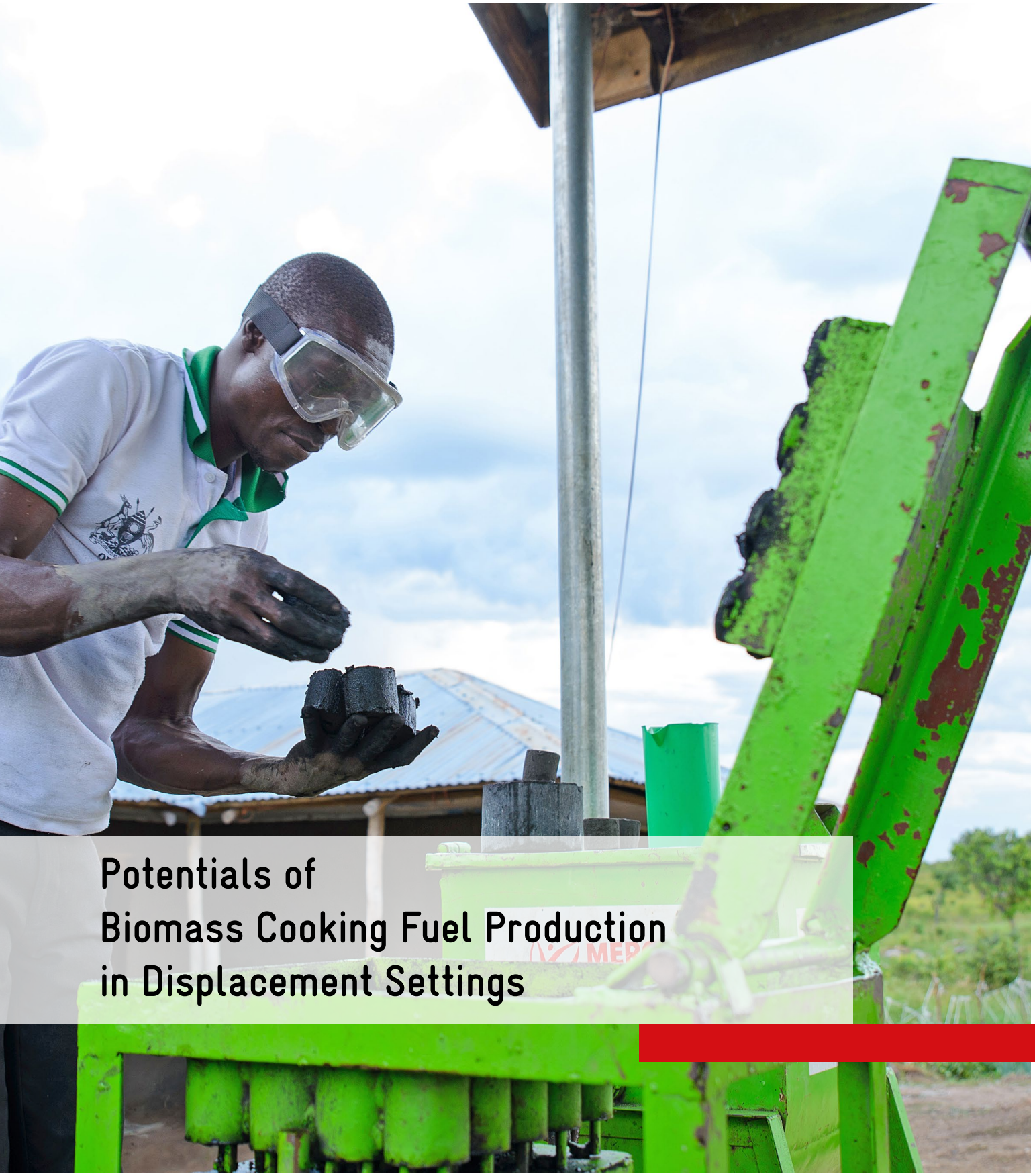

Potentials of Biomass Cooking Fuel Production in Displacement Settings

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

In cooperation with

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As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

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Programme description:
Support to UNHCR in the implementation of the Global Compact on Refugees in the Humanitarian-Development-Peace Nexus
Energy Solutions for Displacement Settings (ESDS)

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Bonn, 2022

Federal Ministry
for Economic Cooperation
and Development

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Acronyms and abbreviations

ANE	Action for the Needy in Ethiopia
ARRA	Administration for Refugee and Returnee Affairs (Ethiopia)
BMZ	German Federal Ministry for Economic Cooperation and Development
DCA	DanChurch Aid
EnDev	Energising Development
ESDS	Energy Solutions in Displacement Settings
FAO	Food and Agriculture Organization of the United Nations
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
HADS	Humanitarian Assistance & Development Services (Ugandan NGO)
ICRAF	World Agroforestry (originally International Centre for Research in Agroforestry)
ILF	International Lifeline Fund
INT	INTEGRATION environment and energy GmbH
LHV	Lower Heating Value
LOKADO	Lotus Kenya Action for Development Organization
LPG	liquified petroleum gas
LWF	Lutheran World Federation
MBEA	Market-Based Energy Access (EnDev programme at Kakuma)
OSD	Organisation for Sustainable Development (Ethiopian NGO)
PSN	Person with Specific Needs
PV	Present Value
RGF	Raising Gabdho Foundation
SUN	Support to UNHCR in the Implementation of the Global Compact on Refugees in the Humanitarian-Development-Peace Nexus
ToR	Terms of Reference
UNHCR	United Nations High Commissioner for Refugees
WFP	World Food Programme

Energy Solutions for Displacement Settings
Ethiopia, Kenya and Uganda

Project Info: **SUN-ESDS**

The BMZ commissioned Global Program "Support to UNHCR in the implementation of the Global Compact on Refugees in the Humanitarian-Development-Peace Nexus (SUN)", implemented by GIZ, seeks to support UNHCR in its role as facilitator of the implementation of the **Global Compact on Refugees** (GCR) and the Comprehensive Refugee Response Framework (CRRF) in selected refugee contexts and sectors. The program is part of the German Special Initiative "Tackling the Root Causes of Displacement, (Re-)integrating Refugees". It currently provides advisory services to UNHCR on a global level and supports UNHCR in creating and mainstreaming knowledge on the operationalization of the GCR.

The Energy Solutions for Displacement Settings (SUN-ESDS) component works closely with UNHCR and local partners to provide energy solutions that cater to the needs of both refugee and host communities in our project countries- Uganda, Kenya, and Ethiopia. SUN-ESDS is also the German contribution to the **Clean Energy Challenge** issued by UNHCR in 2019 with the following objective: **"All refugee settlements and nearby host communities will have access to affordable, reliable, sustainable and modern energy by 2030."**

The SUN-ESDS project works through three intervention areas:

Improving the policy framework through providing advisory services to governmental stakeholders to promote the inclusion of refugees into national service delivery systems. The project collaborates with the affected communities, and governmental, non-governmental and private sector partners to develop more sustainable energy solutions.

Greening infrastructure in displacement settings through supporting the solarization of UNHCR offices as well as settlement/camp and communal infrastructure, thereby promoting more environmentally sustainable and cost-efficient energy solutions. The project develops energy delivery models that are attractive to the private sector.

Increasing energy access through developing self-sustaining markets for basic energy related services and products, improving access to finance and promoting participatory design processes benefitting households, social services, and small businesses of both refugees and host communities while reducing the pressure on the environment.

We contribute to the following SDGs

Executive Summary

Introduction

The Energy Solutions for Displacement Settings (ESDS) project, commissioned by the German government and implemented by German Development Cooperation (GIZ), seeks to improve energy access in refugee-hosting areas of Gambella Region, Ethiopia; Turkana County, Kenya; and West Nile, Uganda. Imbalance between woodfuel requirements and sustainable biomass supply in these areas can result in increasing collection distances, greater commoditisation of fuel and rising energy prices, and may also contribute to environmental degradation. ESDS commissioned a study to identify the most viable options for increasing access to safe, reliable and sustainable biomass cooking fuel for refugees and hosts; and to develop business models and implementation approaches for the selected solutions. The study was carried out by a team from INTEGRATION environment and energy GmbH, a Germany-based consulting company.

Country context

Fuel supply to refugees in the three ESDS locations is dominated by locally sourced firewood and charcoal. In West Nile and Gambella, most firewood is self-collected at little or no cost, so willingness to pay for alternatives is likely to be low. In Kakuma, the fuel economy is largely monetised. This offers more potential for market-based alternatives since people are already paying for their fuel. For alternative fuels to be adopted, however, price and performance needs to compete closely with existing low-cost options. Across all three sites, most refugees have limited purchasing power and woodfuels will continue to dominate cooking energy supply.

There have been various initiatives to promote non-woodfuel sources of energy for cooking over the decades in which refugees have been hosted in these regions, none of which have been able to compete on cost and quality with charcoal or firewood. The challenge has been to ensure reliable supply of good quality fuel at a competitive price, relative to woodfuels, after introductory funding for alternatives has been phased out.

Fuel shortlisting and lessons learned

Through a multi-criteria shortlisting process, firewood and charcoal were identified as the most viable biomass-based fuels for cooking in the three locations. Fuel briquettes manufactured from carbonised biomass (char) showed the most promise as a biomass-based alternative to firewood and charcoal, out of 21 fuels considered. Other biomass-based options such as pellets, ethanol and non-carbonised briquettes were assessed as less realistic for reasons of cost, availability or user acceptability. Solutions based on fossil fuels and electricity were deemed out of scope for the assignment.

Char briquettes have been widely produced in East Africa and private firms have penetrated niche markets outside the humanitarian sector, primarily for commercial and industrial use. Their experiences indicate that briquettes should be mass produced in mechanised operations to achieve reliable output, consistent quality and economies of scale. A compelling price/performance offering is required to incentivise a shift away from charcoal, the next most affordable option. Manufacturing briquettes for household cooking has not been a viable business proposition, however, with most producers reliant on grants and unable to sustain sales to the domestic cooking market.

Business model

To determine the cost of production for a commercial briquetting operation, a customisable business model was developed to simulate the mass production of char briquettes for refugee operations. The model reveals that the selling price for char briquettes in the refugee locations would need to be almost double the prevailing price of charcoal, the next cheapest alternative, for the business to be viable. To promote such fuel would require subsidy of around $3.2m in the first year to meet the needs of 10% of refugees across the three locations, and upwards of $3m per annum thereafter.

Conclusions

For reasons of cost, convenience and familiarity, woodfuels will remain the dominant source of cooking energy in the ESDS locations. Continued support is therefore required for measures to improve the sustainability of woodfuel supply and maximise the efficiency with which it is used. Alternative energy sources may also become part of the solution, with char briquettes the most viable of the biomass-based options available. But analysis for this study has shown that the production and promotion of such briquettes would require large subsidy over an indefinite period, which could be more effectively invested elsewhere. There would also be significant market development challenges.

Recommendations

A package of measures is proposed to address woodfuel supply/demand imbalances and energy access challenges in the ESDS locations, as summarised in the table below:

	Potential Measures		
Location	**Reducing woodfuel consumption**	**Enhancing sustainable supply of biomass**	**Promoting alternative fuels**
West Nile	Support 'last mile' marketing, sales and distribution to get higher tier charcoal cookstoves into the refugee settlements, building on existing support to 'energy kiosks'.	Promote higher biomass yields from natural forests, private plantations and homestead planting through interventions in (agro-) forestry and improvements in wood processing (e.g. carbonisation).	Conduct a wider cost-benefit comparison of cooking options, including electricity, to fully evaluate investment and subsidy levels, infrastructure challenges and long-term health, social, economic and environmental benefits.
Gambella	Support the user-centric design and local manufacture of simple clay stoves for refugee use, which can make an affordable and appropriate contribution to easing the fuel sourcing burden on refugee families.	Promote conservation-friendly agriculture and agroforestry on farms and around homesteads, and support the protection of natural forests. Research the impacts of refugees on forest resources, similar to those by FAO in W. Nile and Kakuma.	Consider the procurement of firewood from sustainable sources for groups identified as vulnerable.
Kakuma	Strengthen and sustain the promotion of improved cookstoves through EnDev's SNV-managed Market-Based Energy Access programme.	Improve efficiencies in the Prosopis value chain (including better charcoal production), establish and protected 'greenbelts' and plant drought-resistant tree species in micro-catchments.	Conduct a wider cost-benefit comparison of cooking options to evaluate investment and subsidy levels, infrastructure challenges and long-term health, social, economic and environmental benefits.

In addition to the above measures, a cross-cutting package of measures to provide a supportive **enabling environment** for sustainable cooking fuel solutions is recommended. This should include cross-sectoral coordination, donor engagement, host/refugee working groups, the development of decentralised policies on renewable energy and natural resource management, policy advocacy to tackle unhelpful regulatory barriers and a programme of targeted research. The long term goal should be to move to electricity for cooking, with effective trials of new technologies to help the transition.

1. Introduction

1.1 Biomass energy – relevance and rationale

This study concerns the use of energy for cooking in three refugee-hosting areas of Uganda, Ethiopia and Kenya. More specifically, it investigates options for sustainably sourced, biomass-based cooking fuels in West Nile, Gambella Region and Turkana County. Before the study objectives and approach are outlined, it may be helpful to highlight the relevance of this topic and the rationale for the research.

Refugees tend to use sources of energy for cooking that are already familiar to them and readily available in the areas where they are temporarily settled (UNHCR, 2002). For the predominantly South Sudanese refugees in the three locations being researched, this generally means woodfuels (firewood and charcoal).

The woody biomass[1] from which these fuels are derived regenerates continuously, making it conditionally renewable. But unusually high demand for woodfuel – as may result from a large influx of refugees on top of existing local populations – can lead to rates of biomass extraction that exceed the rate of replenishment. If users consume more biomass than is being regenerated, a vicious circle can develop where over-harvesting causes depletion of stock, resulting in lower annual production and exacerbating over-harvesting, resulting in further loss of stock. This may be evidenced by an evolution from collection of dead and fallen wood in close proximity to a refugee camp or settlement, to the cutting of live branches and standing stems progressively further away.

This can become a source of conflict with host governments and local communities. It may also mean that refugees have to expend significant amounts of time, money or bartered food to secure sufficient cooking fuel to meet their needs, in a context of diminishing biomass availability, growing commoditisation and rising prices. The burden tends to fall disproportionately on women and children, who may even be exposed to physical risk in the process of sourcing fuel.

While the harvesting of wood for cooking fuel (and also construction materials) may contribute to the degradation of forests and woodland, care should be taken in framing woodfuel use as a cause of 'deforestation'. This is defined as a permanent change in land cover and is brought about mainly by the expansion of agriculture.[2] Addressing the rapid increase in farming, may be a more effective way to address deforestation than intervening in the cooking fuel economy (e.g. through measures to raise agricultural productivity, such as mechanisation).

It is also worth stressing that refugees are never the sole contributors to the unsustainable extraction of biomass and the environmental degradation that this may cause. They are more likely to exacerbate situations of imbalance that already exist. In West Nile, for example, refugees have added to existing pressures on the environment, but Uganda's rate of forest loss was already one of the highest in the world (FAO, 2019), and the total number of refugees in the country is equivalent to only one year's national population increment.[3] Attributions of environmental damage to refugees should be appropriately contextualised, to avoid unreasonable scapegoating.

1 'Biomass' is defined as material of biological origin, excluding material embedded in geological formations and transformed to fossil. 'Woody biomass' is biomass from trees, bushes and shrubs (FAO, 2004).

2 Deforestation implies the long-term or permanent loss of forest cover. It includes areas of forest converted to agriculture, pasture or urban areas (FAO, 2000).

3 There were 1.5 million refugees in Uganda on 30th September 2021 (UNHCR Uganda, 2021). With a mid-2020 population of 45.7 million and a growth rate of 3.27% p.a., this matches the country's population increment in 2021 (*data.worldbank.org/indicator/SP.POP.GROW?locations=UG*).

Providing alternative cooking fuels to refugees will have only negligible impacts on reducing environmental degradation. Nevertheless, ensuring a sustainable balance between biomass energy supply and demand is an important goal for ensuring their wellbeing and security, and for reducing avoidable expenditure or exchange of scarce assets to secure cooking fuel.

The most effective way to balance demand for woody biomass with sustainable supply is to mainstream environmental considerations in physical planning by dispersing refugees across the landscape in the smallest possible aggregations, at a suitable distance from sensitive areas and with an accessible supply of fuel. UNHCR recommends that each site for a planned camp should have sufficient ground cover of grass, bushes and trees, be at least one day's walk from any environmentally-protected areas, have access to a locally negotiated supply of firewood and contain no more than 20,000 people (UNHCR, 2015).

The three study locations have hosted successive inflows of displaced people since the 1980s. It is now too late to apply these pre-emptive measures to protect the environment and ensure the necessary conditions for durable biofuel supply chains. Bidibidi settlement in Uganda has almost 240,000 refugees, for example, while Kakuma camp and the adjacent Kalobeyei settlement in Kenya have a population of nearly 220,000. Refugees at Kyangwali in Uganda were settled adjacent to the Bugoma Central Forest Reserve and those at Rwemwanja adjacent to the Katonga Wildlife Reserve, with significant negative impacts on these sensitive environmental assets (FAO & World Bank, 2020).

It is now a matter of managing local natural resources shared by refugees and host communities in the most sustainable manner possible, aiming to minimise the gap between woody biomass supply and demand, within the limits of available funding and considering competing priorities. While no country can expect zero impacts from hosting asylum-seekers who depend upon natural resources to meet their basic energy needs, negative outcomes can be mitigated through targeted interventions to ensure a safe, sustainable and affordable supply of cooking fuel.

1.2 Study background

This study was undertaken for the Energy Solutions for Displacement Settings (ESDS) project. ESDS is one component of the 'SUN' programme (Support to UNHCR in the Implementation of the Global Compact on Refugees in the Humanitarian-Development-Peace Nexus), commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by German Development Cooperation (GIZ).4 ESDS seeks to improve energy access in displacement settings through a combination of advisory support to UNHCR, policy advocacy and the development of markets for sustainable energy products and services.

ESDS works in three locations in East Africa (see Annex A for maps):

- Gambella Region, Ethiopia
- Turkana County, Kenya
- West Nile region, Uganda

Imbalances between woodfuel requirements and sustainable biomass supply in these locations can result in longer collection distances, commoditisation of fuel and rising energy prices, and may contribute to environmental degradation. ESDS is exploring market-based options for biomass-based cooking fuels to achieve a more sustainable supply-demand situation, strengthen local economies and create livelihood opportunities for both refugees and host communities.

ESDS commissioned this study to investigate the potential for commercially sustainable models for the supply of biomass-based cooking fuels in West Nile, Gambella and Kakuma. The assignment was undertaken between May and November 2021 by a team from the Germany-based consulting firm INTEGRATION environment and energy GmbH (INT). The INT team members and their designations are summarised in Table 1. The study employed a combination of key informant interviews, literature review, web-based research and field visits, as described further below.

4 For more information see *www.giz.de/en/worldwide/78682.html*

Table 1: Study Team Members

Role	Name	Home base
Team Leader	Matthew Owen	UK
International experts	Paul Quigley	Ireland
	Eugene Ntananga	Uganda
National experts	Mekonnen Kassa	Ethiopia
	Lelisa Alemu	Ethiopia
	Allan Marega	Kenya
	Gilbert Kibekityo	Uganda
Technical backstopper	Christa Roth	Germany
Administrative backstopper	Priya Behrens-Shah	Germany

1.3 Objectives and approach

The simplified Objectives of the assignment were to:

a) identify the most viable options for increasing access to safe, reliable and sustainable biomass cooking fuel for refugees and host communities in the ESDS project locations; and
b) develop business models and implementation options for the selected solutions.

An Interim Report was produced in September 2021, at the completion of the fuel identification process. This Final Report summarises the contents of that report and goes on to analyse the commercial case and financing options for the prioritised fuels, and to develop recommendations for GIZ and UNHCR.

1.4 Launch and inception phase

The assignment was launched with an online Inception Meeting on 18th May 2021, attended by staff of ESDS and Energizing Development (EnDev) in Germany and the three target countries, together with representatives of the Global Platform for Action (housed at UNITAR) and the project team.

The INT team's understanding of the ToR was set out, noting that although the main objective of ESDS is to improve energy access for refugees, additional considerations such as health, wellbeing, security, job creation and sustainable natural resource management are important in the development of cooking fuel value chains.

An ESDS emphasis on biomass-based fuels was also noted, this being the likely dominant source of cooking energy for the short- to medium-term. Liquified petroleum gas (LPG) and electricity ('e-cooking') were discounted as possible solutions for this particular study, LPG on the grounds of climate impacts and reliance on international supply chains; electricity on the grounds of technical limitations.

A requirement for market-based approaches to fuel supply was also highlighted, this being a core principle of ESDS, though appreciating that external financing will inevitably be required to launch any new fuels. The study therefore adopted an economic orientation when comparing fuel options.

The Inception Meeting was followed by an extended round of consultations with staff of EnDev, ESDS, UNHCR and other organisations active in household energy in each country from the development community and private sector. A list of organisations consulted is available in Annex B (with names redacted for personal data protection). From these interactions and accompanying online research, a directory of relevant organisations and activity descriptions was prepared. The result is a database of organisations with practical experience of delivering cooking fuel solutions in the respective operating environments, summarising their main activities in relation to the study theme. Please refer to Annex C for an extract. Relevant lessons emerging from these organisations' experiences are applied throughout the study.

The INT team also compiled a catalogue of literature on refugee energy programmes in the three target countries and beyond, as documented in the bibliography in Annex D. This literature was systematically reviewed to extract experiences and lessons concerning refugee cooking energy in the target regions, especially relating to the viability, availability and commercial opportunities around sustainably sourced fuels derived from biomass.

1.5 Field research and impacts of COVID

No domestic or international travel by the INT team members for in-country data collection was initially possible, due to COVID-related restrictions.

The Ireland-based expert was eventually permitted to travel quarantine-free and conducted 6-day missions to Uganda and Kenya in September and October 2021, together with the respective national consultants. In Uganda they visited refugee settlements in West Nile and various agencies in Kampala, but in Kenya they could not visit Kakuma due to GIZ isolation rules. A local enumerator[5] was instead recruited to collect socio-economic data in Kakuma, while the other two team members visited humanitarian agencies, development organisations and fuel suppliers around Nairobi.

As quarantine requirements persisted in Ethiopia for international visitors, field data collection there was undertaken by the two national experts. In October, they visited both Gambella Region, where ESDS works, and Benishangul-Gumuz Region, where UNHCR is funding fuel briquetting initiatives from which experiences can be transferred.

The scheduling of the country missions is summarised in Table 2.

More detailed information on dates and locations visited during the missions is in Annex E. A selection of photographs from the country missions is in Annex F.

Table 2: Study travel schedule

Activity	Sep					Oct																		
	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
weekends																								
Paul arrival. Team prep in Kampala																								Paul, Eugene & Gilbert
Field visit to West Nile																								
Debrief in Kampala w / GIZ																								
Fly Kampala-Nairobi																								Paul
Team prep in Nairobi																								Paul & Allan
Meetings in and around Nairobi																								
Debrief in Nairobi w / GIZ																								
Final meetings in Nairobi. Paul departure																								
Data collection in Turkana																								George Ekisil
Field visit to Assosa																								Mekonnen & Lelisa
Field visit to Bambella																								

5 George Ekisil, a Kakuma resident and former employee of the Lutheran World Federation and LOKADO, UNHCR's implementing partner for energy and environment-related activities in Kakuma.

2 Intervention options

As outlined in the Interim Report (September 2021), there are three main ways to reduce gaps that may arise between sustainable biomass supply and the combined cooking fuel demands of refugees and local people:

a) Reduce the consumption of woodfuels for cooking;
b) Enhance the sustainable supply of biomass; and
c) Identify and promote alternative fuels.

2.1 Reducing woodfuel consumption

Given that woodfuels will continue to be the dominant cooking fuel in the ESDS project locations, a range of measures can be usefully introduced to reduce consumption, including the dissemination of fuel-saving appliances and the promotion of more efficient cooking practices. Suitable stoves for refugee operations may include user-built mud and brick stoves, artisan-produced ceramic and/or metal stoves, and higher-tier factory-made appliances, once it is demonstrated they are more efficient and aspirational in practice than stoves already in use. Support might be required to bridge the 'last mile' distribution gap to facilitate market entry for commercial stove producers. These can be promoted alongside insulated slow cookers, pressure cookers and fuel-saving measures such as pre-soaking beans and properly preparing and drying firewood. Interventions such as these form part of existing demand-side approaches to cooking fuel management by various organisations in the region's humanitarian operations, some working as implementing partners for UNHCR and others operating with their own resources.

2.2 Enhancing sustainable supply of biomass

In order to maximise the rate of biomass production and improve the efficiency of supply, measures such as the following can be effective:

- Increase the productivity of degraded forest resources through protection, enrichment planting and natural regeneration;
- Increase the production of biomass from multi-purpose species in mixed-use homestead agroforestry systems and kitchen gardens;
- Produce woody biomass in dedicated plantations, typically as a by-product of more lucrative outputs such as building poles and timber;
- Improve the harvesting, drying, storing and transport of firewood, to reduce losses and improve efficiency in the supply chain;
- Raise efficiencies in the charcoal supply chain, especially by improving the performance of earth kilns or disseminating more advanced charcoaling technologies; and
- Promote inclusion of refugees in local natural resource management plans, combined with joint host community and refugee environmental committees or working groups.

Measures such as these are typically introduced by agencies specialising in sustainable natural resource management, forestry or agriculture. They are already ongoing to a greater or lesser extent in each ESDS project location, but are frequently constrained by low prioritisation of environmental support in the humanitarian sector.

2.3 Promoting alternative fuels

Improving energy access and alleviating pressure on biomass resources can also be achieved by switching to alternative fuels, biomass-based or otherwise. This is the principle focus of the current assignment.

A 'long list' of all possible biofuels[6] for the three locations was filtered down to a more realistic subset, based on the potential of each fuel for cooking. This pre-screening resulted in the elimination of 14 types of biofuel, while seven were retained (Table 3).

Table 3: Biofuels retained and eliminated at first screening stage

Type of biofuel	Fuels retained	Fuels eliminated	Reasons for elimination
Solid biofuels	• Firewood • Charcoal • Non-carbonised* briquettes • Pellets • Char briquettes • Charcoal briquettes	• Unprocessed biomass • Wood processing residues • Agri-harvesting residues • Agri-processing residues • Animal manure / dung • Organic fraction of municipal solid waste	• Not safe for cooking due to high emissions of smoke & particulate matter • Inferior combustion performance in loose form, without further processing or densification • User challenges and high likelihood of rejection • Difficulties in securing sufficient aggregated quantities
Liquid biofuels	• Ethanol	• Pyrolysis oil • Vegetable oil • Biodiesel • Black liquor • Plant methyl ester	• Unavailable due to absence of required technologies • Unsafe or unsuitable for domestic cooking
Gaseous biofuels	• None	• Biogas • Syngas • Lower calorific value gas	• Biogas inherently unsuitable for dispersed household use, without adequate land, livestock and water • Other fuels require expensive & inaccessible gasifier technology

* 'Non-carbonised', in this context, refers to densified fuels that are used in their original state as fuel 'logs', and not converted into carbon-rich fuels through the process of heating in an oxygen- limited environment.

Source: Adapted from FAO (2004).

6 'Biofuel' is another term for 'biomass fuel'. When burned, biofuels release biomass energy. Biofuels exist in solid, liquid or gaseous form (FAO, 2004). As this study is focussed on cooking, it concerns the direct thermal application of biofuels for the preparation of food in homes, institutions and commercial enterprises.

The seven retained fuels (plus LPG and electricity-based options) were scored qualitatively from 1 to 3 against the following criteria, to generate a shortlist of the most promising options for in-depth assessment:

1. Is its production fully renewable, or potentially so?
2. Is it biomass-based (in accordance with the Terms of Reference)?
3. Can the necessary feedstock or raw material be local sourced?
4. Does it avoid any seasonality constraints?
5. Is the feedstock under clear ownership, to ensure reliability of pricing and supply?
6. Does the feedstock avoid conflict with competing uses?
7. Does feedstock sourcing offer local livelihood opportunities?
8. Are there existing producers and supply chains for the fuel?
9. Does it have low emissions (especially smoke and particulate matter)?
10. Is it familiar to users?
11. Can it be used in existing stoves without modification?
12. Is it aspirational and likely to be desired by refugees and local people?
13. Could its production generate new commercial opportunities?
14. Does its production offer the potential for innovation?

The ranking of the fuels by combined score against the chosen criteria is summarised in Figure 1, with the full scoring details provided in Annex G.

Figure 1: Ranking of Fuel Types Against Chosen Suitability Criteria

1.	The top-ranked fuel in the assessment was **charcoal**, which is an energy-dense, adaptable and popular fuel that is readily available in local markets.	
2.	Charcoal was followed by **firewood**, Africa's most widely used fuel due to its availability, access, cost, familiarity and suitability for a variety of diets and cooking traditions.	
3.	Ranked below woodfuels were two types of briquette: • a **charcoal briquette** made by densifying raw biomass and carbonising the resulting 'log', and • a **char briquette** made by densifying carbonised biomass plus a binder. These fuels have higher calorific values than non-carbonised fuels, making them more desirable for users and potentially competitive with charcoal, depending on price and performance attributes.	 
4.	**Electric** cooking using a self-contained solar PV system was the next highest-scoring option, but was considered out of scope as it is not biomass-based. Cooking using renewables-based electricity is a an interesting prospect and there has been promising research in Uganda by the Modern Energy Cooking Services programme (**mecs.org.uk**) and by INTEGRATION environment and energy GmbH.	
5.	**Pellets** scored relatively poorly due to lack of supply, user unfamiliarity and a requirement for custom-built stoves with induced air supply. Pelletised fuels and stoves in the humanitarian context received a major setback with the collapse of the Inyenyeri operation in Rwanda in 2020, which paired pellets with Mimi Moto gasifier stoves.	
6.	**LPG** also scored poorly against the chosen criteria, as it is not biomass-based, requires a costly new stove and provides no local livelihood benefits. LPG remains an aspirational option for urban households.	
7.	**Non-carbonised briquettes** ranked close to the bottom in this analysis. These fuels are made from loose biomass such as sawdust or crop processing residues (husks, shells, stalks). They have been promoted in both the Uganda and Ethiopia refugee programmes, fabricated both at artisanal facilities with hand-operated equipment and at semi-industrial facilities. There has been no demonstrated commercial uptake due to performance limitations and high cost.	
8.	**Ethanol** scored lowest in the analysis, and has a patchy and unsatisfactory history in the region's refugee operations. A long-term pilot by the Gaia Foundation in Ethiopia ended due to cost and supply chain constraints for both the fuel and stoves, and an SNV-managed pilot in Kakuma was terminated after less than one year due to similar supply chain constraints.	

Based on this multi-fuel screening process, it was concluded that the study should proceed with in-depth investigation of **charcoal briquettes** and **char briquettes** as the most promising alternative biomass-based cooking fuels in the three ESDS settings. Business plans and financing models would be elaborated for these fuels, comparing them with firewood and charcoal as the default options. ESDS also requested that any experiences in the target countries with **pellets** and **ethanol** should be looked into, to the extent that time allowed.

As the study went ahead with more thorough research into the commercial prospects for briquettes, it transpired that there were in fact no producers of charcoal briquettes in the ESDS target countries – and indeed none could be located in the rest of Sub-Saharan Africa. These high-performance briquettes are only produced in advanced industrial economies for barbecue markets, and are not used as a household cooking fuel due to high cost of production, which makes them uncompetitive with other available energy sources (such as charcoal and electricity). This not only means that there are no operations in East Africa from which to draw technical and economic data for business modelling, but also that there would be no prospect of a successful launch in a refugee operation. The focus of the remainder of the research was therefore on **char briquettes**, of which there are numerous producers across the ESDS project countries from which to draw experiences and extract technical and economic data.

3 Country context

A brief overview will be provided of the refugee-hosting context of the three ESDS locations, and pertinent issues related to cooking fuels. A common theme in all three areas is the ubiquitous nature of woodfuels for cooking and a prevailing situation of weakly regulated access to woody biomass resources. The result is that wood for direct use or conversion to charcoal is available at little or no financial cost from bushland, woodland and areas being cleared for farming, in return for little more than the cost of labour, which is typically undervalued or not costed at all. There is lax enforcement of regulations on harvesting, processing and transport and – in the case of Gambella and Kakuma – an outright ban on any charcoal production at all, which is ineffective in practice. Market demand drives a vibrant woodfuel trade for local and regional non-refugee markets, which largely exists outside the formal economy and tax net. In this situation of informality, quasi-legality and marginalisation, woodfuels are under-priced in relation to their true economic value, which compounds the challenges of promoting alternative sources of energy.

3.1 West Nile, Uganda

Uganda hosts over 1.5 million asylum-seekers from five primary countries (UNHCR Uganda, 2021). Uganda's policy toward refugees is unique in Africa. The government grants refugees freedom of movement and the right to work, establish businesses and access public services such as education, on a par with nationals. Host districts are required to develop Integrated District Development Plans that incorporate the needs of refugees. Thanks to these policies, refugees have relatively open access to land and other resources, subject to any stipulations from the local customary leadership or existing occupiers of the land.

ESDS works in the north-western region of Uganda historically defined as 'West Nile', which houses 805,174 mostly South Sudanese refugees in 23 settlements across six districts (Madi-Okollo, Terego, Yumbe, Koboko, Obongi and Adjumani).[7] ESDS currently works mainly in the Rhino Camp settlement (which spans Madi-Okollo and Terego Districts) and Imvepi settlement (in Terego District).[8]

7 The addition of Palabek settlement in Lamwo District takes the total refugee population of the wider 'northern Uganda' to 863,716, almost all of them from South Sudan.

8 ESDS is in the process of expanding to Palabek (Lamwo District), Bidibidi (Yumbe District) and Palorinya (Obongi District), and has private sector partners in Kiryandongo settlement.

West Nile is a relatively under-developed region of the country with poorer infrastructure and lower levels of economic development than the central and southern regions. It lies within the 'North-western Savannah Grasslands' agricultural production zone, characterised by high average temperatures and low agricultural productivity, with about half the annual rainfall of Kampala. Productivity is generally low due to the high temperatures, an extended dry season and shortening fallow cycles, and subsistence farming dominates. Many families keep livestock to sustain mixed agro-pastoral livelihoods.

A 2018 survey found that the dominant source of cooking fuel for refugees in West Nile is firewood, with 8% of households in Bidibidi settlement (Yumbe District) and 25% in Maaji settlement (Adjumani District) sometimes using charcoal, almost always in combination with firewood (FAO & World Bank, 2019). The same study found that only 12.6% of refugee households ever purchase firewood, as they can usually source their own supplies from nearby bushland and woodland. The dominance of firewood for cooking and a lack of fuel commoditisation indicate relatively unhindered access to woody biomass (whereas greater use of charcoal and more fuel purchase would be evidence of the opposite). The refugees have been settled among related Sudanese ethnic groups – the Lugbara, Kakwa and Madi (Garimoi Orach & De Brouwere, 2006) – and there are not thought to be constraints on access due to any ethnic animosities. Fuel purchase is challenging for many refugees, given that average household income in the settlements is less than USD ($) 66 per month (FAO & Practical Action, 2020a).

Small numbers of 'Persons with Specific Needs' (PSNs) are provided with an allocation of fuel briquettes in the West Nile settlements, produced manually by refugee groups supported by NGOs such as DanChurchAid (DCA). The Lutheran World Federation (LWF) also plans to provide factory-made briquettes from a facility in Nwoya run by Mandulis Energy, though this is not currently operational. From late 2022, it is also anticipated that PSNs will be provided with 50% of their estimated firewood requirements under a new $58m, World Bank-funded forestry support programme in 18 refugee-affected districts,[9] including those in West Nile (World Bank, 2020).

Looking at the implications for this study, there may be some challenges in promoting alternative fuels in a context of low average incomes and open access to relatively abundant, non-monetised fuel resources, especially if there is an expectation that refugees must pay for them.

9 There are 13 refugee-hosting districts but the World Bank programme includes others deemed affected.

3.2 Gambella Region, Ethiopia

In October 2021, Ethiopia's Gambella Region was hosting 351,677 South Sudanese refugees in eight camps: Nguenyyiel, Tierkidi, Jewi, Kule, Pugnido, Okugo, Pugnido II and Akula, in declining order of population (data from ARRA office in Gambella). ESDS works in Nguenyyiel on market development for household energy access.

Gambella is one of the least developed regions of Ethiopia, characterized by poor infrastructure and high poverty (ESDS, 2020c), as well as periodic insecurity. It is nevertheless a fertile region, with a mixture of tropical forest, savannah, grasslands and marshes. Four major rivers and their tributaries provide irrigation water, and rainfall and temperature create a conducive environment for agriculture (WINS Global Consult, 2020a). Over 89% of Gambella's forested area is classified as 'dense forest', a higher proportion than for any other region of Ethiopia (Behrens-Shah et al., 2018). Thanks to relatively high stocking and a conducive climate, biomass regeneration rates are likely to be high and firewood collection is unlikely to have significant impacts on the environment.

Refugees' movement outside the camps is legally restricted by the Administration for Refugee and Returnee Affairs (ARRA), but a lack of enforcement capacity means that they can, in practice, source woodfuel locally, not only for household cooking, but also for commercial activities and firewood trade (WINS Global Consult, 2020a). There is intra-ethnic solidarity among Anywaa and Nuer from both sides of the border, and the line between refugees and hosts is sometimes blurred (ibid.). Access to local sources of woodfuel is largely unimpeded. But this is not the case in all camps, and for all groups. At Pugnido, for example, Anywaa host communities allow Anywaa refugees to enter the forests to cut wood for sale, and Anywaa refugee women are allowed to travel to Pugnido town to sell alcohol, but Nuer women have been barred from leaving the camp for the last few years (ibid.). So the access picture is mixed, and while harvesting of woodfuel is in most cases tolerated, for some groups in some locations it can result in conflicts with host communities along ethnic lines.

As in Uganda, refugees largely gather firewood as a freely harvested resource. 97% of refugee households in the Gambella camps use the open 3-stone fire for cooking (ESDS, 2020c), suggesting that people feel little need to use firewood conservatively. Confirming this relatively good availability situation, firewood is rarely traded, and any wood seen for sale in the camp markets is mostly bought by small catering businesses or by women making alcohol commercially, rarely for domestic use. The barter of food or other goods for firewood is also rare. Firewood for refugee schools and health centres is paid for by UNHCR, through ARRA, and freely collected using tractor-trailers and hired labour.

It is illegal to make charcoal in Gambella Region, which means that no data is collected on its production or use. Charcoal is rarely used by refugees for household cooking, although there is some charcoal use in restaurants and tea shops by both refugees and local people.

The dominance of firewood for household cooking, the widespread use of the inefficient open fire and the lack of fuel commoditisation are all indications that refugees are able to access woody biomass in Gambella, even if the access situation may be deteriorating over time. Refugees have limited means with which to pay for alternative forms of energy, as they lack viable livelihood options apart from their rations (WINS Global Consult, 2020b) and median household income is only around $70 per month (ESDS, 2020). As in West Nile, this presents challenges for moving towards a market-based approach to fuel supply, and indicates a likely need for some form of subsidy to plug the affordability gap.

3.3 Kakuma, Turkana County, Kenya

Turkana County in north-western Kenya houses two refugee camps at Kakuma and Kalobeyei. Kakuma camp was opened in 1992 and is located immediately west of Kakuma town, the headquarters of Turkana West Sub-County. With an influx of new arrivals in 2014, Kakuma surpassed its capacity and land for a new settlement was identified at Kalobeyei, about 7 km further west. Kakuma camp and Kalobeyei Integrated Settlement had a combined population of 218,048 registered refugees and asylum seekers at the end of August 2021 (UNHCR Kenya, 2021). 57% are from South Sudan, 17% from Somalia and smaller numbers from DR Congo, Burundi, Ethiopia and other countries. For the purposes of this analysis, Kakuma and Kalobeyei are collectively described as Kakuma camp.

In contrast with West Nile and Gambella, the host community at Kakuma (who are Turkana) have no ethnic affiliation with the refugees and assert their control over the surrounding land and natural resources. Subjected also to movement controls by the Government of Kenya, the refugees are largely unable to source their own fuel and must purchase it; less than 5% of households collect firewood themselves (Practical Action, 2018). The restriction on movement reduces refugees' livelihood opportunities and results in over-reliance on humanitarian aid (Freshon, 2021). Unable to work legally, refugees at Kakuma rely more heavily than those in Uganda on remittance and donations (FAO & Practical Action, 2020a).

This is an arid and challenging region, dominated by treeless rocky plains dissected by dry sandy riverbeds (known as luggas), which become seasonally inundated and are lined with narrow strips of Acacia-dominated woodland. The situation has changed dramatically since the camp was created, however. The invasive Prosopis Juliflora tree (known in Kenya as *'mathenge'* and locally in Turkana as *'etirae'*) was actively promoted during the 1990s by the government and its development partners (including GIZ) as a source of fuel and building material in Kenya's arid and semi-arid lands. But the tree is highly invasive and easily spread through ingestion of the seeds by livestock, and has radically altered the Turkana landscape. Areas once bare are now thick with Prosopis bushes, and riverine canopy forests once dominated by indigenous trees are being converted to Prosopis, as it out-competes local species.

From a biodiversity point of view, the situation is of great concern, but due to the rapid growth and regeneration of Prosopis stocks, there is now a "virtually infinite supply of firewood" at Kakuma (Mwangi, 2021). A 2018 World Bank-funded study by FAO found there had actually been a *gain* in biomass stocking within a 25 km radius of the camp over the preceding four years (FAO & World Bank, 2018), largely due to the rampant spread of Prosopis. The Prosopis supply chain is well developed and apparently sustainable, from harvesting through to transport, distribution and use. Both local and refugee communities fully accept Prosopis as a suitable primary source of cooking fuel, whether as charcoal or firewood, and it offers an energy option that is inclusive, accessible and cost-effective (Mwangi, 2021).

All refugee households at Kakuma use firewood for cooking, but a remarkably high 50% also use charcoal (FAO & World Bank, 2018). This is indicative of a high degree of fuel commercialisation, as well as a cultural preference for charcoal among some refugee groups, such as the Somalis and Ethiopians. The charcoal trade at Kakuma has an annual value of $2 million and is run exclusively by the host community (Corbyn & Vianello, 2018). So in a situation of relatively good biomass availability, refugees still experience access challenges as they have to pay (in cash or in kind) for almost all woodfuel. Reflecting this paradox, 91% of the refugee population has adopted some type of improved cookstove to conserve fuel, compared with only 7% of the host community (FAO & World Bank, 2018).

Refugees at Kakuma were given a monthly firewood allowance until the end of 2020 that met about 7% of their needs (UNHCR Kakuma Sub-Office, 2021). This was funded by UNHCR and purchased from local communities up to 100 km away via the NGO LOKADO.[10] Suppliers were permitted to supply only dead Prosopis wood in 10 kg bundles, which were transported to the camp by truck for distribution. The programme was valuable both for its own sake, in a poor and marginalised region of Kenya, and for its social and political benefits in improving host:refugee relations. In line with UNHCR's global shift to cash-based interventions, the firewood ration has been replaced by an individual monthly cash payment of KES 42 ($0.39), said to be sufficient to buy fuel for two to three days. Refugees meet the balance of their energy needs by using cash or exchanging food or non-food items for firewood or charcoal.

Organised firewood procurement via LOKADO has scaled back from over 13,500 t to 2,100 t p.a. and now targets only schools, hospitals, a transit centre and reception centre. The termination of firewood purchasing contracts has resulted in a lost cash injection into the local community of $745,000 for wood purchase and transport, assuming that all distribution targets were previously met. The cash-based intervention is likely to result in a concentration of woodfuel sourcing from areas much closer to Kakuma and Kalobeyei, rather than spreading the community benefit more widely as was the case when LOKADO sourced fuel.

There were more than 2,000 recorded businesses serving Kakuma and the adjacent town in 2018, with combined annual turnover totalling $56.2 million (IFC, 2018). But this gross figure conceals low levels of individual spending and significant wealth disparities between the residents of the town and the camp. Average per capita household consumption amongst the refugees is just $94 per annum (ibid.) and at least 16% of both the refugee and host community earn less than KES 1,000 ($8.92) per month (SNV Kenya, 2020), suggesting a limited ability to move to sources of cooking energy that might cost more than woodfuels.

In summary, Kakuma has a highly monetised cooking fuel economy, in which locals with a strong tradition of sustainable natural resource management capitalise on the opportunity to sell firewood and charcoal to the refugees in exchange for cash and food. So although there is an abundance of biomass thanks to the rapid spread of Prosopis, refugees cannot access this resource without paying for it. There could be an opportunity for alternative fuels at the right price point, taking into consideration the very limited spending power in the camp.

10 Lotus Kenya Action for Development Organization.

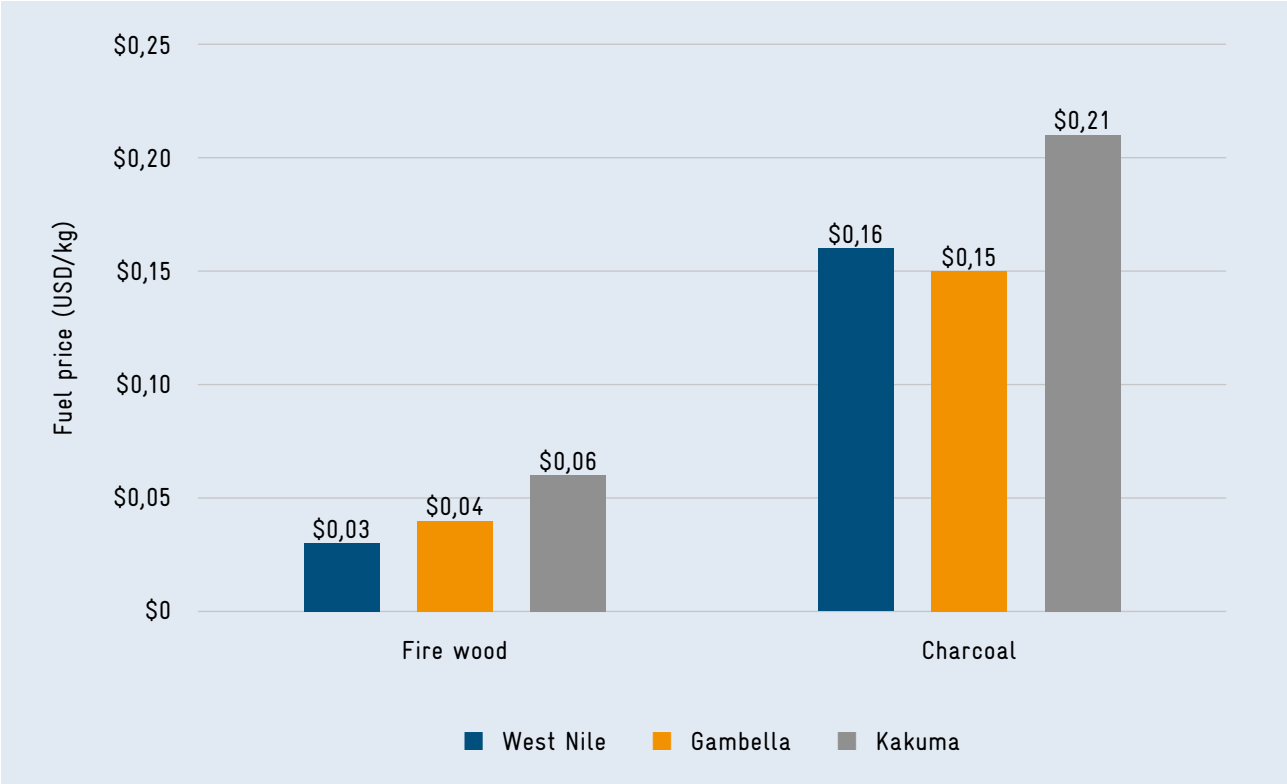
3.4 Summary

As outlined, fuel supply to refugees in the three ESDS locations is dominated by locally sourced woodfuels, primarily firewood. In Uganda and Ethiopia, most firewood is self-collected by refugees from areas within walking distance of the camps and settlements. Only in Kakuma is fuel gathering significantly restricted, resulting in greater monetisation and higher rates of charcoal use, primarily among non-Sudanese refugees.

Willingness to pay for cooking fuels is likely to be low in West Nile and Gambella, given the availability of free biomass within accessible walking distance. "Given the perception of biomass being a free resource, for many, the notion of paying for an alternative fuel such as briquettes [is] not logical" (FAO & Practical Action, 2020b). The cooking fuel economy is largely monetised at Kakuma, offering more potential for the marketing of alternatives if the price and performance proposition is attractive. But refugees' ability to pay for cooking fuels is low across all sites, with minimal expendable income and other pressing household priorities. At Kakuma, cooking fuel is often acquired through exchange of food or other commodities.

The differing fuel supply situation across the three locations is reflected in woodfuel prices, which are summarised in Figure 2. As would be expected, firewood and charcoal are cheapest in West Nile and Gambella (to the extent that they are traded at all) and highest at Kakuma.

Figure 2: Woodfuel Retail Prices in the three ESDS locations



Source: Field research. Prices for W. Nile, Gambella and Kakuma of UGX 105, ETB 1.67 & KES 6.0 per kg for firewood and UGX 581, ETB 6.67 & KES 23.3 per kg for charcoal, respectively. Rates to USD from *www.exchangerates.org.uk*: UGX 3,547; ETB 44.84; KES 109.06.

Note: Prices are based on purchase at the camp or settlement in the largest standard retail size (large firewood bundle or whole charcoal sack). They are per kg prices that do not take into account calorific content or the efficiency with which the respective fuels are used. This net cost of delivered energy is explored in 3.5 below.

There have been numerous efforts to promote alternative (non-woodfuel) sources of energy for cooking over the decades in which refugees have been hosted in these regions. These have included solar energy with various types of cooking device (bag, box, parabola and solar PV), kerosene, ethanol, dried grass (Caveng, 2000) and different types of carbonised and non-carbonised briquettes made from agricultural residues, charcoal dust and sanitised excreta.[11]

At Kakuma, for example, alternative fuels are being explored under EnDev's SNV-managed Market-Based Energy Access (MBEA) programme, now in its second phase, which facilitates commercial entities entering the refugee energy market. Ethanol was promoted under MBEA in 2018/19 and proved popular in a trial by Rural Development Solutions, but supply chains could not be sustained when the pilot funding ended. Kenya's largest ethanol company, KOKO Networks, told the study team that they could not risk an investment in Kakuma due to supply chain constraints and the commercial priority for their company is to focus on more lucrative urban markets before expanding to geographically marginal areas. Efforts to promote fuel pellets in gasifier stoves have stalled because Iko Briq and Lean Energy, the two companies showing initial interest and running small-scale pilots, did not find it commercially worthwhile to proceed. A 'non-wood cooking prize' run by the Moving Energy Initiative led to an award of $50,000 to the National Oil Corporation of Kenya for a concession to supply LPG to refugees and locals (Patel & Gross, 2019), but donor funding could not be secured to operationalise this proposal.

The challenge in sustaining such initiatives at Kakuma and in the other locations has been to ensure reliable supply of good quality fuel at a competitive price, relative to firewood and charcoal, especially after donor-funded pilot projects come to an end.

3.5 Cooking fuel cost comparison

A cost comparison was undertaken for the shortlisted biomass fuels. The total cost of cooking with a particular fuel goes beyond the purchase price per kg as it also depends on the quantity of fuel required to meet an individual's needs (itself a product of its energy content, defined as Lower Heating Value [LHV]12, and the efficiency with which that energy is delivered to the cooking pot) plus the long-term cost of the cooking appliance.

There are many nuances to these calculations, such as the use of multiple fuels and appliances in the same home (known as 'stacking'), variations in fuel properties and sub-optimal combustion efficiencies. But using referenced figures, Table 4 summarises the estimated quantity of fuel required to deliver a standardised quantity of 1,050 MJ13 of energy per person per year to the pot, using the most common type of stove or hearth for each fuel in the ESDS locations.

11 For the latter, see *sanivation.com/kakuma*

12 LHV assumes that the water component of a combustion product is in a vapour state at the end of the combustion process, whereas Higher Heating Value assumes that water has been condensed at the end of a combustion process. LHV is more appropriate for comparing cooking fuels with quite different properties (Behrens-Shah et al., 2018).

13 Household energy requirement averaged for Kenya and Uganda and converted to per capita requirement assuming five persons per household (Global Alliance for Clean Cookstoves & Eastern Research Group, 2015).

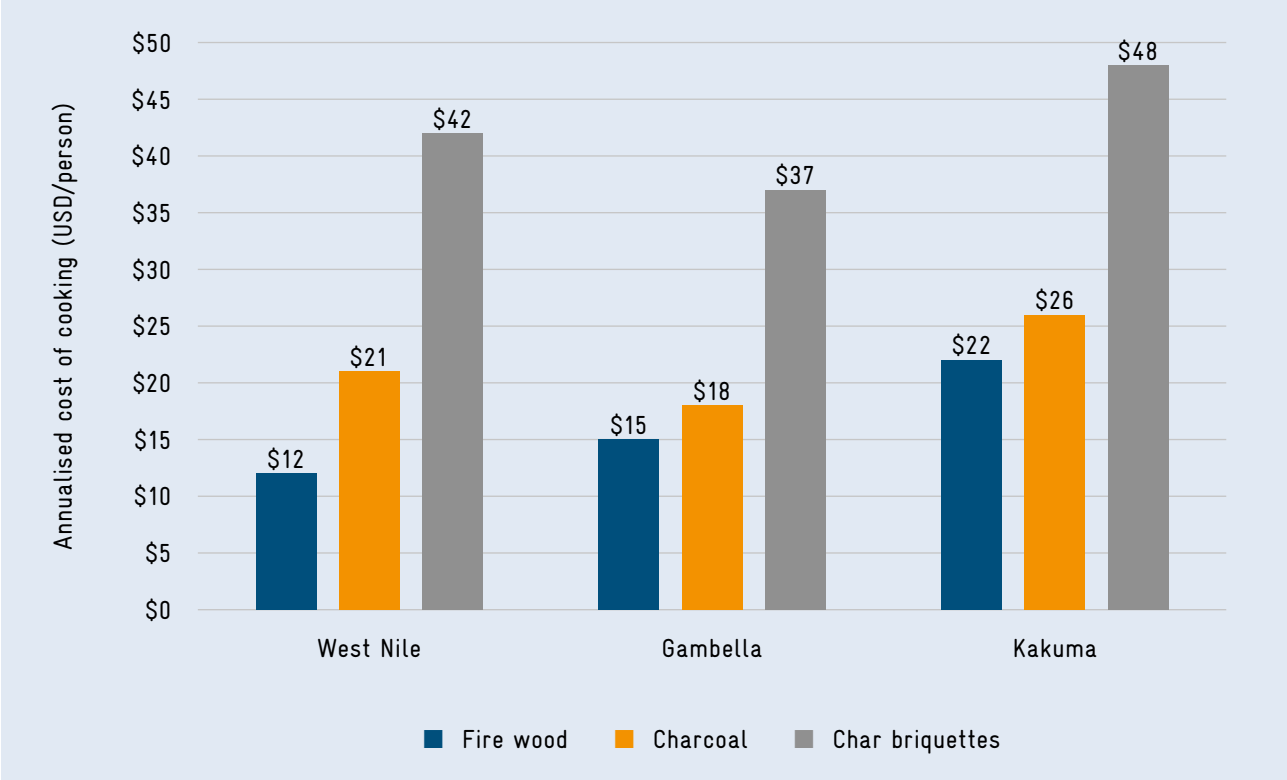
Table 4: Cooking Fuel Requirements for Delivery of 1,050 MJ per person per year

Fuel	LHV (MJ/kg)	Thermal efficiency of stove	Quantity needed per year (kg)
Firewood	15.0	17.3%	405
Charcoal	30.8	31.0%	110
Char briquettes	21.3	31.0%	159

Sources: See Annex H

Taking these annual fuel requirements, together with recorded fuel costs in each location (Figure 2) and the annualised cost of using the most common stoves for each fuel (see Annex H), total annual cooking costs are summarised in Figure 3.

Figure 3: Annual per person Cooking Fuel Cost Comparison, by ESDS Project Location



Note: The chart illustrates the total annual cost of cooking, considering both the annual fuel cost plus the annualised stove cost. See Annex H for details and sources

As noted in the shortlisting process carried out for the Interim Report, firewood is the cheapest cooking fuel in each location, followed by charcoal. Char briquettes cost more than twice as much to use as charcoal, taking into account the long-term costs of the fuel and stove, in part because of the under-pricing of woodfuels due to open access to resources and a weakly regulated industry referred to previously. The difference between the cost of using charcoal and the cost of using char briquettes is the gap that must be closed in order to promote briquettes as a realistic alternative to woodfuels. This economic and behavioural challenge is discussed in sections 4 and 5 below.

4 Experience and lessons from briquetting initiatives

4.1 Overview

There have been a variety of efforts to promote char briquettes in the ESDS project countries, though not always in the specific regions of ESDS operation. These range from NGO-supported refugee or host community groups, who have been issued with equipment for the production of hand-made briquettes from carbonised agri-residues, through to larger-scale semi-commercial producers supported with equipment and/or guaranteed purchase contracts for their fuel. International agencies have sometimes set up their own facilities for the production of briquettes for sale or free distribution. Parallel to these efforts in the humanitarian sphere, private firms across the region have been manufacturing char briquettes for commercial sale since the late 1990s, with Kenyan firms leading the way. See Annex F for a selection of photos of briquetting enterprises of each type.

4.2 Country experiences

4.2.1 West Nile

In West Nile, DCA, LWF, ZOA and Save the Children, among others, have supported refugee groups to make hand-pressed char briquettes for sale within the refugee settlements. DCA has supported 21 briquetting groups in Rhino Camp, Imvepi and Bibibidi settlements with a start-up package worth an estimated UGX 50m ($14,000) comprising a carbonizer, mixer, honeycomb press, stick press, production shelter and drying racks, plus training and working capital. Examples visited include the 'Nyosu Ko Ngingire' group in Rhino Camp and the 'Work Hard' group at Imvepi, who carbonise maize and cassava stalks in metal drums and bind the crushed char with clay, cow dung or cooked cassava flour before manual densification.

These groups rely on NGO purchase of their fuel for targeted distribution to refugees deemed vulnerable, including the elderly and at-risk women and children. DCA pays UGX 1,000 ($0.28) per kg, which is well above the local prevailing rate for charcoal (UGX 581 [$0.16] per kg; see Figure 2). Each beneficiary family is given a briquette allowance of 15 kg per month. The distribution is managed and monitored via an e-voucher system using the RedRose 'ONEapp',[14] through which the producers claim back the funds via bank accounts or mobile money. The facilities visited have very low output, with one group of 15 members producing only 115 kg per week over 12 working hours (an average of just 9.6 kg/hr). This is reportedly because sales outside the DCA voucher system have not taken off, so the groups are over-manned and their equipment is under-used. Group members report challenges in selling the briquettes due to difficulty in sourcing feedstocks and binders, poor fuel quality due to low calorific value and fragility, and high price compared with charcoal.

Outside West Nile, at least three companies15 have been supported by UNHCR to provide char briquettes to PSNs in the western and southwestern refugee settlements. These briquettes were purchased in bulk and distributed through the ration card system, rather than via physical or electronic vouchers. One supplier was paid UGX 850 ($0.24) per kg, again well above the prevailing price of charcoal. Supply contracts were based on quantity targets and there were no quality stipulations, so excessive quantities of clay binder were reportedly added to reduce production costs, in one case delivering a fuel with ash content of 52% and LHV of just 12.2 MJ/kg (CREEC, 2018), against15-16 MJ/kg for dry firewood. Such fuels would be almost unusable and could even self-extinguish.

14 *https://redrose.io*

15 Understood to include Green Elephant, Uganda Green Fire, Green Bioenergy Briquettes and Adapt+.

Such practices are reported to have tarnished the image of briquettes in several settlements and will make future efforts to promote briquetted fuels more challenging (pers. comm, Deputy Head of GIZ Uganda Refugee Response).

A new initiative through FAO aims to source higher quality fuels from a company called Mandulis Energy, which has a production facility in the north-western district of Nwoya and is setting up a second operation in Lamwo District to the northeast. The owner reports that these fuels will be distributed through a digital voucher scheme targeting 7,500 refugee households in Lamwo and Kiryandongo Districts, though the initial package of stove plus fuel will be donated to stimulate the market, making it too early to determine the existence or scale of commercial demand.

4.2.2 Gambella and Benishangul-Gumuz

A number of NGOs have produced char briquettes for refugees in different regions of Ethiopia (such as ZOA and EnDev in Tigray, Organisation for Sustainable Development (OSD) in Afar and Action for the Needy Ethiopia [ANE] in Benishangul-Gumuz). None are yet believed to have set up similar facilities in Gambella, where ESDS and EnDev are in the process of establishing production centres to supply briquetted fuel to the refugee camps.

These past briquetting operations have entailed carbonisation of elephant grass and/or agri-residues (e.g. bagasse) in metal drums to produce char, which is mixed with a binder (usually clay), then densified using a manual or mechanical block press. The usual result is a cuboid or 'honeycomb' briquette,[16] the latter having the drawback that it cannot be extinguished for later re-use, meaning that an entire stove-sized briquette weighing around 0.4 kg (ESDS, 2020) is required for each cooking session.

These operations have been donor-funded rather than commercially oriented, and the fuel is given away to individuals identified as vulnerable. In ANE's Assosa operation, around 8% of refugee households benefit from a monthly per capita ration of 0.5 kg of briquettes, purchased from one of its five production facilities for ETB 6 ($0.13) per kg. This is a little cheaper than charcoal in the same area, but the quality is inferior, with LHV of only 13.4 MJ/kg, partly because 25% clay is added as a char binder.

As in Uganda, productivity is low, with a facility visited at Sherkole camp with 18 workers producing only 2,800 kg of briquettes per month, for a gross income of ETB 16,800 ($375). This is well below the group's outgoings for salaries (ETB 18,000) and feedstock (ETB 26,250), without taking into account maintenance, packaging, electricity and other operating costs. No briquettes have been sold outside the PSN support system, as this would not be commercially feasible with such a mismatch between price, quality and operating costs.

The mechanised dryers, crushers and presses that were installed when these enterprises were originally set up (by the Gaia Foundation) are broken and have not been repaired, so all production is now manual. UNHCR's Assosa sub-Office reported a budget cut for fuel procurement of 27% in 2021, further undermining the continued viability of these struggling operations, despite a commitment in Ethiopia's 2020-2021 Country Refugee Response Plan to target "25% of the unmet needs for cooking fuel" in Benishangul-Gumuz with briquettes or ethanol (UNHCR, 2020). A lack of funding has meant this is no longer possible.

16 Often locally known as a 'beehive' briquette.

4.2.3 Kakuma

In Kenya, FAO has recently set up a mechanised briquetting facility at Lopacho village near Kakuma town. The original intention was to carbonise and densify agri-residues such as groundnut shells for subsidised sale to refugees. As these are not locally available, a switch was made to Prosopis as the feedstock. LOKADO will supply the wood to the plant under its existing contract with UNCHR, where it will be carbonised. The charcoal will be milled to powder and cooked cassava will be added as a binder and the mixture extruded to produce hexagonal char briquettes. This is a well-equipped set-up imported from China,[17] with a 3-chamber batch carboniser, 11 kW crusher, 3 kW mixer and 10 HP char briquetting machine, plus an 18.5 kW extruder for non-carbonised briquettes, with total output capacity of at least 2 tonnes (t) per day and a genset to run the operation off-grid. Itemising the individual items of equipment suggests a procurement cost of around $40,000, plus at least a similar amount for constructing the production building, installing the machinery and covering ancillary costs such as wiring and switchgear.

The facility was commissioned only a few weeks before the study commenced, so it is too early to make definitive conclusions on viability. As a fully grant-funded and agency-run project, a vision for the transition to commercial independence will clearly need to be articulated. There are also questions around the logic of carbonising Prosopis and then crushing the charcoal to make a briquette, given that the charcoal would be of higher quality and lower price in its original form. This approach may have been inherited from the original plan to make briquettes from carbonised groundnut shells, which would have been difficult to use in domestic stoves without densification. This limitation does not arise with Prosopis charcoal, but the production method has remained unchanged.

17 From *www.victorpelletmill.com*

4.3 Lessons learned

A number of lessons can be drawn from the char briquetting experiences in the three ESDS countries to guide the current research:

- Char briquetting is a well explored process for which suitable techniques, technologies, feedstocks and fuel characteristics are now well known. Experiences from enterprises in East Africa and beyond provide knowledge and understanding with which to determine the viability of these fuels, without the need to replicate previous pilot projects or research trials.
- Commercial briquetting firms have made some headway in non-refugee markets, mainly in Kenya and Uganda for heating poultry houses and supplying urban BBQ consumers, but there has been very little market penetration for household cooking.
- Briquettes must be mass produced in mechanised operations to increase the prospects for reliable output and consistent quality. Handmade briquettes made by groups in refugee settlements are of very low quality and high cost compared with charcoal. This being the case, production should be located beyond the immediate vicinity of the camps or settlements, for more reliable access to power, water, feedstocks, spare parts and skilled workers. The fuel can then be transported to the camps for sale via distributors.
- Cuboid, pillow-shaped or cylindrical briquettes are preferable to large 'honeycomb' briquettes, as they allow greater flexibility and reduce wastage.
- Private investors bring a commercial outlook and realistic market orientation, whereas communal or group-run operations lack sufficient profit motivation and tend to be overstaffed.
- Maintaining fuel quality is a challenge, with a need to maximise heating value and fixed carbon while minimising ash content, and for these parameters to be monitored and enforced.
- Targeting wealthier refugees to buy fuel under a market-based approach will represent a major shift from current strategies, which have followed the opposite approach by targeting the most vulnerable with free fuel. The price/performance offering will need to be highly compelling to stimulate a shift away from charcoal, the next most affordable energy option.
- Most companies have relied on grants to set up and continue production. Subsidies will be required to introduce briquettes or other alternative fuels in humanitarian operations, which donors will need to pay for if they wish to support a shift away from woodfuels.

5 Char briquetting business model

5.1 Model parameters and structure

A key output of the study was a ground-truthed, Excel-based business model for the mass production of char briquettes to supply refugee and local markets in the three ESDS locations, this being the most promising of the alternative biofuels considered,

Technical parameters and costings were derived from real-life operations in each country, extracting those processes, equipment specifications and business practices most likely to deliver commercial success. Best practices from the following 18 enterprises were brought together to generate an optimised business case:

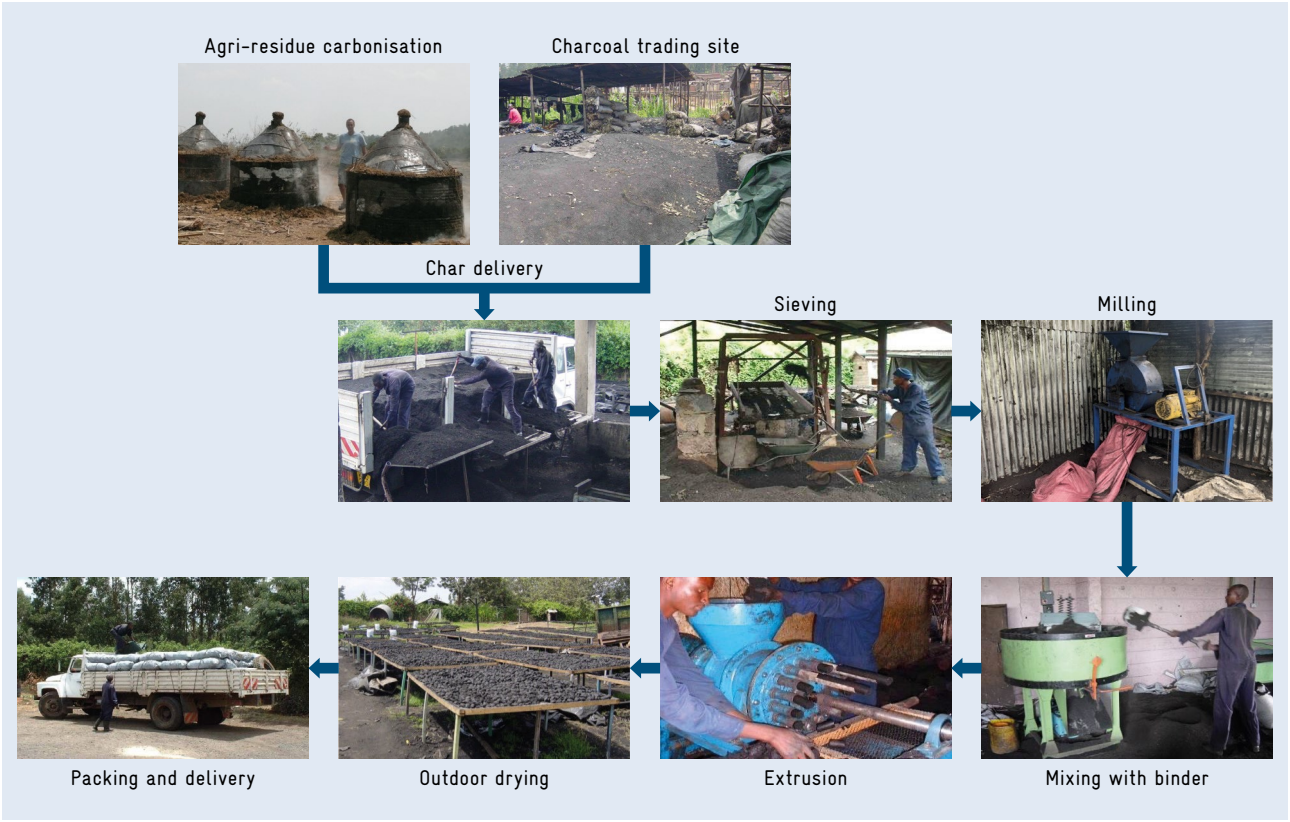
Uganda:	• Adapt+, Kyaka II settlement (call) • JK Biomass & Machinery, Kampala (visit) • Mandulis Energy, Nwoya (visit) • Nyosu Ko Ngingire briquetting group, Rhino Camp settlement (visit) • Rocket Energy & Environment Savers, Arua (visit) • Uganda Green Fire, Kampala (visit) • Work Hard briquetting group, Imvepi settlement (visit)
Kenya:	• Bentos Energy, Nairobi (visit) • Chardust, Nairobi (previous visit) • EcoMakaa, Nairobi (visit) • FAO, Kakuma (visit) • Global Supply Solutions, Thika (call) • Kawi Industries, Nairobi (call) • Kings Biofuels, Murang'a (previous visit) • Lean Energy Solutions, Nairobi (off-site meeting) • Sanivation, Naivasha (call) • Waka Waka, Nairobi (visit)
Ethiopia:	• ANE briquetting facility, Sherkole camp, Assosa (visit)

5.1.1 Capital Expenditure Requirements

Requirements for equipment and other capital expenditure (CAPEX) were standardised for each country, based on the cost and capacity specifications presented in Annex I.

The business model assumes that charcoal dust or charred biomass is brought to the production plant, where it is sieved for size-grading and separation of contaminants before being milled and mixed with a binder. It is possible to produce char briquettes using ram presses, agglomerators, roller presses or block presses, but the option selected for modelling was the screw extruder. Extruders have the advantage of being locally available at competitive price (though imported models are available from China and India[18]). The steel screws require frequent re-facing or replacement due to abrasion, but this is straightforward technology resembling a scaled-up meat mincer, and can be operated and maintained with limited experience. Outdoor drying racks are included in the equipment costs, with plastic cover sheets to give protection from rain. The whole process is summarised in Figure 4.

Figure 4: Schematic Diagram Showing the Proposed Char Briquette Production Process



18 e.g. see *www.wealthfromwaste.com*

Additional equipment included in CAPEX includes water tanks, a standby generator, bag stitching machine and weighing scales. Allowances are also made for the cost of constructing a workshop and concrete slab, procuring tools and office equipment, installing the machinery and connecting it to power, providing a basic stock of spares and paying for shipping, importation and business licensing.

The model was configured to incorporate the costs of acquiring additional equipment over time, in line with increasing briquette output. For example, for an assumed factory output of 150 t/mth (which could meet the demands of about 2,200 households), two extruders with a rated capacity of 120 t/mth would be required. If factory output was to rise above 240 t/mth, a third such unit would be needed. The model auto-calculates these incremental requirements from project start-up ('Year 0') through to Year 10.

The model's default setting assumes that 50% of Year 0 CAPEX will be funded by a donor (though this is customisable). Partial grant financing is typical for development-oriented enterprises such as this, to de-risk market entry for investors. The balance of start-up costs is assumed to be taken as a loan, repayable by the owner in accordance with the terms stated in 5.1.3 below.

5.1.2 Operating costs

The model includes cost assumptions for raw materials such as charcoal dust, biochar and binder (e.g. cassava flour), operational parameters such as output per worker and a variety of itemised costs for salaries, tools, protective clothing, maintenance, packaging, electricity, water, diesel, site rental, security, communications, admin overheads, marketing, sales and briquette delivery. A full breakdown is provided in Annex I. The model is structured in US dollars for inter-country comparison, but operating costs are calculated in local currency.

To avoid excessive complexity, the initial output of the modelled enterprise was set at 150 t per month, starting from month 7 (to allow time for commissioning and start-up). It is assumed that the briquettes are made from a 50:50 blend of salvaged charcoal dust and biochar. Again, this is customisable.

Suitable feedstocks for carbonisation depend on the dominant local crops and other available sources of biomass. In West Nile and Gambella these will include maize cobs, cassava stalks and sorghum stalks, supplemented in Gambella with elephant grass. These should be carbonised at source to minimise the costly haulage of low density biomass. Low-cost carbonisation options include oil drums or – cheaper still – shallow pits covered with metal sheets. Peak output of these feedstocks is between October and December, so a significant stock of char would need to be accumulated in the early part of each year to sustain year-round production. Payment should be made to suppliers upon delivery. Kakuma presents more significant feedstock challenges as the only viable material is Prosopis, and it may not be economically rational to carbonise this wood for the sole purpose of milling it to manufacture briquettes (see below for further discussion).

5.1.3 Financial parameters

The financial parameters used in the model are summarised in Table 5.

Table 5: Financial Parameters for the Proposed Char Briquetting Business Model

Parameter	West Nile	Gambella	Kakuma	Comments
Exchange rate	UGX 3,547	ETB 44.84	KES 109.06	per USD
Annual inflation rate	4.0%	16.8%	8.9%	
Annual sales growth	5.0%	5.0%	5.0%	assumes development of non-refugee markets
Loan terms	3 yrs, 10% p.a. interest rate, monthly repayments			on owner's (non-grant) share of CAPEX
Depreciation	10%, straight line			on CAPEX items
Owner's profit take	10% of gross profit, if any			

Sources: Exchange rates from *www.exchangerates.org.uk* (180 day average). Inflation rates from: *www.statista.com*

Note: There is no allowance for VAT on sales, as briquettes are zero-rated in Kenya and Uganda, and an exemption is assumed for Ethiopia.

The model delivers an annual cashflow, positive or negative, based on the difference between total income and total expenditure for each year. This is quantified in terms of Present Value (PV) using the assumed interest rate of 10% p.a.. The sum of PV Netted Cashflow over ten years reveals whether the business will make a net profit (positive value) or a net loss (negative value), under the stated assumptions.

5.1.3 Model results

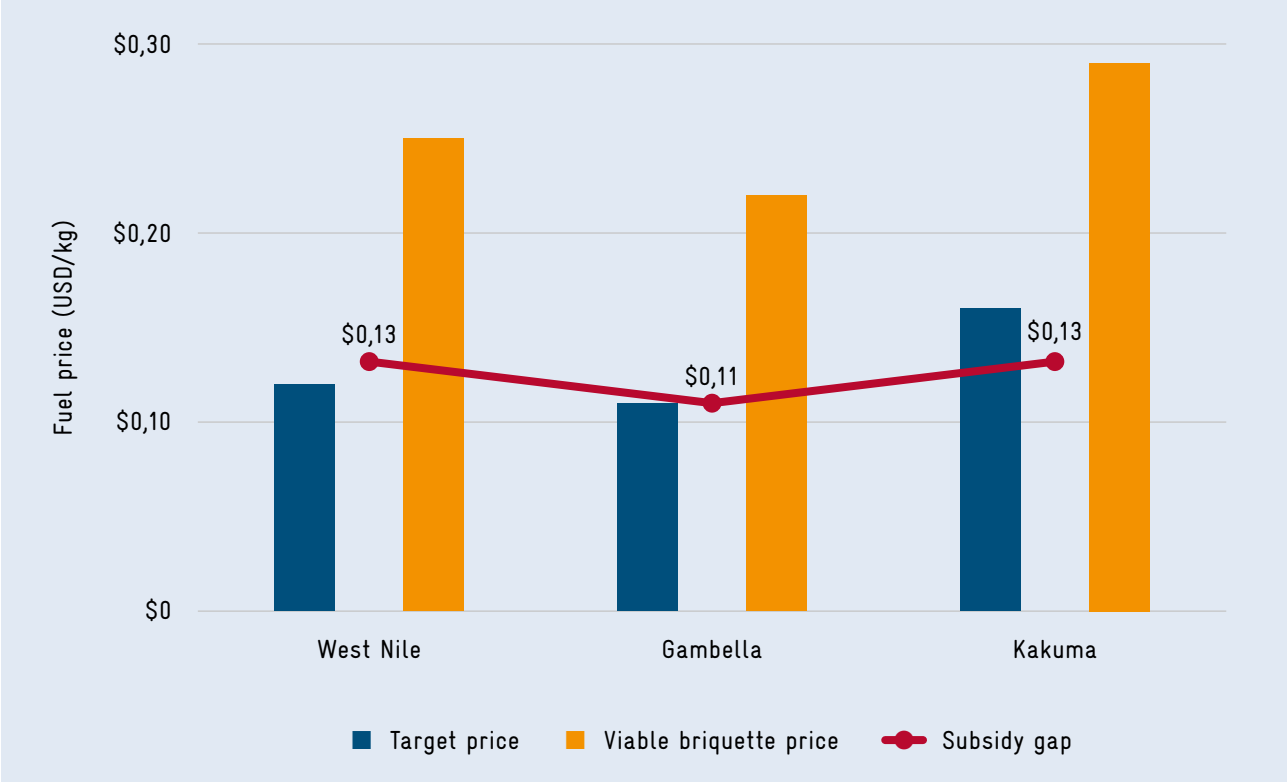
Excel's 'goal seek' function was used to determine the camp-delivered briquette price that delivers a positive value for total PV Netted Cashflow; that is, the required price per kg to ensure a profitable outcome over 10 years. For each country this price was slightly different. While space does not allow the entire model to be included, a summarised example is provided for West Nile in Annex J and the Excel sheet is available on request.

It was assumed that the briquettes would need to be made available 25% cheaper than charcoal (per kg) in each location, given their unfamiliarity and performance limitations. The difference between the briquette price required for the business to be commercially viable and this locally competitive price against charcoal is the 'subsidy gap' that would need to be closed to launch char briquettes into each market at a competitive price.

Figure 5 compares the target briquette price with the commercially viable ex-factory price, highlighting the 'subsidy gap' for the three ESDS locations.

As illustrated, a subsidy of between $0.11 and $0.13 per kg of fuel is required to get char briquettes into the refugee market at a price deemed competitive with wood charcoal. This is in addition to the 50% start-up grant support built into the model.

Figure 5: Subsidy Gap between Viable Briquette Price and Proposed Target Price, by ESDS location



Note: 'Viable briquette price' is the price required to deliver a positive value for total PV Netted Cashflow over 10 years (UGX 891, ETB 10 and KES 31.4 per kg). 'Target price' is the local retail price of charcoal purchased by the sack, minus 25% to encourage briquette sales. 'Subsidy gap' is the difference between the two.

5.2 Funding implications

The total funding required to support a briquette supply programme under these assumptions is a combination of the 50% CAPEX grant (just under $32,000 per facility) plus the subsidy gap on briquette sales. For modelling purposes, one facility is assumed to have production capacity of 150 t/mth and the potential market is taken as 10% of the total refugee population. The quantity of briquettes required is 159 kg per person per year (Table 4).

Based on these assumptions, the total financing requirements for a char briquetting supply programme across the three countries are summarised in Table 6.

The figures reveal that a fuel subsidy of approximately $20 per person per year would be required for West Nile and Kakuma, and $18 for Gambella. The total financing requirement would be around $3.15m in the first year, falling to $3.0m in Year 2 and rising thereafter with population growth and increasing sales. Additional funding would be required to administer, monitor and evaluate the programme, to provide marketing support to manufacturers and to manage the subsidy scheme. This would clearly be a programme of significant size and financial backing, even at the 10% target level illustrated here.

Table 6: Funding Requirement for a Regional Char Briquetting Programme

		West Nile	Gambella	Kakuma	
Refugee population (Oct 2021)		805,174	351,677	218,048	
Target market (10% of total)		80,517	35,168	21,805	
Briquette requirement (kg/pers/yr) (Table 4)		159 kg			
Total briquette requirement (t/yr)		12,802 t	5,592 t	3,467 t	
Charcoal price (local currency/kg) (Annex G)		UGX 581	ETB 6.7	KES 23.3	
Charcoal price ($/kg)		$0.16	$0.15	$0.21	
Target briquette price ($/kg) (25% lower)		$0.12	$0.11	$0.16	
Break-even briquette price (local currency/kg)*		UGX 891	ETB 10.0	KES 31.4	
Break-even briquette price ($/kg)		$0.25	$0.22	$0.29	
Subsidy gap ($/kg)		$0.13	$0.11	$0.13	
Y1 subsidy requirement ($/yr)		**$1,643,884**	**$619,072**	**$442,319**	
No. of facilities required (each 150 t/mth)		8	4	2	
CAPEX grant per facility (50%)		$31,746			
Y1 CAPEX grant (all facilities)		**$253,971**	**$126,986**	**$63,493**	
Y1 total requirement		***$1,897,856***	***$746,058***	***$506,812***	***$3,149,725***
Y2	Rising subsidy considering inflation and 3% p.a. popn. growth	$1,760,929	$744,769	$496,136	**$3,001,833**
Y3		$1,886,307	$895,986	$556,501	**$3,338,794**
Y4		$2,020,612	$1,077,907	$624,210	**$3,722,730**
Y5		$2,164,479	$1,296,766	$700,158	**$4,161,403**
Y6		$2,318,590	$1,560,061	$785,346	**$4,663,998**

* Target briquette price derived from business model, to achieve positive PV Netted Cashflow

6 Financing options

6.1 Introduction

In contrast with past initiatives to promote briquettes in the ESDS project locations, the assumption underpinning the current analysis is that the new fuels will be sold, not given away. Interventions to date have essentially been fuel distribution programmes, in which producers are awarded equipment and guaranteed purchase contracts, with selected beneficiaries given a regular ration of free fuel. A voucher may be used to formalise the transaction and to track adoption, but no financial outlay is required on the part of the user, and little or no risk is taken by the producer.

Under the type of market-based system that ESDS seeks to endorse, this is not a viable or sustainable approach. Consumers must be expected to pay for the fuels, otherwise the supply chain will collapse when external funding is withdrawn. The preceding analysis has nevertheless shown that char briquettes require subsidy to compete with charcoal, the current woodfuel against which they could most realistically compete. Mechanisms are required to deliver this subsidy and launch these fuels into the market.

There are two types of potential subsidy. One is supply-side finance, which targets the producers of the fuel. The other is demand-side finance (also known as end-user finance), which targets the intended customers.

6.2 Supply-side finance

Supply-side finance is intended to ensure the profitability of doing business by reducing the cost of producing the briquettes, such that it becomes worthwhile for investors to establish production facilities.

6.2.1 Investment subsidy (grant)

The most common form of supply-side subsidy in humanitarian operations is grants to producers to set up facilities to manufacture the product. Such grants are typically used to buy machinery, this being the most accountable and verifiable channel of support. Donors may also be able to secure waivers of tax on capital items, especially if imported, that commercial operators cannot enjoy. The result is a faster payback time for the investment, by reducing the CAPEX burden on which interest is payable. The business model adopted in this study assumes a 50% subsidy, which is built into the CAPEX, loan repayment and briquette cost calculations.

6.2.2 Direct payment subsidy

This form of subsidy, a type of results-based financing, involves the transfer of money to the producer through direct cash payment or voucher reimbursement on the basis of the quantity of briquettes sold. Essentially it allows the producer to sell briquettes at a sub-profitable price, but for the gap between that price and the viable (profit-making) price to be plugged with subsidy. In practical terms, for every unit of briquettes sold, the producer claims back a subsidy. The required subsidy in this case has been calculated at between $0.11 and $0.13 per kg of briquettes, depending on the location. The volume of sales could be monitored based on recorded output at the production facility or it could be verified by the submission of vouchers from distributors and sales agents, to evidence actual purchases (see next section).

6.2.3 Reduction in input costs

Another option for supply-side finance would be to help the operator lower their input costs, which in this case would require subsidy for raw materials such as charcoal dust, char and binders, or operating costs such as water, electricity and diesel. This is more complex than donating items of equipment, and therefore less appealing. It would also require the financier to carefully track the producer's internal operations to determine the exact level of subsidy required, which would probably need to be retrospectively calculated based on provable expenditures. As well as these practical challenges, underwriting operating costs also brings into question the commercial viability of the set-up, as it suggests that an enterprise cannot maintain a net margin of income over expenditure. Even an enterprise that is partially grant-funded at the outset should at least be able to maintain a positive annual balance sheet, without a need for ongoing subsidy of inputs.

6.2.4 Indirect support for energy access

Additional subsidy support could be indirect, assisting the producer with technical assistance, quality assurance, fuel testing, sales initiatives or product marketing. Such support would contribute to the overall effort to grow the market and ensure reliable supply of quality fuel, but would not pass through the books of the producer.

6.3 Demand-side finance

Demand-side finance is directed at consumers, aimed at giving them the means of buying or otherwise obtaining the product, in this case briquettes. A key drawback is that dealing with a heavily fragmented customer base is expensive, when compared to a limited number of players involved in the supply chain, both at transactional level (i.e. the cost to manage and process requests and financing for small amounts) and at interest level, due to the lack of collaterals of most final users (compared to provide financing to enterprises on the supply side) (ESDS, 2021). Some blend of supply-side and demand-side finance may nevertheless be appropriate, provided the latter can be managed without undue complexity.

6.3.1 Earmarked voucher

Consumers can be provided with vouchers loaded with a monetary equivalent for a given period of time. This is the approach used by DCA and other leading NGOs and humanitarian agencies, for distributing briquettes to refugees in West Nile. The voucher, electronic in that case, is earmarked for briquette purchase and is issued to targeted individuals. In a market-oriented intervention the vouchers could be made available to all refugees, to open up the purchasing opportunity to anyone interested. Such vouchers may cover all or part of the fuel price, so the customer can cash them in for free or subsidised fuel.

6.3.2 Cash-based intervention

Refugees can also be given cash to secure their needs, including fuel. This approach is applied by UNHCR in Kakuma, where each refugee receives KES 42 per month in lieu of a firewood ration that was supplied via LOKADO until the end of 2020. This system gives free choice to the individual on how to spend the money, for buying whichever products and commodities they require. It recognises the dignity and choice of individuals. The drawback for an initiative introducing a new type of fuel is that they may opt to use the funds for woodfuels, entrenching the status quo. Such systems are also difficult to monitor as it is hard to track how much of the cash is spent on fuel. It would therefore be preferable to earmark any demand-side support for briquettes via a voucher, at least during the initial introduction of the new fuel.

6.3.3 Purchase and distribution

This more traditional system involves the purchase of fuel in bulk for distribution to the intended consumers, which could be the whole refugee population or a subset. The per capita ration can be identical or can be weighted towards individuals in smaller households, who do not benefit from economies of scale in cooking. This is the system used by UNHCR in Gambella, where briquettes are bought from ANE facilities and distributed to refugees on a monthly basis. Such a mechanism is not compatible with a market-based approach unless combined with a subsidy, but may be valuable in improving community relations by injecting money into the local economy (as was previously the case at Kakuma) and in stimulating local investments in sustainable forestry to supply woodfuel, provided that the tracing system is watertight.

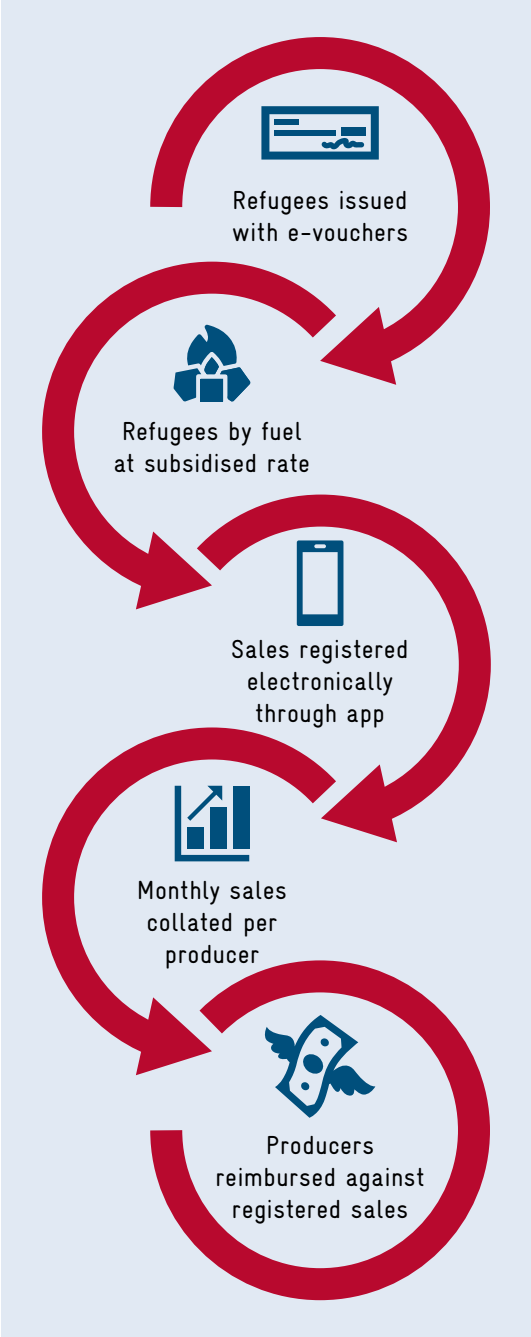
6.3.4 Community material collection

Under this system, consumers contribute to the manufacturing process by supplying inputs, such as the charred agricultural residues required to make briquettes, which can in turn subsidise the purchase price. The quantity of material collected by a particular household would determine the extent of the price reduction they enjoy on the final output. While this arrangement appealingly creates a circular flow between producer and consumer, it would be hard to administer, particularly when the suppliers of feedstocks would be unlikely to be the same people as the buyers of the product. This system would also only be attractive to the producer if the supplier was to sell inputs at sub-market rates, which would then not be attractive to the supplier.

6.4 Conclusion on subsidies

A combination of investment (grant) subsidy and direct payment subsidy is deemed the simplest and most workable of the financing options available for char briquettes. Manufacturers would receive partial grant finance for CAPEX at start-up (50% has been assumed). Refugees would be issued with vouchers for fuel purchase at a reduced rate, up to the agreed annual quantity to be subsidised. At the point of purchase, they would be required to cash in the voucher to enjoy the subsidy. Based on demonstrated evidence of the purchase, ideally electronic, the producer would retrospectively claim the subsidy according to the total quantity of recorded sales. Measures would be required to prevent fraud through the circulation of vouchers in the absence of actual purchase. This is illustrated in Figure 6.

Figure 6:
Fuel Subsidy System using Electronic Vouchers



Intermediation through specialised financial service providers would be possible, but challenging. Larger formal financial institutions cannot easily be found in displacement settings, while smaller and more informal structures often lack the capacity to operate at medium scale and to meet the financing needs of large groups (ESDS, 2021). It would be preferable for the donor and briquette companies to jointly manage the financing arrangements and proposed e-voucher system.

7 Conclusion

The INTEGRATION environment & energy team set out to identify the most viable options for ensuring access to safe, reliable and sustainable biomass cooking fuel for refugees and host communities in the ESDS project locations; and to develop business models and implementation options for the shortlisted solutions.

Firewood and charcoal are the default cooking fuel options and are likely to remain so for the short- to medium-term, based on availability, accessibility, familiarity and suitability. Positive social, economic and environmental benefits can be achieved from measures to enhance woodfuel supply and reduce consumption, which are outlined further below. The primary focus should therefore be on implementing measures that target woodfuel value chains.

The introduction of alternative fuels is also worth considering if the price/performance proposition is attractive. Char briquettes were selected for in-depth analysis, having been identified as the most viable biomass-based alternative to woodfuels for cooking in the ESDS locations, based on a multi-criteria shortlisting process. Solutions based on fossil fuels and electricity were deemed out of scope for the assignment, and other biomass-based options such as pellets, ethanol and non-carbonised briquettes were assessed to be significantly poorer choices for reasons of cost, availability or user acceptability.

An analysis of the annualised costs of cooking with char briquettes reveals that using even this relatively competitive fuel would cost users around twice as much as charcoal, the next cheapest alternative in each location. This is due in part to weak regulation and open access to under-valued wood resources. The cost differential implies a need for subsidy to close the affordability gap, which has been calculated at around $3.15m in the first year to meet the needs of 10% of registered refugees, and upwards of $3m for each successive year for continued subsidy of $0.11 to $0.13 per kg. This would ideally be managed via an e-voucher scheme. As the production costings already assume savings from large facilities using modern machinery, there is little room for the subsidy gap to be reduced over time on the basis of economies of scale. Administrative and managerial costs would be additional, as would the costs of in-camp distribution infrastructure and associated monitoring.

There are limited prospects of raising funds at this scale for the long-term promotion of char briquettes as a market-based solution to household energy challenges in the region's refugee programmes. With poor prospects for increased income generation by refugees that would enable them to purchase fuels, these subsidies would be required indefinitely. Investigation of commercial briquetting operations outside the humanitarian context also indicates little market demand from households buying briquettes for cooking, combined with continued reliance on grants to stay in operation. For many companies that manufacture briquettes, business sustainability necessitates a focus on building and retaining urban and commercial users as their primary target market.

There are a number of promising initiatives that can be explored instead, some of which are already underway in the ESDS locations or have been effective elsewhere. These are outlined in the Recommendations section below.

8 Recommendations

Based upon the study findings, there are several recommendations for positive actions to enhance access to affordable, reliable and sustainable energy for cooking in settings of forced displacement. Social, economic and environmental benefits can be achieved from measures to reduce fuel consumption and enhance the sustainable supply of biomass, in addition to promoting alternative fuels where viable. Examples for the ESDS project locations are summarised in Table 7 and outlined in more detail below.

Within and across the three countries, a cross-cutting package of measures is also recommended to provide a supportive **enabling environment** for sustainable cooking fuel solutions. This should include encouraging more donor support, supporting cross-sectoral coordination, engaging with development actors to address this wide-ranging issue more holistically, supporting local host/refugee working groups, facilitating the development of decentralised policies on renewable energy and natural resource management, undertaking policy advocacy to tackle unhelpful regulatory barriers (e.g. tariffs and taxes) and managing a programme of targeted research. The long term goal should be to move to electricity for cooking, with effective trials of new technologies to help the transition.

Table 7: Proposed Interventions in Cooking Fuel Supply, Demand and Alternatives

Location	Reducing woodfuel consumption	Enhancing sustainable supply of biomass	Promoting alternative fuels
West Nile	Support 'last mile' marketing, sales and distribution to get higher tier charcoal cookstoves into the refugee settlements, building on existing support to 'energy kiosks'.	Promote higher biomass yields from natural forests, private plantations and homestead planting through interventions in (agro-) forestry and improvements in wood processing (e.g. carbonisation).	Conduct a wider cost-benefit comparison of cooking options, including electricity, to fully evaluate investment and subsidy levels, infrastructure challenges and long-term health, social, economic and environmental benefits.
Gambella	Support the user-centric design and local manufacture of simple clay stoves for refugee use, which can make an affordable and appropriate contribution to easing the fuel sourcing burden on refugee families.	Promote conservation-friendly agriculture and agroforestry on farms and around homesteads, and support the protection of natural forests. Research the impacts of refugees on forest resources, similar to those by FAO in W. Nile and Kakuma.	Consider the procurement of firewood from sustainable sources for groups identified as vulnerable.
Kakuma	Strengthen and sustain the promotion of improved cookstoves through EnDev's SNV-managed Market-Based Energy Access programme.	Improve efficiencies in the Prosopis value chain (including better charcoal production), establish and protected 'greenbelts' and plant drought-resistant tree species in micro-catchments.	Conduct a wider cost-benefit comparison of cooking options to evaluate investment and subsidy levels, infrastructure challenges and long-term health, social, economic and environmental benefits.

8.1 West Nile

Support 'last mile' marketing, sales and distribution to get higher tier charcoal cookstoves into the refugee settlements.

In West Nile, there is modest but growing demand for charcoal for which modern, higher-tier cookstoves are available, but largely not accessible in the refugee-hosting areas. Commercial distributors do not find the refugee market sufficiently concentrated and dependable to justify setting up local retail outlets. There is an opportunity for humanitarian funding to bridge the 'last mile' cost gap by supporting marketing, sales and distribution to get next-generation cookstoves into the refugee settlements. Since charcoal is a fully traded fuel, there are financial benefits for users from switching to modern, highly efficient charcoal stoves, and this is an area of work that can build naturally on GIZ's existing support to the marketing of cookstoves and solar homes systems through 'energy kiosks'. Save the Children operates a similar energy kiosk project at Bidibidi settlement that could also be potentially extended to include higher tier charcoal stoves.

Promote higher biomass yields from natural forests, private plantations and homestead planting

In West Nile there are opportunities to support higher biomass yields from natural forests, private plantations and homestead multipurpose planting, through a variety of interventions in (agro)forestry and improvements in wood processing (e.g. more efficient carbonisation techniques). Such interventions are at the heart of the €5m EU-funded *Forest Management and Sustainable Charcoal Value Chain* project being implemented by FAO, and the upcoming $58m World Bank-supported *Investing in Forests and Protected Areas for Climate-Smart Development* (IFPA-CD) project (World Bank, 2020), which will be implemented by technical service providers in collaboration with District Local Governments across West Nile.[19] Significant additional investments in sustainable forest management in West Nile are being made by the governments of Sweden and Japan, and the German Development Bank (KfW) has recently commissioned a needs assessment for additional environmental funding in the same region.20 There is scope to strengthen refugee inclusion in District Local Government programmes for natural resource management and supporting host-refugee environmental working groups to enhance cooperation. It is recommended that GIZ supports the promotion of policies and interventions that aim to engage charcoal producers in sustainable production.

Conduct a wider cost-benefit comparison of several cooking options

The Uganda refugee operation is likely to see progressive adoption of non-woodfuels considered desirable and aspirational, such as LPG and electricity. The economic and social case for these fuels should be investigated in more detail through a wider cost-benefit comparison across several cooking options, to fully evaluate investment and subsidy levels, infrastructural challenges, long term health, social, economic and environmental benefits.

19 The total IFPA-CD budget is $148m, of which $58m is the allocation for grant-funded activities on private and customary land in refugee-affected districts.

20 Via joyn-coop, a Munich-based consultancy.

8.2 Gambella

Support the user-centric design and local manufacture of simple clay stoves for refugee use

An appropriate demand-side intervention in Gambella would be the development and local manufacture of simple clay or ceramic stoves for refugee use, which can make a contribution to easing the fuel sourcing burden on refugee families in a way that is affordable and locally appropriate. The user-centred design approach trialled at Nguenyyiel by ESDS (Roth & Ayele, 2021) is a suitable way forward. There is unlikely to be a market in these areas for more sophisticated or expensive factory-made stoves, due to relatively good firewood availability and minimal spending power.

Promote conservation-friendly agriculture and agroforestry on farms and around homesteads, and support the protection of natural forests

Supply-side measures are also recommended for Gambella, despite the relatively good availability of woody biomass and lack of evidence that refugees are causing significant or permanent degradation of sensitive environmental assets through their cooking fuel use. Sustainable natural resource management is still important, particularly in light of the advance of large-scale mechanised agriculture in the region and the inevitable impacts of climate change on the livelihood security of refugees and local people. Measures to promote conservation-friendly agriculture should be supported by UNHCR and other concerned actors, alongside agroforestry on farms and around homesteads, and measures to enforce the legal protection of natural forest assets. This could be achieved through implementation partnerships with actors engaged in agricultural development, farming and agroforestry. Refugees should be included in the coordination and implementation of the Integrated Land Use and Development Master plan for Gambella Regional State.

Consider the procurement of firewood from sustainable sources for groups identified as vulnerable.

Since firewood is available at no financial cost for household use promotion of alternative fuels in Gambella will likely require significant subsidy, as seen under the UNHCR-funded briquette programme through ANE in Assosa. If there are protection concerns for specific vulnerable groups of refugees, firewood could be procured for them, in the same way that it is already procured via ARRA for institutional consumers.

8.3 Kakuma

Strengthen and sustain the promotion of improved cookstoves through EnDev's SNV-managed Market-Based Energy Access programme.

The promotion of improved cookstoves is already well covered by the SNV-managed MBEA programme at Kakuma, now in its second phase, which facilitates commercial entities seeking to enter the refugee energy market. MBEA includes a range of stoves at different price points, ranging from locally made portable 'maendeleo' stoves up to high tier charcoal stoves from companies such as BURN Manufacturing. It is recommended that this programme is strengthened and sustained, rather than focussing on multiple cookstove programmes.

Introduce measures to improve efficiencies in the Prosopis value chain, establish and protect forested 'greenbelts', and plant drought-resistant tree species in micro-catchments.

Supply-side measures to improve charcoaling efficiencies in the Prosopis value chain are worth considering at Kakuma, since previous measures implemented jointly by FAO and the Kenya Forestry Research Institute (KEFRI) came to an end. FAO had engaged with host communities to promote more sustainable production of charcoal through the provision of steel kilns and training of more than 400 community members (FAO & Practical Action, 2020b). The draft Turkana County Energy Sector Plan, which EnDev has supported, recommends capacity building for local Environmental Management Committees, including on effective utilization of Prosopis and charcoal production (Republic of Kenya, 2021). Additional environmental measures that have been initiated in the past and which should be sustained are the establishment and protection of forested 'greenbelts' protected from livestock with live or constructed fencing, and the planting of drought-resistant tree species in micro-catchments. Research by KEFRI identifies Acacia eliator, Cordia sinensis and Balanites aegyptiaca as suitable options (Muturi et al., 2014).

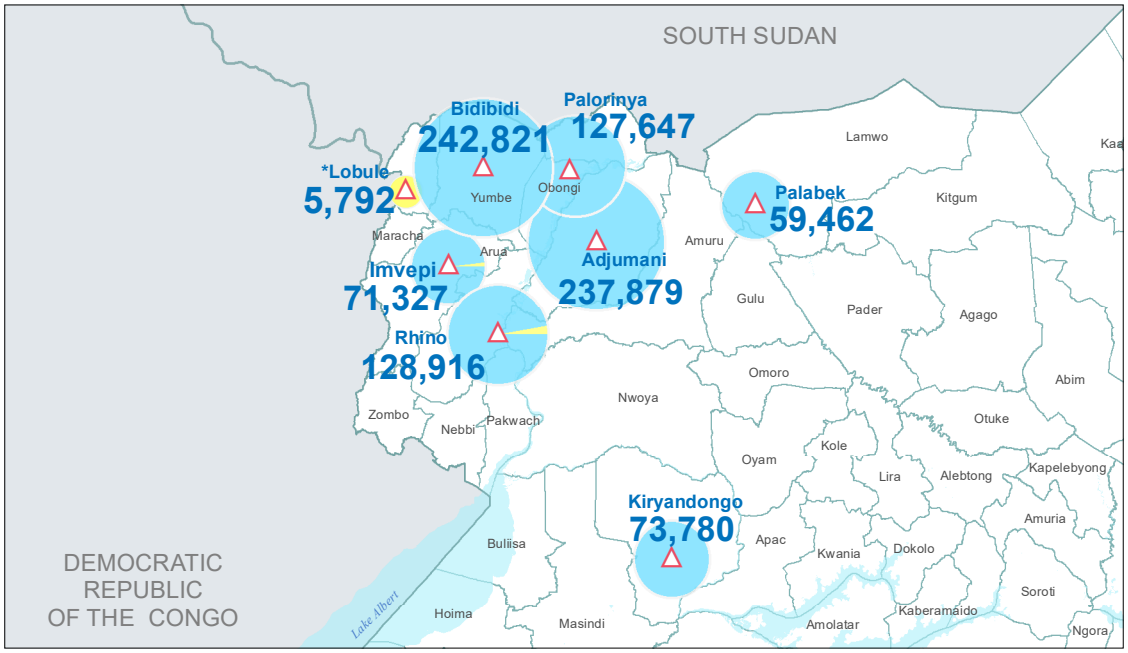
Conduct a wider cost-benefit comparison of all cooking options

The draft County Energy Sector Plan proposes encouraging private sector investments in supply and distribution of LPG, including establishment of depots, which would build on the winning proposal in the non-wood cooking competition run by the Moving Energy Initiative. As in West Nile, cost-benefit research is proposed into the comparative advantages of investing in large scale infrastructure for clean fuels and electricity to the Kakuma area, compared to other investments or subsidies, to fully evaluate investment and subsidy levels, infrastructural challenges, long term health, social, economic and environmental benefits. Though fossil fuels do not fall within the scope of ESDS's programme objective, if the ultimate priority is to serve refugees' cooking energy needs, it may be imperative to garner support from other actors, especially the private sector, to further investigate LPG. This could build on the lessons learned from the UNHCR-funded Access to Gas project in the Diffa Region of Niger.[21]

21 *www.unhcr.org/niger-access-to-gas-project.html*

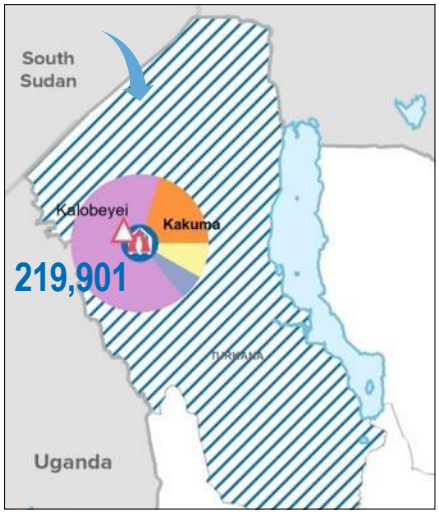
Annex A: Maps of ESDS project locations

West Nile (plus Palabek and Kiryandongo)



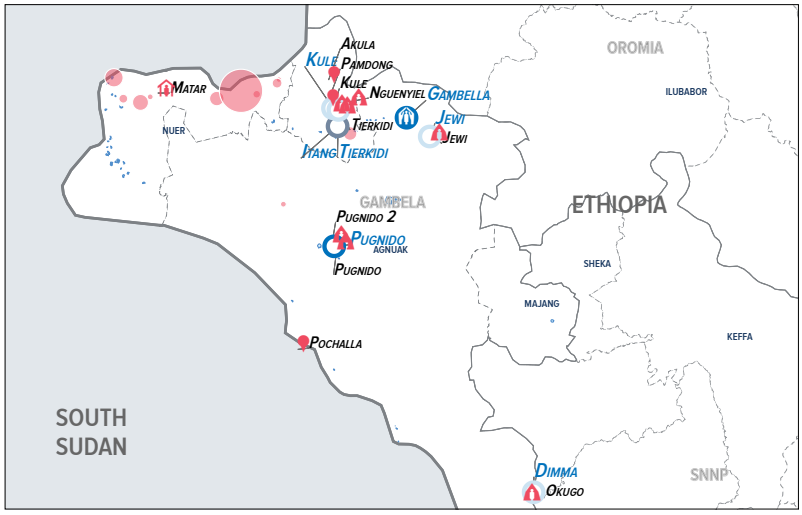
Source: *https://data2.unhcr.org/en/documents/details/89510*

Turkana County, Kenya



Source:
https://data2.unhcr.org/en/documents/details/89494

Gambella Region, Ethiopia



Source: *https://data.unhcr.org/en/documents/details/83160*

Annex B: Organisations consulted

Ethiopia

Location	Organisation
Addis Ababa	ESDS
	EnDev
	UNHCR
Assosa and Sherkole camp, Benishangul-Gumuz	ANE
Assosa, Gambella and Nguenyyiel & Pgunido I camps, Gambella	ARRA

Uganda

Location	Organisation
Arua	Rocket Energy & Environment Savers
Imvepi settlement	Work Hard briquetting group
Kampala	ESD /EnDev
	UNHCR
	FAO
	ICRAF
	DanChurchAid
	Response Innovation Lab
	LWF
	Raising Gabdho Foundation
	International Lifeline Fund
	Nsamizi Training Institute of Social Development
	Humanitarian Assistance & Development Services
	Adapt+
	Independent
	JK Biomass & Machinery
Kampala & Nwoya	Mandulis Energy
Kiryandongo settlement	Save The Children
Nwoya	Bukona Agro Processors
Rhino Camp settlement	Omugo Energy Kiosk
	Try Hard Savings & Loan group
	Nyosu Ko Ngingire briq. group

Kenya

Location	Organisation
Dar es Salaam	Consumer's Choice
Kakuma	UNHCR
	LOKADO
	FAO
Murang'a	Kings Biofuels
Nairobi	ESDS
	EnDev
	WFP
	FAO
	World Bank
	SNV
	AECF
	Practical Action
	Bentos Energy
	EcoMakaa
	Kawi Industries
	Lean Energy Solutions
	Waka Waka
Naivasha	Sanivation

Annex C: Extract from stakeholder database

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
ICRAF	Research programme	x	x	x	Implementing BMZ-funded Resource Recovery and Reuse (RRR) project in refugee settlements in Et, Ke & Ug. Includes sustainable biomass harvesting, conversion of organic residues into briquettes, agroforestry and improved mudstoves.	Emails
Action for the Needy Ethiopia	Humanitarian agency	x			UNHCR IP. Running former Gaia briquetting operations in Assosa (Benishangul-Gumuz Region), including 5 char briquetting plants. UNHCR Assosa estimates that 8% of refugee HHs are receiving fuel from these operations. All plants use manual methods (electric machinery was tried at Sherkole camp but broke down and spares were not available).	Visit
EnDev Ethiopia	Development agency	x			EnDev's work in the humanitarian sector is limited to Gambella, where it is in the process of setting up 4 briquetting operations: 2 in Itang woreda nr. Ngunyyiel camp; 2 in Gog woreda nr. Pugnido I+II camps. The model is based on previous experience of briquetting carbonised sesame straw at Humera in Tigray. The staple food of refugees and locals in Gambella is kisra, which can be cooked with lightweight fuels such as elephant grass. But for the accompanying dishes, such as 'kop', more substantial fuels are needed, and this is where briquettes are targeted. The project will set up youth cooperatives to run the operations. It is likely that two plants will be run by refugees and two by host communities. The intention is that local people and refugees will bring feedstock to a briquetting facility, where it will be carbonised (not sure why it will not be charred at source). The feedstocks are yet to be determined, but are likely to be agri-residues (once per year) and elephant grass (Oct-Feb). They have not yet decided what form the briquettes will take (pillow shape, honeycomb, spherical, etc). UNHCR may agree to purchase briquettes for ARRA'S school feeding programme, to replace firewood. Apart from this, the marketing approach is not yet determined. Pricing, subsidy and mechanisms for marketing, sales and distribution are also to be agreed. Securing tax exemption on imported equipment can be difficult, but EnDev say this is avoidable if the consignee is the cooperative (it is unclear how this can be the case, if equipment has already been procured, yet the cooperatives have not yet been selected). EnDev's support to briquetting seems to overlap substantially with ESDS, also working in Itang woreda and Ngunyyiel camp. EnDev claim to have started first, through an MoU with UNHCR, and use a separate funding channel. And in general, EnDev also targets higher tier, proven technologies for upscaling, whereas ESDS supports transitional, user-centred technologies. But in the briquetting domain, the difference in approach or substance is so far not clear.	Call

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
ESDS Ethiopia	Humanitarian agency	x			Support the development of multiple actors cooking energy strategy for refugee camps and host communities in Ethiopia. Promotion of alternative cooking fuels and technologies. Installation of briquetting plants in refugee camps and host communities through market-based approach. Technical assistance for energy enterprises/cooperatives/ social enterprises Construction of energy kiosks. ESDS is working on both cooking stoves and fuels in Gambella. On the cookstoves front, Christa Roth and Egzialew(?) Ayele were on location in April 2021 launching a user-led design approach, likely to result in support for local production of a portable, single-pot, fired clay stove. On fuels, ESDS will be supporting two(?) briquetting plants at Ngunyyiel camp (Itang Woreda), to be run by newly formed cooperatives. According to Christa, the expected feedstocks are cotton stalks and maize stalks, using a single-shaft grinder for shredding (but requires a lot of electricity). It is understood (from Christa) that the briquetting plants will be equipped with piston presses to make non-carbonised briquettes, but this was not confirmed by Christian (they could possibly be char briquettes). The intention is to bring in feedstock from a radius of up to 10 km from each facility, sourcing from large commercial farms. There seems to be an overlap with EnDev plans for a similar br4iquetting project, also in Itang Woreda. There is also a plan to establish energy kiosks where the briquettes would potentially be sold, alongside solar products and cookstoves. The exact mechanisms are still under development. It is understood that UNHCR has committed to funds a fuel subsidy for briquettes, but details are not yet available.	Call
UNHCR Ethiopia	Humanitarian agency	x			UNHCR's main IPs are the Regional Energy Bureaus, and it also has sub-agreements with the NGOs Action for the Needy in Ethiopia (ANE) in Assosa and Save the Environment Ethiopia (SEE) in Afar. Operating partners include ESDS, EnDev, ZOA and CISP (Italy), of which only ESDS and EnDev implement energy activities in Gambella. The activities of ANE in Assosa are of interest, as they have taken over the former (2019) briquetting programme of Gaia Foundation. Briquettes are produced by cooperatives from elephant grass and agri-residues in all 5 camps and distributed to vulnerable refugees through a voucher system. In 4 camps, the briquettes are made from char plus clay binder in honeycomb form, while in the 5th camp, the milled feedstock is extruded into cylinders and then carbonised (using Chinese equipment). This produces a better briquette that refugees find more acceptable, whereas the char briquettes require a special stove, quality is reportedly poor and an entire briquette must be used for each cooking session. The honeycomb briquettes are priced at ETB 6-7 and burn for up to 3 hours (prices pending on extruded briquettes). As UNHCR moves from annual programming to a three-year planning cycle from 2022, the emphasis in Ethiopia will shift from free fuel to a market-based approach, although the practical implications of this change are yet to be clarified. UNHCR also supports the NRDEP via regional bureaus of Agriculture and Natural Resources (see separate listing). This mainly concerns afforestation and other forms of environmental rehabilitation. Lastly, coordination in the sector is via a national Energy & Environment Working Group, which meets monthly (virtually at present).	Call

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
AECF	Development initiative		x		AECF receives multi-donor funding and awards grants and technical support to commercial entities for clean energy solutions. This is done via competitive funding rounds, usually on a national basis. They have been involved in funding one biomass briquetting plant in Kenya, which is Global Supply Solutions. Their only other engagement with clean cooking was with stove manufacturer BURN, which ultimately did not result in funding. Their first foray into the refugee setting is the on-going Kakuma-Kalobeyei Challenge Fund (KKCF), which put out a call for proposals in early 2021 and is now at the application assessment stage. William is the KKCF Manager and can provide further information on grantees as the KKCF confirms its awards.	Call
Bentos Energy	Briquette manufacturer		x		The company makes both char briquettes and biomass briquettes for industry. Main buyers of char briquettes are poultry farmers, plus household heating and some cooking. Feedstocks are carbonised biomass, paper sludge, iron ore filings and waste from cinchona tree (used for malaria drugs). For carbonised weeds, twigs, macadamia shells and maize cobs, they pay KES 2.85 per kg (KES 200/70 kg) – higher than EcoMakaa). 15 HP milling machine plus a mixer and extruder. Capacity of 15 t/day but producing well below this. Used to have a 200 kg/hr electric dryer, but it burned out so they have moved to sun drying. Previously had 13 employees, not only three (blames COVID). Marketing through social media. Some bought by dealers @ KES 1,500 for 40 kg bag. Retail @ KES 2,800-3,000 per 70 kg (KES 40-43/kg).	Visit
Consumer's Choice	Ethanol supplier		x		Used to sell rectified ethanol and ethanol stoves in Kenya. Now scaled back to gel fuel sales via supermarkets, while Consumer's Choice have partnered with UNIDO on a GEF-funded project (2018-22) to distribute stoves and liquid ethanol fuel in Dar es Salaam. The stoves come from Clean Cook (Sweden) and are assembled in Tanzania. They plan to switch to a new model made in Kenya by BURN. An initial target of 100,000 stoves was scaled down to 60,000 (by Oct 2022), with half via Consumer's Choice and the balance via another distributor. The stoves are sold with a subsidy of almost 50% ($13 subsidy while user pays TZS 33,000 [~$14.30]). The subsidy scheme is managed by TIB Development Bank. Consumer's Choice buys the ethanol from Kilombero Sugar Co. (Ilovo Group) @ $0.45/l and sells it on @ TZS 2,000/l ($0.86). They initially used HDPE re-usable bottles in 1, 2 and 5 l sizes, but the returns process was cumbersome and some customers lacked empties to exchange, so they now use non-returnable PET bottles in 0.5, 1 and 5 l sizes. The best-seller is the 1 l size, which lasts 3.5 hrs, or 2-3 days for an ave. family of 5. They estimate monthly demand is 10 l per family. Mohamed mentioned Koko Networks in Kenya, who partner with Vivo Energy and buy in bulk at lower prices, recently importing 5 million litres from Kenana Sugar in Sudan at $0.35 to $0.40 per litre, retailing at KES 77.8 ($0.70), so quite a bit cheaper than Consumer's Choice in Dar. Vivo's next purchase may come from POET (USA) at similarly low (bulk) price. Mohamed supplied ethanol to GIZ in Dadaab 2010-2013 but it didn't pick up. Another company spiplied to Kakuma in 2018/19, but again it wasn't sustainable after the subsidies ended, due to length of supply chain and local cheap woodfuels.	Call

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
EcoMakaa	Briquette manufacturer		x		Make briquettes using carbonised rice husks from Mwea @ @ KES 2/ kg In operation since 2018 but COVID affected sales to schools and hotels, so they have been trying to target households. Molasses & lime as binders, manually mixed in. Molasses KES 1,500 per 5 litre drum. Briquettes are sun-dried for 2 days & packed in 30 kg bags. "3 times longer burning, no smoke, lasts longer, economical". Also sell machines and offers feed-paid training on how to produce briquettes (KES 20,000 for up to 10 people). Thanks to connection via Brian Onyango, technical consultant to FAO in Kakuma, she has orders for machines from both FAO and UNDP (FAO using 10 HP machine in Kakuma, UNDP in local community group). 5 HP machine costs KES 75,000, 200 kg/hr. Some briquettes also reportedly sold to FAO and sent to Kakuma. Rose claims that the market is not an issue, and wants to set up a larger factory with everything under one roof, including carbonisation, but is constrained by finance.	Visit
EnDev Kenya	Development agency		x		The GIZ energy cluster in Kenya comprises around 10 programmes, including EnDev and ESDS. While ESDS concentrates on electrification in the refugee context, EnDev is active in cookstove promotion country-wide. EnDev had hoped to get involved with development of fuel supply chains (e.g. charcoal, briquettes, pellets), but their donors were not willing to support this, so their focus remains on the user technologies. Funding comes from GCF (for professionalising production and distribution of cookstoves) and from Swiss cooperation (for RBF-based social impact incentives), among others. The RBF model provides a post-sale rebate of 5 to 25% of the stove price, with the size of the rebate linked to the distance of the sale from the manufacturing location. The RBF system is monitored and managed by Micro-Enterprise Support Programme Trust (MESPT). EnDev is not directly working on cooking stove or fuels in the refugee context, but works in partnership via SNV, who manage the Market-Based Energy Access (MBEA) programme at Kakuma.	Call
ESDS Kenya	Humanitarian agency		x		ESDS works in Turkana in two main areas: (a) policy support, coordination and capacity building for the Turkana County Government, incl. development of the County Energy Sector Plan (in draft); and (b) electrification in Kakuma and Kalobeyei, to improve energy access for households, businesses and institutions. This includes two solar/diesel hybrid mini-grids and solar PV installations at 4 schools and 3 health facilities. They have supported a 20 kW mini-grid in Kakuma town and a 60 kW mini-grid in Kalobeyei (with plans to increase this to 540 kW). These are run by private operators and the tariffs charged are regulated to match those of on-grid customers of Kenya Power and Lighting Co. This is only KES 20/kWh, compared with up to KES 100/ kWh charged by unregulated grid operators within Kakuma/Kalobeyei, raising some questions over commercial sustainability. ESDS does not currently work on cooking issues, though EnDev supports such work via its partnership in Kakuma with SNV.	Calls

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
FAO Kenya	Development agency		x		FAO has funding from IKEA Foundation for energy projects in Uganda and Kenya. In Kakuma, the intention had been to link agriculture and energy with a groundnut shell briquetting project, but shortage of feedstock led this to pivot to a Prosopis-based briquetting project. The aim is to replicate similar FAO-implemented projects in Djibouti and Ethiopia. A Chinese mill and screw extruder have been installed at a plot in Kakuma town owned by LOKADO. After some procurement delays, the machinery arrived in July 2021 and a technical consultant was recruited (Brian Onyango). They get Prosopis logs delivered by LOKADO, with UNHCR funds, in 20-45 cm diameter sizes. This is purchased locally as part of LOKADO's contract to supply institutions. They chip the logs to <10 mm and then put the chips through the extruder to make hexagonal briquettes. They had not planned to carbonise, but Brian has done some trial carbonisation runs with metal kilns. The intention is to run this as a business, but the exact business model is not yet determined and will need to be followed up locally. The intended market is refugees and local people. Mercy at UNHCR is reportedly talking to FAO about a joint funding proposal for a larger briquetting operation. FAO also previously had a charcoal value chain project with KEFRI in Turkana County, but this has now ended.	Calls
IKO Briq	Briquette manufacturer		x		Sawdust briquettes and pelllets, in conjunction with MimiMoto gasifier stove. Thought to be supplying stoves and fuels to SNV's 'MBEA' project at Kakuma (RBF). Not very forthcoming with information - max production capacity of 10 t/day though producing nowhere near that at present. Sell on the phone, not through vendors @ KES 40/kg. Also sell Mimi-moto stoves @ KES 11,000. SNV informed us they did pilot ~ 10 stoves in Kakuma, response was positive but Iko did not continue.	Call
Kawi Industries	Briquette manufacturer		x		Make 'Eco Flame' briquettes from charcoal dust and sawdust, mainly for commercial catering, with customers buying direct. KES 1,500 per 50 kg bag. Sell up to 150 bags/day.	Call
Kings Biofuels	Briquette manufacturer		x		Biomass briquette producer in Murang'a County making extruded fuel from sawdust and agri-residues. Issues with unreliable electricity. Sells mainly to hotels, factories and schools. Not many domestic customers, as the briquettes can't compete with low cost firewood (rural) or LPG (urban) and the fuel needs a special stove @ KES 1,500-2,000. Sells @ KES 15/kg wholesale and KES 20/kg retail. Primarily for industrial market, also some institutions. Schools still believe firewood is cheaper. Household market is a challenge - free/cheap firewood too difficult to compete with. 50 t/week capacity.	Call
Lean Energy Solutions	Briquette manufacturer		x		Lean Energy provide energy audit, boiler supply and installation, boiler fuel production and supply and steam supply services to industries. They had not been involved in the domestic supply of cooking fuels until recently, but in early 2021 took part in a pellet supply project in Kakuma. Under an RBF-funded project with SNV, they designed a battery-powered fan stove to burn pellets, of which 50 units were produced and consumer response at Kakuma was reportedly positive. The pellets are 6 mm in diameter and made from both bagasse and coffee husks. There is no suitable feedstock or production capacity at Kakuma, so they had to be transported there from Nairobi. They faced challenges as people cannot afford the stove (KES 6,000) or the pellets (KES 35/kg), and long-distance management from Nairobi was difficult. The activity took place in the first quarter of 2021 and has now ended.	Calls & mtg

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
LOKADO	NGO		x		LOKADO is UNHCR's long-standing IP at Kakuma for energy and environment activities. Pre-2021, they ran a large-scale Prosopis firewood supply operation for all refugees, which has now been converted to a cash-based programme and scaled back to 2,101 t per year, targeting only schools (933 t), the Nadapal transit centre (30 t), reception centre/new arrivals (670 t), and hospitals (468 t). Previously they supplied an additional 11,520 t/yr via 6 firewood distribution centres, with 6 distribution cycles per annum, at which each refugee was given one 10 kg bundle. This was an important livelihood activity for residents of Turkana County, who were paid KES 30 per bundle (while transporters were paid KES 40). The cessation of the programme has resulted in an annual loss of up to KES 35.5m (USD 320,000) to the host community, plus KES 46m (USD 425,000) to transporters, assuming that all purchasing and distribution targets were previously met. The funds have been converted to monthly cash allowance of KES 42 per refugee ($0.39), which will presumably benefit host community members living close to the camp, but disadvantage those further away. LOKADO also fabricates and distributes hybrid maendeleo stoves to new arrivals, runs 6 tree nurseries from which seedlings are distributed to refugees, locals and institutions, and supports 90 households (15 close to each nursery) in home gardening. They also provide environmental training to schools and have set up 293 acres of fenced and protected greenbelts. The FAO-funded briquetting plant is being set up on LOKADO's plot in Kakuma town, which is co-located with SNV's Energy Centre. LOKADO staff will be trained by Brian Onyango (FAO technical consultant) in briquette production, though it is unclear what role they may have in managing the operation, sourcing feedstock or supporting sales.	Call
Practical Action	Development agency		x		Partner in former UK-funded Moving Energy Initiative, with UNHCR, NRC, Energy4Impact and Chatham House. Useful analytical reports on energy markets (cooking & lighting) in Kakuma and Burkina Faso. No current work in refugee energy.	Emails
Sanivation	Briquette manufacturer		x		Worked in Kakuma from 2014-2019 on sanitation issues, with a waste-to-value briquetting business. Initially replaced some pit latrines with above-ground container-based latrines, though went back to pit-latrines which were much cheaper and did not require continual emptying. Briquettes were made using treated human waste and charcoal dust (dust being 75-90%). There was initially plenty of charcoal dust @ KES 6/kg, then vendors raised prices to KES 15/kg. They then tried to make their own Prosopis charcoal and mill it to char. Briquettes sold @ KES 20/kg. Reported positive feedback based on money saved and longer burn time. Initial reluctance to use poo to cook was apparently overcome with time and marketing. Primary reason for discontinuation was challenge of competing on price as the cost of distribution & sales was KES 20/kg on top of the retail price. Actual level of demand was also unclear. They now plan to produce non-carbonised briquettes for Institutions with a grant award from the Kakuma-Kalobeyei Challenge fund. Challenge in finding raw materials. Nearest sawdust supply in Kakuma is ~400 km away in Kitale. Need to assess local biomass sources, could use milled Prosopis. May also use human waste from GIZ Kakuma town plant. Have estimated only need drying under sun, as they didn't use milling with sawdust in Naivasha. Target to produce 100 t by the third year of the project.	Call

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
SNV Kenya	NGO		x		SNV manage the Market-Based Energy Access (MBEA) project at Kakuma, including clean cooking using an RBF system for stoves. A pilot phase (2017-19) explored lighting, clean cooking and alternative fuels. This included trials with biomass briquettes (from Global Supply Solutions) and briquettes from faecal waste (from Sanivation), neither of which proved commercially viable for household use. The same applied to ethanol, which was trialled with Rural Development Solutions. ~9,000 'Safi' ethanol cookers were disseminated. The fuel worked well and seemed competitive with charcoal, but the stoves were subsidised, the logistics were challenging and there was a shortage of (imported) ethanol. Solar Cookers (SunBucket) did not work well and were not liked, and too expensive. IKO Briq introduced pellets and about 10 MimiMoto stoves. These were liked but the pilot was very short-lived. Another company (Lean Energy?) was considering trialling pellets, but is still looking for funding. Based on these experiences, SNV now only supports fuels that can be locally produced. During the current MBEA implementation phase (since late 2019), SNV is facilitating commercial entities entering the refugee energy market by providing help with licensing, awareness-raising and product promotion, including public demonstrations, radio campaigns, posters, raffles, signage, a stove catalogue and a 'library' for borrowing and testing stoves, targeting Kakuma, Kalobeyei and Kakuma town. They are working with 4 stove outlets at present, one being the stove production unit in Kakuma camp (from which all new arrivals receive a maendeleo stove), plus BURN, Envirofit and one other. The stove centre gets grant funding and produces 400 KCJ (charcoal) stoves/mth. Charcoal stoves cost KES 350 for small size, KES 800 for 800 larger and KES 2,000 for commercial size. Almost all stoves they promote are charcoal stoves (only one woodstove). Combined sales of higher-tied charcoal stoves from all outlets of only ~40 units/month. Savings are good, but the prices are high compared with artisanal stoves. They could potentially support behavioural change to adopt briquettes (e.g. from the FAO facility), but only if convinced that the fuel is viable and of high quality. They do not see this as a good option due to cost and quality, unless possibly for primary and secondary schools (~1,000 students), but firewood remains the cheapest option. There is a plan to trial eCooking in Kalobeyei, but even with a 'social tariff' for electricity of $0.35/kWh, it will be a lot more expensive than charcoal. Suggests LPG might be the best solution for the region, though the same issues of supply chain infrastructure come to light.	Calls & mtg

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
UNHCR Kenya	Humanitarian agency		x		UNHCR has two energy and environment staff in Kakuma, and works through LOKADO as its local IP. Cash-based interventions (CBI) were introduced in Feb 2021. Assistance at Kalobeyei is now 100% CBI, while refugees at Kakuma still get food, but receive cash for 'co-relief' (soap, sanitary products, fuel, etc). Cash has replaced the former firewood supply programme that UNHCR previously funded through LOKADO, and which was intended to provide 10 kg per person every 2 months, which met around 7% of refugees' requirements. The same funds are now awarded directly to refugees at a rate of $0.39/person/month (currently KES 42). This lasts only 2-3 days, assuming that refugees actually buy fuel with it (many exchange food). A 10 kg bundle was priced at KES 70 under LOKADO (KES 30 to gatherer + KES 40 to transporter). Local retail prices may now differ. LOKADO continues to supply fuel to reception centres, new arrivals, schools (x45), hospitals and child-headed households. But with the huge drop in the organised purchase and delivery, former gatherers and transporters have lost out. The Turkana West Sub-County government has allocated an 'energy marketplace' in Kakuma town where it hopes external traders can bring fuel and find buyers. UNHCR also funds LOKADO in tree nursery development (x6), tree planting, community gardens, environmental training and the production of energy-efficient stoves for new arrivals (fabricated at a production unit within the camp). UNHCR co-chairs (with the sub-county government) an energy working group that meets quarterly and a technical working group that meets monthly. UNHCR is also instrumental in the development of an Action Plan for Clean Cooking Solutions as part of the Kalobeyei Integrated Socio-Economic Development Program (KISEDEP). They remain supportive of partners' efforts to promote cooking energy solutions, including SNV's market-based cookstoves programme and the new FAO briquetting pilot based on Prosopis.	Call
Waka Waka	Briquette manufacturer		x		Make briquettes from charcoal dust & sawdust, with 5% molasses as binder. Sawdust is reportedly easy to source, but charcoal dust sometimes a challenge. Could also use carbonised biomass. Buys both sawdust and charcoal dust @ KES 5 per kg (KES 350 per 70kg bag), almost KES 8 once delivered (KES 500-600). Quite a lot higher than prices reported by Eco Makaa. Briquettes are reportedly smokeless, though it is hard to understand how this is the case, as the "sawdust is soaked for 72 hours and that's how its carbonised. Then there's no smoke" Used to make ~ 20 bags per week, now only makes to order, mostly for chicken brooders and restaurants, with some supermarket sales for HH use. Sells @ KES 40/kg (retail KES 50-60/kg). 3.5 HP extruder can make 6-7 bags/day. The shaft wears out quickly and needs to be replaced. Main challenges are the rain, unreliable power, transportation to customers and weak market uptake.	Visit

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
WFP Kenya	Humanitarian agency		x		WFP do have a component on energy for refugees, but little action as it is a large challenge with little interest from their donors, and others are already doing fuel and cookstoves interventions. Focus more on school feeding programmes productive energy for farmers (irrigation, solar drying, processing). WFP is not using cash for refugees in Kenya. They have created their own digital system using mobile phones and people access food vouchers through this system, which can be redeemed at certain retailers ('Bamba Chakula'). UNHCR, on the other hand, does have some cash provision to refugees. WFP is striving to shift 100% to cash-based transfers in place of food, through a full switch is not yet possible as some donors still prefer to donate food. They also need to target children and others with fortified rations under their nutrition programme. At Kakuma, WFP make payments once per month via mobile money to refugee e-vouchers, while at Kalobeyei the payments go into refugee bank accounts (via heads of household). Refugees may then buy the food they require using a bank card. UNHCR, on the other hand, uses bank accounts only, at both Kakuma and Kalobeyei. Felix Okech thinks that any CBT scheme for fuel should be earmarked/restricted, to ensure proper targeting and to permit monitoring of how the subsidy is used. He says this could easily be 'layered' onto the existing voucher systems.	Call & mtg
Adapt+	Briquette manufacturer			x	Company specialising in char briquettes. Also provide advisory services to other orgns (e.g. Oxfam, ADRA) and manufacture various biomass stoves (KCJ, 'Nyota' natural draft gasifier, 'Biosave' fan stove with volcanic rocks). Facility at Kyaka II since 2015 where they carbonise maize cobs (plus sometimes maize stalks, bean stalks & groundnut shells) and also buy in charcoal dust from as far away as Mubenda & Kampala. The char is milled and blended with binder (usually molasses, sometimes cassava flour) and densified into cylindrical or pilow-shaped briquettes. Mainly sell to UNHCR IPs (Nsamizi, LWF) for distribution to PSNs and subsidised sale to refugees via SACCOs @ UGX 300/kg (2015 price). But direct sales to refugees have been minimal and most fuel is given out free. Ex-factory price is UGX 850/kg but charcoal is available locally @ ~UGX 300-400/kg. Challenges in the north would be more acute due to lack (and dispersal) of feedstock, and even lower charcoal prices.	Call
Bukona Agro Processors Ltd	Ethanol supplier			x	Though to be the only company in Uganda manufacturing ethanol from cassava as cooking fuel. 40% owned by Uganda Development Bank. Major investment costing >USD 3 m. They pay farmers UGX 600,000/t of dried cassava (delivered), grown from seedlings distributed by the Office of the Prime Minister. They buy from over 20,000 farmers. Installed production capacity is 50,000 l/day, which would supply around 50,000 families. Current output is reportedly 45,000 l/day. 1 acre of land can yield 2-3 t of cassava/yr, and 2.5 kg of dried cassava can produce 1 litre of ethanol. So they need 50,000 acres under production to meet their target. Ethanol price is UGX 3,800/l (or UGX 5,700 for 1.5 l). They claim this is 40% cheaper than LPG (but our calcs suggest ethanol is actually 3% more expensive, and needs more time and effort for refilling. Sales are currently in Arua, Gulu and Kampala, but they plan >50 outlets across the country. They report limited market awareness and low take-up by consumers. They also sell subsidized Indian-made ethanol stoves at UGX 250,000 ($69) as well as pressure cookers (various sizes and costs). Proposing to manufacture in Uganda later. They would like to sell carbon credits from the cookstoves. They would like to see a circular arrangement where suppliers are also consumers, but it seems like a family would need to put 0.2 acres exclusively under cassava to provide adequate ethanol for their needs, and many don't have this much available land.	Visit

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
DanChurchAid	Humanitarian agency			x	UNHCR 'Lot 1' Implementing Partner (Bidibidi, Imvepi, Rhino Camp, Kiryandongo), also tasked to build capacity in local NGOs Raising Gabdho Fdn (RGF) and HADS. Core funding from Danida (5 yrs) plus annual funding from UNHCR (which may increase to 2 yrs). Working on E&E activities since 2018 as part of wider support to environment-friendly IGAs. Working in West Nile under 2 x 1 yr projects (funded by UNHCR and Danida). Supporting 21 x 10-person briquetting groups (Bidi-Bidi 10, Imvepi 8, Rhino Camp 3). Each group (mainly women) receives an equipment package worth UGX 15m (crusher, mixer, honeycomb press, stick press). Some also get bi/tricycles for promotion and distribution. Briquettes made using charcoal dust, maize cobs, sawdust and agri residues. Charcoal dust costs UGX 100-150/kg. Agricultural waste is free from refugees and hosts, but costs UGX 100/kg for transport, so the delivered cost is similar to charcoal dust. Binders could be cow dung, molasses, clay or cassava flour, though anthill soil is mostly used due to availability challenges. Average group income is ~UGX 1.5m/month. Partnership with RedRose ONEapp for e-voucher system to track payments of UGX 15,000 per month to 400 vulnerable households (e.g. elderly, at-risk women & children). 100% subsidy earmarked for briquettes, which are 'sold' @ UGX 1,000 (stick) and UGX 2,000 (honeycomb), with the funds reimbursed to the groups via bank accounts or mobile money. They monitor transactions between beneficiaries and vendors to avoid fraud, and have a field support team to make physical checks on production. The briquetting groups also try to make cash sales to refugees and locals, both directly and via energy kiosks. Challenges are reported in selling the briquettes due to poor quality of the hand-pressed product, low calorific content, high price compared with charcoal, difficulty in sourcing feedstocks and binders, and poor access to markets. DCA also supports groups to make haybasket insulated slow-cookers, promotes improved cookstoves (both ~10,000 fixed lorena and ~15,000 portable Potential Energy model) and has an incentive-based tree planting programme plus support to cash cropping, beekeeping, etc. Potential Energy received a €40,000 RBF grant under a DCA-managed Innovation Challenge, but has struggled to sell stoves (@ UGZ 80,000/USD 23) that were previously given out free. Lastly, RGF is only supporting DCA in Kampala, for urban refugees.	2 calls
ESDS Uganda	Humanitarian agency			x	ESDS is one of 7 GIZ programmes in Uganda, which also include EnDev. EnDev had a DFID-funded partnership at Rhino Camp, Imvepi and Omugo in 2017/18 to test market-based approaches to distribution of energy products, mainly Tier 0-3 cookstoves (while ICRAF focussed on supply-side measures via afforestation). EnDev and ESDS promote other 'last mile energy products' such as pico-solar and solar lanterns. One part of their work is greening UNHCR operations in the refugee operation (mainly through solar PV). They also apply an RBF model for cookstove promotion through partners including Raising Gabdho Foundation (RGF), BM Energy Services (charcoal stoves) and International Lifeline Fund (wood, charcoal and dual-fuel stoves). They have trialled an 'energy kiosk' model, the details of which need to be further explored. ESDS also supports solarisation and cookstove installation at health centres, schools and reception centres. There are plans to expand activities to Kiryandongo settlement, in addition to the original three settlements in West Nile. They do not work on cooking fuels specifically, though ILF is understood to be developing a pellet stove.	Call

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
FAO Uganda	Development agency			x	FAO Uganda is implementing two projects of relevance to cooking energy: (a) 'Sustainable and affordable energy solutions for refugees and host community' in Lamwo and Kiryandongo, funded by Innovation Norway (and also by IKEA Foundation at Kiryandongo); and (b) the EU-funded project 'Forest Management and Sustainable Charcoal Value Chains' across 8 northern districts (plus 5 in the central belt), over 4 years with €5 m (plus FAO own funds €0.5m). The first project has partnered with Mandulis for the setting up of four 'multi-purpose hubs' (two in each district, one in the settlement and one outside). These will be centres for promotion of cookstoves and briquettes, alongside productive energy services (e.g. crop processing, milling, cold storage). The stoves and briquettes will be subsidised via an electronic smart card connected to a smartphone app. This is independent of the DCA-supported voucher system and that of WFP, so there may be a proliferation of similar cash/voucher services. They are considering a 50-75% subsidy against the stove plus two rounds of fuel distribution, though this is still under development as an energy needs assessment (which will assess willingness to pay) has been delayed by COVID. The stoves will come from commercial suppliers, who will be selected via an upcoming call for EoI. The briquettes for Kiryandongo will come from Mandulis's plant at Nwoya, and a second plant is being set up in Lamwo to supply Palabek settlement. The feedstocks for Lamwo have not yet been determined. The briquettes will be of the non-carbonised variety. It is probable that customers/beneficiaries will be asked to enter into supply arrangements to supply agri-residues for making the briquettes. The separate EU-funded charcoal value chain project is working in Lamwo (but not in Kiryandongo). It is not clear if/how it will work with the Norway-funded refugee energy project, given that the latter is looking only at briquettes, but perhaps there will be internal coordination and collaboration arrangements.	Call
Humanitarian Assistance & Development Services	NGO			x	HADS is a humanitarian NGO with most of its funding coming from DCA. HADS is currently implementing a 2-year livelihoods and environmental project at Kiryandongo and Koboko that promotes access to sustainable cooking energy technologies and fuels. The project supports 3 producer groups to make briquettes, which are partly sold to the community and partly to HADS for distribution to vulnerable groups. With funding from UNHCR, HADS also supports tree nurseries for forest development, restoration, food, fuel and timber. In addition, HADs conducts behavioural change engagements with communities to reduce their energy consumption, as well as training for making lorena cookstoves, beekeeping, pigeon pea cultivation for woody biomass and agroforestry. The majority of households reportedly prefer charcoal and firewood, with <10% using briquettes. In one of the past projects as IP for DCA, HADs distributed ILF dual-fuel cookstoves to the vulnerable in the settlements. HADS has also worked with ACF, AFI, WFP and Danish Refugee Councill (protection).	Call

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
ICRAF	Research programme			x	ICRAF works in Rhino Camp and Imvepi refugee settlements to support a variety of work in livelihoods, resilience building, energy (stoves and fuels), sustainable environmental management, with a strong emphasis on tree nurseries, woodlots, homestead mixed use planting and coppice management. ICRAF has four refugee-related projects underway: (1) Agroforestry with refugees through a resource centre, tree planting, monitoring of survival rates, livelihood training for women, incl. briquette making, tree planting and tree management for improving nutrition (fruit trees) and income, with carbon incentives. (2) Resource Recovery and Reuse (RRR), incl. agroforestry, sustainable biomass harvesting, conversion of organic residues into briquettes and training of women in construction of lorena cookstoves. (3) Response to Increased Environmental Degradation and Promotion of Alternative Energy Sources in Refugee Hosting Districts (RED Project), a 4-year project (2021-2025) funded by the EU Trust Fund and implemented by a consortium led by Save the Children, also including Enable, Joint Energy and Environment Projects (JEEP) and Vision for Humanity. JEEP is responsible for the energy component (training community groups to make lorena cookstove and briquettes), while ICRAF is responsible for gender and agroforestry. (4) Resource Recovery-Biogas project, funded by Shell and Total. A new project with Caritas that will utilize human faecal waste to produce biogas (to be sold in plastic bags) for cooking and fertilizer for tree nurseries. The dry faecal sludge will be used to make briquettes.	Call
Independent	Consultant			x	Consultant carrying out research for ESDS: End User Finance and Payment systems in refugee settings (in the northern region and specifically in rhino and imvepi refugee settlements). Study focused on a) describing livelihood interventions with an energy component b) researching end user finance and payment solutions that are currently in use/planned for the future and c) describing framework conditions.	Call
International Lifeline Fund	NGO			x	ILF seeks to use market-based mechanisms to deliver clean water and energy to unserved areas. They started work in Uganda in 2006 selling the 'Okello Kuc' cookstove in IDP camps and to the peri-urban poor, and this model is still sold alongside their current 'Eco Smart' brand. ILF has a cookstove factory in Lira operating as Eco Energy, a social enterprise that provides employment to over 100 people and produces ~15,000 charcoal and wood stoves per month under the Eco Smart brand. The factory also produces dual-fuel stoves costing UGX 7,500-12,000 (USD 2-3.5). ILF has won several awards and has partnered with WFP, LWF, GIZ (RBF), PSFU/WB, UNHCR and AVSI, among others. In partnership with WFP with support from BMZ and the OPM, ILF implemented the Safe Access to Fuel & Energy (SAFE) pilot project, which utilized grants from WFP to conduct awareness, demonstrations and distribution of stoves and training of sales agents in three settlements. Energy kiosks selling ILF stoves and solar PV (D-light) products were established, with vendors recruited from the refugee communities to sell the Eco Smart cookstoves. The energy kiosks were reportedly successful, but the kiosks in two of the settlements have closed, reportedly due to the lack of ownership of the business. ILF is currently developing a partnership with Mandulis Energy to provide a holistic cooking solution. Mandulis will supply briquettes to ILF, which can be sold on to households bundled with the Eco Smart stoves. ILF also has an ongoing collaboration with Opportunity Bank to implement an institutional ICS programme. ILF has also partnered with Carbon Sink, a carbon emissions offset company in Italy.	Call

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
JK Biomass & Machinery	Briquette manufacturer			x	The company has been in business for 10 years with an engineering unit located in Kyebando and briquette production in Bwaise (both suburbs of Kampala). They make a variety of briquette manual and electric briquetting machines to order, as well as crushers and mixers. Customers are mostly NGOs, and INGOs (UNHCR, DCA, LWF, SNV, etc), as well as the Office of the Prime Minister. For their own briquette production, they source mostly sawdust and wood shavings from low income city areas, plus some cassava and banana peels, which are dried (~5 days) then carbonised, crushed, mixed, extruded and dried. The briquettes are sold under the brand name "Fumba Briquettes" through supermarkets like Mega Standard Supermarket and (formerly) Shoprite. They also work with the Uganda Small Scale Industries Association (USSIA) who market the briquettes through their networks (mostly online). Prices are UGX 1,000 ($0.28) per kg for stick briquettes and UGX 1,500 ($0.42) per honeycomb briquette, with discounted prices of UGX 700-850 ($0.19-$0.24) per kg for bulk purchase and humanitarian agencies. They are thought to produce up to 2.5 t per week, which is well below their capacity. The main challenge is reported to be the lack of sound local knowledge of energy technology and briquetting science. Most knowledge is self-taught.	Visit
LWF				x	UNHCR 'Lot 2' Implementing Partner (Adjumani, Lobule, Palabek, Palorinya) plus Kikuube and Kamwenge with separate funding, for a total of 21 settlements. LWF operates livelihoods, environment and protection programs, and has also partnered with WFP for food and fuel distribution. They promote access to sustainable cooking energy technologies that include biogas, wood stoves and briquettes. Community groups are trained to make lorena stoves and briquettes, which they can use or sell for income (bartering or UGX 10,000-18,000 per stove). As an IP for UNHCR, LWF also distributes portable stoves and briquettes to vulnerable groups. Over 20,000 ILF Eco-Smart wood stoves have been distributed in the settlements. LWF also supports tree nurseries and tree planting for food, fuel and timber. In Adjumani, LWF supports agroforestry initiatives by offering incentives to private land-owners and community groups to establish tree nurseries and forests, which provide additional income (timber) and fuel for cooking. The uptake of briquettes is reportedly very low, mainly due to poor quality of the handmade briquettes and their high price compared to charcoal and firewood. LWF is working on a partnership with Mandulis Energy to source higher quality briquettes. LWF recommends vouchers earmarked for sustainable energy products, incorporating a certain level of subsidy across the value chain.	Call

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
Mandulis Energy	Briquette manufacturer			x	Mandulis is the brainchild of Peter Nyeko, an engineer and entrepreneur with a track record of securing donor funds to co-finance rural energy projects (e.g. PREO, IKEA, UKAid, USAid, Dutch MFA, Grant Challenges Canada, EEP Africa, Innovate UK, FAO, GET.Invest). He reports raising an average of 50% towards the capital costs of setting up various ventures, the main one being a briquetting facility in Nwoya District with 24/t day capacity, from which he sells briquettes to humanitarian agencies (e.g. LWF and others for Kiryandongo anf the Adjumani settlements). The briquettes are made from maize cobs, rice husks and groundnut shells. Mandulis describes these as commercial relationships where briquettes are sold to refugees via distributors, but this seems improbable with ex-factory prices quoted UGX 500-800 per kg. Peter is himself clear that briquetted fuels must reach the consumer at least 20% cheaper than firewood or charcoal that they are designed to compete with. He is currently setting up a similar operation in Lamwo District with FAO support under its Innovation Norway project. This will pilot a digital voucher scheme targeting 7,500 refugee households in Lamwo and Kiryandongo, with which they can buy stoves and briquettes at a subsidised price. Mandulis has experimented (in Nwoya) with the production of char briquettes (like Adapt+ at Kyaka), and still has a large stock of char at the facility, but is focussing on non-carbonised briquettes for now. He does plan to make char briquettes in the future, but this will be linked to separate plans to set up 16 x 0.5 MW gasifier-based mini-grids across northern Uganda, from which char would be a by-product that could be densified into fuel. It is fair to say that gasification has had a discouraging track record in Uganda, so it would be risky to rely on this supply chain for briquetting feedstock. Mandulis has ambitions to go much further, with a 20 MW gasifier in Gulu to feed power to the grid (generating 40,000 t/yr of biochar), six biomethane plants with combined 5 million m3/year output as an LPG replacement and a 24 t/day briquetting plant in Gulu, with three kilns to give the option of both 'raw' and carbonised briquettes. Mandulis aims to produce fuels that can be used in existing stoves and hearths, so does not support gasifier stoves for pelleted fuel. He instead focusses on fuels that can be used in existing stoves, and has established a partnership with ILF in Lira, who mass produces a low-cost multi-fuel clay stove that can burn firewood charcoal or briquettes.	Call & visit
Nsamizi Training Institute of Social Development	NGO			x	UNHCR 'Lot 3' Implementing Partner (Kyangwali, Kyaka II, Rwamwanja Nakivale, Oruchinga). Started in 2008 a WASH and livelihoods organization, but now also energy & environment. Among other things, they train households and institutions to plant and manage trees and train community agents/groups in making lorena cookstoves, institutional stoves and fuel briquettes. Producer groups make briquettes, which Nsamizi buys for distribution to PSNs, especially during the October-November rainy season when supplies of fuel are at their lowest. No evidence was provided of briquettes sales outside this channel.	Call

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
Raising Gabdho Foundation	NGO			x	Raising Gabdho Foundation (RGF) is a for-profit social enterprise that was founded in 2015, with a focus on improving access to sustainable energy. It supports a briquette factory in Kapeka, Luweero District, targeting the Kampala household market (with plans to expand to institutions). Under a partnership with DCA, RGF also supplies briquettes to refugee households in Kampala. In the refugee settlements, RGF has partnered with UNHCR, GIZ, Mercy Corps, DCA and others to implement RBF cookstove programs, training for cookstoves and briquette production, awareness-raising for heat retention bags and tree planting / agroforestry). RGF participated in the Response Innovation Lab's AMPERE project in Bidi Bidi, supporting energy kiosks and an energy hub with Energy Ventures, which sells sustainable energy products. RGF aims to build capacity of local communities to produce stoves and fuels. RGF highlights challenges around top-down planning by UNHCR and other partners, and short project duration that is inappropriate for holistic livelihood interventions.	Call
Response Innovation Lab	Development initiative			x	Competitive innovation fund managed by Save the Children. Focuses on "innovation", linking partners, supporting the ecosystems, capacity strengthening etc. In 2019/20, supported pilot interventions in Bidibidi via AMPERE Project: Access to Modern Energy in Humanitarian Settings Pilot. Project partners - Mercy Corps, Save the Children, SNV. Focus on off-grid solar and mobile money/PAYGo. No current cooking energy intervention programme, but interesting work on 'challenge mapping' at Bidibidi and trialling interactive voice response to learn about clean energy solutions. Also worked with Raising Gabdho and Enventure (project scaled up by Save the Children) to create jobs and distribution points for clean energy products at Bidibidi.	Call
Save The Children	NGO			x	SCF's energy and environment activities are mostly components of wider programmes on livelihoods, protection, etc. SCF is in a consortium with Raising Gadbho Foundation and EnVenture in a 1-year pilot Clean Energy Project funded by Relief Alliance Fund, targeting 1,000 refugees (500 from Kiryandongo and 500 from Bidi Bidi; 70% women and 30% youth). Energy kiosks have been set up and are run by cooperatives (each cooperative is a collection of multiple VSLAs). They raise awareness on clean energy and beneficiaries buy vouchers to access clean energy solutions. The project provides interest-free loans to the cooperatives worth UGX 2 million to stock their shops with energy solutions from approved suppliers (namely improved cooking stoves, briquettes, solar products and energy-efficient light bulbs). The briquettes come from groups supported by RGF. SCF also works with UNDP on cash for work for forest regeneration.	Emails

Organization	Function	Countries			Relevance & other details	Interaction?
		ET	KE	UG		
UNHCR Uganda	Humanitarian agency			x	UNHCR co-chairs the WorkGrEEn national coordination group (with UNDP and OPM), through which around 31 relevant actors can be identified and contacted. UNHCR also has its own 3 IPs for energy and environment under three regional 'lots': 1. DCA for Bidibidi, Imvepi, Rhino Camp, Kiryandongo; 2. LWF for settlements in Moyo, Obongi, Adjumani and Lamwo; 3. Nsamizi Institute for Social Development for Kyangwali, Kyaka II, Rwamwanja, Nakivale and Oruchinga. There is an increasing emphasis on refugee self-reliance and choice, moving towards cash and voucher systems. DCA supports around 20 briquetting groups and distributes to PSNs using a virtual voucher system. Nsamizi also purchases briquettes for PSNs, but to distributes directly under a more traditional handout arrangement. These briquettes are artisanally produced, though Adapt+ has been making mass-produced char briquettes at Kyaka II since around 2015, which UNHCR previously purchased for free distribution. UNHCR observe that current briquetting approaches are not sustainable, as they rely on 100% subsidy. They quoted UGX 1,000 per kg for briquettes bought by their partners from producer groups, whereas charcoal locally costs UGX 300-400 per kg (UGX 15,000-20,000 per 50 kg bag), rising to UGX 500/kg at Oruchinga. Adapt+ were selling a higher grade char briquette at Kyaka II @ UGX 850/kg, but the price gap with wood charcoal is still wide. Several briquetting outfits entered the refugee programme but have since scaled back or left (they mentioned Green Elephant, Uganda Green Fire and Green Bioenergy Briquettes). UNHCR are also aware of e-cooking trials at Bidibidi with the Pesitho cooker by Mercy Corps (and Caritas?), and ethanol trials in Nwoya District by Bukona Agro Processing, outside the refugee operation. On a separate note, UNHCR is supporting tree and bamboo plantation development, though the bamboo is for construction, not fuel. And they support homestead tree planting by refugees, but this is constrained by government rules that exclude exotic species, which are those that the refugees generally prefer.	Call

Annex D: Country travel schedules

Mission 1: Uganda

Paul Quigley, Eugene Ntananga and Kibekityo Gilbert

Date	Activity
Sun 26 Sep	Paul arrive in Kampala from Ireland
Mon 27 Sep	Travel to Arua via Bukona Agro-Processing Factory (ethanol) and Green Fuel Uganda (briquetting company in Nwoya)
Tue 28 Sep	Visit Rhino Camp settlement, including refugee briquetting groups, Village Saving and Loan Association, camp markets, GIZ energy kiosk
Wed 29 Sep	Visit Imvepi settlement, including refugee briquetting groups, Village Saving and Loan Association, camp markets, GIZ energy kiosk and farming group
Thu 30 Sep	Travel to Kampala via Mandulis Energy and Amatheon Farm (both in Nwoya)
Fri 1 Oct	Debrief with GIZ in Kampala
	Paul depart for Kenya

Mission 2: Kenya

Paul Quigley & Allan Marega

Date	Activity
Fri 1 Oct	Paul fly Entebbe-Nairobi
Mon 4 Oct	Meet WFP
	Team discussion
Tue 5 Oct	Meet SNV
Thu 7 Oct	Visit EcoMakaa, Waka Waka and Bentos Energy (briquette manufacturers)
Fri 8 Oct	Virtual meeting with GIZ for discussion and debrief
Mon 11 Oct	Meet FAO
	Paul depart for Ireland

Mission 3: Ethiopia

Mekonnen Kassa & Lelisa Alemu

Date	Activity
Sun 10 Oct	Fly Addis Ababa-Assosa
Mon 11 Oct	Meetings with ANE, UNHCR and ARRA
Tue 12 Oct	Visit Sherkole Refugee camp, incl ANE charcoal briquetting plant
Wed 13 Oct	Fly Assosa- Addis Ababa
Thu 14 Oct	Fly Addis Ababa - Gambella
Thu 14 Oct	Meetings with UNHCR and ARRA
Fri 15 Oct	Visit Pugnido I refugee camp, incl ARRA field office and market assessment
Sat 16 Oct	Visit Pugnido I refugee camp, incl ARRA field office and market assessment
Sun 17 Oct	Market visits for price survey of stoves and fuels
Mon 18 Oct	Fly Gambella-Addis Ababa

Annex E: Selection of photos

West Nile (photos by Paul Quigley and Eugene Ntananga, INTe&e 2021)

Weighing firewood in market, Rhino Camp

Carboniser, Work Hard group, Imvepi

Briquette ingredients, Nyosu group, Rhino Camp

Briquettes on drying rack, Work Hard group, Imvepi

Nyosu briquetting group, Rhino Camp

EnDev-supported energy kiosk, Rhino Camp

Gambella and Assosa (photos by Mekonnen Kassa & Lelisa Alemu, INTe&e, 2021)

Firewood collection, Pugnido 1, Gambella

3-stone fire, Pugnido 1 camp, Gambella

Charcoal stoves for sale, Gambella town

Elephant grass, Gambella

Harvested elephant grass,
ANE Sherkole briquetting site, Assosa

Carbonisers, ANE Sherkole, Assosa

Dryer & extruder (non-functional), ANE Sherkole

Mill, ANE Sherkole

Manual block press, ANE Sherkole, Assosa

Manual honeycomb press, ANE Sherkole, Assosa

Cuboid briquettes, ANE Sherkole, Assosa

Honeycomb briquettes, ANE Sherkole, Assosa

Injera mudstove, Pugnido 1 camp, Gambella

Undistributed charcoal stoves, Pugnido 1, Gambella

Kakuma and Nairobi (Photos by Allan Marega and George Ekisil, INTe&e, 2021)

Prosopis wood for carbonisation, FAO briquetting facility, Kakuma

Carbonising unit, FAO Kakuma

Carboniser chambers, FAO Kakuma

Mill for char, FAO Kakuma

Extruder heated die, FAO Kakuma

Briquette production, EcoMakaa, Nairobi

5 HP extruder, EcoMakaa, Nairobi

Briquette drying, WakaWaka, Nairobi

Annex F: Evaluation grid for cooking fuel options

Cooking fuel or energy source	Fully renewable?	Biomass-based?	Local feedstock?	No seasonality constraints?	Clear feedstock ownership?	No competing feedstock uses?	Local livelihood opportunities?	Existing supply chains?	Low emissions?	Familiar to users?	Works in existing stoves?	Aspirational?	New commercial opportunities?	Innovation potential?	**Combined score**
1. Charcoal	2	3	3	3	3	3	3	3	2	3	3	2	1	2	**36**
2. Firewood	2	3	3	3	3	3	3	3	1	3	3	1	1	1	**33**
3. Briquettes - carbonised	2	3	2	2	2	2	2	1	2	3	3	3	2	3	**32**
4. Briquettes - char	2	3	3	2	2	2	2	1	2	1	2	2	2	3	**29**
5. Electricity - self-contained solar	3	1	2	2	2	2	1	2	3	1	1	3	2	3	**28**
6. Pellets - non-carbonised	2	3	2	2	2	2	2	1	2	1	1	3	2	3	**28**
7. Electricity - diesel/solar mini-grid	2	1	2	3	2	2	1	2	3	2	1	3	1	2	**27**
8. LPG	1	1	1	3	2	2	1	2	3	2	1	3	2	2	**26**
9. Briquettes - non-carbonised	2	3	2	2	2	2	2	1	1	2	2	1	1	2	**25**
10. Electricity - on-grid	2	1	1	3	2	2	1	2	3	2	1	3	1	1	**25**
11. Ethanol	2	3	2	2	1	1	1	1	3	1	1	3	1	2	**24**

Annex G: Cooking fuel and stove cost data

Cooking fuel requirements for delivery of 1,050 MJ per person per year

Fuel	LHV (MJ/kg)	Thermal efficiency of stove	Quantity needed per year (kg)
Firewood	15.0	17.3%	405
Charcoal	30.8	31.0%	110
Char briquettes	21.3	31.0%	159
Pellets	14.7	34.7%	206
Ethanol (litres)	20.0/l	51.5%	102 l

Sources: LHVs:

- Firewood (15% MC): *www.ethicalteapartnership.org/wp-content/uploads/2019/09/Thermal-Training-manual-new.pdf*
- Charcoal: *www.fao.org/docrep/x2740e/x2740e05.htm#P3854_103806*
- Char briquette from five companies' products tested in Uganda (Behrens-Shah et al., 2018)
- Pellet averaged for all crop wastes: *www.pellet-making.com/blog/wood-pellets-calorific-value.html*
- Ethanol (assuming 5% additives): *www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html*

Efficiencies:

- Firewood average of cold, hot and simmer phases for shielded fire: *www.mtu.edu/peacecorps/programs/civil/pdfs/nicholas-h-schreiner-thesis-2011.pdf*
- Charcoal/briquettes assumes clay-lined metal stove: *gadgillab.berkeley.edu/wp-content/uploads/2015/04/FINAL-Comparisons-of-Charcoal-Cookstoves-for-Haiti.pdf*
- Ethanol stove Oorja: *catalog.cleancookstoves.org/stoves/45*

Annual cooking fuel cost comparison, ESDS locations

	West Nile				Gambella				Kakuma			
Fuel	Fuel cost (UGX/kg)	Fuel cost ($/kg)	Quantity required (kg/pers/yr)	Total cost ($/pers/yr)	Fuel cost (UGX/kg)	Fuel cost ($/kg)	Quantity required (kg/pers/yr)	Total cost ($/pers/yr)	Fuel cost (UGX/kg)	Fuel cost ($/kg)	Quantity required (kg/pers/yr	Total cost ($/pers/yr)
Firewood	105	0.03	405	12.0	1.7	0.04	405	15.0	6.0	0.06	405	22.3
Charcoal	581	0.16	110	18.0	6.7	0.15	110	16.4	23.3	0.21	110	23.5
Char briquettes	881	0.25	159	39.5	9.9	0.22	159	35.1	31.3	0.29	159	45.6
Pellets		0.40	206	83.0		0.40	206	83.0	44.0	0.40	206	83.0
Ethanol (litres)	4,180	1.18	102	119.9	20.4	0.45	102	46.3	93.0	0.86	102	87.1

Sources: For firewood and charcoal, see Figure 2. For briquettes see Figure 5. Pellet prices from IKO Briq Nairobi + 10% delivery cost (adopted for W.Nile & Gambella). Ethanol price for West Nile from Bukona Agro Processors (Nwoya) + 10% for delivery; for Kakuma from Koko Networks in Nairobi, + 20% for delivery (*www.kokofuel.com/faqs*); for Gambella ETB 17 + 20% for delivery, from Finchaa Sugar Factory (Behrens-Shah et al., 2018).

Annualised cost of cookstoves for different fuels, ESDS locations

Stove type	West Nile				Gambella				Kakuma			
	Cost (UGX)	Cost ($)	Lifetime (yrs)	Annualised cost ($)	Cost (ETB)	Cost ($)	Lifetime (yrs)	Annualised cost ($)	Cost (KES)	Cost ($)	Lifetime (yrs)	Annualised cost ($)
Basic mudstove	n/a	n/a	n/a	-	n/a	n/a	n/a	-	n/a	n/a	n/a	-
Basic charcoal stove	10,000	2.82	1	**2.82**	70	1.56	1	**1.56**	300	2.75	1	**2.75**
Stove for char briquettes	10,000	2.82	1	**2.82**	70	1.56	1	**1.56**	300	2.75	1	**2.75**
Pellet stove		100.90	4	**25.22**		100.90	4	**25.22**	11,000	100.90	4	**25.22**
Ethanol stove	250,000	70.48	5	**14.10**		44.87	5	**8.97**	2,101	19.26	5	**3.85**

Sources: Uganda: Charcoal/briquettes, smallest BM stove, Rhino Camp energy kiosk. Pellets: as Kenya. Ethanol: UGX 250,000 from Bukona Agro Processors. Ethiopia: Charcoal/briquettes: traditional clay stove (large). Pellets: as Kenya. Ethanol: average of Uganda and Kenya prices. Kenya: Charcoal/briquettes, KCJ from Usafi Energy. Pellets: KES 11,000 for Mimi Moto form IKO Briq. Ethanol: KES 2,201 from Koko Networks, minus KES 100 fuel credit: *www.kokofuel.com/faqs/*

Total annual per person cost of cooking for different fuels, ESDS locations

Fuel option	West Nile			Gambella			Kakuma		
	Annual fuel cost	Annualised stove cost	Total annual cost of cooking	Annual fuel cost	Annualised stove cost	Total annual cost of cooking	Annual fuel cost	Annualised stove cost	Total annual cost of cooking
Firewood	$12	$0	$12	$15	$0	$15	$22	$0	$22
Charcoal	$18	$3	$21	$16	$2	$18	$24	$3	$26
Char briquettes	$39	$3	**$42**	$35	$2	**$37**	$46	$3	**$48**
Pellets	$83	$25	$108	$83	$25	$108	$83	$25	$108
Ethanol	$120	$14	$134	$46	$9	$55	$87	$4	$91

Annex H:
Char briquetting business model assumptions

Capital expenditure (CAPEX) assumptions

Cost item	Cost (USD)	Throughput (t/mth)	Requirement
Vibrating sieve	$800	60	min. 1
Mill	$2,350	150	min. 1
Mixer	$2,350	100	min. 1
Extruder	$3,750	120	min. 1
Drying racks & cover sheets	$70/sqm		1 sqm/tonne; 3 days drying
Office furniture	$1,500		lumpsum
Water tank	$650	90	10,000 litres; min. 1
Gen set (50 kVA)	$14,000	1,000	if output > 30 t/mth
Stitcher	$700	200	min. 1
Scales	$680	250	min. 1
Permits & licences	$2,000		lumpsum
Shipping containers	$750	150	min. 1
Slab construction	$7,500		lumpsum
Workshop & tools	$2,900		lumpsum
Office equipment	$2,000		lumpsum
Installation	$8,750		
Freight + import charges			2% of CAPEX; min. $1,000
Misc. & spares			2% of (CAPEX + freight); min. $1,000
Switchgear & wiring			1% of CAPEX; min. $1,000
Contingency			3% of CAPEX

Operating cost assumptions

Cost item	Units	WEST NILE	GAMBELLA	KAKUMA	Sources
Briquette price	per kg,ex-factory	UGX 891	ETB 10.0	KES 31.4	'Goal seek' used to set price that delivers positive value for PV netted cashflow
Cost of charcoal dust	per kg, delivered to facility	UGX 200	ETB 2.5	KES 6.1	Field research
Cost of biochar		UGX 800	ETB 10.1	KES 24.6	
Cost of binder		UGX 1,400	ETB 17.7	KES 43.0	
Delivery cost of briquettes	per t	UGX 50,000	ETB 600	KES 1,500	
Output / skilled worker	t/mth (min. 1 worker)	60.0	60.0	60.0	
Output / unskilled worker	t/mth (min. 2 workers)	2.0	2.0	2.0	
Skilled labour cost	per person/mth	UGX 0.5m	ETB 5,000	KES 25,400	*www.take-profit.org/en/statistics/wages-low-skilled/uganda*
Unskilled labour cost		UGX 0.3m	ETB 2,283	KES 16,700	*www.abc.net.au/triplej/programs/hack/ethiopian-garment-workers-are-being-paid-worlds-lowest-wages/11098232* *www.wageindicator.org/salary/living-wage/archive-no-index/kenya-living-wage-series-september-2109*
Servicing & repairs	per 10 t	UGX 50,000	ETB 600	KES 1,500	Field research
Electricity requirement	kWh/t briquettes	20.0	20.0	20.0	
Electricity tariff	per kWh	UGX 750	ETB 0.32	KES 15.6	*www.umeme.co.ug/tariffs* *www.globalpetrolprices.com/Ethiopia/electricity_prices* *www.kplc.co.ke/category/view/77/electricity-tariffs*
Water requirement	litres/t briquettes	150.0	150.0	150.0	Field research
Water tariff	per cbm	UGX 3,516	ETB 35.00	KES 100	*www.nwsc.co.ug/tariff-guide* *www.openknowledge.worldbank.org/bitstream/handle/10986/32455/WPS9025.pdf* *www.nairobiwater.co.ke/water-tariffs*
Diesel requirement	litres/t briquettes	3.0	3.0	3.0	Field research
Diesel cost	per litre	UGX 3,760	ETB 18.75	KES 112.73	*www.globalpetrolprices.com*
Rent	per mth	UGX 2m	ETB 25,300	KES 61,500	Field research
Communications		UGX 0.2m	ETB 2,500	KES 6,100	
Insurance	per annum	UGX 3m	ETB 37,900	KES 92,200	
Banking, legal, audit		UGX 1.5m	ETB 19,000	KES 46,100	
Sales & marketing	per mth	UGX 1m	ETB 12,600	KES 30,700	
Packaging	per 50 kg bag	UGX 400	ETB 5.1	KES 12	
Tools, uniforms, boots	per worker	UGX 40,000	ETB 500	KES 1,200	
Security	per mth	UGX 0.5m	ETB 6,300	KES 15,400	

Annex I:
Sample output of char briquetting business model

West Nile example. Briquette price set to UGX 891/kg to ensure positive PV netted cashflow over 10 yrs. Example shown assumes 50% donor CAPEX subsidy.

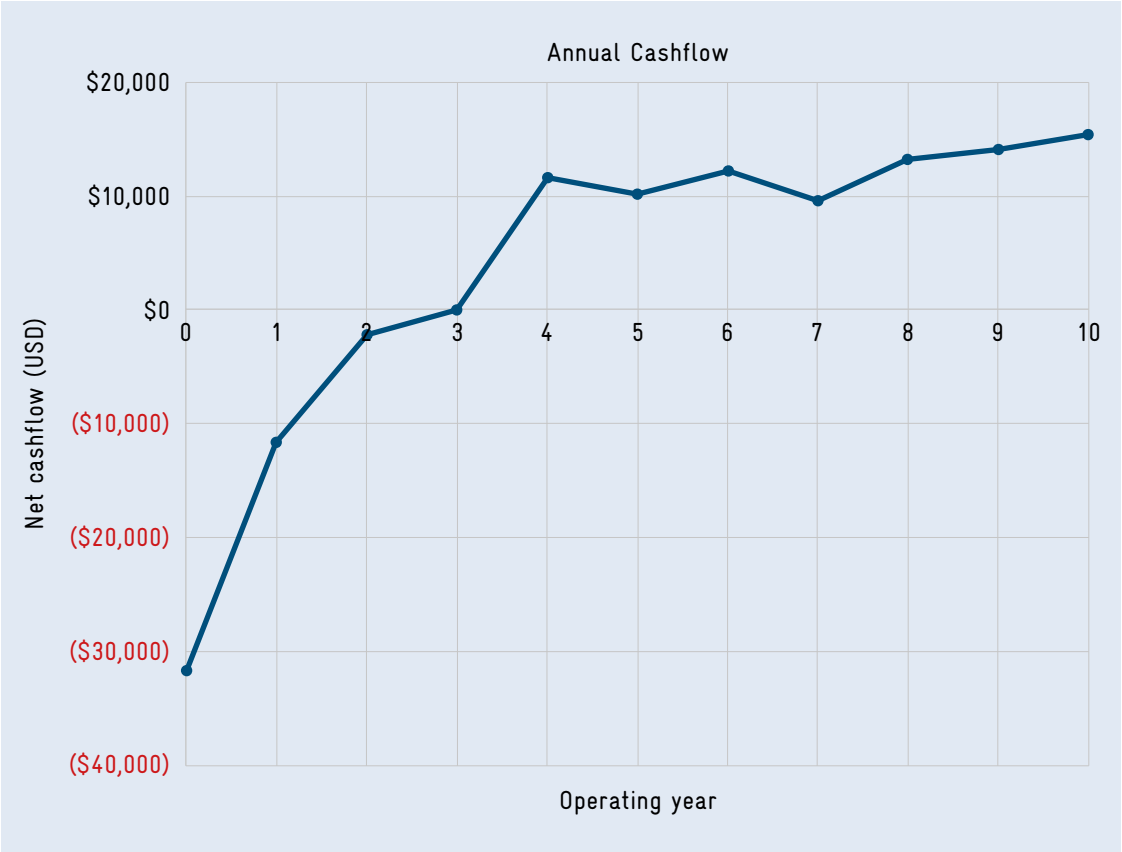
	Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Capital expenditure											
Vibrating sieve	$2,400	$0	$0	$0	$0	$973	$0	$0	$0	$0	$0
Mil	$2,350	$0	$2,542	$0	$0	$0	$0	$0	$0	$0	$0
Mixer	$4,700	$0	$0	$0	$0	$0	$0	$3,092	$0	$0	$0
Extruder	$7,500	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drying racks & cover sheets	$1,036	$0	$56	$61	$67	$73	$80	$87	$95	$104	$113
Office furniture	$1,500	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Water tank	$1,300	$0	$0	$0	$0	$791	$0	$0	$0	$0	$0
Gen set	$14,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Stitcher	$700	$0	$0	$0	$0	$0	$0	$921	$0	$0	$0
Scales	$680	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Permits & licences	$2,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Shipping containers	$750	$0	$0	$844	$0	$0	$0	$0	$0	$0	$0
Slab construction	$7,500										
Workshop & tools	$2,900										
Office equipment	$2,000										
Installation	$8,750										
Freight + importation charges	$1,201	$0	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
Miscellaneous & spares	$1,225	$0	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
Switchgear & wiring	$1,000	$0	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
Sub-total CAPEX	**$31,746**	**$0**	**$5,598**	**$3,905**	**$3,067**	**$4,837**	**$3,080**	**$7,101**	**$3,095**	**$3,104**	**$3,113**

	Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Operating costs											
Charcoal dust		$25,374	$55,416	$60,514	$66,081	$72,161	$78,800	$86,049	$93,966	$102,611	$112,051
Biochar		$101,494	$221,663	$242,056	$264,326	$288,644	$315,199	$344,197	$375,863	$410,443	$448,203
Binder (cassava, 5%)		$17,761	$38,791	$42,360	$46,257	$50,513	$55,160	$60,234	$65,776	$71,827	$78,436
Rent		$6,766	$7,037	$7,318	$7,611	$7,916	$8,232	$8,562	$8,904	$9,260	$9,631
Communications		$677	$704	$732	$761	$792	$823	$856	$890	$926	$963
Insurance		$846	$880	$915	$951	$989	$1,029	$1,070	$1,113	$1,158	$1,204
Banking, legal, audit		$423	$440	$457	$476	$495	$515	$535	$556	$579	$602
Fuel (gensets, vehicles)		$2,862	$6,251	$6,826	$7,454	$8,140	$8,889	$9,706	$10,599	$11,574	$12,639
Sales & marketing		$1,692	$3,518	$3,659	$3,806	$3,958	$4,116	$4,281	$4,452	$4,630	$4,815
Transport & delivery		$3,172	$6,927	$7,564	$8,260	$9,020	$9,850	$10,756	$11,746	$12,826	$14,006
Packaging		$2,030	$4,433	$4,841	$5,287	$5,773	$6,304	$6,884	$7,517	$8,209	$8,964
General servicing & repairs		$1,269	$2,771	$3,026	$3,304	$3,608	$3,940	$4,302	$4,698	$5,131	$5,603
Skilled labour		$2,537	$7,037	$9,148	$11,417	$13,852	$16,464	$19,263	$22,260	$25,465	$28,892
Unskilled labour		$38,060	$83,388	$91,114	$100,467	$110,423	$121,014	$132,275	$145,580	$159,737	$174,794
Statutory expenses (10% of salaries)		$135	$281	$293	$304	$317	$329	$342	$356	$370	$385
Tools, uniforms, boots		$5,278	$11,526	$12,587	$13,745	$15,009	$16,390	$17,898	$19,545	$21,343	$23,307
Security		$1,692	$1,759	$1,830	$1,903	$1,979	$2,058	$2,140	$2,226	$2,315	$2,408
Water		$134	$292	$319	$349	$381	$416	$454	$496	$541	$591
Electricity		$3,806	$8,312	$9,077	$9,912	$10,824	$11,820	$12,907	$14,095	$15,392	$16,808
Sub-total operating costs		**$216,007**	**$461,427**	**$504,637**	**$552,670**	**$604,791**	**$661,347**	**$722,714**	**$790,639**	**$864,337**	**$944,300**

Sub-total costs	**$31,746**	**$216,007**	**$467,025**	**$508,542**	**$555,737**	**$609,629**	**$664,427**	**$729,815**	**$793,734**	**$867,441**	**$947,414**
Depreciation (10%, straight line)		$3,617	$3,617	$3,876	$3,883	$3,889	$4,073	$4,081	$4,491	$4,500	$4,511
Contingency (3% of operating costs)		$6,480	$13,843	$15,139	$16,580	$18,144	$19,840	$21,681	$23,719	$25,930	$28,329
Loan repayment		$12,292	$12,292	$12,292							
Total costs	**$31,746**	**$238,396**	**$496,777**	**$539,850**	**$576,200**	**$631,662**	**$688,340**	**$755,577**	**$821,944**	**$897,871**	**$980,253**

Income											
Briquettes sales		$226,130	$493,869	$539,305	$588,921	$643,101	$702,267	$766,875	$837,428	$914,471	$998,603
Sub-total income		**$226,130**	**$493,869**	**$539,305**	**$588,921**	**$643,101**	**$702,267**	**$766,875**	**$837,428**	**$914,471**	**$998,603**

Gross margin (pre-tax and owner's draw)	**($31,746)**	**($12,266)**	**($2,908)**	**($545)**	**$12,721**	**$11,440**	**$13,927**	**$11,298**	**$15,484**	**$16,600**	**$18,349**
Owner's draw (10% of gross margin, if positive)	$0	$0	$0	$0	$1,272	$1,144	$1,393	$1,130	$1,548	$1,660	$1,835
Gross margin (pre-tax)	**($31,746)**	**($12,266)**	**($2,908)**	**($545)**	**$11,449**	**$10,296**	**$12,534**	**$10,168**	**$13,936**	**$14,940**	**$16,514**
Profit margin	-100%	-5%	-1%	0%	2%	2%	2%	1%	2%	2%	2%


Annual Cashflow
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($10,000)
($20,000)
($30,000)
($40,000)
0
1
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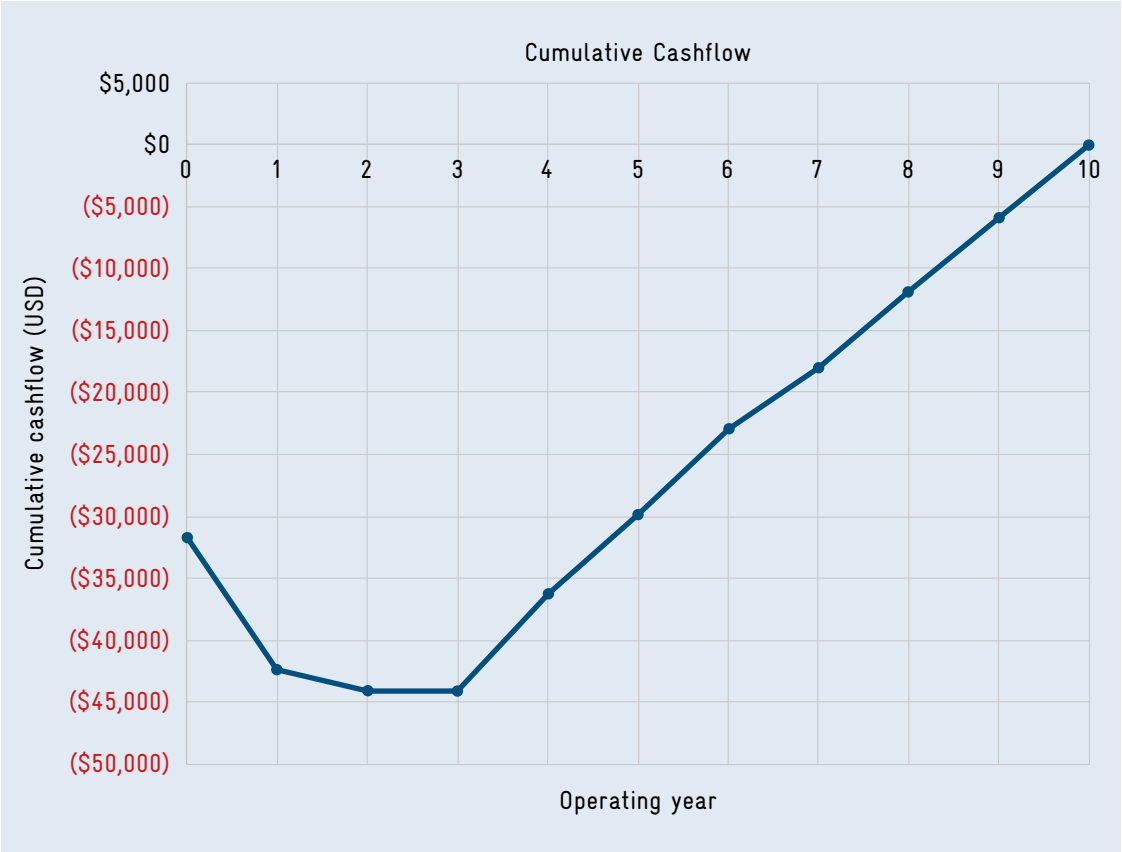
3
4
5
6
7
8
9
10
Net cashflow (USD)
Operating year


Cumulative Cashflow
$5,000
$0
($5,000)
($10,000)
($15,000)
($20,000)
($25,000)
($30,000)
($35,000)
($40,000)
($45,000)
($50,000)
0
1
2
3
4
5
6
7
8
9
10
Cumulative cashflow (USD)
Operating year

Annex J: Literature consulted

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