Final Report

BIOENERGY DIAGNOSTICS STUDY

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Content

Executive summary

A study on biomass as an energy source for clean cooking and productive uses
The Investment Climate Reform (ICR) Facility approved technical assistance (TA) to the Ministry of Energy of Zambia (MOE), and specifically the Off-grid Taskforce (OGTF) within the Department of Energy for a bio-energy diagnostic study. The objective of this assignment is an analysis of the investment barriers currently holding back the bioenergy sector (biomass) for cooking and industrial use and how to remedy them. The study will support the implementation of the 2019 National Energy Policy's (NEP) objective to provide universal access to clean, reliable, and affordable energy at the lowest total economic, financial, social, and environmental cost by 2030.

Study scope
The bio-energy diagnostic study focuses on clean cooking, specifically on improved wood stoves, improved charcoal stoves, domestic biogas, pellets, bioethanol and char-briquettes, and productive use of bioenergy for curing and drying purposes (tobacco sector), for power generation (biogas and biomass) and for space heating purposes (piggeries and poultry sector). The study relies on an extensive literature review and stakeholder consultations, both in-country (2 missions of in total 3 weeks) and virtual consultations.

Key conclusion and recommendation
The overall conclusion of this study is that the bioenergy market in Zambia is nascent, both for cooking and productive use. A range of activities and projects take place, but few have received scale. There is a general lack of information and coordination in the sector which makes it difficult to track progress and to build on on-going initiatives. In this study a great number of recommendations are provided to overcome those barriers. Selected key recommendations which would unlock significant investment are:

1. levelling the playing field by appropriately taxing charcoal or abolishing taxes on sustainable alternatives (technologies and fuels);
2. abolish excise duty on bio-ethanol fuels;
3. create awareness at all levels on energy efficiency and sustainable fuels;
4. set-up an ICS support program for ICS producers and sustainable char-briquettes producers including a carbon financing program.

Detailed and more elaborated recommendations are mentioned in chapter 3 and 4 and in the conclusion.

Background cooking sector
The cooking sector is dominated by inefficient charcoal stoves in urban areas and open fires in rural areas. Stoves used have a very low thermal efficiency and coupled with inefficient charcoal kilns, most of the energy stored in the wood is wasted. This is contributing to the rapid pace of forest degradation in Zambia, high exposure to health-damaging particulate emissions emitted during the combustion process (4th highest risk factor to premature death) and a significant time or monetary expenditure to respectively collect wood or purchase charcoal.

Improved cookstove sector analysis
This study concludes that there are ample opportunities to encourage the adoption of energy efficient stoves and to increase investment in alternative cooking fuels. Key barriers holding back investment is the competition with a largely informal and improperly taxed fuel, charcoal. Levelling this playing field requires enforcing of current regulation in the charcoal sector and the provision of fiscal incentives for alternative fuels and stoves, such as import duty and VAT exemption.

Numerous local artisan tinsmiths produce traditional stoves (Tier 0), and currently serve the bottom of the market and are dispersed over the whole country. There is an opportunity to engage with these artisans and providing capacity and tools to improve the production capacity and the stove efficiency. The latter can be realised by introducing existing or improving the current stove designs. Moreover, given that a large share of the population relies on inefficient traditional stoves, an increase in stove efficiency, will significantly reduce wood and charcoal consumption. Concerted action, such as setting up an ICS (improved cookstove) support program on capacity building, improved efficient stove design and discouraging the production of traditional stoves by providing the right incentives and supporting structure (marketing, promotion, carbon finance) is essential. Multiplier benefits, in terms of wood savings, are possible by simultaneously encouraging adoption of energy efficient charcoal kilns.

Established and new ICS companies have entered the market, but sales are limited. Various ICS companies, have, or are in the process of accessing carbon finance. This is foreseen to greatly accelerate sales and investment.

Char-briquette sector analysis
Various start-up companies have started producing char-briquettes from agricultural and wood waste. However, their main market are poultry and pig farmers. Venturing into cooking market requires a switch from manual to mechanised production to boost production and lower costs, but technologies and financing schemes are not readily available.

Pellet sector analysis
One company is producing pellets and selling pellet gasifier stoves. The company however is struggling with securing sufficient feedstock and the cost associated with pre-financing of stoves. There are various companies exploring valorisation of residues for pellets or char-briquettes. For the sector to grow sustainably and to secure the pellet and stove supply chain, it is necessary that more companies enter this market and that plantation residues are made available at reasonable costs.

Review the excise duty to release investment on bioethanol
Bioethanol holds a great promise. Zambia has a unique opportunity to significantly scale up production and serve a significant share of the population with bio-ethanol fuels for cooking and transportation. Denatured bioethanol is taxed with a 60% excise duty, which is by far the main barrier to unlocking investment. Abolishing this excise duty would, according to the stakeholders interviewed, significantly increase investment, and could even be transformative in terms of creating opportunities for farmers, rural economic development and could significantly reduce cooking fuel and gasoline imports. Addressing the excise duty barrier, should apply to both using bioethanol for gasoline blending and cooking fuels. Bioethanol for gasoline blending will be the main market for bio-ethanol producers and would create the scale required for significant investment in upscaling of production capacity. The market for cooking fuels will be complementary and benefit from the upscaling as well.

Domestic biogas sector analysis
Domestic biogas is another sector with great potential. Less than 5,000 plants are built while there are 1 million households engaged in animal raising, which potentially all could benefit from a biogas digester. The sector is at the moment heavily subsidized preventing other private parties entering the market. This is also partly the result of the low replacement value of biogas (most households rely on wood in rural areas which is generally free to collect), insufficient attention to the bio-slurry benefits to improve agricultural productivity and the high capital investment required. The overall value proposition of biodigesters could be improved by appropriate valuation of the bio-slurry benefits through applied research as sustainable organic fertilizer. Innovative financing models, such as lease to own or pay as you go models are necessary to improve affordability.

Moving forward in the clean cooking sector
In the clean cooking sector, concerted action is required to build awareness and to support companies to increase their reach, including measures to improve access to finance. The off-grid task force, chaired by the Ministry of Energy (MOE) is ideally positioned to lead this action. Other important stakeholders to be included are the Ministry of Agriculture (on agricultural aspects of biogas), Ministry of Green Economy and Environment (currently promoting char-briquettes), Ministry of Health and other relevant stakeholders.

Productive use of bioenergy sector analysis
There is a significant potential for biogas for pig pen and chick brooding stable heating – as a source of reliable and sustainable energy with significant monetary savings. Likewise, wood consumption in the tobacco and fish sectors, could be reduced significantly with the introduction and promotion of existing energy efficient barns while at the same time improving quality of the cured and dried product. There is also a potential to produce most of the wood required on farms by investing into fast growing tree species.

Biogas and biomass to power is challenging. On-grid alternatives do not seem viable due to the low electricity tariffs. Off-grid alternatives are challenging due to low demand, the highly geo-spatial rural settlement patterns which increases cost in distribution networks. There are successful examples in the world where villages were electrified with a small gasifier however and that experience could be replicated, provided there is sufficient demand. On a case-by-case basis however, electrification should be assessed as to what alternative energy source (e.g., biogas, hydro, solar, wind) is most appropriate.

1 General introduction

1.1 Bio-energy diagnostic study

The Investment Climate Reform (ICR) Facility approved technical assistance (TA) to the Ministry of Energy of Zambia (MOE), and specifically the Off-grid Taskforce (OGTF) within the Department of Energy.

In order to focus its policy and regulatory activities, the MOE (and with that the bioenergy sub-committee of the OGTF) requires an assessment of the Zambian bioenergy market. This includes an analysis of the market opportunities and potential for market expansion; market access and regulatory barriers for the private sector, and recommendations on overcoming them. In this regard, the MOE requested for technical assistance to undertake a diagnostic study of the Zambian bioenergy sector.

1.2 Objectives and scope

The objective of this assignment is to prepare an analysis of the investment barriers currently holding back the bioenergy sector (biomass) for cooking and industrial [1] use and how to remedy them. The study will support the implementation of the 2019 National Energy Policy's objective to provide universal access to clean, reliable, and affordable energy at the lowest total economic, financial, social, and environmental cost by 2030. As part of the policy, the country is expected to develop a biomass strategy and support private sector companies to promote the more efficient use of biomass.

The scope of the study encompasses the following sectors:

(1) **cooking in the residential sector** focusing on:
   a. improved wood and charcoal stoves (Tier 2 and 3) [2]
   b. modern bio-energy fuels (pellets, briquettes, bioethanol, and biogas), and;

(2) **productive use of bioenergy** focussing on fuel substitution at agro-processing facilities with mini-grid consideration in off-grid rural areas for:
   a. thermal energy generation for tobacco curing and biogas for barn heating (poultry and piggeries)
   b. biomass and biogas for power generation

The study includes the following components:

- The demand side (market size, customer segmentation and trends, cultural and socioeconomic aspects of energy consumption (incl. ability/ willingness to pay, gender parity), and supply side (current market players and business models, supply chain robustness and reliability, technical and operational skills, access to finance, employment structures by gender and age) of the Zambian bioenergy space.
- Framework conditions (policy & regulation, finance, infrastructure, donor programmes) for bioenergy. This should cover fiscal incentives, financing needs and available financing models and services, and the needs of new market entrants and business models ready to scale.
- The study will provide clear recommendations for measures that will promote a more efficiently operating bioenergy sector through an effective governance and finance framework. In doing so, the study is also expected to draw on lessons learnt from other countries that have diversified their competitive landscape.

[1] The word 'industrial' originates from the ToR, however the meaning here is limited to the application of biomass for power generation, curing of tobacco and barn space heating.
[2] The International Workshop Agreement (IWA) established tiers of performance to rank stove performance across each of the 4 criteria (efficiency, total emissions, indoor emissions, and safety), across a ranking spectrum from 0, which represents the performance of typical baseline open/three-stone fire, and 4, which represents a longer-term aspirational goal for biomass stoves. Tier 2 and 3 are improved stoves. Annex 2 details the Tier performance attributes.

1.3 Methodology

The study relies both on primary and secondary data collection methods. The secondary data collection and analysis consist of key documents review pertinent to the sector and primary data was collected through consultations with key stakeholders in the sectors during a 1-week mission in February, a 2-week mission in June 2022 and virtual consultations held in July-September 2022 and 2 workshops (kick-off workshop and the validation workshop) This includes various meetings with government actors, private sector actors, and projects of development partners (table 1).

Table 1: Stakeholder consultations and workshops

Stakeholder consultations	Interviews/participants
Kick-off workshop	28 participants
First mission	9
Second mission: consultations in Zambia, including visits to Ndola, Kabwe, Petauke and Chongwe (2-week mission)	28
Virtual consultation meetings	10
Validation workshop	54 participants

Annex 1 contains the list of people consulted.

The energy access multi-tier framework (MTF) developed by the World Bank [3] is used as guidance for the bio-energy assessment for cookstoves and electricity access. Annex I provide an overview of the MTF and its stove and electricity access performance attributes.

1.4 Study limitations

The diagnostic study covers a total of 5 sectors related to cooking (improved cookstoves (ICS) wood and charcoal, domestic biogas, pellets, and bioethanol) and 5 sectors related to productive use (thermal energy and energy efficiency for tobacco curing, bioenergy for barn heating (piglet pens and chick brooding), biogas for power generation and biomass for power generation.

While some of those sectors overlap, have similar challenges and attributes, there is always a risk that information is anecdotal and not representative for the whole sector. Care was taken not to generalise findings when only a couple of stakeholders in particular sector have been interviewed. These findings are only presented in this report if supported by the literature or deemed representative for a sector. Furthermore, given the nascent nature of the bio-energy sector, no or limited information was available on gender issues in the sector, including employment structures by gender and age.

[3] https://mtfenergyaccess.esmap.org/

2 Country context

2.1 Background

Zambia is generally sparsely populated, but it is also one of Sub-Sahara Africa's most urbanized countries, with 44% of the population living in urban areas, mainly in Lusaka and Copperbelt Province, the core economic hubs of the country (Luzi, Lin, Koo, Rysankova, & Portale, 2019). Zambia is currently going through a substantial demographic transition, as the population is both one of the world's youngest (by median age) and growing at 2.8% per year. This is partly due to high fertility rates and will result in the population doubling close to every 25 years, putting an increasing pressure on the demand for jobs, health care and other social services. In addition, urbanization is still ongoing: over the past decade the urban population grew annually at a rate of about 4% (The World Bank, 2021).

Zambia is resource-rich and has large reserves of copper. Its mining sector is well-developed and accounts for three-quarters of national export earnings. While mining is the major driver of Zambia's economy, agriculture is the economy's backbone (Standard Bank, 2022). Despite its limited contribution to GDP, agriculture provides for the livelihoods of more than 70% of the population. The primary sector is dominated by smallholder farmers and is focused on crop farming (primarily sugarcane, maize, and cassava) and livestock production (typically traditional animal husbandry by households). Due to abundant fertile land and good rain, the agricultural sector has a major potential for growth, which will be crucial for rural poverty reduction. However, productivity remains low compared to global standards, due to low access to inputs, inappropriate farming practices that lead to soil degradation, and dependency on (irregular) rainfall. The secondary sector accounts for 21.7% of GDP and consist mainly of mining, construction, and manufacturing. The tertiary sector accounts for 54% of GDP, and includes a large wholesale and retail sector, as well as tourism (FAO, 2020) (KMPG, 2017).

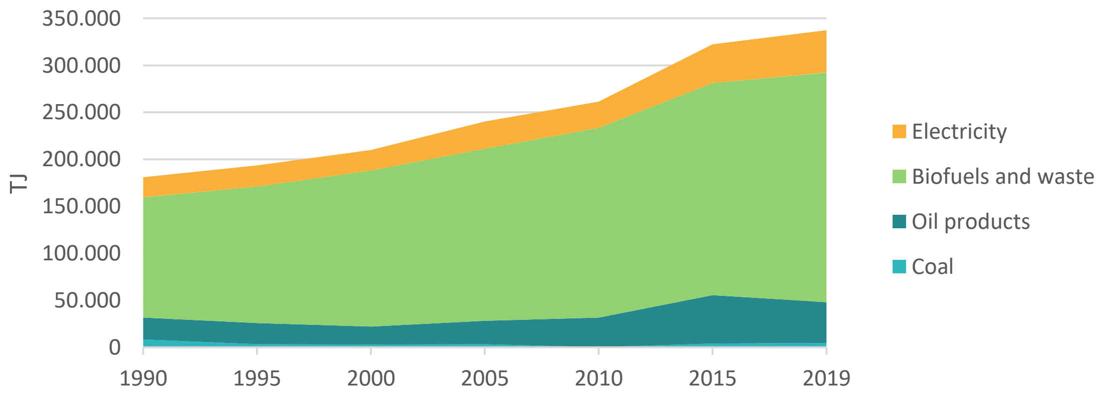
Between 2000 and 2014, Zambia experienced steady GDP growth averaging 6.8% and achieved a lower middle-income status in 2011 (The World Bank, 2021). The economic performance has benefitted only a small segment of the urban population and did not significantly reduce poverty or inequality (FAO, 2020). According to the most recent data, 58.7% of Zambians were living below the poverty line in 2015. Mainly due to falling copper prices, combined with declines in agricultural output and reduced hydro-electric power generation due to insufficient rainfall, Zambia's economic growth has slowed down in the past 10 years. Recently the World Bank re-classified Zambia to low-income economy in 2022 because of the deterioration of Gross National Income per capita (World Bank, 2022)

2.2 Energy

Zambia's total primary energy mix is dominated by biofuels and waste, which mainly comprise of wood fuels (i.e., firewood and charcoal) and account for an estimated 77% of the total primary energy supply. Electricity, which makes up only a fraction of Zambia's total final energy consumption, is almost entirely (85%) generated by Zambia's hydropower plants. The remaining share of electricity is produced by one coal power station, with minor contributions from oil-powered generators and solar photovoltaics (PV) (IEA, 2021), figure 1:

Figure 1: 77% of total TFEC comes from biofuels and waste

Total Final Energy Consumption Zambia;



Source: IEA, 2021

Zambia imports all petroleum products from the international markets. Primary energy consumption has doubled in the past two decades, but both per capita energy supply and electricity consumption have remained more or less stable (IEA, 2021). Relative to the Sub-Sahara African average, the per capita electricity consumption is high, but it is low with respect to Zambia's social and economic potential when compared to countries with similar levels of GDP per capita and large mining sectors (Power Africa, 2018)

2.3 Energy use by sector

Sixty percent of Zambia's total final energy consumption (TFEC) is accounted for by the residential sector, followed by industry (22%) and transportation (9%). Almost all energy used by households (94%, 206,178 TJ) is traditional biomass, which is mainly used for cooking and heating, and typically comprises charcoal (in urban areas) or firewood and animal dung (in both rural, but also in urban areas). Over half of Zambia's electricity is consumed by the industrial sector. The mining sector located in the northern Copperbelt Region requires a large amount of energy, which is transported straight from the hydropower installations in the south of the country (Power Africa, 2018). After the mining sector, Zambia's major electricity consuming sectors are manufacturing (32%), the service sector (7.2%) and the agricultural sector (2.5%) (FAO, 2020). A breakdown by sector and fuel in terajoule (TJ) is provided in the table below:

Table 2: Most energy is consumed in the residential sector followed by the industrial sector

Total final energy consumption by sector

2019 (TJ)	Coal	Oil products	Biofuels & biomass	Electricity	Total	%
Industry	4,600	7,294	38,212	25,415	75,521	22%
Transport		28.682		112	28,794	9%
Residential		200	206,178	14,481	220,859	65%
Commercial & public services		890		3,268	4,158	1%
Agriculture / Forestry		1,224		1,125	2,349	1%
Fishing						0%
Non-specified		1,997		696	2,693	1%
Non-energy use		2,982			2,982	1%
TOTAL	**4,600**	**43,269**	**244,390**	**45,097**	**337,356**	**100%**
%	1%	13%	72%	13%	100%	

Bioenergy is also a major source of energy for the industrial sector, making it Zambia's second largest bioenergy consumer, after households (FAO, 2020). A breakdown of fuelwood and charcoal consumption is depicted in the table below by province (Gov. of Zambia, 2017).

Table 3: Wood and charcoal are consumed in all provinces

Provincial firewood and charcoal consumption

Consumption (tonnes)	Firewood		Charcoal	
	Industrial	**Domestic**	**Industrial**	**Domestic**
Central	17,675	628,573	14,545	122,606
Copperbelt	27,558	162,555	22,677	332,863
Eastern	21,156	650,128	17,409	145,874
Luapula	13,153	467,753	10,824	77,425
Lusaka	32,402	139,165	26,663	402,222
Muchinga	10,442	371,338	8,593	61,466
Northern	15,218	541,179	12,523	89,579
North-western	9,727	345,931	8,005	57,261
Southern	22,256	564,737	18,315	178,348
Western	11,567	372,904	9,518	76,115
Total	**181,153**	**4,244,263**	**149,071**	**1,543,759**

In terms of consumption by sector, the domestic sector is with 82% the largest consumer of biomass, followed by the industry (6.4%), commercial and public sectors (6.4%), fish drying 2.7% and tobacco curing (2.5%) (Gov. of Zambia, 2017). Most wood is consumed in the Eastern and Central provinces.

2.4 Bio-energy resource assessment

Zambia's current consumption of traditional biomass is mostly firewood and charcoal, which is almost entirely produced from domestically sourced wood fuel. It is estimated that 90% of the roundwood obtained from natural forests is used as wood fuel. Since the level of annually sourced wood exceeds the mean annual increment of biomass, deforestation takes place, at an annual rate of an estimated 172,000 hectare per annum (Ministry of Finance and National Planning, 2022). Although the major drivers of deforestation are attributed to the expansion of agricultural land and human settlements, replacing current sources of wood fuel with sustainably sourced woody residues or with other types of biomass residues would reduce the pressure on natural forests (FAO, 2020).

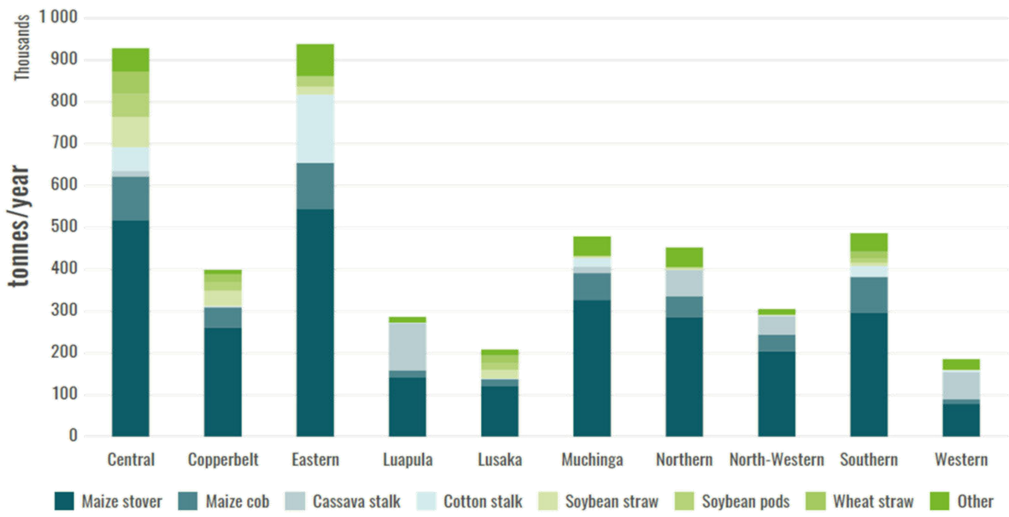
FAO, in its bioenergy and food security (BEFS) study, outlines viable feedstock and sustainable bioenergy supply chains. The study concludes that briquettes (i.e., charcoal briquettes or biomass briquettes) and biogas are potential variable alternative cooking fuels and could meet 14% of the countries clean cooking target. Alternatively, these fuels could be used to generate up to 1,192 MW electricity. However, valorisation of these resources would require a considerable investment to ensure that the identified bioenergy supply chains are established and function effectively (FAO, 2020).

2.4.1 Agricultural residues bio-energy potential

Agricultural residues stem mainly from cereals (maize, rice, millet, wheat, sorghum, barely), oil seeds (soybeans, groundnuts, sunflower), tubers and roots (sweet potatoes, cassava, Irish potatoes), cash crops (tobacco, cotton) and sugar crops (sugar cane). These residues comprise primary and secondary residues, which are respectively generated in the field and co-produced during processing. Up to over 50% of primary residues may be required to maintain soil fertility. Other current uses of agricultural residues considered are utilization as animal feed and bedding, fuel for cooking and heating, building material, food, planting material for the next season. The amount of available crop residues is estimated by FAO based on the RCR (residue to crop ratio), minus the share that should be left on the soil (for mulching, maintaining soil health, 30%) minus the amount already utilized (FAO; The Ministry of Energy of Zambia, 2020) and totals around 4.67 million tonnes per annum for bioenergy production. The amounts of residues available for bio-energy purposes by province is disaggregated below (figure 2):

Figure 2: Agricultural residues are available in all provinces, but maize is the most important

Volume of residues available for bioenergy by province



Source: FAO 2020

The availability of crop residues is mainly concentrated in the Eastern and Central provinces, though the Copperbelt, Muchinga, Northern and Southern region also offer a substantial share of residues. The main crops residues available are maize stover (leave, stalks) in all provinces. In Central, Eastern cotton stalks are also significant sources of residues while in Luapula, Northern and Western cassava stalks are important residues next to maize residues.

Wheat straw is mostly available in Central province. During the field visits some farmers indicated they have increased production of wheat in response to the increase in wheat prices. The international wheat price has increased to its highest value in the period 1960 to 2022, even higher than the value during the 2008 financial crisis and around 3 times higher than in 2016 [4] driven by the war in Ukraine which has disrupted global food supply chains.

There is no systematically recorded data available on most of the secondary residues generated by processing facilities, such as cassava flour mills, cotton ginneries, cashew nuts and groundnuts de-shelling plants. An assessment on the volume of residues generated by these facilities is yet to be made. Rice husk, with an estimated production of 9,392 tonnes/year, is not utilized systematically either.

2.4.2 Wood residues

It is estimated that 451,500 m^3 of felled timber is produced annually on plantations in Ndola, Ichimpe, Chati and Lamba. This would annually generate 102,700 m^3, or around 60,000 ton of residues (FAO, 2020).

In addition, roundwood processing by sawmills generates an annual average of 2,830,632 m^3 of residues. However, most of these residues are recovered and further processed or used for other purposes, leaving an estimated 145,715 m^3 or 72,858 ton of residues available to produce bioenergy products. A large share of chips and saw dust, 63.3% and 66.2% respectively, are given away indicating that there is a potential to valorise these resources for other purposes and create additional value.

The residues generated from forest plantations and sawmills however are relatively small compared to total energy demand for cooking and electricity at national level (FAO, 2020). At local level however, using these residues for modern cooking fuels, and/or improved charcoal production, could replace traditional fuels and reduce the demand for freshly cut wood.

2.4.3 Animal manure for biogas production

The number of agriculture households accounted for 2,267,999 of the total number of households in the country, or 60.8 percent. Out of those, 641,826 households are active in cattle, aquaculture, or honey production. Households with livestock, cattle, pigs, chicken and goats, have the technical potential to generated biogas for cooking provided that the quantity and quality of manure available is sufficient [5]. The amount of manure available depends on livestock production levels, production systems, the practicality of manure collection and the feasibility of using the manure collected for the production of biogas based on various characteristics (e.g., composition, moisture content and impurities). For cattle production, manure can only be collected when animals are stabled, while manure from free-ranging pigs and chicken may not be practical to collect. The estimated availability and spatial concentration are displayed in the table below:

Table 4: Manure is available from mainly cattle and pigs

Manure availability by animal type

Type	Annual availability (tonne/annum)	Spatial concentration
Cattle	2,504,901	Central and Southern Province
Pig	572,532	Eastern and Southern Province
Chicken	34,642	Central Province and Lusaka
Goat	18,718	Central and Southern Province

Source: FAO 2020

Of these feedstocks, only small fractions originate from commercial activities. This is especially the case for cattle and pigs which are kept by households, while most chicken are kept commercially.

Consequently, there is a significant amount of manure available at household level which would be used to support domestic scale biodigesters for biogas production. SNV estimates that the theoretical number of households with the financial and technical capacity (having enough manure for the smallest digester model) to invest in a digester is around 166,748 (AgriProFocus, 2016) which is around 10% of all rural households (CSO Zambia, 2015).

[4] https://www.macrotrends.net/

[5] Typically, at least 20 kg manure is required daily to produce sufficient biogas for cooking

2.5 Bio-energy valorisation technologies

2.5.1 Production of cooking fuels

Densification of agricultural and wood residues is often necessary to improve combustion properties and reduce bulk volume to reduce transportation costs.

- **Briquetting**

The following technologies are available to densify woody residues.

Table 5: Common densification methods

Densification method	Reliably profitable feedstocks	Picture
Piston press (cold pressing)	Cotton husk, cotton stalk, soybean straw.	
Screw press with post heating (hot press)	Cotton husk, cotton stalk, soybean straw, cassava stalk, maize cob, maize stove, sunflower stalk, millet stalk, sorghum stalk, wheat straw, soybean pods.	
Carbonized briquettes	Good quality feedstocks [6]: Maize cob, cotton and cassava stalk, Poor quality [7]: maize stover, wheat straw, cotton stalk, cotton husk.	

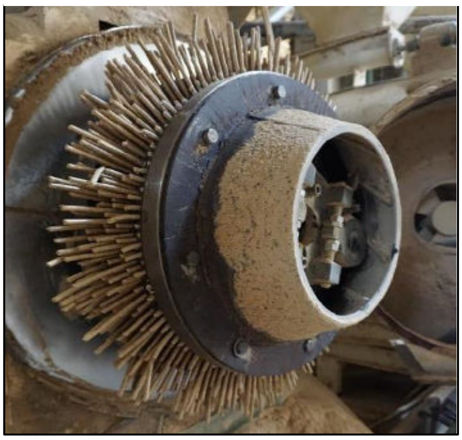
Hot or cold pressed briquettes could reach 23% of the clean cooking target, but cannot be used in existing stoves, new stoves are required. Charcoal briquetting improve the fuel properties of the briquettes and allows it to be used in ordinary stoves, but the carbonization process also results in losses. Charcoal briquettes could therefore only meet 7% of the target (FAO, 2020).

- **Pelleting**

Pelleting is grouped in the BEFS study under briquettes (FAO, 2020). This is not surprising as the production of pellets is similar to cold pressed briquettes, except that the extruder is a ring die (figure 3). Pellets are much smaller than briquettes and can be used in higher tier stoves, such as gasifier stoves (i.e., ACE, Mimi Moto) and allow for precise fuel feeding.

The company SupaMoto in Zambia is currently producing pellets from plantation residues and residues from sawmills. Pellets are used in Mimi Moto stoves and in-house developed institutional stoves. In Lusaka, households can buy the stove via a fuel subscription, where the stove is paid back via a top-up on monthly fuel purchases (Supamoto, 2022). More details are provided in paragraph 3.5.

Figure 3: Ring die pellet extruder (author's picture taken in Vietnam)



[6] Interview with Carlo Figa Talamance, CEO of OTAGO – leading char-briquetting producer in SE Asia
[7] Poor due to low fixed carbon content and difficult to carbonize due to low bulk density

2.5.2 Biogas production for cooking

Domestic biogas with animal manure as feedstock is a well-established technology in many countries worldwide. Biodigesters could supply next to gas for cooking, lighting, and energy for productive use. This could include applications such as stable heating (radiating or via a medium, i.e., floor heating), powering converted petrol /diesel engines, for mechanical power (i.e., water pumping, grain milling and grinding, chaff cutters) or electricity generation. Small farms, however, may not have enough feedstock to use gas for other uses than cooking. But larger models, above 10 m^3, often produce more gas than the household requires, and energy is available for other purposes.

FAO estimates that biogas could meet 3% of the national energy demand. In addition, co-digestion of cattle manure with crops residues (maize stover, cotton stalk, rice straw, sunflower stalk, wheat straw and sorghum stalk) could raise biogas production from 3% (cattle manure only) to 5% of the target energy demand. However, this would reduce the number of residues available for other energy products. (FAO, 2020).

Next to utilizing manure for biogas, there is also a potential to use organic matter such as vegetable and market waste. Larger institutional biogas systems could be a viable option in urban markets, providing gas to nearby food vendors, piped to neighbouring households, or bottled for home consumption (USAID, 2021).

2.5.3 Bio-energy potential for productive use

Productive use is defined in this study as the utilization of energy – both electric, and non-electric energy in the form of heat, or mechanical energy to support income generating activities. The FAO estimated that there is a potential of 1192 MWe from gasification or combustion of agricultural residues (maize stover, maize cob, cotton and cassava stalk).

The levelized cost of electricity (LCOE) generated using combustion or gasification of crop residues is estimated to be lower than the LCOE of more wide-spread off-grid energy generation technologies (PV+ battery systems and diesel generators) (FAO, 2020). However, these conclusions of FAO should be interpreted carefully. That is because a reliable and secure biomass supply chain is necessary in terms of pricing and year-round availability. Moreover, biomass to power technologies require a certain base load to operate cost efficiently. This is in contrast with the demand patterns of households which are often low and concentrated in evening hours, for which a solar home system might be more applicable.

2.6 Policy environment

The National Energy Policy (NEP) 2008 which was revised in 2019 aims to macro-economic policy objectives of sustainable energy development and the creation of a market environment promoting increased private sector participation. The NEP calls for sustainable exploitation of biomass in its 4th objective. Specifically, the following policy measures are identified:

- promote efficient and sustainable exploitation of biomass for household utilization
- promote the use of alternatives to wood fuel
- promote biofuels in the national fuel mix; and
- ensure that the use of biofuels for the energy market is given priority without compromising food security

Key activities are developing a biomass strategy, support private companies to produce more efficient cookstoves, enforce biomass regulations, conduct awareness campaigns (MOE, 2019).

The Energy Efficiency Strategic Action plan (EESAP), which is currently under validation, entails the necessary objectives and measures to achieve the overall target of NEP 2019 which is ultimately the optimal energy-resources utilization to meet Zambia's domestic and non-domestic needs at the lowest total economic, financial, social, environmental and opportunity cost and to establish Zambia as a net exporter of energy. This action plan foresees in the following concrete actions and targets when it comes to biomass energy.

- 20% of all public/administrate buildings equipped with biodigesters by 2030
- LPG and biomass systems: develop a biomass and improved cook stove distribution centre

- Pay as you go cooking solutions: 100,000 stoves by 2027- and 10,000-ton pellets per year
- Fuel blending programme: 5% biodiesel and 10% bioethanol

Note that the EEASP is under validation, and the targets mentioned are therefore not yet adopted.

Various other plans and agendas propose measures to increase the adoption of clean cooking technologies. These include:

- The Sustainable Energy for All Initiative (SEA4ALL) Action agenda for Zambia stresses the need to shift to clean cooking solutions through promoting clean alternatives technologies and fuels. To achieve the clean cooking target of 100% by 2030 in urban areas, the action plan outlines the following strategies which includes providing financial and fiscal instruments to stimulate the production of alternative technologies and fuels including smart subsidies, concessional loans, loan guarantees, blended financing provision of tax incentives and waivers on biomass energy capital equipment.
- The National Investment Plan to Reduce Deforestation and Forest Degradation (2018-2022) identifies charcoal as one of the major threats to forests in Zambia due to the huge demand for charcoal in urban areas. The Plan prioritizes: (i) investments aimed at the promotion of alternatives to charcoal (including biogas, LPG, solar), (ii) measures to reduce the urban demand for charcoal, and (iii) alternative livelihoods for charcoal producers as priorities to reduce charcoal production.
- The draft 2021 Gender Equality Strategy and Action Plan (GESAP) recognizes that the high dependency on charcoal and firwood in Zambia disproportionately affects women, including their time and health. The strategy recognises the need to create an enabling environment through provision of tax incentives such as VAT removal on improved/clean cookstoves.

Currently however, alternative fuels (AFT) are subject to custom duty, VAT and in the case of ethanol, except gel fuel, a 60% excise duty (see table below) (A2C, 2021)

Table 6: Alternative fuels are subjected to VAT, custom duty and in the case of bio-ethanol also excise duty

<table>
<tr><th colspan="3">Taxation of ATFs details</th><th colspan="3">Current tax rates</th></tr>
<tr><th>Alternative fuel</th><th>Component</th><th>HS Code</th><th>Customs Duty</th><th>VAT</th><th>Excise Duty</th></tr>
<tr><td>LPG</td><td>Cylinders</td><td>7311.00.00</td><td>15%</td><td>16%</td><td>-</td></tr>
<tr><td>Biomass stoves / pellet fuel</td><td>Pellets</td><td>4401.31.00</td><td>40%</td><td>16%</td><td>-</td></tr>
<tr><td rowspan="3">Electricity-based</td><td>Hotplate cooker</td><td rowspan="3">8516.60.00</td><td rowspan="3">40%</td><td rowspan="3">16%</td><td rowspan="3">-</td></tr>
<tr><td>Electric pressure Cooker</td></tr>
<tr><td>Induction cooker</td></tr>
<tr><td rowspan="2">Ethanol</td><td>Gel fuel</td><td rowspan="2">2207.10.00 (of alcoholic strength by volume of 80%)</td><td rowspan="2">5%</td><td rowspan="2">16%</td><td rowspan="2">60%</td></tr>
<tr><td>Liquid fuel</td></tr>
</table>

Source: A2C, 2021

A2C proposes, in line government's national policies and strategies, to institute various fiscal incentives to ATFs to make them more affordable and accessible to the majority of Zambians. Removal of import duty and zero-rating value-added tax for an initial period of 5 years is being proposed on the fuels and components mentioned in the table above, except for maintaining 5% custom duty on imported ethanol, to accelerate rapid uptake of ATFs (A2C, 2021).

3 Bioenergy for cooking

Chapter 2 concluded that there is a significant potential to utilize existing bio-energy resources for cooking. Investment into the cooking sector, however, is limited. This chapter assesses the barriers to investment in the sector and provides recommendations on how to overcome those barriers.

The chapter focusses on improved cookstoves to reduce reliance on wood and charcoal and sustainable alternatives fuels: char briquettes, domestic biogas, pellets, and bioethanol.

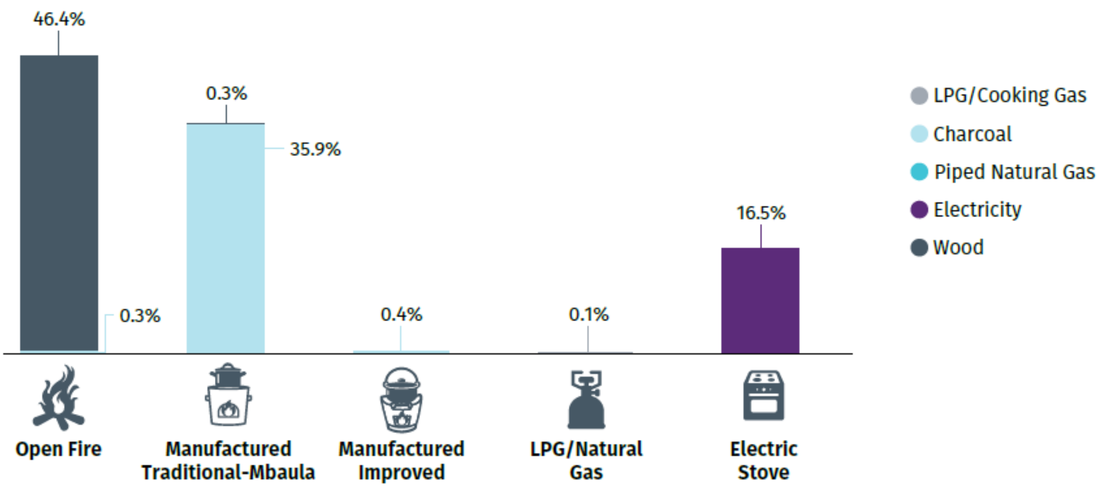
3.1 Cooking sector overview

3.1.1 Cook stoves and fuels

Traditional biomass: wood, and charcoal, are used by 83.4% of the household in Zambia in open fires in the case of wood (46.4%) and 0.3% with charcoal, 32.9% traditional brazier stoves (mbaula) fuelled with charcoal or wood (0.3%). Improved manufactured stoves are used by 0.4% of the population and 0.1% relies on LPG. A relatively large share of households is cooking on electricity (16.5%), see figure 4:

Figure 4: Most households rely on open fires and traditional mbaula stoves

The bar chart sequence is from least clean to cleanest cooking options



Source: ESMAP, 2019

The dominant cooking technologies, open fires and mbaula stoves fall in the Tier 0 or Tier 1 performance category, which means that the thermal efficiency is around 10% (90% of the heat is wasted), combined with a high PM2.5 (particulate matter less than 2.5 µM) and high CO emissions, poor convenience, and poor safety. The emissions of health damaging particles, PM2.5 and CO is contributing to the high burden of disease attributed to household air pollution in Zambia. Annex 2 elaborates on the Tier performance attributes.

3.1.2 Charcoal production

The production of charcoal requires large quantities of wood. In Zambia charcoal is primarily produced using traditional earth-kiln method (MOE, 2017). It is estimated that between 5 to 10 tonnes of wood is required to produce 1 tonne of charcoal. Thus, using the IPCC default net calorific value (NCV) of wood of 15.6 MJ/kg and charcoal of 29.5 [8], between 81% to 62% of the energy is lost during the conversion process (author's calculations). The overall energy efficiency, from charcoal production to cooking therefore is, with an assumed mbaula stove efficiency of 10%, just 2 % to 4%. Thus, over 95% of the energy is lost during the various conversion processes. It should be noted that the heat radiated from the stove is appreciated during the colder month as a source of space heating.

[8] IPCC default values for National Greenhouse gas inventories

Charcoal consumption is growing due to Zambia's rapid population growth and urbanization and may be driven by the frequency of power outages. As a result of growing demand, less experienced producers have entered the sector as well, as the only precondition for entering the market is the availability of labour and common household equipment (Gumbo, et al., 2013). According to stakeholders interviewed, this situation is continuing in 2022. The less experienced producers generally have even less efficient kilns which further aggravates the pressure on local forests, from which 75.29% of the wood for charcoal production is taken (Snow Systems Zambia, 2020). In some areas charcoal production has contributed to up to 30% of deforestation. Other causes of deforestation are agricultural activities, infrastructure development and human settlements. Since specific species are preferred for charcoal production this also impacts biodiversity. Despite various efforts to regulate the sector through licensing, charcoal production remains an informal activity, which is carried out illegally. The practice deemed is too widespread to police effectively.

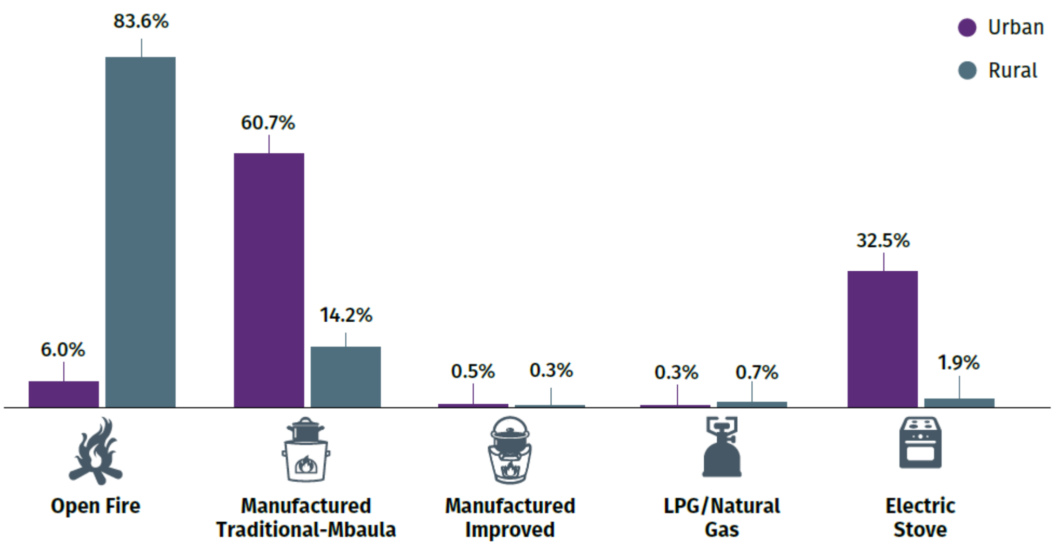
Charcoal production accounts for an estimated 3.7% of GDP, offering a source of cash income and employment for both urban and rural dwellers that is derived from producing and packaging, trading and transporting, and retail. In terms of retail channels, most charcoal is sold on roadside markets and door-to-door or by arrangement in districts centres and urban areas. These markets are both supplied by producers and intermediate traders, who may also sell to wholesalers, restaurants and stallholders. While the bulk of Zambian charcoal is consumed domestically, policy makers should also take into account that significant informal trade flows exist to Malawi, Mozambique, Tanzania and Zimbabwe (Gumbo, et al., 2013).

3.1.3 Urban and rural area cooking schism

Cooking patterns are different in rural and urban areas, open fire is most common in rural areas (83.6%) and mbaula (60.7%) in urban areas, modern cooking solutions, defined as tier 3 or above, are restricted to urban areas and consist of LPG and electric stoves (figure 5)

Figure 5: Modern cooking solutions such as LPG and electricity are restricted to urban areas

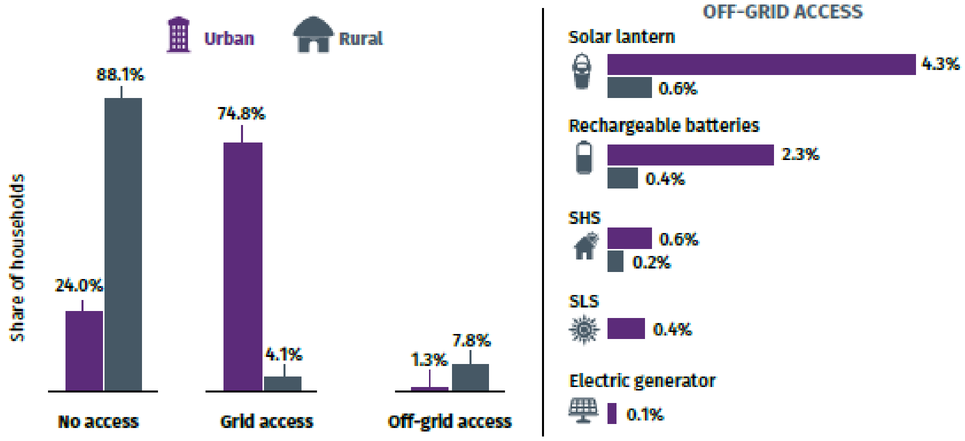
The bar chart sequence is from least clean to cleanest cooking option



Source: ESMAP, 2019

Zambia has a relative high share of households cooking on electric stoves. Usage is restricted to on-grid urban areas which can be explained by the differences in electricity access (figure 6) (ESMAP, 2019).

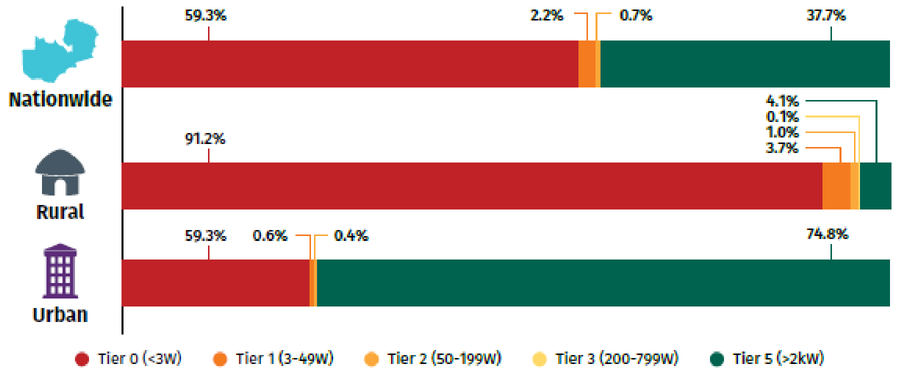
Figure 6: Access to electricity is much higher in urban areas compared to rural areas
Access to electricity in rural versus urban areas



Source: ESMAP, 2019

Electric cooking requires having an electricity connection of at least 2 kW next to being reliable and affordable. In terms of capacity, very few rural households (4.1%) have the ability to cook on electricity in stark contrast with 74.8% of urban households, see the figure below (ESMAP, 2019):

Figure 7: Higher Tier access to electricity is restricted to urban areas
Distribution of households based on electricity Capacity, nationwide, urban and rural



Source: ESMAP, 2019

More households have the ability to cook on electricity than the current 16% cooking with electricity. While there is room to encourage a higher adoption of cooking with electricity, the switch is hampered by interruptions due to load shedding; cultural factors (preference to cook certain dishes on charcoal); or by habit (Tembo, T., & Sitko, 2015). As a result, *fuel stacking* (the use of multiple cooking solutions by a single household) is relatively widespread. 47.3% of households use a combination of traditional cooking and modern cookstoves, and only 43.1% of grid-connected households use electric stoves as primary stove.

3.1.4 Impact on society of using traditional fuels

Some of the key impacts, besides climate change, are, amongst others:

- **Health:** The health impact estimated by IHME (Institute for Health Metrics and Evaluation) in its Global burden of disease study [9]. Household air pollution is the third risk factor to death after unsafe sex and high blood pressure and attributed to 8,822 deaths annually. The burden is mostly on women, being the third risk factor to premature death and less on men (5th cause) or young children below 5-year, 5th risk factor. In 2019, the DALY [10] because

[9] Institute for Health Metrics and Evaluation | (healthdata.org)
[10] DALY, Disability Adjusted Life Years, for a disease or health condition are the sum of the years of life lost to due to premature mortality and the years lived with a disability and estimates the burden of a disease in one metric.

of household air pollution was 442,502 years; the total amount of time lost due to premature mortality and living with a disability attributed to diseases resulting from cooking on solid biomass.

- **Deforestation**: An estimated 276,021-hectare forest is lost annually for the period 2010-2014 (MOE, 2017), and is around 172,000 hectares in 2018 (Ministry of Finance and National Planning, 2022). Some of the stakeholders interviewed branded this as the 'energy crisis', resulting in hardship and degradation of local environments. A2C estimates that charcoal contributes to 25% of the deforestation rate (USAID, 2021). No estimates are available on the contribution of wood consumption to deforestation. However, this is likely lower than charcoal given the high losses during charcoal production and the high share of charcoal users in the country.

- **Time:** A significant share of time is spent on collecting wood, tending the fire, cleaning sooth from pots. Wood collection alone is estimated to amount to 1.7 hours per day per household (WB, 2014),

3.1.5 Addressing the cooking conundrum

The cooking conundrum is the reliance on inefficient stoves resulting in high exposure to dangerous health damaging pollutants and contributing to deforestation. Addressing the conundrum requires investment in a range of measures that can be categorized as follows:

- **Cookstove energy efficiency improvements**

As calculated in chapter 3.1, over 95% of the energy is lost in the charcoal value chain due to inefficient technologies used to produce charcoal and consume charcoal. Measures focusing on improving production, i.e., introduction of energy efficient charcoal kilns and consumption, i.e., improved cookstoves (ICS), could substantially reduce the demand for wood and is elaborated upon in chapter 3.2.

Improved energy efficient **charcoal** kilns could further improve the efficiency in the value chain; however, this is beyond the scope of this study. Beyond doubt however, it is crucial that energy efficiency is improved at the production site.

- **Alternative fuels**

Moving away from wood or charcoal for cooking is the most effective way to alleviate pressure on the forests. This could include a switching to LPG, electricity, modern biomass (pellets and briquettes), bioethanol and biogas. This study focusses on bio-energy alternative fuels and therefore excludes LPG and electricity. Notwithstanding, these fuels have an important role to play in a transition away from wood and charcoal.

LPG and electricity are key cooking fuels promoted in the 5 year USD 25 million USAID supported Alternative to Charcoal project (A2C) implemented by Tetra Tech, next to bio-ethanol and pellets. The A2C project has a goal to reduce charcoal consumption nationwide with 25%.

3.2 Energy efficiency improvement

3.2.1 Improved cook stoves

Improved cookstoves (ICS) are stoves with in which more heat is utilized for cooking and typically also score higher on other MTF performance attributes, such as lower emission of PM2.5 and CO compared to open fires or traditional stoves. Only moderate health gains are achieved with ICS, for a significant reduction in the burden of disease attributed to cooking on solid biomass requires a move to higher tier stoves, 4 or higher is required (Johnson & Chiang, 2015).

- **Wood stoves**

The improved wood stove market is nascent in Zambia. During the various field visits, the team did not encounter tinsmiths producing improved wood stoves at scale. However, there are a number of national and international companies producing or importing wood stoves and initiatives constructing clay mud stove in-situ (table 7).

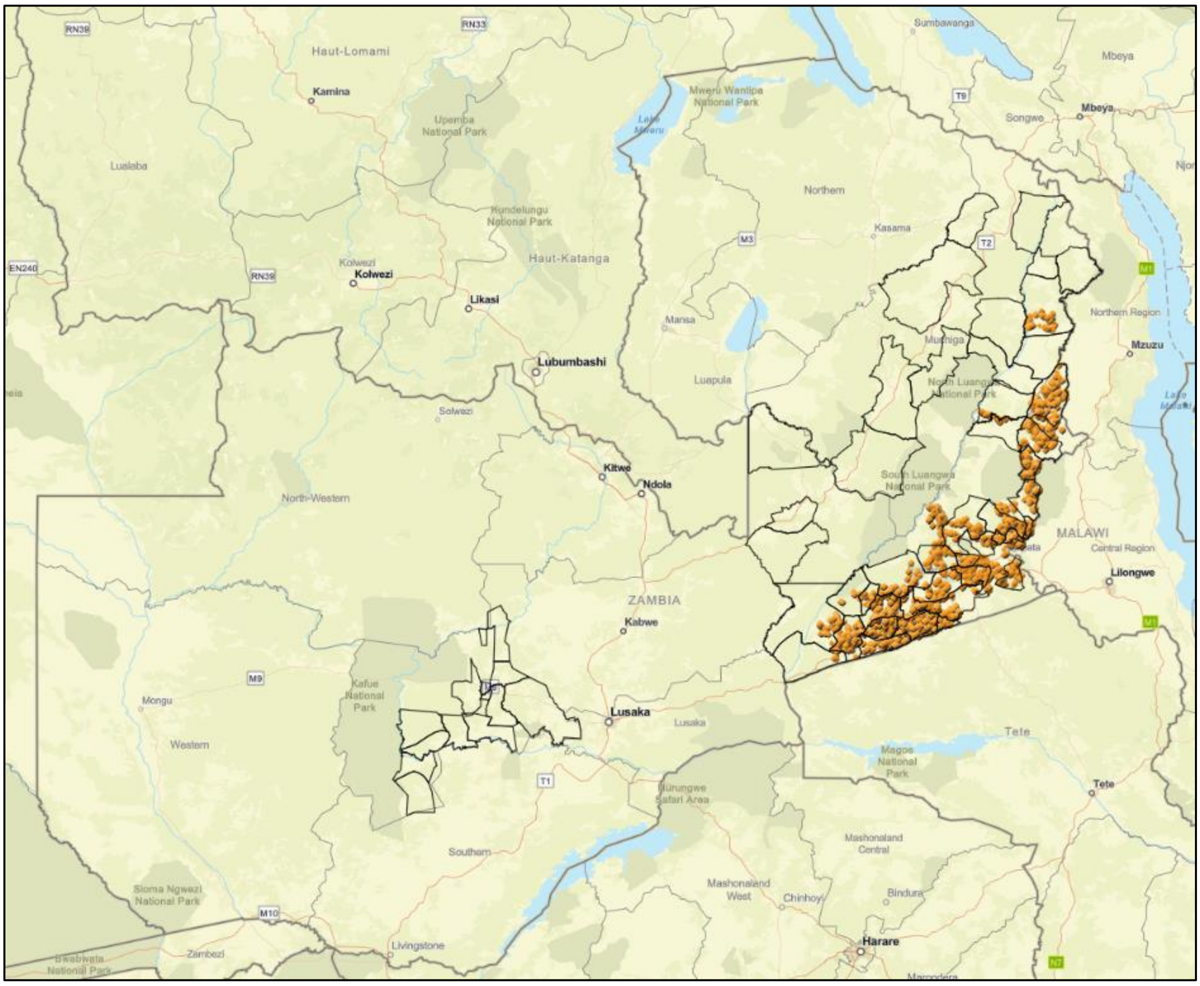
Table 7: Wood stove projects and initiatives met or identified

Stove type	Company/ organisation	Details
Open fires / three stone 	Homemade	This is the baseline of many households, also known as the three stone stove.
Mud/clay stoves 	MoE/Zengo	Snowball mode of implementation. Trainers of trainers (ToT) are trained, who subsequently train local people to construct stoves. Stoves by the ToT are verified by the MOE and once certified, the ToT is allowed to trainer local people and verify stoves constructed. According to Zengo this stove can last for 5 years and reduce wood consumption with 80%. However, this has not been verified independently
Figure 8: C-Quest/COMACO stove [11] 	C-quest capital LLC /COMACO	Improved Cookstoves Program for Zambia Over 100,000 installed supported with carbon finance in the Eastern province. Estimated saving are 60% wood compared to open fires which typically use larger pieces of firewood [12]
Stainless style type – Save80 and the wonder box, a heat retaining vessel for continued passive heating of the staples until cooked.  	Climate Management Ltd	Around 30,000 stoves between 2008 and 2012 and 6,000 in subsequent years in combination with the wonder box have been sold. The estimated saving, compared with open fire, are around 60% and a thermal efficiency of 47% The wonder box is very much appreciated by the end-users as staples, i.e., beans, only have to be heated until boiling and then placed in the wonder box to continue for several hours until cooked. Sales are on hold due to currency devaluation, lack of funding to pre-finance the stoves and the low carbon credit price. Stoves used to be sold through an instalment model of 36 months. The company is now focusing on solar PV solutions. One stove including the wonder box, costed around ZMW 2,500 but this might be around 3,000 to 3,500 currently due to the currency devaluation.

[11] *https://itswild.org/causes/energy/*
[12]*https://www.facebook.com/COMACOZambia/*

C-Quest and COMACO are maintaining a geographical database containing the locations of the stoves sold [13]. A screenshot of their database is shown below containing 97,258 stoves with GPS data out of a total of 102,358 disseminated at time of report writing.

Figure 9: C-Quest Capital/COMACO ICS dissemination is restricted to the Eastern Province



Source: C-Quest Capital

Dissemination is limited to the Eastern province, however COMACO is planning to upscale to other areas in Zambia in the coming years.

Table 7 with the list of ICS companies is not comprehensive. There are more companies active in Zambia disseminating improved wood stoves, such as the Africa Stove Company (TASC), Greenway and local initiatives such as Simalaha Community conservancy- clean cooking initiatives (4,200 Ecozoom wood stoves) [14] and the UNDP/GEF funded project Strengthening Management Effectiveness and Generating Multiple Environmental Benefits Within and Around the Greater Kafue National Park and West Lunga National Park in Zambia (5,000 mud-stoves) [15].In the last decade also SNV Zambia was active with disseminating fixed mud stoves and the pulumusa (type of improved mbaula) in 2010-2012: 8,200 stoves, Katete (CEEEZ, 2016).

However, due to time constraints, these companies and initiatives were not contacted.

[13] Available here: Energy - COMACO - Community Markets for Conservation (itswild.org)

[14] *https://www.peaceparks.org/simalaha/*

[15] Wood-saving cookstoves are helping Zambia cut forest loss | GEF (thegef.org)

- Cutting edge developments

C-quest is trailing Jet-Flame, a device designed by the Gates funded Global Health Laboratories and Aprovecho Research ICS Zambia with 75,000 stoves and local SME's such as Afred Mumbi (1999 to date), 100 ziko stoves per week and others Centre and Shenzhou Stove Manufacturer to improve combustion. The Jet-flame would clean up combustion by introducing force draft with a fan powered by a small solar panel or batteries – which increases combustion efficiency and reduces particulate emissions [16].

Figure 10: Jet-flame insert for rocket stoves

- Charcoal stoves

The charcoal stove market is dominated by the omnipresent mbaula stove. Improved charcoal stoves on the other hand are relatively rare, with a market penetration of just 0.5% and 0.3% in urban and rural areas respectively (USAID, 2021). The next table provides an overview of the stove's initiatives assessed:

Table 8: Stove types and initiatives assessed

Stove type	Company / organisation	Details
Mbaula 	Tinsmiths	Traditional omnipresent stove. Inefficient and non-standardized produced by local artisans (tinsmiths) and often made from scrap metals to reduce costs. The stove performance is not rated, but likely falls into the Tier 0 or 1 performance category.
Mbaula improved 	Tinsmiths	Some tinsmiths encountered produce an improved version of the mbaula. The tinsmith on the left, claimed his stoves reduces 50% charcoal consumption. However, despite the stove being just ZMW 30 more expensive than the traditional mbaula (ZMW 50) and with an estimated pay-back of less than a month [17], the stove was not popular and only produced on demand. Price sensitivity was the reason according to the tinsmith.
SmartHome stove 	UpEnergy	UpEnergy does not produce stoves but works with existing companies; the NGO Zengo will produce the ceramic liners and with another company the metal cladding. The retail price will be around ZMW 130 and partly subsidized by carbon finance. This Tier 2 stove is very successful in Uganda and according to the company the demand is also high in Zambia. The stove is said to reduce charcoal consumption with around 50% and has a thermal efficiency of 39%. Sales are at the moment minimal as the production has just started.

[16] *http://cookstoves-admin.digitopia.net/news/12-09-2020-jet-flame-insert-for-rocket-stoves-may-increase-speed-and-ease-of-cooking.html*
[17] *10 days in fact. Households spent around ZMW 6 on charcoal in Ndola according to the tinsmith*

	Rasma Engineering	Rasma sold 1400 domestic stoves and 20 industrial stoves in eastern province in 2021. Domestic stoves retail at ZMW 220 with a 20-30% profit margin for retailers. Savings are in the order of 50% but not independently verified. There is high demand for their stoves and opportunities to work with existing tin smiths. Rasma also designed a firewood stove.

This list is not comprehensive. There are more companies on the market disseminating improved wood stoves, such as the Vitalite (Ecozoom stove), Engie Mysol, and Pick n'Pay. However, due to time constraints, these companies and initiatives were not contacted.

The payback period of the stoves mentioned is generally in the order of 2 to 3 years (CEEEZ, 2016). However, based on estimates in the field, in certain circumstances the payback period could be in terms of just a number of months.

Many ICS companies have in common that carbon finance is an integral part of their business model. The next table provides an overview of the carbon financing projects in Zambia for ICS, including ECS, a pellet-stove company (more on pelleting in chapter 3.4.2). Most are carbon finance Programme of Activities (PoA) registered under the Voluntary Gold Standard (VGS) and one project under the CDM (Clean Development Mechanism), (table 9).

Table 9: Carbon finance projects in Zambia

Company	Name	Stoves eligibility	Standard
Emerging cooking solution	Clean cooking with biomass gasification	Gasifier stoves	VGS PoA
The African stove company ltd. (tasc)	Tasc clean cooking PoA (40,000 stoves)	> 20% thermal efficiency Burn stove, 41% efficiency, 20,000 installed	VGS PoA
C-Quest capital stoves Asia ltd	Installation of high efficiency firewood cookstoves in Zambia	> 20% thermal efficiency	VGS PoA
	Improved cookstoves program for Zambia	Mud-stoves	CDM PoA
UpEnergy	Social and climate impact programme-cooking devices vpa-6	Electric/lpg/ethanol/ Improved biomass stoves	VGS PoA
Commonland b.v.	Commonland African improved cookstove programme	Energy efficient biomass stoves	VGS PoA
Presbyterian church of Africa in Zambia Climate interchange ag, Germany	Lusaka sustainable energy project (lsep)	Save80	CDM project (not active) [18]

Source: VGS and CDM registry

A challenge encountered during the mission is that the progress of all these companies is not tracked and recorded systematically in a publicly available database with the notable exception of C-Quest Capital/COMACO. The lack of a national database will make it challenging to assess if the government is on track in meeting its clean cooking targets. Attempts were made to set-up a meeting with the charcoal association of Zambia for more information, but these were not successful.

3.2.2 Barrier analysis

The key barriers encountered based on the consultations and literature review are:

Barriers	Elaboration
Awareness	Awareness on the benefits of an ICS in terms is limited. This is partly because of lack of exposure, but also because there is no national definition of what constitutes an ICS,

[18] Until approximately 2015 when the CDM market collapsed rendering the CER prices too low for continuation of the project. In addition, due to the devaluation of the ZMW in 2018, the stoves also became expensive to import

	standardizing and transparent independent stove performance rating is required for effective communication of the benefits (see the next row)
Standardization and rating	Artisanal stoves are not standardized, and their performance is not verified. Similarly, no stove testing labs exist to verify claims made by ICS companies. It is therefore not transparent to the consumer if savings claims are reasonable and if the additional stove cost is worth the savings and other benefits.
Availability	Mbaula stoves are sold at every street corner, while ICS's only at exclusive locations
Affordability	The willingness to pay for (the full costs) improved cookstoves is low. 58% of urban households are not willing to pay for improved cookstoves, because they don't deem them necessary, and 36.2% of households indicate they cannot afford them (Luzi, Lin, Koo, Rysankova, & Portale, 2019). Affordability is the primary reason for household not to adopt clean, modern alternatives for three-stone fires (Luzi, Lin, Koo, Rysankova, & Portale, 2019). Compounding by the fact that 72.5% of households in rural areas collect their fuelwood from local forest and hence ICS's do not result in monetary savings.
Uneven playing field with the informal charcoal sector	The charcoal sector is not formalized and not appropriately taxed. Companies entering the market from the formal sector therefore face an uneven playing field.
Access to finance	Several companies mentioned that it is challenging for their businesses to grow without access to capital to pre-finance stoves

Creating awareness is necessary at all levels with sustained effort. Examples mentioned by stakeholders to promote ICS are schools and health centres and other places frequented by people. Noteworthy was an example mentioned in Malawi, where free tickets to a sport event were provided by buying a stove at the location. Even thought that event was visited by men, and there were worries that these stoves would be left behind, all men brought the stove with them after the game.

Tinsmiths indicated access to finance is needed to buy tools and machinery for upscaling. An interviewed tinsmith in Ndola planned to form a local cooperative, which would facilitate access to finance. There are opportunities to work with those tinsmiths to produce improve stoves through such a cooperative.

Moreover, lessons could be learnt from other countries in terms of the content of the message to be spread in a concerted way.

3.2.3 Recommendations

- **Quality control and assurance**: set-up a national stove laboratory, able to test stove on basic parameters identified for the rating system, including, but not limited to thermal efficiency established using a water boiling test, a controlled cooking test (CCT)
- **Rating system:** it is recommended to set up a stove label in Zambia which would effectively communicate to potential consumer stove performance. A three star or similar ranking could be considered, i.e. improved, highly improved and clean, this could be inspired by WB's clean cooking Tier system or adapted to the local context and circumstances.

  Inspiration and lessons learned from the Malawian experience. The Malian Alliance for Clean Cooking (M-ACC) introduced a GWA+ (meaning Stove+ in Bambara language) performance label and is awarded by a neutral committee, made up of representatives of the Malian Agency for Standardisation and Quality Promotion (AMANORM), the Malian Agency for the Development of Domestic Energy and Rural Electrification (AMADER), the Collective of Women of Mali (COFEM), the Consumers Association of Mali (ASCOMA) and the Malian Alliance for Clean Cooking (M- ACC). GWA+ will only be granted to stoves meeting specific quality and efficiency requirements for fuel consumption. One to three stars can be attributed to a stove. The more efficient the stove model, the more stars will be awarded. This graduated nature of the label intends to attract interest of companies to aim for better quality (SNV, 2022). It is recommended to set up a similar stove label in Zambia which would effectively communicate to

  Figure 11: Example of a GWA+ certified stove with one star out of 3

potential consumer stove performance. A three star or similar ranking could be considered, i.e., improved, highly improved and clean, this could be inspired by WB's clean cooking Tier system or adapted to the local context and circumstances.

- **Communication campaign:** design a clean cooking awareness campaign in a holistic manner using a sector wide approach. This includes sensitization campaigns on what constitutes an improved stove, a clean stove, the various fuels available, the benefits, financing where applicable.
- **Fiscal reform**: enforce regulations in the charcoal value chain including taxation. This may result in more expensive charcoal, but significant savings are possible with ICS offsetting the increase in charcoal price. It would also stimulate the adoption and investment in alternative solid biomass fuel products such as char-briquettes or even a switch away from using solid biomass
- **Improved cook stove support program**: consider setting up an improved cookstove programme with an experienced development partner such as SNV for local tinsmiths and local institutions with capacity to train, design, standardize and improve stoves (this could be Rasma engineering). Such a program would work with the existing infrastructure and capacity to produce stoves, and address issue related to quality control, and access to finance for machinery. Such a programme could be eligible for carbon financing to fund cover programme costs but also to subsidize stoves or improve supply side infrastructure. This would also improve the competitiveness of local tinsmiths participating and make improved cookstoves more affordable.
- **Financing:** develop new financing instruments including risk mitigation facilities. Current financing schemes have not benefitted SME (small and medium Scale) companies, such as ICS (DT Global, 2021). Without access to long-term concessional finance, it is challenging to stock and pre-finance significant numbers of stoves. Thus, new innovative and inclusive finance needs to be mobilised to achieve scale and develop the young ICS market in Zambia. Different forms of blended finance provide financing options and can be augmented with credit risk mitigation mechanisms suited for different types of projects. Such financing mechanisms are vital to reduce risks and costs of business and thereby encourage growth in RE investments, as well as encourage uptake of ICS (DT Global, 2021)
- **Database**: set-up a national database on ICS activities, to monitor ICS designs available, new ones emerging together with their efficiencies and access to carbon financing.

3.3 Domestic biogas

3.3.1 Domestic biogas

Biogas is generated during anaerobic digestion processes using solid waste, and organic waste, (e.g., animal manure), and other sources of biomass. Around 4,877 domestic digesters at farming households are installed under SNV supported initiatives: Energy for Agriculture (E4A) and currently the SIDA funded INCREASE (Increasing Climate Resilience in Energy & Agriculture Systems and Entrepreneurship) project (SNV, 2021) . Most digesters, 60%, are installed in the Southern province. This higher uptake in the southern province is explained by the dominance of dairy farming in that area in which dairy collection centres serve as Biodigester Market hubs (BMH). The hubs are mobilised by the project to serve as marketing channels and are involved in the repayment of biodigester and receive incentive payments when signing up members.

The digester installed are all fixed dome models consisting of a digester with a fixed, non-movable gas holder that sits on top of the digester. As the volume of the gas produced augments, in turn the pressure of the gas expands and the difference in height between the slurry level in the digester and the slurry level in the compensation tank increases. This then pushes the slurry into the compensation tank where the excess overflows. The digester is built underground and has an expected lifespan in the range of 20 years. The investment cost of a fixed dome biodigester, the Zamdigester, is related to its size and materials used. Prices range from ZMW 11,000 (EUR 761) for a 4 m^3 installation to ZMW 26,786 (EUR 1,853) for a 21 m^3 installation.

Figure 12: Fixed dome biogas plant in Petauke

Left to right: mixing tank, turret (structure on top of the underground reactor with main gas valve), compensation tanks and a slurry pit without roof.

At the sectoral level there are around 400 biogas installers trained and by 50 biodigester construction enterprises (BCE) established.

The SNV-trained masons have further benefited from being a part of a network through benefits including introductions to dairy farmers and associations (in Southern, Eastern and Lusaka provinces) who can in turn become biodigester customers.

The greatest challenge to businesses in this sector is logistical, particularly as it affects access to customers. Business owners indicated higher sales volumes in areas where roads were passable. The state of roads in some parts of the target communities also makes access with small cars difficult. In instances where they had been able to service customers, the challenge became their access to provide after sale services such as maintenance of the biodigester and safety screenings to ensure that there were no gas leakages (USAID, 2021).

In addition to this, a number of home-biogas plants are installed. Home-biogas is a prefabricated digester produced and designed in Israel and can be installed within a day, as compared to around 10 days for a fixed dome digester. The home-biogas plant is more expensive however and no subsidies are available. Home-biogas is used with success by the Figtree restaurant business in 5 digesters fed with cattle manure. Gas is used for cooking food during the whole day. One system was encountered at Fringilla, a restaurant/farm business and fed with cattle manure.

Table 10: 5 home-biogas plants, a healthy garden fertilized with bio-slurry and a biogas stove at Fig Tree

Source: Author's pictures

The home-biogas systems were imported by farmers/business owners. Since recently, there is an official Zambian distributor of home-biogas: Ecogas Zambia Ltd based on Lusaka.

At Fringilla also a larger biogas system was installed, waste from their slaughterhouse. In chapter 4 the opportunities in that sector are elaborated upon.

Other actors in the sector are People in Need (PIN). PIN constructed 25 fixed dome biodigesters in the Western province and plans to set up a market-oriented project in that province.

3.3.2 Barriers

SNV has administered various studies on the biogas sector development, i.e., the Market Analysis study for Uptake of Biogas and Bio-slurry in Zambia, lessons learnt from the Energy for agriculture report (2021) which contain an elaborate set of relevant barriers and recommendations. In this report only the key barriers are presented that prevent investment into the sector.

- In the literature digesters are often only evaluated for the replacement value of biogas, and not on using bio-slurry as fertilizers. This may lead to conclusions that biogas is not financially viable (i.e., FAO BEFS and A2C). However, productive use of bio-slurry can significantly increase agricultural yield and reduce pests if used appropriately. There is a lack of research in Zambia on this however, and three is a need to quantify the expenditure reduction potential on chemical fertilizers, yield improvement (both in terms of quantity and quality) and overall soil health improvement.

- Biodigesters are expensive, the average size costs around ZMW

- 12,000. However, the subsidy level offered via INCREASE is high at around 70 to 80% including the farmer's contribution. This contribution consists of sourcing materials (sand, cement, bricks, labour and providing meals and accommodation for the masons). The only payment charged is fee for the masons and some parts (stove, PVC pipes, valves). This high degree of subsidization makes digesters affordable for farmer's, however, this may deter market entry of other companies offering different biogas solutions. In Kenya for example, no biogas subsidies are offered, only result based finance for all biogas companies. This helped Sistema Biobolsa to enter the market offering a prefabricated digester through a very popular lease-to own mechanism. The Zambian market will be difficult to enter for those companies due to higher subsidy level on the Zamdigester.

- SNV has set-up a large number of localized private enterprises. While this model works well, sales are low. Due to geo-spatial disbursement, distances are large which makes it challenges to set-up shops for biogas equipment, both for cooking and productive use oof biogas and bio-slurry.

- Access to concessional finance, just like the ICS sector, is a barrier for companies to up-scale.

3.3.3 Reform recommendations and roadmap

- **Set-up a taskforce:** consider setting up, in close cooperation with the Ministry of Agriculture a biogas task force. This task force would fulfil the following roles:
  - coordinate the sector – such as directing companies to areas with high potential PIN and SNV target different areas, link distributors and companies with farmers.
  - investor match making - invite international biogas companies interested in the Zambian market, i.e., home biogas, Sistema Biobolsa, ATEC, to explore the market. Assist these companies with identifying promising areas not targeted by current programs. Assess market entry barriers for those companies.
  - applied research on bio-slurry application for various crops and design based on this - produce a practical handbook for farmers. This research should also focus on appropriate ways of storing and composting bio-slurry and mixing it with catalytic agents to improve the fertilizer value and on other uses of bio-slurry, such as fish feed, duck feed and as pesticide. ABP, the Africa Biogas Programme, will set-up a research activity into productive use of bio-slurry, resulting of that activity might be applicable to Zambia as well. Collaboration should be explored.
  - develop and enforce biogas quality standards in cooperation with Zambia Bureau of Standards (ZABS) and the Zambia Compulsory Standards Agency (ZCSA)
  - continued business coaching of established BCE on business development, sales and expansion with the aim to set-up a commercially oriented biogas market sector. It takes 10 to 15 years of support to reach that stage (Buysman & Mol, 2013)

- **Assess the potential of promoting biodigesters:** through marketing hubs, savings groups and other places frequented by farmers.

- **Developing carbon financing**: set-up a carbon financing project to support biogas investment. Potentially this could be included in one of the ICS carbon programmes in Zambia, or linkages could be made with regional PoA's such as the Africa Biogas Carbon Programme active in Kenya, Uganda, and Tanzania.

- **White paper**: develop a business case for the biodigesters in relation to the dairy, piggery and horticultural enterprises for farmers and companies (more on productive use of biogas in chapter 4). Including demonstration projects for farmer-to-farmer exchanges. Experience has learnt that peer to peer knowledge exchange is often the most the most effective and persuasive (Buysman & Mol, 2013).

- **Innovation and investment fund**: formulate an innovation investment fund that is targeted at the private sector as an incentive to participate in the value chain as accessory suppliers. This can be achieved through start-up matching grants.

3.4 Bioethanol

3.4.1 Introduction

Bioethanol is a clear, colourless liquid and typically produced via microbial fermentation of fermentable sugars, such as glucose, to ethanol. Two types of feedstocks are used in first-generation ethanol production, namely sugary and starchy feedstock. The first type is feedstock rich in sugars such as sugar cane, sugar beet, and sweet sorghum. The second type includes plants rich in starch such as maize, cassava, potatoes, and grain sorghum (FAO, 2020).

Bioethanol is a versatile fuel and can be used for both cooking and blended with gasoline. To support production, in 2009 blending ratios for ethanol and biodiesel were set at 10 percent and 5 percent, respectively (FAO, 2020). In August 2022, the government announced to set-up ethanol plants in provincial centres for blending fuel as a measure to reduce cost of petroleum in the country (Lusaka times, 2022).

3.4.2 Bioethanol for cooking

Ethanol for cooking predominantly takes two forms, gel and liquid and can be produce from molasses and cassava starch.

Table 11: Bio-ethanol stoves and fuel

Ethanol gel stove	Liquid fuel stove
	

It is estimated that approximately 29 million litres of ethanol could be produced in Zambia from existing sugar cane molasses, sufficient to serve over 110,000 households with cooking fuel each year (FAO, 2020). Unlike LPG, ethanol could be produced in Zambia, increasing energy security and reducing exposure to exchange rate fluctuations.

The Energy Regulation Board (ERB) with support from A2C has developed draft bioethanol standards for cooking which at the time of the study had been made available for public commenting[19]:

- DZS 1236 Denatured Hydrous Ethanol for use as Cooking and Appliances Fuel – Specification
- DZS 1237 Non-Pressurized Ethanol Cooking Appliances Using Liquid Fuel – Specification
- DZS 1238 Ethanol Gel for Cooking and other Gel Burning Appliances – Specification
- DZS 1239 Ethanol – Gel Fuelled Appliances – Specification
- The closing date for submitting comments is the 17th of June – by the time this report is published the consultation period will be closed.

3.4.3 Bio-ethanol production

There are a number of bio-ethanol companies active in Zambia, these include: Zongkai Ethanol plant, Thomro investment limited, Kainos Green Energy, Suray Energy, Sunbird ethanol and retail companies such as Shoprite. The following companies were interviewed":

Table 12: Bio-ethanol companies interviewed

Company	Products	Production	Established
Sunbird	None: Once excise is removed on bioethanol, the company will produce bio-ethanol transportation and cooking liquid fuel.	Will set-up a cassava out-grower program with 10,000 hectares to produce 70 million litre bioethanol to be scaled up to 120 million litre in phase II	January 2022, research and development started in October 2021

[19] request for public comments on draft Zambian standards for bioethanol for cooking and their associated appliances– Energy Regulation Board (erb.org.zm)

Thomro investment	No bioethanol but has a pilot bio-diesel plant – 1.1 million litre per year.	Biodiesel	Started working with biofuels from 2005 onwards and in 2017 registered with ERB
Zhonkai	Bioethanol for export.	50 m^3 bioethanol per day, has the capacity to upscale to 85 m^3 per day once the excise duty is removed. Has contracts with 4,500 households growing cassava on around 10,000 hectares	2017

In addition, the biofuel association was interviewed. Attempts were also made to interview Surya Enterprise, without success. According to other stakeholders interviewed, Surya enterprise focusses on bio-ethanol production for spirits only.

3.4.4 Recommendations

Excise duty is mentioned by all stakeholders interviewed to be the key barrier to attracting investment. This makes production of bio-ethanol uncompetitive both with imported petroleum but also with imported bio-ethanol cooking fuels.The current ethanol fuel taxation is depicted in the table below (A2C, 2021)

Table 13: Bio-ethanol fuel taxation – custom duty, VAT and excise duty is applied on bio-ethanol liquid fuels

Component	HS Code	Customs Duty	VAT	Excise Duty
Bio-ethanol gel	3606.90.00	15%	16%	-
Bio-ethanol liquid	2207.10.00 (of alcoholic strength by volume of 80%)	5%	16%	60%

Source: A2C, 2021

In order to increase the overall investment environment, it is necessary to reduce taxation by instituting a number of fiscal incentives. A2C proposed several fiscal incentives:

- Ethanol gel: remove custom duties, VAT and to maintain 0% excise duty on gel fuels.
- Denatured liquid fuel: Maintain 5% custom duty but remove VAT and excise duty. There is no risk that ethanol fuel for cooking is used as alcohol because denatured ethanol has a chemical substance added that makes it unpalatable and unfit for human consumption. Removal of taxes on denatured liquid ethanol for cooking would help to decrease costs and support the development of the sector in Zambia.

The companies interviewed fully support A2C's proposal. They mentioned it would entail a paradigm shift and would attract millions in investment and create employment for thousands in rural areas. The companies are able to upscale production significantly, as Zambia has land demarcated as farming blocks of which only 20% is utilized. According to their own calculations, if that is increased to 40%, Zambia can be energy independent and even become an energy exporter without compromising food security and also produce products with high added value such as cassava starch and even cassava modified starch.

The rationale for lowering the duties could be justified with:

- Budget neutral policy measure – the bio-ethanol sector will not develop without the removal of excise duty. However, with removal of the duty, the sector will develop and while not directly contributing to the state budget, it will create numerous economic benefits (employment, wages, reduced fuel imports, rural development).
- Create a level playing field with charcoal. As with all other cooking sectors, charcoal produced and sold in an unregulated untaxed environment. In order to create a level playing field, but also promote a shift to sustainable fuels, the tax regime for all fuels should be harmonized.

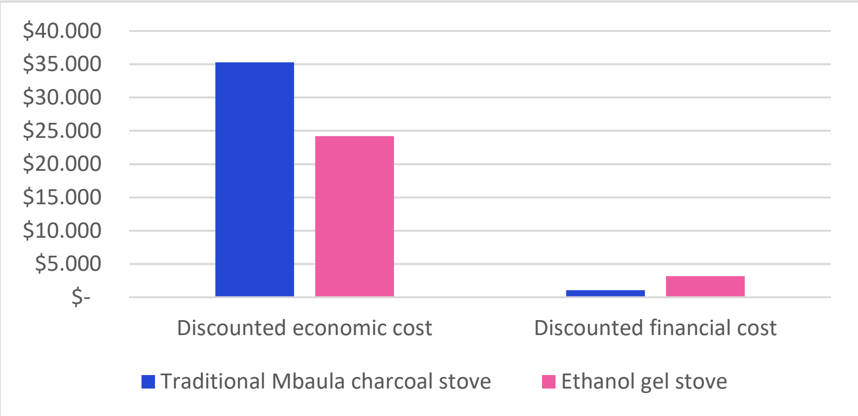
- The economic benefits are positive, but the financial cost to households is negative compared to cooking with Charcoal (see box 1 below).

Box 1: Economic and financial benefits of cooking with ethanol versus charcoal

An analysis by the USAID-funded Climate Economic Analysis for Development, Investment, and Resilience (CEDAIR) project in Zambia concluded that cooking with ethanol has a significant lower economic cost to Zambia than cooking with charcoal (even on an efficient charcoal stove) (A2C, 2021). These costs took account of the financial costs to households, the social cost of GHG emissions, value of statistical lives lost from premature mortality to PM2.5 exposures and the lost value of forest products from forest degradation.

However, the financial cost to households is higher when cooking with ethanol compared to charcoal (see table below). Therefore, to realise the national economic benefits, it is imperative to make alternatives to charcoal more affordable. One way to achieve this is to implement a favourable tax regime for a limited period of time to allow the market to develop. The next table illustrates this for a discount rate of 7%, the CEDAIR study also calculated this for a discount rate of 3% and 12%, with similar conclusions regarding the financial and economic cost.

Figure 13: The economic cost of the mbaula stove is higher than cooking on bio-ethanol, the financial cost however, is lower than bio-ethanol



Source: A2C, 2021

With removal of excise duty, the market outlook will become much more favourable, also for international investors. Koko for example, a Kenyan company is currently suppling ethanol cooking fuels to 1.5 million Kenyan's daily. Koko is expanding to other countries, provided that a government uses all the tools to level the playing field with charcoal. Koko is exploring a range of countries, starting with Uganda where encouraging tax reform was implemented, such as removal of excise tax on ethanol for cooking and partial VAT exemption for local ethanol production.

However, stakeholder indicated that removing excise on bioethanol for cooking alone might not create a sufficiently large market for investment. For this it is necessary to mandate fuel blending (bioethanol in petroleum), then a large market would be created which could also serve the residential market.

3.5 Cooking fuel biomass pellets

3.5.1 Market

There is one company in Zambia producing pellets and selling a matching stove: Emerging Cooking Solutions (ECS), known in Zambia under the brand of SupaMoto - which means strong fire.

- **Pellet production**: pellets are produced from forestry waste at a factory in Ndola. Their pelleting machine has a capacity of around 1.5 ton/hour and is one of the largest in the region. Currently around 100-ton pellets are produced per month. An average household requires around 30 kg pellets per month, meaning that a calculated 3,333 households use pellets as their main cooking fuel.

Figure 14: Mimi Moto stove

- **Stove**: ECS introduced the Tier 4 Mini Moto stove in Zambia. The stove is approaching modern fuel stoves (e.g.) LPG in terms of PM2.5 and CO emission [20]. An estimated 10,000 to 11,000 stoves are sold. ECS has in-house developed a gasifier stove for institutional/commercial use and is in progress developing a gasifier stove, the SupaMoto stove with similar or higher performance compared to the Mimi Moto in South Africa.

- **Sales model**: ECS has various sale models – one that is being trailed in Ndola is the 'utility model', where the household with continued monthly pellet purchases receives a stove for usage. The stove remains ownership of ECS and will be returned in case pellet purchase cease. Another model is gradual repayment of the stove through pellet sales, and another is direct sales.

ECS estimates that pellets are much cheaper on a monthly basis compared to charcoal; the monthly consumption of pellets amount to around ZMW 130 while for charcoal this is around ZMW 220.

The Tobacco Association of Zambia (TAZ)'s farmers grow next to tobacco an increasingly amount of wheat. TAZ has prepared a proposal to collect wheat residues for on-farm pellet production as cooking fuel and alternative fuel for tobacco curing.

3.5.2 Challenges

During the study only ECS was consulted. ECS however indicated they welcome investment in both pellet production and stove sales. ECS recognizes that for a healthy market multiple parties are required. Ideally, there are companies specialised in pellet production and others in stove sales.

There are 4 main barriers to up-scaling and attracting investment:

(1) **Catch 22- Stove fuel barrier:** it is challenging for companies to investment in pellet production capacity because a specific stove is required for cooking on pellets. Not only few households own such a stove, but these stoves are also expensive. Vice versa, companies introducing pellet gasifier stoves, will have difficulty selling stoves due to lack of a sufficient supply of pellets. ECS is currently only producing for their own clients for example.

(2) **Cash flow:** since many stoves are pre-financed, a significant upfront investment in stoves is required. This prevents ECS but also potential new market entrants, to up-scale their operations or investment in equipment. ECS expects that late 2022 the first income from carbon credits is expected, which would to some extent alleviate cash flow problems.

(3) **Stove supply chain**: the Mimi Moto stove is produced in China. However, due to COVID-19, the supply of spare parts is frequently interrupted or delayed. As a consequence, ECS has a large number of stoves in their warehouse that are awaiting spare parts for repair. This is further exacerbating the cash flow challenges. For this reason, ECS initiated research and development to manufacture gasifier stoves in South Africa.

(4) **Raw material**: ECS used to source raw materials from ZAFFICO, a state-owned forestry company for free and was later charged for the collection of branches. The fee charged was too high making pellet production unprofitable. ECS is currently relying on residues from sawmills with lower quality and high bark content. The latter cannot be used for pellet. Also, there are logistical challenges, as distances covered to reach the sawmills are significant. Finally, sawmills do not operate year-round and as a result feedstock is at times not available.

3.5.3 Recommendations to attract investment

- ECS specific: There should be an opportunity for ECS and ZAFFICO to come to an agreement. The current situation is not serving any party, and valuable biomass is lost. Especially given that previously, ECS only collected a small share of all the residues. It is recommended that OGTF and MOE follow up on this and investigate this issue.

[20] Mimi_Moto_IWA-Tiers-of-Performance-WBT-4.2.3-Report-REV.A.pdf (mimimoto.nl)

- There is only 1 pelleting company in Zambia, vertically integrated company, from production of fuel to the stoves. As a result, there is no competition and no consumer choice. In case there are disruptions in the supply chain of pellets, household have no other choice than to switch back to other fuels. Therefore, a follow up study should assess the potential of setting up other pellet factories. The Tobacco association of Zambia for example has interest in exploring this and utilizing agricultural residues available for pellet production (wheat straw) at the farms of their members, but also the Copperbelt Forestry production (CFP), who are now exploring char-briquetting, could also consider producing pellets. The advantage of pellets compared to char-briquettes is two-fold 1) no energy is lost during the production and 2) pellets stoves are cleaner and more efficient compared to the best performing charcoal stoves. Thus, with the same amount of raw material, more households could be reached. ECS is welcoming investment into pelleting.

- Consumer financing. Equipment purchasing decisions are dominated by upfront costs, which are high for modern fuel cooking devices. Innovative business models taking advantage of micro-payment technology are needed to overcome this barrier. Grant programmes are effective in proving business models, and larger scale result based finance programmes are helpful in achieving scale. It is therefore recommended to explore which programs could aid the sector the most at the lowest cost. Moreover, this should cover company finance, i.e., a revolving fund that can be accessed to overcome cash flow challenges (see chapter 5.2) for an elaboration on financing mechanisms to be considered).

- Level playing field: this is a common barrier to any investment in the sector: the charcoal value chain is insufficiently regulated and taxed and therefore the price of charcoal is artificially low. A fair price for charcoal, would make alternatives, including pellets, more attractive for investors and consumers. Fair pricing of electricity, i.e., tariffs that cover ZESCO's costs and fair pricing of LPG would also help to improve the value proposition of pellets.

- Plantations and fuel production: SNV's INCREASE project is promoting intercropping including fast-growing trees for fuel production. This has multiple benefit for farmers, additional income by selling wood to ECS or other companies and fast-growing species such as Leucaena have many other benefits, the leaves can be used as fodder with high digestibility and the tree fixed nitrogen improving soil fertility. Initiatives like these should be documented in a follow up study and assess how such an out-grower scheme can be up scaled to the more than 1.6 million agricultural households in Zambia.

- VAT is not charged currently, however, there is no sector wide regulation on VAT exception for pellets and pellet stoves. New market entrants, therefore, will have to request exemption on a case-by-case basis. It is recommended therefore to develop a comprehensive and inclusive fiscal policy on tax incentives and VAT exception for sustainable fuel products and stoves.

3.6 Biomass briquettes

3.6.1 Market

The char-briquetting market is nascent in Zambia. Until recently, production was limited to small initiatives but in recent years, several start-up companies have entered the market. The following companies were consulted:

Table 14: Char-briquettes companies interviewed

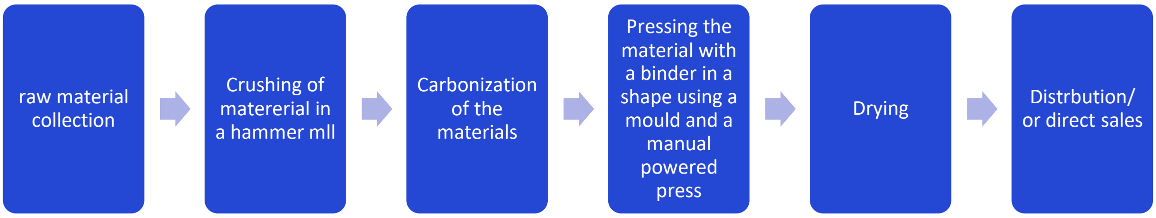
Company	Products	Raw material	Production	Start date production
SN Enterprise (Livingstone)	Honeycomb (blocks) briquettes for poultry farmers Charcoal briquettes for household cooking	Agricultural residues, wood residues	500 blocks/month 0.5 ton/month briquettes	Jan 2022, research and development started in October 2021
Asum Xela (Lusaka)	Honeycomb (blocks) briquettes for poultry farmers and piggeries	Charcoal dust and fragments	200 blocks/day	June 2022
Comaco	Biomass blocks	Peanut shell briquettes	Up to 300 briquettes per day, for own use only	Since 2015

Company	Products	Raw material	Production	Start date production
GreenFire	Blocks	Agro waste	2000 to 3,000 per day for the poultry	August 2021
EcoCharcoal	Char-briquettes	Wood from sustainable managed plantations	0 due to logging ban previously 250 ton per year	2012

All companies are relatively young with the exception of COMACO and EcoCharcoal. Their mode of process is in all cases manual with little mechanisation. The production therefore is labour intensive and difficult to scale. All companies consulted are considering mechanisation and are looking for machinery with the exception of EcoCharcoal, who produce their own briquette extruder press. Mechanisation is essential for scaling up, for example, it takes one person 3 minutes to mould 1 block, while a briquetting machine produces 18 blocks per minute.

Raw materials used are saw dust, charcoal residues from charcoal selling/distribution locations, discarded trash, tree branches leaves, or as one entrepreneur put it, anything that can be carbonized. The basic process of char-briquette production of these companies is the following:

Figure 15: The various processing steps involved in char-briquette production



Source: Author's assessment

Figure 16: COMACO briquette

COMACO on the other hand is using a Germany technology to compress peanuts shell under high pressure into a firm briquette without carbonization. According to COMACO their product when lighted generates nevertheless limited smoke and has a very long burn time, which makes it ideal for roasting peanuts and drying agricultural produce. After COMACO receives the peanuts from the farmers, the shells are removed (30 tons/month) and then compressed into briquettes. The company is using between 50 to 100% of the shells depending on the season and if there is a surplus, the remaining shells are used as green manure. Occasionally, on demand, COMACO sells briquettes, but generally produces only for their own demand.

According to COMACO, there are opportunities to up-scale production with a new briquetting machine. While not comprehensively studied by the company, the briquettes are thought to be cheaper than charcoal and competitive with wood. User examples mentioned were using it to replace wood in industries such as medium-scale beer brewing (i.e., the brewery in Petauke uses significant volumes of wood) but also for drying/curing agro-cultural produce (mango, mushrooms, tobacco, fish etc). The main challenge is the upfront cost to purchase the technology, access to finance and that technologies are not available on the domestic market but need to be imported.

There used to be a clean energy project in Mongu supported by CELIM, an Italian NGO, where since 2009 briquettes were produced from saw dust, which were first compressed in a briquetting press and then carbonized. Ideally however, raw materials are first carbonized and then compressed into briquettes, this, would yield higher quality briquettes (Talamanca, 2022)

Figure 17: Left: briquettes extruder and right: carbonization of biomass briquettes [21]

This project was, according to ZENGO, successful. However, at a certain moment, at project closure, the machinery was handed over, or sold, to a local entrepreneur. Some years later the entrepreneur sold the equipment for unclear reasons.

3.6.2 Other developments

- **Copperbelt Forestry Company (CFC)**

Large investments in the sector are being considered by the Copperbelt Forestry Company (CFC). CFC is developing a business proposal for a 14,000-ton char-briquetting line at a USD 825,000 investment. CFC wants to enter the market at a lower price point (USD 150, or ZMW 2,454 per ton) than charcoal (USD 180/ton, ZMW 3,000). Entering the market at a competing price is a strategic choice to entice customers to switch.

- **ZAFFICO**

In 2012 there were more than 1000 sawmills operating in the country (FAO; The Ministry of Energy of Zambia, 2020). However, nowadays, the number could be much higher as ZAFFICO is already supplying round wood to 1,024 mills. Sawmills, after processing trade their products downstream for further processing and production of furniture, panels, crates, pallets, mine lug boxes, cable drums, and other products. A major part of the processed wood is used in Zambia and only a portion is exported.

The wood waste is utilized (82%) mostly by households followed by bakeries, lime companies and brick kilns (MOE, 2017). According to ZAFFICO, however, most residues, consisting of saw dust and off-cuts are not utilized. The amount available is significant, as the recovery rate is only around 40% at sawmills.

ZAFFICO is exploring business models to collect and valorise residues at sawmills and from their own plantations (branches) as part of a bigger transition towards creating more value-added and a circular business model this could be particle boards, OBS (oriented strand board), MDF (medium density fibreboard) but also fuel products in a move to transition to a circular mode of operation with no wastage. ZAFFICO has around 52,000 hectares of pine and Eucalyptus trees and on average harvests around 239,000 m^3 pine and 37,000 m^3 eucalyptus wood. According to the FAO, around the volume harvested is around 65% of all biomasses, and the remainder, 35% are branches and leaves and around 40% of that is available for collection. Thus, a calculated 35,667 [22] ton biomass annually is available at ZAFFICO's plantations alone.

3.6.3 Briquettes for household cooking

Companies interviewed focus mostly on the poultry sector where they struggle to meet demand. The household sector is a more challenging as producing char-briquettes is more expensive due to costs related to packaging. Nevertheless, some companies are venturing in this market

[21] Clean Energy in Mongu - Celim
[22] Calculated based on 1 m3 wood = 600 kg

Table 15: Examples of char-briquettes sold for cooking

Company	SN enterprise	Eco-charcoal
Product	 	
Price	7 kg is ZMW 35, 15 kg is at ZMW 70	N/A no sales currently
Retail channels	Production location, social media	Shoprite and several retail shops in Lusaka and at offices in Chinyunyu, Nyimba and Mfuwe

Challenges mentioned to enter the cooking fuel market are the extra costs required for packaging and the low price of charcoal. According to SN Enterprise, ordinary charcoal retails for ZMW 75 for 40 kilograms, while their charcoal retails at ZMW 70 for 15 kg. Upscaling and reaching an economy of scale is required to compete with regular charcoal.

Shoprite mentioned that demand for char-briquettes is mostly seasonal for braais and camping during holidays and during load shedding. Their main clientele are upper-income households and briquettes sold are all imported. Charka briquettes from South Africa retail at ZMW 139 for a 4-kilogram bag. Eco-charcoal from Zambia used to be sold at a much lower price, ZMW 24.99 for a 4 kg bag, but they stopped supplying 6 months ago (due to a logging ban in their sourcing area, production was discontinued).

Figure 18: Facebook post of Greenfire illustrating the use of char-briquettes for space heating

In addition, the poultry and piggery sector are considered a more attractive market as that market is not only focussing on costs but also on quality (burning time, less sparks etc).

3.6.4 Briquettes for the poultry sector

Most briquette manufactures interviewed focus on the poultry sector. Charcoal is pressed and dried in large blocks weighting typically 2-3 kilogram in 22 cm in diameter [23] and are sold unpackaged. The demand for blocks, especially in the cold season is very high. This is attributed both to an increased awareness of the advantages of blocks compared to ordinary charcoal and to reduce heating costs. The main advantage is that blocks burn much longer and provide heat for a whole night, while ordinary charcoal has to be replaced every 3 to 4 hours (thus requires getting up a night a couple of times). Burning is also spark free and therefore less of a fire hazard. The next table shows details of blocks produced and retailed by companies interviewed:

Table 16: Char-briquettes producers for the poultry/piggery sector

Company	SN enterprise	Axum Xela	Greenfire
Product			
Price	n/a	ZMW 15	ZMW 13, ZMW 10 for 100 blocks
Retail channels	Production location, social media	Sales in Lusaka	Delivery from factory

[23] *Actual dimensions may vary – as far as could be confirmed, block sizes are not standardized. However, blocks are produced for stoves famers own, such as the brazier shown in figure 14. Blocks are design to fit.*

3.6.5 Barriers and recommendations to attract investment

- **Operation is manual and labor intensive**

Up-scaling production requires mechanization of the production. All companies indicated that raw material and that the market is sufficiently large to absorb any new production. The main issue therefore is procuring machinery, which could be encouraged by:

  - **access to finance**: companies mentioned that access to finance is an issue, both the loan conditions (interest) but also the hesitation of financial institutions to finance start-ups. Access to concessional loan with a certain grace period to cover the period in which investments are made but sales are low or negligible, is required;
  - **level playing field**: char-briquettes are competing with a product from the informal economy. Either equal taxation or abolishing taxes on char-briquettes is required to level the playing field;
  - **access to technology**: there are no briquetting machines available on the market. The briquetting machines are designed at location and put together with parts not designed for the process. Importing the technology is expensive, partly due to the duties levied. A duty exemption on importing briquetting machines, and other clean cooking technologies, will help the sector to access suitable technologies;
  - **integrated awareness and promotion support**: promotion of briquetting is fragmented involving several ministries and at the same time sustainable charcoal production is not discouraged and sufficiency taxed. An overarching support program for the private sector with support of relevant development partners focusing on creating awareness for the products, working with financial institutions on creating suitable loan products and to encourage producers to start operations in all parts of the country.

- **Carbon financing:** all producers are confident that there is high potential to upscale production. As such, there is likely enough scale to develop a carbon finance project for those producers with finance and other support. Such a carbon finance programme could be managed by the overarching support programme on behalf of all producers, which would be more cost-effective. Given the rapid development of the sector, carbon pre-feasibility studies should be initiated as soon as possible to ensure that all producers could be part of the project and benefit from the carbon rebates, which are essential for upscaling. Carbon financing could also support a large enterprise support program as recommended earlier.

- **Medium term:** certification of the product by ZABS: this would address issue that formal retail face related to consistency of the product and packaging quality. Certification, however, could also become an entry market barrier and is therefore only recommended once the market has reach a certain stage (i.e., not dominated by start-ups, but by successful commercial enterprises)

4 Sustainable bioenergy for productive use

In chapter 2 a bio-energy resource assessment was made. The assessment concluded that there is potential to utilize residues and manure for productive use of energy (PUE). In this chapter the barriers to investment in bioenergy for PUE is studied and recommendation on how to overcome those. The following sectors were prioritized for this study in collaboration with OGTF/MoE:

(1) Thermal energy for tobacco curing (chapter 4.1) with some recommendations relevant to the fish smoking/drying activities as well.

(2) Biogas and biomass for power generation (chapter 4.2)

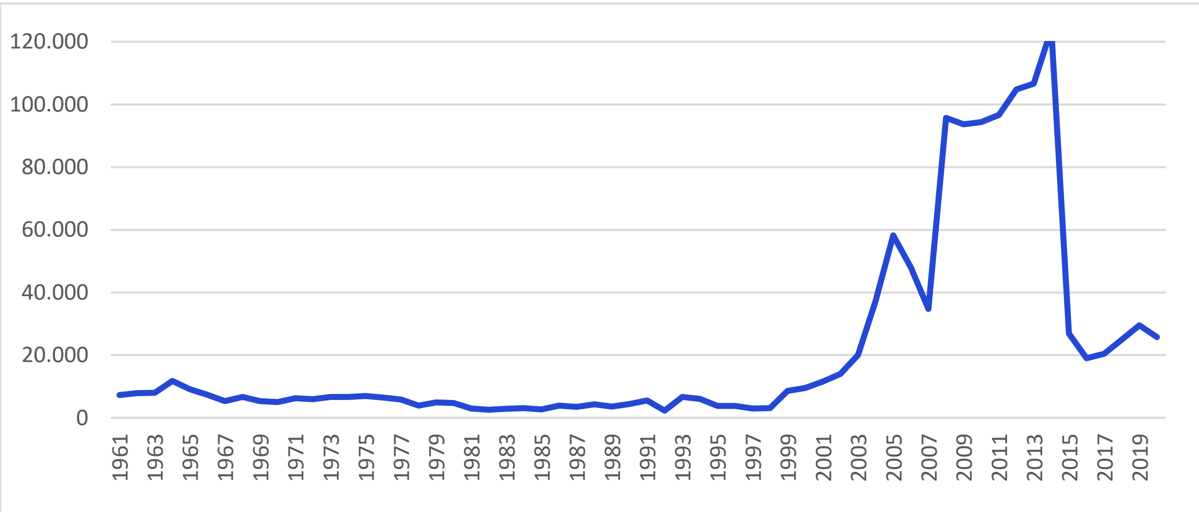
(3) Biogas for stable heating and communities (chapter 4.3)

4.1 Thermal energy for tobacco curing and other sectors

4.1.1 Sector overview

Tobacco production has increased considerably between 1994 to 2014 in Zambia and then dropped and stabilized to around 20,000- to 25,000 ton annually in the period 2015 to 2020 (figure 19).

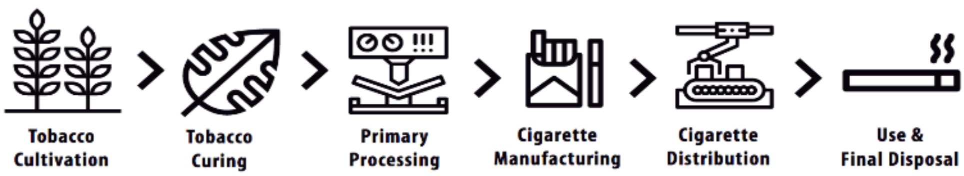
Figure 19: Tobacco production was stable until 1994, peaked in 2014 and then dropped to around 20,000 to 25,000 ton. Tobacco production quantities between 1961 and 2020



Source: FAOstat 2022

The tobacco value chain consists of the following steps (figure 20), of which step 1 to 3, tobacco cultivation, curing and primary processing takes place in Zambia. Step 4 to 5, cigarette manufacturing and distribution takes place outside Zambia. Step 6: usage and disposal, almost all cigarettes smoked in Zambia are imported.

Figure 20: Tobacco value chain



Source: World Health Organisation, 2018

4.1.2 Tobacco curing and wood consumption

Tobacco curing is the most energy intensive processing step taking place in Zambia. Curing of tobacco is necessary to increase quality and retain flavours by slowing down oxidation and degradation of carotenoids in the tobacco leaf. This produces various compounds in the tobacco leaves that give cured tobacco its sweet hay, tea, rose oil, or fruity aromatic flavour that contributes to the "smoothness" of the consumed product. This process is executed under controlled conditions in which the leaves are exposed to hot dry air for a period of 1 to 2 weeks. In Zambia tobacco is fire-cured in barns with hot air supplied by smouldering logs of wood. Based on the data available, the total wood consumption is around 0.46 million metric tonnes for 2015 (National woodfuel study) and 0.6 million metric tonnes in 2019 (extrapolated). (MOE, 2017)

Most farmers use traditional hut-like (beehive) barns which require 20-24 m^3 of wood to cure one hectare of tobacco (1,200kg, under optimal conditions 2,000 kg), whereas new rocket barns need only 10 cubic metres (GEF/UNDP, 2019). This estimate aligns with estimate in the national fuelwood study, where it was estimated that around 15.2 kg of wood is needed per kg of tobacco in traditional barns. According to Tombwe Processing limited, the largest tobacco off-taker in Zambia, the actual amount of wood used to cure tobacco could be much higher. However, this has not been systematically studied.

According to the stakeholder interviewed, smallholders are generally wood deficit and need to cut down trees for curing while large commercial farms with large plots of land have enough wood. However, also these farms, and especially the smaller commercial farms, are using coal as well.

Wood plantations could address the wood deficits. Eucalyptus trees yield about 90 m^3 of wood in their seventh year of growth but are not favoured by tobacco companies because they require management, and are susceptible to fires, termites, etc. Indigenous species are favoured, which yield 50m^3/ha wood from year 7. Tobacco companies estimate that they would need to plant 0.2-0.4 hectare each year for seven years for a farmer using tobacco barns (1.5-2 hectare), after which trees coppicing if cut carefully is sufficient (GEF/UNDP, 2019).

The Tobacco association of Zambia (TAZ) and Tombwe Processing limited are trailing bamboo as alternative fuel. Bamboo has a number of advantages; it is fast growing and drought resistant.

4.1.3 Energy efficient barns for curing

Curing tobacco is a lengthy process which has to be carefully managed. Tobacco that is not cured properly, or inconsistently, yields a low value, and may not be accepted by the main importing country, China. Controlling environmental conditions in traditional barns is challenging for various reasons. The barns are not properly insulated resulting temperature gradients in the barn. Consequently, some tobacco might be cured too much, others at cold spots insufficiently. Curing barn improvement, therefore, has next to addressing the efficiency, an important economic angle.

Figure 21: Rocket barn

The rocket barn is a well-known improved barn with an estimated wood savings of at least 50%. In most of Zambia, it costs farmers USD 1,500 to build a rocket barn, but costs in Western Zambia are much higher because of technical issues associated with soil and the need to import bricks (GEF/UNDP, 2019).

Given these challenges and costs, Mr. Kamanga, a small-scale tobacco farmer, in cooperation with Tombwe Processing ltd., has developed, an energy efficient barn which can be constructed by farmers with some assistance using mostly local materials. The Kamanga barn, named after its inventor, has similar savings compared to the rocket barn. The actual savings compared to the traditional barns are difficult to estimate however, as there are many varieties of traditional barns, each with its own efficiency characteristic.

In the next table the Kamanga barn is compared with the conventional barns on various performance attributes:

Table 17: Comparison between conventional and the Kamanga barn

Attribute	Conventional barn	Kamanga barn
Picture		
Fuel	Wood logs	Branches and sticks

Attribute	Conventional barn	Kamanga barn
Wood demand	15.2 kg wood per kg tobacco, but often much higher	2 to 6 times less
Materials/investment	Relies on local materials but requires metal flue pipes	Mud mortar stabilized with white wood ash and metal flat sheets
Operation and maintenance	Operated through individual farmers' expertise, high in maintenance, low in durability (1-3 years)	Standardized operation (through a provided curing guide), minimized maintenance, improved durability (10-25 years)
Design	Non-standardized	Standardized, Tombwe developed a construction manual
Quality of the product	Inconsistent	Consistent
Curing time	8-9 days	5-6 days
Number installed	There are an estimated 30,000 tobacco farmers; most use a conventional curing barn type	1000 (out of the 10,000 farmers cooperating with Tombwe)

Thus, next to better quality product, faster curing, the Kamanga barn can be fed with branches and sticks as fuel. These can be obtained from coppicing trees instead of cutting down the whole tree.

Commercial farmers on the other hand, utilize systems with one or more furnaces supplying heat to a number of drying barns.

Figure 22: Curing system at a commercial farm.

Right to left. A wood/coal fuelled furnace supply hot water, 90ºC to 10 heat exchangers in parallel in which air is heated to the desired temperature for optimal curing in the barns (metal containers).

Challenges at commercial tobacco farmers are different. They tend to switch to coal when not enough wood is available. Coal is not only expensive but is also a fuel with the highest CO_2 emission factor on calory basis. Thus, this switch may be beneficial to the forests, it is not for the climate.

Solar thermal is considered an alternative in the mid to long term. Some farmers are experimenting with this, by heating up air between 2 metal sheets and using this as heat source for curing, but this could not be confirmed during the study. One farmer mentioned that curing takes place 24/7, and therefore active heating is required at night.

Applied research into developing efficient and cost-effective solar dryer with thermal energy storage system for continuous drying of agricultural food products at steady state and moderate temperature (40–75 °C) is necessary. It is possible to store latent heat in solids, such as the soil, and use it at night as thermal energy source, but this has not been tried and tested in Zambia. A review article on the various solar dryers with thermal energy system by Bal et al (2010), provides a good overview of the various solar thermal energy storage technologies that could be applied (Bal, Satya, & Narayan, 2010).

Collection of spent (machinery) oil from the mining industry was also mentioned as alternative fuel for small and commercial farmers. However, opinions deviate on the availability and desirability. A switch from a potentially sustainable fuel, wood if well manged, to a fossil fuel, would not improve the environmental performance of the industry.

4.1.4 Barriers

The main barrier to adopting energy efficient technologies is awareness and availability (few farmers have access or are aware of energy efficient technologies). The supply chain is not developed, and likely the awareness of those technologies is low. At TAZ and Tombwe in Lusaka, tobacco is traded, and Tombwe has strategically built a demonstration model of the Kamanga barn there. This is attracting great interest, but dissemination of the technology has just started.
It was mentioned several times that convincing farmers to plant trees is challenging for reasons due to culture, habits and lack of land ownership. This study was unable to assess the exact nature of these barriers.

4.1.5 Recommendations

- Little is known about the farmers not linked with Tombwe and if initiatives take place to improve their curing barns. It is therefore recommended that a baseline and market survey is organized amongst tobacco farmers, stratified by tobacco offtaker or any other organization influencing decisions made by individual farmers. Such a study should investigate the following: Wood consumption, barn types and specific wood consumption (kg/kg tobacco), source of wood, deforestation, awareness, and interest of farmers to invest in improved barns, and map the sector to understand which parties yield influence. There are several ongoing initiatives for example such as the Sustainable Tobacco Programme internationally, and sustainability demands of buyers that affect the sector, etc. The study would assess opportunities to upscale initiatives and to create leverage through functions (actors) in the subsectors with influences (i.e., buyers)

- Curing barns could also be used to dry other produce, such a maize. The study should therefore also assess opportunities other than tobacco curing to further improve the value proposition of energy efficient barns

- Bamboo and fast-growing trees, in combination with energy efficient curing barns, could greatly reduce deforestation attributed to tobacco farming. A follow up study should assess the barriers and opportunities for farmers to plant trees and what is necessary to persuade farmers to grow their own biomass.

- Applied and academic research into solar thermal drying with thermal energy storage systems for curing and drying. Public private partnerships into supporting this type of research between universities, tobacco farmers and association should be explored. One commercial farmer welcomed this and could support a couple of PhD students. It is recommended that the MOE/OGTF follows up on this.

4.1.6 Other sectors

Similar challenges most likely exist in other sectors with a demand for thermal energy to dry produce. It was already mentioned that curing barns could also be used to dry maize. Similar opportunities may exist for other produce, such as the fishery sector which is after tobacco curing the largest consumer of firewood.

Zambian fishery resources comprise 15 million hectares of water in the form of rivers and lakes. Annual fish catch hovers around 70 to 80,000 ton in the period 2010 to 2015 of which around 67% is dried and the remainder is sold fresh (MOE, 2017). An estimated 8 kg of fuelwood is required to dry 1 kg of fish, which would add up to 0.417 million tonnes of wood per annum on average in the period 2010-2015 (Snow Systems Zambia, 2020).

A study conducted in the northern province, examined the thermal performance of the most common smoking systems, a Modified Three-Stone Fire system (MTSF), a charcoal smoking system and a recently introduced smoking kiln (Kwofie, 2019). A MTSF is similar to a three-stone fire system except that the stone arrangement is different.

Figure 23: Pictures of fish processing systems (a) kiln (b) charcoal stove and (c) Modified Three-Stone-Fire (MTSF) stove.

(a) (b) (c)

Source: Snow systems Zambia 2017

The MTSF or TSF have a thermal efficiency of around 10% to 15% and is the most wildly used smoking system. The kiln was introduced through participatory action research, is more efficient with additional benefits such as improving the quality of fish and efficiency with fish processing. The coal pot stove is not a common stove. The study estimated that the specific energy consumption is the lowest of the coal pot with around 70 MJ/kg followed by the kiln with a marginal higher energy consumption, while the TSF has a significant higher consumption of around 140 MJ/kg.

Figure 24: Passive solar fish dryer in India (example)

Switching from a MTSF to a kiln can result in 50% wood savings, similar savings can be obtained with a coal pot, however considering the amount of wood required to produce charcoal, this is not advisable.

It is therefore recommended that a follow up study, not only assesses opportunities to upscale energy efficient tobacco barns, but also kilns for fish, its baseline and the market for energy efficient drying solution, and drying of other produce such as meat, fruit and other, as most of the challenges and needs are similar. Such a study, however, should not only focus on bio-energy efficiency improvements, but also on fuel switch opportunities, i.e., passive solar drying technologies for fish and other produce.

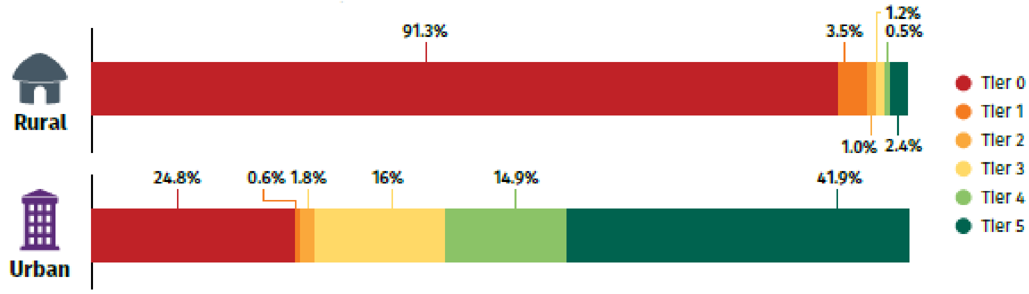
4.2 Biogas and biomass for power generation

4.2.1 Access to electricity

According to the latest statistics of ZAMSATS, rural electrification rate is 8.1% and 70.6% in urban areas. The Worldbank's Multitier Framework (MTF) breaks down access to electricity in Tiers, where having at least Tier 2 electricity supply (>200 Wh/day) is defined as having access to electricity. According to that definition, electrification is in urban areas 74.6% and 5.2% in rural areas. In rural areas, 91.3% do not have access to electricity at all (Tier 0 access as per WB multitier Framework MTF [24]), (see figure 22) (Luzi, Lin, Koo, Rysankova, & Portale, 2019)

[24] Tier 0 = Electricity is not available or is available for less than 4 hours per day (or less than 1 hour per evening). Households cope with the situation by using candles, kerosene lamps, or dry-cell-battery-powered devices (flashlight or radio).

Figure 25: Access to electricity is limited in rural areas in stark contrast to urban areas
MTF access to electricity in Zambia, urban versus rural



Source: ESMAP, 2019

Access to electricity is vital for the social and economic development of a country and its unavailability in rural areas will undermine efforts to improve the rural economy, living conditions and deter investment in agro-processing and other productive facilities. Opportunities to provide access to rural off-grid households are:

(1) Extend the grid and / or connect households 'under the grid'
(2) Provide off-grid access such a solar home system or solar lanterns
(3) Ensure access via mini grids

In this study the third option is studied with focus on utilizing bioenergy for electricity generation in off-grid areas. In addition to this, captive power generation is considered for agro-businesses with mini-grid consideration. Demand for electricity in off-grid areas are households and small cottage industries. Very limited information is available on the potential demand for electricity and willingness to pay. However, some on-grid industries may have the opportunity to supply electricity on-grid or share with neighbouring households.

4.2.2 Potential sectors with power generation potential in off-grid areas

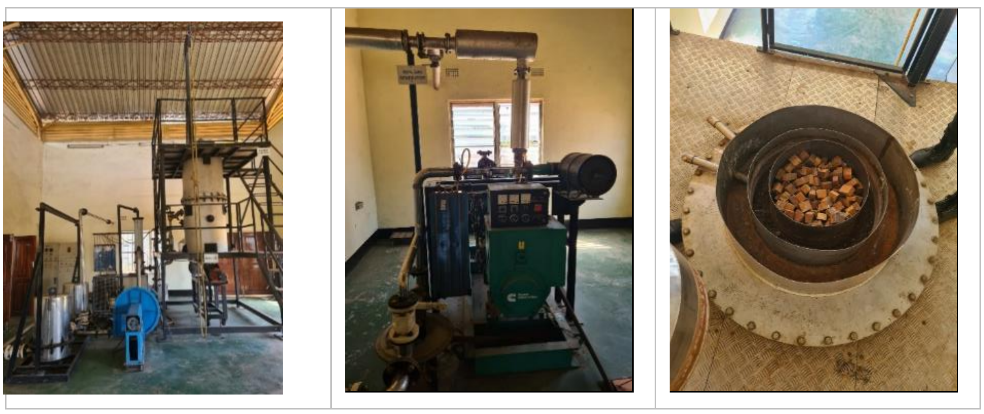
- **Gasification of agricultural residues for power generation - the ZESCO gasifier**

Biomass gasification involves the production of gaseous fuel from biomass feedstock. The gas produced, can be used in a gas engine, or modified gasoline and diesel internal combustion engines for electricity generation.

There is very limited experience with gasification in Zambia. ZESCO, in conjunction with UNIDO, planned to install 1 MW biomass electricity generation plant to meet the electricity needs of Kaputa District. This facility was meant to replace 440kW installed capacity of a diesel power generation system. However, due to the extension of the national grid to Kaputa, the project was not viable and therefore not pursued. The CEC (Copperbelt Energy Cooperative) considered a 1 MW plant investment using wood waste from Copperbelt Forestry Corporation sawmills near Kitwe. However, preliminary costing indicates that the tariff obtained with this system is not competitive with grid electricity.

As part of the UNIDO project, a demonstration unit of 20kW was installed at ZESCO Training Centre, with the aim to obtain experience on the use of the gasifier. The system however broke down several years ago. Prior to that, the system was only powering a couple of lights. ZESCO indicated that the gasifier will be repaired.

Figure 26: ZESCO's Gasifier: the down draft gasifier (20kW), the gent-set (40 kW) and inlet



Source: author's pictures

Other than this gasifier, there is no experience in Zambia with gasification. Also, REA (Rural Energy Authority), has no experience. This is a significant barrier to introducing this technology.

One of the most prominent gasification technology manufacturers is an Indian company based in Gujarat, the company is called Ankur and has installed 100s of gasifiers around the world in the capacity of 3 to 500 kW (CEEEZ, 2016). An example of this is a project in Cambodia in 2005 for village electrification using branches from fast growing species planted by community members (E.Buysman, 2009), see below (box 2).

Box 2: Gasifier village electrification project in Cambodia

In 2005 a 7 kW Ankur gasifier was installed at a newly formed Community Energy Cooperative. During the first year of operation, the gasifier ran for 6 hours a day serving 81 households. Feedstock used was *Leucaena* branches which the cooperative bought for USD 30/ton from members working at the plantations. The electricity price was set at USD 0.30/kWh (Hitofumi, Katayama, Bhuwneshwar, Torio, & Samy, 2007) and covering OPEX. CAPEX was granted by Canadian International Development Agency.

Picture 1: Left to right: Ankur gasifier, dried Leucaena branches, CEC

This proved successful and in 2009 another 20kW gasifier was installed and the number of households served increased to 250 and electricity was now provided from 8 AM to 11 PM. The load during the day was around 25% of peak load during the evening. A drip irrigation pump is being installed which will increase the electricity consumption during the day (Middelink, 2008). The key to success of this project is the close cooperation with a company providing technical assistance and that the system is operated by a cooperative with well trained staff and procedures. SME, the company providing technical assistance asserts that technology is the easy part; the rest is the difficult part. This stresses the assumption found in literature; the focus should not only be on technology but also the embedding of the technology, the socio-technological regime (Barnett, 1990). The system was decommissioned with expansion of the national grid somewhere in 2015-2016 offering electricity prices.

Alternatively, mini-grids could be developed, powered by a gasifier or combustion system fuelled with agro-residues. Discussions with experts in the field however, indicated that this is very challenging [25], not necessarily because of costs or technology but more related to the organisation of the primary matter supply. Setting up a reliable long term biomass supply chain is challenging given that the supply is finite, complex and that biomass availability varies by season. The quality of the feedstock, its volume and moisture content could also be a challenge.

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Moreover, the load profile of rural off-grid is often low and concentrated during a few hours in the evening. Therefore, the biomass energy technology would be running below its optimum load for a number of hours during the day, or production is restricted to a short period in the day, i.e., evening hours. Consequently, much of the capital will be idle for an extended period. Ensuring mini grid viability, therefore, requires the development of demand during off-peak hour, preferably from a large off-taker. Mini grid development, therefore, is likely most feasible when centred around an existing or new industry. Otherwise,

[25] Interview with Guy Dekelver – lead expert Least Cost Electrification Planning 2021 study in Zambia
[26] Interview with Guy Dekelver – lead expert Least Cost Electrification Planning 2021 study in Zambia

other renewable energy technologies, such as Solar PV solutions might be more flexible and appropriate to meet household energy demand. Finally, gasifiers are rather complex and experienced and well-trained technicians are necessary for the actual operation, after sale services and for repairs.

- **Gasification of residues at grain mills**

Zambia's milling industry comprises 78 milling operations categorized into three main groups, namely large-scale millers or commercial millers, medium-scale, and small-scale millers (MOE, 2021). The main grain processed in this industry is maize or corn, which is usually transformed into maize flour and livestock feed. The commodity largely serves the domestic market and is part of the export market. The milling activities are predominant in Lusaka and Copperbelt provinces.

Generally, production capacities range above 40 Mt per day considered as commercial, while production capacities ranging between 10 to 20 Mt per day are considered as medium scale milling operations and small-scale milling operations range between 1 to 5 Mt per day. Energy requirements for the milling industry differ depending on the product being milled. However, for common grains such as maize and rice, energy requirements for the processing of one tonne of grain ranges from 350 to 920 kWh.

Access to energy for milling is a challenge. Recognizing this challenge, in 2015, with a USD 200 million loan from China 1,684 [27] solar power milling plants were set-up through the Zambia Cooperative Federation at farmer cooperatives. Many of these mills however did not work reliably, as they came without batteries, thus the performance therefore varies with insolation levels. During overcast cast the mills often did not work and otherwise milling is slow (Makanday, 2021). Moreover, the repayment of the loan, USD 100 per month per mill was also a challenge.

During the mission a mill was visited in Kampekete in Chongwe district. This mill was also installed without batteries but later through REA a mini grid was set-up with storage batteries. The micro-grid was set-up with the observation that the solar PV arrangement of many solar hammer mills is oversized and much of the power is underutilized, probably aided by the lack of batteries to store the surplus.

Figure 27: Solar array and the blue solar hammer mill shed in Kampekete

A load management system was set-up in which households can determine, within the total amount of electricity available, how much they want to purchase, and can adjust this whenever desired. For example, a household could subscribe to a package of 100 Wh/day to power lights, phone charging and other small uses.

This site was visited to assess if there are opportunities to utilize residues produced on-site, i.e., corn cobs for gasification to support the current grid or even extent the grid. However, during the visit it was difficult to assess the number of residues available. Furthermore, gasification is a complex technology and may not lent itself well for a smart grid as set-up in Kampekete. Batteries are flexible and can easily switch between high and low load, a gasifier on the other hand, only works efficiently at a certain load.

The same recommendations apply here as with the ZESCO's gasifier, see above, on how to examine the potential of gasification for micro or mini grids.

- **Biogas for captive power**

Large livestock farms and slaughterhouses have significant amounts of manure available for biogas generation. Zambeef has been visited for this purpose, but other farms with good capacity that include Crest Zambia, Country Choice, Copperbelt Chickens, Supreme Choice, Zamchick, Golden Lay, and Colchi Farms Limited. Equally there are dairy farms with reasonable numbers of cattle e.g Kusiya and Rosedale Farms who could install biogas generating plants (CEEEZ, 2016).

Zambeef is the largest livestock farm in Zambia, with 100,000 dairy cattle, 340,000-day-old chicks and has 6 large abattoirs for cattle and pigs. Zambeef is planning to invest in a biogas plant to treat slaughterhouse waste at their largest abattoir combine with solar PV through power purchase arrangement (PPA) , in which Zambeef guarantees the purchase of electricity at a certain price for a longer period (20 years was mentioned) and supplies the feedstock (manure). A tender inviting companies will be published later this year. However, Zambeef noted that it will be impossible for companies to provide

[27] According to company that installed the mills, Shandong Dejian Group Company Ltd, the number is closed to 2,000

electricity at a competitive tariff compared to ZESCO, in their pre-feasibility study it was estimated that at least USD 0.12/kWh is necessary for a profitable investment in a biogas to electricity plant, which is more than 2 times higher than ZESCO tariffs.

The reason for pursuing this investment is because the economic impact due to load shedding on the business is significant, as running back-up generators is expensive but necessary. On top of that, Zambeef is looking for this investment is improving its environmental footprint, which is a focus of their partners.

More details on the sizing of the plant were not shared, these will be shared with the companies that submit a proposal for the tender. Likely however, the size will be in magnitude of 2 to 4 MW.

A key barrier for biogas to power, or biomass to power, for on-grid application is the low grid electricity tariff. While tariffs have increased recently, these remain lower than the average in sub-Saharan Africa. Only companies severely affected by load-shedding and with an environmental agenda, may invest. Another barrier, Zambeef, noted, is the lack of experience in Zambia with large scale power generation. For that reason, Zambeef is only inviting international companies with a track record to submit a proposal.

In terms of the focus of this study, on off-grid applications, there might be opportunities, but these are likely at a much smaller scale. This has to be studied in more detail. The integrated resource plan (IRP) under development for Zambia has an allowance for Biomass and this could be the basis for a follow up study.

4.3 Biogas for heating barns and communities

- **Thermal energy generation for heating**

Pig and poultry farms have a demand for space heating. During the first weeks after birth, piglets and chicks are unable to keep themselves warm. In nature sows would build nests, and chicks would flock under the feathers of hens for warmth, but this is not possible in a farm setting. Therefore, a source of external heating is required, which is often either a 250-Watt infrared lamp, a metal bucket with charcoal or biogas heaters.

In 2019 electricity tariffs increased significantly, and therefore many farmers switched from using ZESCO electricity to using charcoal for heating. Charcoal, especially when bought in bulk, is relatively inexpensive (ZMW 250 for 210 kilogram). However, as discussed in chapter 2, the charcoal kilns are inefficient and thus the demand of wood has increased significantly due to this switch. A study survey conducted by A2C estimated that poultry farmers have become a larger consumer of charcoal compared to school and colleges with an annual per farm use of 1,390 kg charcoal (USAID, 2022).

A farmer in the peri-urban area of Lusaka was visited who switched from using electricity for piglet box heating to biogas. The farm is feeding its digester with pig manure (700 fattening pigs, 42 sow, 3 boars and 60 piglets) in a 31 m^3 fixed dome digester at an estimated cost of ZMW 75,000[28]. The gas from the digester is used for cooking by 5 households of workers and heating of 3 piglet pens. Directly after birth, heating is provided 24/7 and after a week this is reduced to night-time heating only. This farm was able to cut their monthly electricity bill from around ZMW 6,000 to 7,000 to ZMW 3,000. Other and perhaps even more important benefit is the improved reliability of the heating system. Previously, heating was affected by load shedding and subsequent power cuts which in certain cases forced the famer to use a simple mbaula stoves with charcoal for heating during extended periods without electricity.

Figure 28: Sow and 7 piglets in a separate space with some bedding materials. Above the piglets, the saucer, a biogas space heater provides heat

Utilizing biogas for heating for these types of farms is therefore very attractive. Biogas heaters, however, are not readily available on the market, and those available are expensive at around ZMW 1,100, which is rather expensive compared to other countries. Low-cost alternative are biogas lamps; however, these lamps often require relatively frequently replacement of the mantels (every 2 months), which is not that

[28] As per discussion with SNV, ZMW 45,000 material and ZMW 30,000 labour. The latter is a maximum and could be lower depending on location and negotiation

difficult but does require access to spare parts, which are not always readily available.

The digester, including 3 heaters is 75,000 + 3 * ZMW 1,100 = ZMW 77,300. With a savings on electricity of around 3,000 to 4,000 ZMW, the simple pay-back period is between 19 to 26 months, not taking into account the benefit of supplying gas to 5 households, and the bio-slurry value. While this calculation is based on rough estimates, and does not include financing cost and financial discounting, it does however indicate that the investment is profitable. Similar models could be replicated to other farmers, there are a range of digesters available for all types of small to medium farms which could achieve similar pay-back period.

During the field visits, attempts were made to assess the opportunities in the poultry sector, but physical visits could not be made given the short time allowed to complete the assignment. Interviews with other farmers revealed there are some challenges with utilizing poultry dropping for biogas. This is only possible when the chickens are caged as otherwise the droppings are often mixed with bedding materials which would reduce the quality of the feedstock.

In other countries with SNV supported programs such as Burkina Faso and Bangladesh there are a number of biogas chicken farms near the capital cities. This is possible because chickens are held in cages and not on beds with bedding material such as rice husk, saw dust etc. A challenge is the high nitrogen content of chicken manure, thus for the start-up phase cow manure is a perquisite (which has an ideal carbon/nitrogen ratio of around 20). Once the digester is working, it often works fine, provided no antibiotics is used by the farmer (Lam, 2022).

- Biogas for communities (Petauke biogas plant)

Figure 29: Petauke biogas plant billboard

The New Apostolic Church Relief Organisation -NACRO- developed a ZMW 3.8 million bio-gas production project in partnership with NAK-KARITATIV of Germany. The plant is run by the Energy Cooperative for farmers in Nkhundye village.

The plant, a 75 m^3 fixed dome digester is fed with the manure from cattle of the cooperative members which are stabled at night near the biogas plant. In the morning the stable is cleaned and manure flows through a trench to the biodigester inlet. The project planned to use bio-slurry to grow fodder for the cattle to be fed in the evenings and for horticulture practices by the cooperative members. Initially the biogas is piped to 10 households and later upscaled. A part of the gas will be used to power a generator for lighting in the vicinity of small shops and to pump water into an elevated tank. From that tank, water is piped to connected households.

However, this project is not well managed. Households are disconnected from the biogas distribution network due to a refusal to contribute ZMW 10 per month for this service, the generator is broken and (under repair), and bio-slurry is not being used for growing fodder. Consequently, it is not easy to feed cows during night-time stabling which makes stabling at the location less attractive, and less manure is available for digester feeding. Moreover, slurry could be used for productive use, such as horticulture at household level.

According to the persons interviewed, there is an issue with community ownership and management of the plant.

Community-based biogas has significant potential according to SNV. However, before initiatives like this are replicated, it is necessary to evaluate the Nkhundye community biogas project and draw lessons from the experience. Moreover, it should be noted that the community plant was grant funded, it is not likely that a commercial investor would set-up such a facility given the limited ability (and willingness) to pay by the villagers for biogas and bio-slurry.

- Other

Noteworthy is PIN (People in Need) a Czech NGO explorative work into utilizing market waste for the production of biogas. Biogas would be piped or bottled for household use and restaurant usage and bio-slurry sold as fertilizer. According to PIN the potential of this is significant at fruit and vegetable markets. A feasibility study into this is ongoing.

4.3.1 Recommendations on PUE

- FAO in its BEFS study identified biomass hotspots, areas where there is a substantial number of agricultural residues or forestry remedies are available. A follow up study should assess the opportunities to utilize these residues for power generation for min-grids by assessing the technical and financial feasibility of a gasifier or combustion system to power a mini-grid and where possible usage of electricity for productive use (i.e., agro-processing). The study should be holistic and compare the viability with other source of renewable energy, such as solar PV. In case solar PV is cheaper or more attractive, the study should assess opportunities to utilize the residues for cooking, i.e., through pelleting or briquetting.

- Utilizing biogas for stable heating is good business case for pig farmers and perhaps also for poultry farms with a short pay-back period. Further elaboration is required on assessing the financial benefits for farmers and financing options. Cooperation with the ministry of Agriculture and experienced development partners active in the biogas sector such as SNV or PIN is vital at all these stages.

5 Conclusions and implementation roadmap

5.1 Conclusions

This diagnostic study shows that there is an enormous potential to reduce wood and charcoal consumption in Zambia. In the cooking sector only a small fraction of the wood energy is effectively used; 10% when cooking with wood and less than 5% for cooking with charcoal including losses incurred during the production. Thus, most of the energy is wasted. Measures focussing on improving the energy efficiency of cooking value chains will result in substantial wood savings. Measures should include making improved (more efficient) cookstoves more available, affordable and accessible. Similarly, the production of charcoal requires attention as the production is inefficient and unregulated.

This study concludes that there are ample opportunities to encourage the adoption of energy efficient stoves and to increase investment in alternative cooking fuels, such as pellets, briquettes, ethanol and biogas. Key barriers holding back investment is the competition with a largely informal and improperly taxed fuel, charcoal. Levelling this playing field requires enforcing of current regulation in the charcoal sector and the provision of fiscal incentives for alternative fuels and stoves, such as import duty and VAT exemption.

Established and new ICS companies have entered the market, many of them, have, or an in process of accessing carbon finance. This is foreseen to greatly accelerate sales and investment. Carbon finance can and will, within a few years, address many challenges in the sector. However, there is a risk that companies without access to carbon finance loose out, such as tinsmiths. Integrating tinsmiths, through cooperatives, in a support program, on producing standardized ICS instead of traditional stoves, and access to (carbon) finance, will help the thousands of families to remain competitive. While transitioning away from open fire and mbaula to Tier 2 and 3 ICS stoves will reduce pressure on the forest it will not be sufficient to address the health burden attributed to cooking on biomass for which a transition to clean stoves and fuels is imperative. Promoting and encouraging the adaptation of all ICS should be encouraged however in order to contribute to the reduction of the consumption of firewood and charcoal.

The demand for charcoal has increased significantly in the poultry and piggery sector for space heating purposes. In response to this, various start-up companies have started to produce char-briquettes as sustainable alternative fuel for the sector.

For farms the char-briquettes value proposition is much more beneficial and financially attractive compared to charcoal. Entering the consumer market with char-briquettes however is challenging as it is difficult to compete with charcoal due to a lack of economy of the scale. In the char-briquetting sector a switch to mechanised production is essential in order to become competitive, but both technologies and financing options for those technologies are not readily available.

One company is producing pellets and selling Tier 4 pellet gasifier stoves. Pellets are cheaper than charcoal in usage, the stove however is much more expensive. Consumer finance or financing the stove through instalments is necessary to improve affordability. While the stove relies on biomass, the combustion is very efficient and clean. The company however is struggling with securing sufficient feedstock and the cost associated with pre-financing of stoves. There are however various companies exploring valorisation of residues for pellets or char-briquettes production. For the sector to grow sustainably and to secure the pellet and stove supply chain, it is necessary that companies enter this market and that plantation residues are made available for pellet production

Domestic Biogas is another sector with great potential. Less than 5,000 plants are built while there are over 1 million households engaged in animal raising, which potentially all could benefit from a biogas digester. The sector is at the moment heavily subsidized which prevents private parties to enter the market. This is also partly the result of the low replacement value of biogas (most households rely on wood in rural areas which is generally free to collect) and the high investment costs for biogas digesters. The potential of using bio-slurry for productive use, however, is not adequately considered. Various biogas programs in other countries (e.g. Burkina Faso and Kenya) have shown bio-slurry to be a crucial factor in the viability of biogas digesters. Practical research is required on productive use of bio-slurry, the application rate, the fertilizer value, the impact on soil health etc, to improve the overall value proposition of biodigesters and to attract investments in Zambia.

Bio-ethanol: The main barrier is excise duty levied on the fuel. Removing this excise duty, would unlock significant investment and capital into the sector through which 1000s of farmers would benefit by supplying feedstock for bioethanol production. This would improve the rural economy and could significantly reduce fuel imports. However, the removal of excise duty should apply to both using the fuel for cooking and as transportation fuel. The latter is crucial to create the economy of scale that companies need for investment

This study also examined the potential for productive use of energy and there are strong indications there is significant potential for productive use of bioenergy.

There is a significant potential for biogas to heat pig pens and poultry farms – as a source of reliable and sustainable energy with significant monetary savings and relative short payback period. Likewise, wood consumption in the tobacco sector and fish, could be reduced significantly while at the same time improving the quality of the cured product. There is also a potential to produce most of the wood required on farms by investing into fast growing tree species.

Biogas and biomass to power is challenging. On-grid alternatives do not seem viable due to the low electricity tariffs. Off-grid alternatives are challenging, due to low demand. There are successful examples in the world where villages were electrified with a small gasifier and that experience could be replicated. However, this option seems to be more appropriate in the long term. On a case-by-case basis, off-grid electrification should be assessed with what alternative energy source (e.g., biogas, solar, wind) is most appropriate.

The study also confirmed that the activities identified in NEP, a biomass strategy to support companies to produce more efficient cookstoves, enforcement of biomass regulations, conduct awareness campaigns are vital to improve the enabling environment for investment in the sector.

The overall conclusion of this study is that the bioenergy market in Zambia is nascent, both for cooking and productive use. A range of activities and projects take place, but few have achieved scale. There is a general lack of information and coordination in the sector which makes it difficult to track progress and to build on on-going initiatives. Nevertheless, with the right policies and measures, the potential to transform the market is very high.

5.2 Implementation roadmap – key actions

The key question to be answered in this study is how to increase investment into the bio-energy sector. In chapter 3 and 4 detailed recommendations are provided by sector. These are not repeated here. However, many of these recommendations have similarities and some could be combined into overcharging strategies and measures to create an enabling environment for investment. Indicatively, these are grouped in short and medium-term recommendations.

Table 18: Generic reform recommendations

Company	Recommendations	
	Short-term	Medium-term
OGTF / Ministry of Energy	Develop a clean cooking strategy with clear annual stove targets.	In the medium terms the strategy should encourage a move away from ICS to clean higher tier stoves and fuels
OGTF / Ministry of Energy		Set-up a database to monitor the status and progress of modern bioenergy in Zambia
OGTF / Ministry of Energy		Implement and enforce a tax regime for charcoal and alternative fuels and technologies that creates a level playing field
OGTF / Ministry of Energy	Set up of a financing facility that clean cookstove companies could access for working capital, such as a revolving fund.	
OGTF / Ministry of Energy and Ministry of Finance	Set up a support facility (e.g. technical assistance, co-funding for feasibility studies, advice and support with legal and tax issues, etc) to make Zambia more attractive for bio-energy investments.	
OGTF / Ministry of Energy and Ministry of Green Economy	Develop programmatic climate mitigation and or adaptation proposals to be submitted to the Green Climate Fund	

Key and overarching actions to be taken that remove barriers to investment are:

- The Bio-energy subcommittee under OGTF is ideally positioned to lead the clean cooking sector activities in close cooperation with the Clean Cooking subcommittee under the Energy advisory group chaired by the MOE (to avoid an overlap). Some activities that we think could be initiated:
  (1) Development of a bioenergy strategy with clear annual stove targets. This strategy should address the barriers and recommendations as identified in chapter 3.
  (2) Set-up a database on modern bioenergy to monitor among others, ICS designs available and new ones emerging, together with their efficiencies; level of access to carbon financing; potential biomass available for energy production etc
  (3) The key barrier to all initiatives is competition with charcoal, an artificially low-priced fuel. The price does not reflect the environmental damages caused, directly and indirectly (deforestation, erosion, damages ecosystem, climate change) but is also not appropriately and consistently taxed. A2C developed a paper on proposed tax incentives for alternative fuels and technologies which could be built upon and where possible expanded in consultation with stakeholders to address all challenges in the sector, i.e. tax removal for spare parts on biogas and other technologies
  (4) Set up of a financing facility that clean cookstove companies could access for working capital, such as a revolving fund. This would enable these companies to increase stocks and reach more customers through lease to own or utility models of stove dissemination.

- Support companies to explore bio-energy business opportunities in a catalyst type of project or investment committee. Zambia is one of the many countries in Africa and attracting investment takes place in a competitive environment including countries with larger markets. For Zambia to stand out, a pro-active facilitatory approach is required to attract investors. Support could entail financial (co-funding of explorative studies) and technical (sharing of information, human resources) and general support on directing a company on potential areas for investment, advice on taxation, incentives, government structure etc. Once a business opportunity is confirmed, these companies could, depending on their stage of development, be introduced to GET.invest – a facility linking projects with financiers (https://www.get-invest.eu/), the Private Financing Advisory Network PFAN (https://pfan.net) offering free business coaching and investment facilitation to entrepreneurs or EEP, a financing facility offering early-stage grants and catalytic financing (https://eepafrica.org).

- The Ministry of Green Economy and Environment is welcoming proposals to develop programmatic approaches focussing on climate mitigation and adaptation activities seeking financing from the Green Climate Fund (GCF). Interventions in the tobacco sector and or biogas piggeries and poultry are likely eligible but also other interventions with a large reach such as an ICS programme with tinsmiths. Together with an appropriate ministry (i.e., agriculture in the case of tobacco farming and livestock) and an experienced development partner, MOE/OGTF should take the lead in identifying these opportunities.

There are various specific barriers and short and medium-term solutions relevant to individual sectors in the cooking space (see table below). Indicatively, these are grouped in short and medium-term recommendations.

Table 19: Sector specific short and medium-term recommendations to promote investment in the bio-energy sector

Sector	Recommendations		Comments
	Short-term	Medium-term	
Improved cook stoves	Review taxation of the charcoal chain	Develop new financing mechanisms (see key actions) to attract more investment into the sector.	Many companies are investing in ICS encouraged by the recovery of the carbon prices.
	Encouraging tinsmiths to set-up cooperatives and supporting these cooperatives with access to capital and knowledge for	Tin-smith cooperative project could access carbon finance to support the investment.	Local artisans, tinsmiths, will only move away from producing mbaula if a perspective is offered.

Sector	Recommendations		Comments
	Short-term	Medium-term	
	exclusive production of improved mbaula stoves. Technical support services (quality control, testing), marketing and promotion, awareness creation.		
Char-briquettes (both for cooking and for farms)	Create possibilities for access to concessional finance, i.e. as proposed under the ICS support programme is essential including support to import briquettes presses and other parts.	Develop char-briquette product quality standards.	The main barrier to upscaling and investment is the lack of technology for mechanisation and access to finance.
Biogas	Organize a taskforce or national program (see chapter 4) to have concerted effort create an enabling environment for demand and investment.		The value proposition of biodigesters has to be clarified by developing business models, and valuation of productive use of bio-slurry.
Bioethanol	Remove the excise duty on denatured bio-ethanol for cooking and transportation to unlock significant investments		Excise duty is preventing investment int the sector.
Pellets	Support Emerging Cooking Solutions with overcoming their feedstock issues by working with ZAFFICO MOE should take a leading role in ensuring that pellet businesses can grow. In the draft EESAP, Min of Energy is the main implementation body for the action to up-scale pellet production from 1,200 currently to 10,000 ton/year. Encourage other companies to invest in pellet production, like TAZ or CFP.	Explore a public private partnership (PPP) model, such as ZAFFICO investing into pelleting and ECS would focus on increasing the supply of gasifiers stove on the market.	ZAFFICO is a government owned company (63% of shares are owned by the Industrial Development Corporation Zambia (IDC). Its mandate is to play a catalytic role by developing projects either on its own or in partnership with private sector players and other development-oriented agencies.
Thermal energy for curing/drying	Understand barriers for existing energy efficient technologies adoption and work with TAZ and Tombwe ltd to reach all farmers including setting up woodlots. Disseminate at scale existing energy efficient technologies which save wood and improve quality of the product.	Applied research into solar thermal drying technologies.	Energy efficient technologies exist which save wood and improve quality of the product but are not disseminated at scale.
Biogas and biomass for power generation	Repair the gasifier at the ZESCO training centre .	Evaluate support companies, which have a business interest in exploring this. This could be a vehicle to attract investment. Rice mills for example, although not	Biogas and biomass for power generation is very challenging, due to low electricity demand in off-grid areas and lack of experience.

Sector	Recommendations		Comments
	Short-term	Medium-term	
	Assess opportunities for power generation in the geographical hotspots identified by FAO.	studied have a significant electricity demand for milling and thermal energy for paddy drying, gasification of rice husk could be viable option but needs more study. Develop a grid feed in tariff for biomass and biogas power projects.	
Biogas for productive use	Heating of barn (piglets and chick brooding): Interview more farmers and other stakeholders in the sector to understand further what is holding back investment in biogas. Integrate productive use of in the taskforce /national program (see sector biogas).		Significant savings are possible with using biogas for heating with a relative short pay-back period.
	Community scale biogas: study the experiences in Petauke and evaluate how to replicate the model.		Community scale biogas for cooking and productive use has great potential to improve livelihoods but are often, and in the case of Petauke 100% grant funded. It is unlikely that the community can bear the cost if the facility if financed by a commercial investor. Business opportunities are therefore absent. If grant funding were available, there might be opportunities for companies to operate and maintain the facility.

Annexes

Abbreviations

CFP		Copperbelt Forestry Products
CO2		Carbon Dioxide
DALY		Disability adjusted life year
EESAP		Energy Efficiency Strategy and Action Plan
ICS		Improved cookstove
MOE		Ministry of Energy
MTF		Multi-tier framework
NEP		National Energy Policy
OGTF		Off-grid task force
PFI		Partners for Innovation
PoA		Programme of Activities
PV		Photovoltaic
TAZ		Tobacco association of Zambia
TFEC		Total Final Energy Consumption
TJ		Terajoule
VGS		Voluntary Gold Standard
ZMW		Zambian kwacha

Annex I: Stakeholders consulted

No.	ORGANISATION	PURPOSE
1	Biogas Association of Zambia/Southhills Enterprise	Kick-off meeting
2	European Commission	Kick-off meeting
3	Integrated Access to Electricity and Renewable Energy (IAERP)	Kick-off meeting
4	Integrated Access to Electricity and Renewable Energy (IAERP)	Kick-off meeting
5	JUNKOFA Energy	Kick-off meeting
6	JUNKOFA Energy	Kick-off meeting
7	Ministry of Energy - Department of Energy	Kick-off meeting
8	Ministry of Energy - Department of Energy	Kick-off meeting
9	Ministry of Green Economy - National Designated Authority	Kick-off meeting
10	Modern Energy Cooking Solutions	Kick-off meeting
11	OGTF	Kick-off meeting
12	OGTF/Centre for Energy Environment and Engineering	Kick-off meeting
13	OGTF/Centre for Energy Environment and Engineering	Kick-off meeting
14	OGTF/Centre for Energy Environment and Engineering	Kick-off meeting
15	OGTF/Lloyds Financials	Kick-off meeting
16	OGTF/Lloyds Financials	Kick-off meeting
17	Rural Finance Extension Program	Kick-off meeting
18	SNV	Kick-off meeting
19	SNV-ICR	Kick-off meeting
20	SupaMoto	Kick-off meeting
21	USAID - Alternatives to Charcoal	Kick-off meeting
22	USAID - Alternatives to Charcoal	Kick-off meeting
23	ZARENA/Plant a Million	Kick-off meeting
24	ZARENA	Kick-off meeting
25	ZARENA	Kick-off meeting
26	Ministry of Energy - Department of Energy	Scoping meetings
27	Ministry of Energy - Department of Energy	Briefing
28	Rural Electrification Authority (REA)	Scoping meetings
29	Rural Electrification Authority (REA)	Scoping meetings
30	Rural Electrification Authority (REA)	Scoping meetings
31	Ministry of Green Economy - NDA	Scoping meetings
32	Ministry of Green Economy - NDA	Scoping meetings
33	Food and Agricultural Organisation	Scoping meetings
34	Ministry of Lands, Natural resources & Environment	Scoping meetings
35	Ministry of Lands, Natural resources & Environment	Scoping meetings
36	Tobacco Association of Zambia	Sector analysis
37	Tobacco Association of Zambia	Sector analysis
38	Commercial Tobacco Farmer	Sector analysis
39	Chonzu Engineering	Sector analysis
40	Tombwe Processing	Sector analysis
41	Tombwe Processing	Sector analysis
42	Tombwe Processing	Sector analysis
43	ZESCO Training Centre, Ndola	Sector analysis
44	ZESCO Training Centre, Ndola	Sector analysis
45	Copperbelt Forestry Company Ltd.	Sector analysis
46	Copperbelt Forestry Company Ltd.	Sector analysis
47	Rural Electrification Authority (REA)	Sector analysis
48	Rural Electrification Authority (REA)	Sector analysis
49	Rural Electrification Authority (REA)	Sector analysis
50	Fig Tree	Sector analysis
51	Fig Tree	Sector analysis
52	SNV Petauke Bio digester	Sector analysis
53	Zambeef	Sector analysis
54	Zambeef	Sector analysis
55	Fringilla	Sector analysis
56	Petauke Bio digester	Sector analysis
57	Petauke Bio digester	Sector analysis
58	Biogas for commercial use - heating for piglets	Sector analysis
59	People in Need Zambia	Sector analysis

60	Poultry Association of Zambia	Sector analysis
61	Tinsmith	Sector analysis
62	Tinsmith	Sector analysis
63	Up Energy	Sector analysis
64	Alternatives to Charcoal	Sector analysis
65	Alternatives to Charcoal	Sector analysis
66	Alternatives to Charcoal	Sector analysis
67	Emerging Cooking Solutions (Supamoto)	Sector analysis
68	Emerging Cooking Solutions (Supamoto)	Sector analysis
69	Zambia Energy and Environmental Organisation (ZENGO)	Sector analysis
70	Zambia Energy and Environmental Organisation (ZENGO)	Sector analysis
71	Department of Forestry, Petauke	Sector analysis
72	Lusanzu District, Petauke	Sector analysis
73	Community Forest Management Group/Mud Stoves	Sector analysis
74	Community Forest Management Group/Mud Stoves	Sector analysis
75	Mud stove recipient -Petauke	Sector analysis
76	Climate Management Ltd. T/A Save 80	Sector analysis
77	Rural Electrification Authority (REA)	Sector analysis
78	Rural Electrification Authority (REA)	Sector analysis
79	ZAFFICO	Sector analysis
80	Rasma Engineering	Sector analysis
81	Ministry of Energy - Department of Energy	Briefing
82	Ministry of Energy - Department of Energy	Briefing
83	Ministry of Energy - Department of Energy	Briefing
82	SM Enterprise	Sector analysis
83	Asum Xela Enterprise	Sector analysis
84	COMACO	Sector analysis
85	COMACO	Sector analysis
86	Green Fire	Sector analysis
87	Green Fire	Sector analysis
88	Biofuels Association/Thomro Investments	Sector analysis
89	Sunbird	Sector analysis
90	Zhongkai	Sector analysis
91	EcoCharcoal	Sector analysis
92	EcoCharcoal	Sector analysis
93	Shoprite Stores	Sector analysis

Annex II: Multi-tier Framework for cooking and access to electricity

- **Multi-tier Framework for clean cooking:**

Figure 30: Multi-tier Framework for Measuring access to modern energy cooking solutions [29]

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
	ISO's voluntary performance targets (Default Ventilation) PM2.5 (mg/MJd) CO (g/MJd) gn	> 1030 > 18.3	≤ 1030 ≤ 18.3	≤ 481 ≤ 11.5	≤ 218 ≤ 7.2	≤ 62 ≤ 4.4	≤ 5 ≤ 3.0
	High Ventilation PM2.5 (mg/MJd) CO (g/MJd)	> 1489 > 26.9	≤ 1489 ≤ 26.9	≤ 733 ≤ 16.0	≤ 321 ≤ 10.3	≤ 92 ≤ 6.2	≤ 7 ≤ 4.4
	Low Ventilation PM2.5 (mg/MJd) CO (g/MJd)	> 550 > 9.9	≤ 550 ≤ 9.9	≤ 252 ≤ 5.5	≤ 115 ≤ 3.7	≤ 32 ≤ 2.2	≤ 10%
Cookstove Efficiency	ISO's Voluntary Performance Targets	≤ 10%	≥ 10%	≥ 20%	≥ 30%	≥ 40%	≥ 50%
Convenience	Fuel acquisition and preparation time (hours per week)	≥ 7		< 7	< 3	< 1.5	< 0.5
	Stove preparation time (minutes per meal)	≥ 15		< 15	< 10	< 5	< 2
Safety		Serious accidents over the past 12 months				No serious accidents over the past year	
Affordability		Fuel cost ≥ 5% of household expenditure (income)				Fuel cost < 5% of household expenditure (income)	
Fuel Availability		Primary fuel available less than 80% of the year				Available 80% of the year	Readily available throughout the year

- **Multi-tier Framework for access to electricity:**

Figure 31: Multi-tier Framework for measuring access to electricity

Load level	Indicative electric appliances	Capacity tier typically needed to power the load
Very low load (3–49 W)	Incandescent light bulb, fluorescent tube, compact fluorescent light (CFL) bulb, LED light bulb, torch/ flashlight/lantern, radio/CD players/sound system, smartphone (internet phone) charger, regular mobile phone charger	TIER 1
Low load (50–199 W)	Television (b&w), computer, fan, flat color TV, regular color TV, VCD/DVD	TIER 2
Medium load (200–799 W)	Indoor air cooler, refrigerator, electric water pump, electric food processor/blender, rice cooker, freezer, electric sewing machine, electric hot water pot/kettle	TIER 3
High load (800–1,999 W)	Washing machine, electric iron, microwave oven, hair dryer	TIER 4
Very high load (2,000 W or more)	Air conditioner, space heater, electric water heater, solar based water heater	TIER 5

[29] ESMAP (2019) Zambia beyond Connections – Energy Access Diagnostic Report based on the Multi-Tier Framework

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