultant
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Martin Chegere	EFD (T)-UDSM-Research Fellow
Benjamin Lane	Director-Mkaa Endelevu
Kozue Araki	Coordinator Economic Cooperation- Embassy of Japan
Ingvild Langhus	Counselor-Norwegian Embassy
RJ Gregory	CEO Mkaa Endelevu
Dr. Felician Kilahama	Chairman-TAFORI
Mary Swai	TATEDO
Ferhat Esen	WB Senior Energy Specialist
Victor Akim	UNIDO-Energy & Environment Coordinator
Lema Mathias	Tanzania Forest Services
Daniel E.Mbilinyi	US Embassy
Mihaela Marco	Program Officer-EU
Priscilla Zengeni	World Bank
Daniel Mira-Salama	World Bank

Annex 3. List of stakeholders consulted

Name	Title & Institution
Ally Majid	Assistant Director Forest Utilization, Tanzania Forest Services Agency
Deogratias Bwoyo	Assistant Director of Forest and Beekeeping Division, Ministry of Natural Resources and Tourism.
Prof Dos Santos Silayo	Chief Executive Director, Tanzania Forest Services Agency
Haji Janabi	Director Policy and Planning Department, Ministry of Energy
Claudia Paul Kinabo	District Forest Assistant Manager, Beekeeping Zone for Kibaha District Council
Almasi Mgalu	District Forest Manager for Kibaha- Tanzania Forest Services Agency Kongowe area
Elias Mwaijele	District Forest Manager for Kisarawe, Tanzania Forest Services Agency
Reginald Lyimo	District Forest Officer for Kisarawe, Tanzania Forest Services Agency
Simon Marandu	LPG Deport Manager, Lake Oil Tanzania Ltd
Depo Nyomola	Municipal Planning and Economist for Ilala
Adam Juma	Municipal Planning and Economist for Kigamboni
Nassoro Shemzigwa	Municipal Planning and Economist for Kinondoni
Deogratias Lukomanya	Municipal planning and Economist for Temeke
Erick Kilangwa	Municipal Planning and Economist for Ubungo
Mathew Mwanuo	North Ruvu Forest plantation (Former Ruvu Fuel wood Pilot Project) – Tanzania Forest Services Agency (TFS) -Kongowe area
Sada Arui and ms. Pauline Bernard	Research, Policy and Planning Officers, Tanzania Revenue Authority
Peter Ndomba	Sales and Marketing Officer, Oryx Gas Tanzania Ltd
John Olomi	Forest Plantation Unit Representative, Tanzania Forest Services Agency
Simon Milledge	Forest Development Trust
Ryan Gregory	CEO Mkaa Endelevu

Annex 4. Employment estimates along the Dar es Salaam charcoal value chain.

Value chain stage	Number of people employed (% of total employment) assuming 950,000 tonnes / yr (upper estimate of Dar market)	Number of people employed (% of total employment) assuming 800,000 tonnes / yr (lower estimate of Dar market)	Median % value
Production	125,379 (71.1%)	101,975 (70.3%)	70.74%
Transportation	16,768 (9.5%)	14,120 (9.8%)	9.63%
Retail	34,200 (19.4%)	28,800 (19.9%)	19.63%
Total	**176,347 (100%)**	**144,895 (100%)**	**100.00%**