ANALYSIS OF THE WOODFUELS SECTOR IN GHANA

With options for demand reduction, supply enhancement, fuel switching and governance changes

REPUBLIC OF GHANA

PROGREEN

Administered by THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

Report No: AUS0002917

Ghana

Ghana Green Growth PASA

Analysis of the Woodfuels Sector in Ghana

November 2022

Environment, Natural Resources, and the Blue Economy Global Practice

Acknowledgements

This report was prepared by a team led by Neeta Hooda. The team was composed of Olamide Bisi-Amosun, Alex Kwame Donyinah, Yann Francois, Ishita Kaushik, Francis Kemausuor, Matthew Owen, Maclean Oyeh and Lesya Verheijen.

The team received expert advice from peer reviewers Klas Sander and Yasmina Oodally.

The report was produced under the overall guidance of Pierre Laporte (Country Director, Ghana) and Sanjay Srivastava (Practice Manager, SAWE4).

The team would like to acknowledge the kind cooperation of Edith Abruquah and Yaw Kwakye (Ghana Forestry Commission), Isaac Acquah (Environmental Protection Agency) and Kingsley Armah (Ministry of Food and Agriculture), and their respective colleagues and regional staff. Anthony Krakah of the Ghana Statistical Service provided useful demographic data.

The field research benefitted greatly from the assistance of Mark Akparibo (Ghana Federation of Forest & Farm Producers) and several of his organization's members, along with partners in the GIZ-managed Forest Landscape Restoration project led by Cisco Aust, especially Daryl Bosu, Godwin Dzekoto and Isaac Ntori (A Rocha), and Daniel Abu and Joseph Asante (Tropenbos). Julius Awaregya (Organization for Indigenous Initiatives & Sustainability) provided helpful facilitation in Upper East Region and Christian Hansen, Lawrence Brobbey and Frank Agyei shared useful contacts and research insights into the charcoal commodity chain from the Danish-funded 'AX' project.

Field surveys were carried out diligently by 20 students from the University for Development Studies in Tamale, under the management of Mubarick Issahaku, Richard Atuna and Mutala Issah.

The team would also like to acknowledge the generous support provided for preparation of the Report by the PROGREEN Trust Fund.

Photo credits: Yann François, except where otherwise stated.

Cover photo: Central market, Tamale, Northern Region.


M-18-UW
8489
NANA
WEFO

Executive Summary

Study background

The consumption and production of woodfuels in Ghana is widely recognized for its contribution to national energy supply and its significance for rural livelihoods. Although the percentage share of woodfuels in the national energy mix fell from 70% to 35% between 1990 and 2019, with a major shift towards fossil fuels, demand for woodfuel is still increasing in absolute terms because of population growth. Firewood or charcoal are the main cooking fuel for 4.5 million households (HHs) and woodfuels are also widely used for institutional and commercial catering, industrial processing and small enterprises.

The continued growth in woodfuel demand has led to concerns over environmental impacts. But the link between woodfuel consumption and loss of trees is not straightforward. Woodfuel extraction is deeply integrated with agricultural production. As population increase brings larger areas under cultivation, more wood is generated from land clearance. Tree cover is also reduced by timber harvesting, wildfires, mining and urban expansion. Sound policymaking for energy supply, agricultural development and sustainable environmental management requires better understanding of the complex interplay of these drivers of land cover change.

This study was commissioned by the World Bank and was carried out to, in part, inform investments under the Bank-funded Ghana Landscape Restoration and Small-Scale Mining Project (GLRSSMP), which seeks to “strengthen integrated natural resource management and increase benefits to communities” in the Northern Savannah Zone (NSZ) and central cocoa belt.

A data gathering mission took place during January and February 2022 to consult stakeholders and conduct field visits. A total of 552 charcoal producers were interviewed, and a price survey was carried out. Woodfuel demand in different sectors was quantified, mapped and overlaid on biomass supply. Computer modelling of ‘woodsheds’ around demand centres enabled hotspots of greatest imbalance between supply and demand to be predicted. Comparing time-series satellite imagery allowed land cover change to be mapped and quantified, and the contribution of woodfuel relative to other drivers of tree loss to be assessed. This study provides an analysis of the woodfuels sector in Ghana for policymakers and practitioners to address these issues, with recommendations addressing demand reduction, supply enhancement, fuel switching, and sector governance changes. Woodfuel demand was projected to 2030 under different scenarios, to compare impacts on tree cover. Proposals were made for interventions to maximise sustainability in the woodfuels sector, including supply- and demand-side actions, as well as institutional and regulatory measures.

Historical context

Following the first global oil price shock in the mid-1970s, interest in the sustainability of energy supply began to grow. Estimations of consumption of woodfuel (mainly firewood and charcoal) suggested that demand was going to exceed the sustainable supply from forest growth in many developing countries. This 'fuelwood gap' was predicted to dramatically affect the livelihoods of rural people and lead to deforestation on a large scale. Although the gap theory was debunked, the characterisation of a crisis based on a claimed relationship between woodfuel use and deforestation continues to receive prominence. More recently, the need to reduce dependence on fossil fuels and to mitigate climate change through the development of carbon sinks has reactivated interest in wood-based energy as a locally produced, low-carbon fuel, integrated in resilient landscapes and forest restoration strategies.

To reconcile these perspectives and to incorporate woodfuels in a modern, sustainable energy mix, policymakers need nuanced, landscape-specific assessments of the structure and dynamics of woodfuel value chains, the environmental implications of woodfuel extraction in comparison with other landscape dynamics, and an informed understanding of the current and future role of woodfuels in energy suppliesWoodfuel value chains and production dynamics

The study reveals that charcoal production in Ghana is moving northwards, and that the Kintampo area is currently a major hotspot. Production in sampled districts of the NSZ is dominated by four tree species naturally occurring in the landscape, with shea (*Vitellaria paradoxa*), dawadawa (*Parkia biglobosa*), mahogany (*Khaya spp.*) and rosewood (*Pterocarpus erinaceus*) accounting for 89% of species mentions by charcoal producers. Further south, greater species variety and use of farm-grown trees is recorded.

While 39% of charcoal producers surveyed declared that they source wood from natural forests, 53% source wood from land being cleared for farming, 29% from land already farmed and 20% from fallow land, confirming the significance of the interaction with agriculture. In Savannah and Upper West Regions, more than 60% of producers report sourcing wood from trees damaged by fire, indicating the additional importance of fire in the north. Over 80% of producers in the NSZ report a significant drop in charcoal output in the dry season, when hard ground makes kiln construction difficult. Further south, production is more balanced between the seasons due to less extreme weather variations.

Value chains for charcoal are more complex, but the industry is well-structured and functionally efficient, with stock outages unheard of. The value chain for commercial firewood has no more than three nodes from collector to customer. Charcoal production was historically dominated by the Sissala ethnic group but is now indigenised across all regions where it takes place. Along the charcoal commodity chain there is clear gender segregation, with women dominating all nodes except production and transport. Women also dominate the harvesting of firewood for subsistence use and commercial trade.

Charcoal is an important cash contributor to rural livelihoods, a gap-filler in slack agricultural seasons and a safety net in case of extraordinary needs. But charcoal is the largest source of income for only 29% of producers surveyed, indicating widespread part-time and seasonal involvement. Charcoal prices average GH¢ 0.5 (US$ 0.07)/kg at the kiln and GH¢ 2.4 (US$ 0.32)/kg at retail in Accra. Wood costs ~GH¢ 0.11 (US$ 0.015)/kg for bulk purchase in the NSZ.

Regulatory environment

Ghana's Energy Commission (EC) is mandated to licence the production, transport, storage and supply of woodfuels, although only the licensing of charcoal exports has so far been operationalised. A permit from the Environmental Protection Agency (EPA) is meant to be obtained before felling any tree. The Forestry Commission (FC) also has the authority to control tree felling 'off-reserve'. But the practical experience reported by most of those involved in extracting woodfuel is that trees can be harvested without reference to central government agencies. Access and control are usually decentralised to traditional authorities, with chiefs acting as custodians of the land and the gatekeepers to trees. While this ensures clear terms of access, it has not resulted in sustainable management of the resource base. This is partly because dead or fire-damaged trees can usually be harvested without chiefs' permission.

The FC manages a system of Charcoal Conveyance Certificates (CCC) for charcoal transport, but these capture only an estimated 17% of charcoal. District Assemblies also charge a fee for the outbound transport of woodfuels, but the collection rate for charcoal is below 45%. Opportunities to raise significantly more revenue from woodfuel are therefore being missed.

Government capacity is insufficient to enforce the legal controls on woodfuel that currently exist. Proposed measures for additional industry regulation could have the opposite of the desired effect and push commercial players further outside state control, while penalising ordinary consumers with higher energy costs.

Woodfuel demand

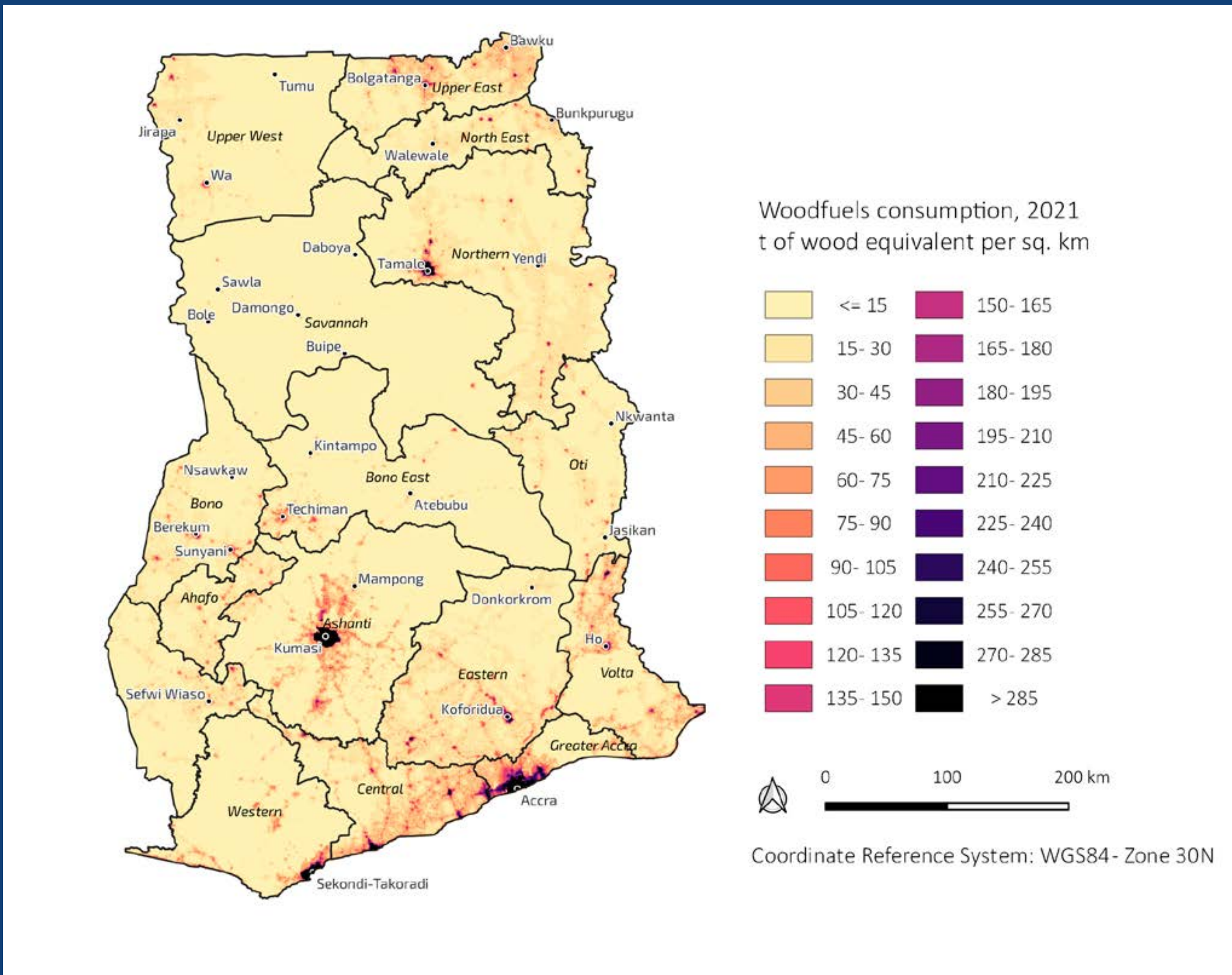
Total annual woodfuel demand is estimated at just under 14.9 million t in wood-equivalent:

Sector		Fuel	Woodfuel demand (t/yr, wood-equivalent)
Cooking		Firewood	6,799,414
		Charcoal	5,572,863
Industry	Brewing	Firewood	924,000
	Fish smoking		225,000
	Shea processing		60,448
	Gari processing		443,000
	Rice parboiling		442,000
	Palm oil processing		380,000
Exports		Charcoal	50,400
		Total	**14,897,125**

Of the woodfuel used for cooking, an estimated 777,000 t (wood-equivalent) is consumed annually in institutions (mainly schools) and 643,400 t in commercial food outlets. Consumption in some industrial processes merits further investigation, e.g., production of bricks and ceramics. An estimated 8,400 t of charcoal p.a. (50,400 t in wood-equivalent) is exported, mainly to Gulf states. 93% of these exports bypass the EC's licensing system.

The spatial distribution of wood demand is shown below:

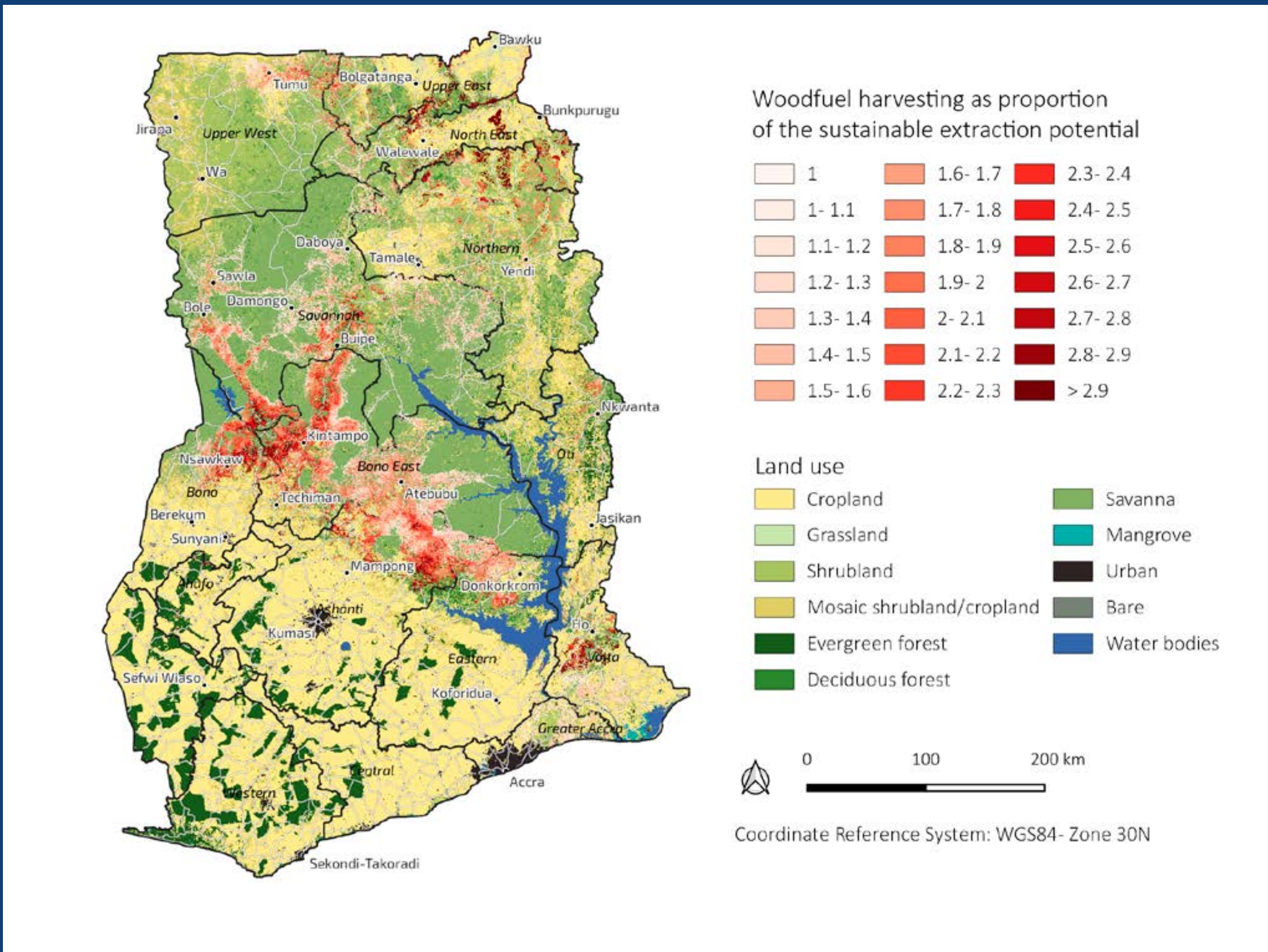
Distribution of woodfuel consumption for cooking, industry and exports



Impacts of woodfuels on tree cover

It is estimated that (15%) of the total national wood demand is being harvested in excess of the mean annual increment (MAI) in the areas where it is sourced. The map below indicates the areas where pressure from wood extraction exceeds sustainable levels. The key hotspots from the modelling match those flagged by previous studies, with the Kintampo and Atebubu areas being especially significant. Additional areas further north in the NSZ are also coming under increasing pressure.

Woodfuels pressure map, indicating areas of unsustainable harvesting (2021)



The study also confirms that woodfuel production is deeply integrated with agricultural production and in turn with population growth. The number of trees removed is often dictated more by the requirements of farm expansion than by charcoal production. Tree cover in woodfuel source areas is also reduced by timber harvesting, wildfires, mining and urban growth. The interaction of multiple drivers makes it difficult to quantify the extent of tree removal attributable to woodfuel. The fact that trees are used for firewood or converted to charcoal does not necessarily mean that they were felled specifically or even primarily for that purpose.

Woodfuel demand projections were made to 2030 under both a 'business as usual' (BAU) scenario and a second scenario with accelerated fuel switching and efficiency improvements in charcoal production and fuel use. The modelling suggests that the demand for woodfuel might grow by 2.14 million t p.a. (14%) by 2030 under the BAU scenario, while interventions may reduce this by 3.24 million t (-19%) against the BAU projection and by 1.09 million t (-7%) against current demand.

Overlaying these demand projections onto current potential biomass supply shows that the level of unsustainable harvesting may rise by 59% by 2030 under the BAU scenario. With the interventions described, the level of unsustainable harvesting can be reduced by 19% compared to the current situation and by 49% compared to the BAU projection.

There is a need for much better sector data, especially on biomass stocking and MAIs on land outside forests, and on land cover change over time. This would improve the accuracy of future supply/demand analyses and provide a better understanding of the drivers of tree loss.

Intervention options

Between 2021 and 2030, the population of Ghana is expected to grow by 19%. **Containing population growth** would be the single most effective way to limit woodfuel demand and to reduce rates of tree loss, because it would directly affect the rate of expansion of farmland. The study recommendations focus on the following **four additional areas**, to maximise the sustainability of woodfuel value chains:

1. Increase supply of woody biomass;
2. Support cleaner and more efficient woodfuel use;
3. Promote alternative energy sources; and
4. Strengthen the enabling framework for sustainable woodfuels.

1 Increase supply of woody biomass

Assisted natural regeneration (ANR) is a flexible approach to forest landscape restoration based on natural regeneration from seedlings, sprouts and stumps. In dryland environments such as northern Ghana, ANR is a more cost-effective way to restore tree cover than new planting. It is recommended that ANR is promoted in the GLRSSMP, incorporating fire control measures and enrichment planting to boost natural biomass stocks.

Agroforestry integrates multi-purpose trees in mixed farming systems. An intensive program of support for agroforestry is recommended in the GLRSSMP, integrating multi-use tree and shrub species on farms, along boundaries and around homes, from which wood for fuel will continuously regenerate.

Energy woodlots are widely promoted to address woodfuel supply. But financial modelling of a woodlot managed for charcoal in the NSZ reveals negative returns under the most realistic scenario. This approach is also detached from the contextual complexities of charcoal production, fails to reflect previous poor outcomes, lacks clarity over who is to be involved and their motivations for engaging, and gives insufficient consideration to impacts on the poor and most vulnerable. Further support for energy woodlots is therefore not recommended.

Improving the efficiency of wood carbonisation can improve the energy balance, reduce greenhouse gas emissions, improve charcoal quality and save time for producers. Uptake of improved kilns remains low due to technology costs, a lack of appropriate skills, the unsuitability of promoted designs for local contexts and a lack of institutional frameworks to incentivise efficiency. A program is recommended to improve the design, operation and management of earth kilns for charcoal making, focusing on raising knowledge and skills, rather than promoting new kiln technologies.

2 Support cleaner and more efficient woodfuel use

Programs to promote improved cookstoves have under-performed due to inconsistent quality, high cost and supply-driven approaches that pay insufficient attention to consumer needs and preferences, and to the long-term financing and growth of the companies involved. There is an opportunity to promote the next generation of high-performance cooking appliance for HHs and catering enterprises. The World Bank-supported National Clean Cooking Strategy will increase the availability of improved charcoal stoves, but is not of sufficient scale. There could be annual demand for at least 650,000 improved HH charcoal stoves. A more **ambitious and scaled-up program to promote high-tier charcoal stoves** is recommended, targeting HHs and commercial users. This should include working capital for manufacturers, importers and distributors, support for marketing and promotion, consumer preference and market intelligence studies, capacity development challenge funds and microloans for stoves. Regulations on stove standards should be finalised and enforced, quality labelling should be introduced and import duties and VAT on high-tier stoves should be removed.

A **program to upgrade institutional catering** is also proposed, given that the majority of kitchens in institutions such as schools, hospitals and prisons use firewood as their main fuel, often in traditional hearths that are wasteful, polluting and harmful to health. This should include awareness-raising and training for school administrators, caterers and cooks, alongside marketing and promotion of clean cooking technology, and a credit scheme to facilitate kitchen upgrades and stove purchase.

3 Promote alternative energy sources

The consumption of liquified petroleum gas (LPG) has been rising steadily in Ghana and the Government aims for LPG to be the main cooking fuel in 50% of HHs by 2030 (up from 37% in 2021). Even allowing for the blended use of multiple fuels ('fuel stacking'), wider adoption of LPG can contribute to a reduction in woodfuel demand and indoor air pollution. But the cooking cost comparison currently favours charcoal due to global pressure on fossil fuel prices, devaluation of the Ghana currency and high inflation. **Financial support to LPG consumers** is required if the Government is to stay on track to meet the 2030 target. For example, it may be feasible to waive certain taxes on LPG; targeted subsidies could support poorer LPG users through vouchers or direct payments; and a credit scheme could be considered for quality-assured LPG stoves and fittings. If LPG pricing was also deregulated, then innovations like pay-as-you-go technology and commercial cylinder distribution could potentially develop.

Up to 1.8% of Ghanaian HHs use electricity in their cooking energy mix, despite no official promotion or support. There could be significant untapped potential for 'e-cooking', especially with LPG facing challenging economic headwinds. It is recommended that the Government formulates a **national e-cooking strategy and plan**, offers **fiscal incentives to manufacturers and importers of electrical cooking appliances,** and introduces **promotional programs for selected devices** such as rice cookers and pressure cookers. To facilitate e-cooking at scale, there is a longer-term need for **grid extension, densification and stabilisation.**

4 Strengthen the enabling framework for sustainable woodfuels

Despite woodfuel being a prominent source of energy in Ghana, there are no reliable data on trade volumes and prices. There is a need for a **comprehensive and consistent data gathering and dissemination system for woodfuels.** Regular woodfuel market surveys should be re-introduced by the EC. Charcoal flows within and between districts should be better monitored, with an **improved and expanded application of the CCC system** to capture revenue from all transported charcoal, even small loads. Further **research on fuel stacking** is needed to better understand its impact and relevance for policy. Questions on secondary and tertiary cooking fuels should be introduced in all Government surveys and censuses.

Data on biomass stocking and growth rates is unreliable outside forests, especially in areas of sparse canopy cover. It is recommended that the FC undertakes a thorough empirical **assessment of biomass stocking and MAIs from trees outside forests,** especially in the drier northern regions, to improve the accuracy of supply-side data.

There is almost no consistent, ground-truthed time series data on land cover changes in Ghana, hence scant knowledge of the drivers of those changes. It is recommended that the Government **publishes satellite-derived land cover data, regularly updated** using consistent classification algorithms. The **raw data should be made publicly available** to facilitate cooperative efforts to identify and address key trends and issues.

There is weak collaboration and institutional coordination between the agencies responsible for woodfuels: the EC, FC, EPA and Ministry of Food and Agriculture. Greater **clarity is needed on respective institutional mandates** for policy and regulatory development, law enforcement, revenue collection, research and data gathering and dissemination, to avoid duplication and more effectively manage the development and use of woodfuels. Given the role of traditional authorities in managing access to land and resources, there is a need for the FC and EC to **collaborate more closely with district assemblies and traditional authorities** when formulating strategies, management priorities and interventions in woodfuel value chains. **District charcoal forums should be supported** in the main charcoal-producing areas under the GLRSSMP.

Ghana's approach to woodfuel regulation has its origins in a deforestation narrative and promotes a combination of technology and regulation intended to protect the environment. But given the interplay of drivers of forest loss, controlling woodfuel extraction would have only a limited effect on unsustainable tree removals. Enforcement of tighter regulation is also unrealistic and will increase energy costs for consumers. There is a need for **regulatory rationalisation for woodfuel** based on more achievable targets and implementable actions. It is recommended that the Government conducts an **inter-agency review of laws and regulations** pertaining to woodfuels, for workability and realism, revoking those that are unenforceable and streamlining the remainder to a minimal set of implementable measures. There is then a need to **enforce the remaining regulations with greater consistency and efficiency,** especially CCCs and charcoal export permits.

Table of Contents

Acronyms and Abbreviations

AGB	above-ground biomass
ANR	assisted natural regeneration
BAU	business as usual
CCC	Charcoal Conveyance Certificate
DFI	Department of Factories Inspectorate
EC	Energy Commission
EPA	Environmental Protection Agency
EPC	electric pressure cooker
ESA	European Space Agency
FC	Forestry Commission
FFB	fresh fruit bunch (oil palm)
GH¢	Ghana Cedi
GhaFFaP	Ghana Federation of Forest and Farm Producers
GLRSSMP	Ghana Landscape Restoration and Small-Scale Mining Project
GoG	Government of Ghana
GRA	Ghana Revenue Authority
ha	hectare
HAP	household air pollution
HH	household
ICS	improved cook-stove
IRR	internal rate of return
KPT	kitchen performance test
LPG	liquified petroleum gas
LULC	land use and land cover
MAI	mean annual increment
MoFA	Ministry of Food and Agriculture
NAMA	Nationally Appropriate Mitigation Actions
NLPGPP	National LPG Promotion Program
NPA	National Petroleum Authority
NPV	net present value
NSFP	National School Feeding Program
NSZ	Northern Savannah Zone
ORGIIS	Organization for Indigenous Initiatives & Sustainability
SNEP	Strategic National Energy Plan
t	metric ton
UDS	University for Development Studies

01 Introduction

1.1 Context for the analysis

Trees have been a source of energy since the beginning of human civilization. With the development of fossil fuels in the 19th and 20th centuries, the use of wood for energy declined in many parts of the world and became seen as retrogressive. But from the mid-1970s, following the first global oil price shock, interest in the sustainability of energy supply started to grow. More recently, the need to reduce dependence on fossil fuels and to mitigate climate change through the development of carbon sinks has reactivated interest in wood-based energy as a locally produced, low-carbon fuel, integrated in resilient landscapes and forest restoration strategies.

To incorporate woodfuels[1] in a modern, sustainable energy mix, policymakers need nuanced, landscape-specific assessments of the structure and operation of woodfuel value chains, the environmental implications of woodfuel extraction in comparison with other landscape dynamics and an informed understanding of the current and future role of woodfuels in energy supplies. This study provides an analysis of the woodfuels sector in Ghana for policymakers and practitioners to address these issues, leading to recommendations addressing demand reduction, supply enhancement, fuel switching and changes to policies, regulations and data gathering and dissemination.

1.2 A historical perspective on woodfuels

1.2.1 1970s: The 'woodfuel gap'

In the mid-1970s, estimations of woodfuel consumption suggested that demand was going to exceed the sustainable supply from forest growth in many developing countries. This supposed 'fuelwood gap' would affect the livelihoods of rural people and could be *"the most profound ecological challenge of the late 20th century"* (Eckholm, 1975). Articles such as *"Shortage of Firewood Reaching Crisis Level In the Third World"* (Frankel, 1984) and *"Fuelwood: Energy crisis of the poor"* (Leistner, 1984) are representative of the prevailing discourse, which led to a multi-decade long discussion on the impacts of woodfuel use on deforestation (Anderson & Fishwick, 1984). To tackle the anticipated woodfuel shortages and associated threats, development actors promoted fuel switching, energy-efficient cooking stoves and dedicated woodfuel plantations to enhance supply.

1.2.2 1980s and 90s: New perspectives

The expected switch to 'modern' fuels did not materialise at scale, given factors such as the cost of new stoves and fuels, safety concerns and cultural preferences. Programs supporting woodfuel plantations were largely unsuccessful, due to unfavourable economics and lack of access for the people intended to benefit from them. At the same time, population growth and migration to urban areas continued to drive a global increase in charcoal consumption.

1 'Woodfuels' are defined as all types of biofuels originating directly or indirectly from woody biomass (FAO, 2004). For this assessment, the term refers more specifically to firewood and charcoal. Agricultural residues are not included.

As these dynamics led to increasing demand for wood-based energy, which in theory would have massively widened the 'gap', it also became clear that the extraction of wood for fuel was not in fact the main force driving deforestation in many regions. Partly this is because firewood for domestic cooking is generally collected close to the point of consumption, and a significant portion comes from trees, shrubs and bushes that can regenerate (Maes & Verbist, 2012). Further significant quantities of woodfuel come from residues from land cleared during agricultural expansion (Arnold et al., 2006).

If there was any supply gap, then considering the significant population growth and urbanisation being experienced, that gap should have become very much worse, but it did not. There were clearly dynamics not fully captured by the supply-demand equations, especially regarding biomass supply from trees outside forests. One highlight was when an *"additional 7 billion 'extra' trees were discovered in Africa"* (Fleming, 2021) simply as a result of better counting methodologies. The growth rates of the biomass used to produce charcoal were also routinely underestimated. And in many instances, harvesting cycles were shortening over time, meaning that mean annual increment (MAI) rates were increasing. Woodfuel users responded to price signals by reducing consumption, challenging the assumption that demand was fixed.

Critical voices had already begun to question the gap theory, the 'crisis' characterisation and the relationship between woodfuel use and deforestation. One paper from 1990 concluded that *"As the literature on fuelwood in Africa has increased in quality in recent times, it has become evident that generalizations about Africa's 'fuelwood crisis' need to be treated with great caution. As a consequence, some commonly held (or 'orthodox') beliefs may now need to be re-examined"* (Cline-Cole et al., 1990). Bradley and Campbell (1998) argued that *"...woodfuel problems are localized, complex in their origins and dynamics; and collectively do not amount to a woodfuel 'crisis'. Woodfuel shortages are not necessarily linked to deforestation, nor can they be addressed simply by planting trees. Gap theory simplifies and obscures the individuality of woodfuel supply and demand balances and should be abandoned."*

Changing understandings led in the 1990s to the development of participatory forest management and community forestry concepts, in which woodfuel was one component (but rarely the primary focus) of integrated forestry interventions (Arnold et al., 2003). The discourse around sustainability shifted from woodfuel supply to switching to 'modern' sources of energy like liquified petroleum gas (LPG)[2] or electricity (Arnold et al., 2006).

1.2.3 2000s onwards: Indoor pollution and climate change

More recently, woodfuel debates have focused on the need to reduce household air pollution (HAP). Burning solid biomass in simple, small-scale devices can release significant amounts of particulate matter, carbon monoxide and other pollutants, affecting women and children in particular. WHO findings rank upper respiratory infections and TB as the second largest disease burden in Africa in terms of Disability-Adjusted Life Years (Roser et al., 2021).

According to the UN Sustainable Development Goals, the share of households cooking with clean cooking fuels and technologies increased from 57% in 2010 to 69% in 2020 (United Nations, 2022). Despite this progress and the attention the issue has been receiving, 2.4 billion people worldwide still rely on wood, coal, charcoal or animal waste for cooking and heating (ibid.) the majority of it used in traditional ways that are inefficient and polluting.

The debate between the need to accelerate the switch to modern fuels and the need to burn biomass in cleaner appliances remains (Simon et al., 2014). Those who frame woodfuels as a cooking and health issue tend to promote a switch to LPG, while energy/environment stakeholders are more likely to promote improved stoves and sustainable

2 LPG is a fuel gas which usually contains a flammable mixture of propane and butane, derived from crude oil refining or natural gas processing and liquefied through pressurization for convenience of transportation and storage.

woodfuel sourcing (Smith, 2015). The high-profile Clean Cooking Alliance is at the centre of these debates and supports a switch to LPG and improved biomass cooking, depending on the context.

Renewed interest in woodfuel and cooking stoves has also been prompted by the development of carbon finance, which has become an important source of funding for clean energy projects. The calculation of the contribution of cooking stoves to carbon dioxide (CO2) emissions is complex, but the development of methodologies based on simplified calculations of the fraction of non-renewable biomass (fNRB) generally leads to high estimates of emissions reduction potential, often significantly higher than more rigorous approaches (Bailis et al., 2005). Carbon finance has been used to catalyse many projects in the field of biomass cooking, including some where the objective of generating carbon credits arguably over-rides the quality of the cookstoves being disseminated and the sustainability of the business model.

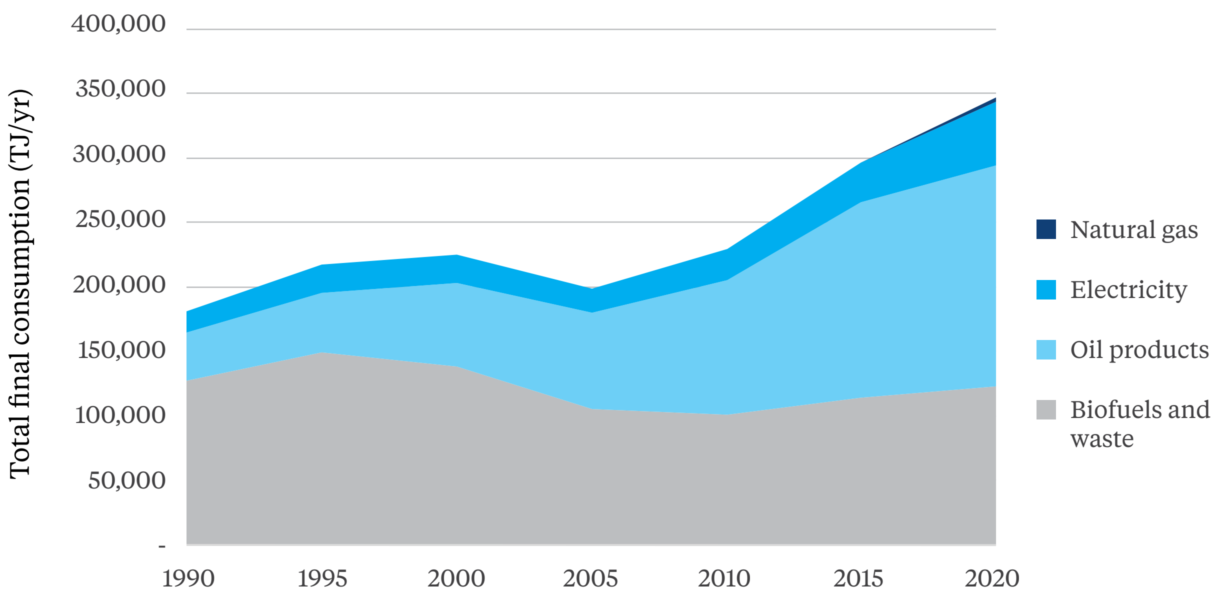
1.2.4 Historical summary

Despite changing priorities over the last 40 years, the negative characterisation of woodfuels has changed very little. The narrative around supply gaps, woodfuel crises and deforestation prevails in public discourse, despite the evidence pointing to a counterfactual. In large part this is because certain parameters used for measuring and modelling woodfuel supply and demand continue to be incomplete or inaccurate, perpetuating misleading conclusions. There is a need for better understanding of woodfuel dynamics to inform more appropriate policies and approaches, to which this study hopes to contribute.

1.3 The woodfuels sector in Ghana

The consumption and production of woodfuels in Ghana is widely recognized for its significance for household energy supply and rural livelihoods. While the share of woodfuels in Ghana's total energy consumption is relatively low in comparison with most other countries in Sub-Saharan Africa, and has been falling, demand is still increasing in absolute terms because of population growth. Woodfuels accounted for 70% of total final energy consumption in 1990, but this had halved to 35% by 2019 (IEA, 2022), due mainly to a massive increase in demand for oil products (see Figure 1). The shift towards fossil fuels was driven by a five-fold increase in energy use in the transport sector.

Figure 1. Ghana total final energy consumption by source, 1990 to 2019



Source: (IEA, 2022). The category 'biofuels and waste', in Ghana's case, refers almost entirely to woodfuels.

The reduction in the contribution of woodfuels is also evident from the most recent (2021) national census, which reveals that the proportion of households (HHs) using firewood or charcoal as their main cooking fuel declined from 73.9% in 2010 to 54.3% in 2021 (Ghana Statistical Service, 2012, 2022). This was accompanied by a doubling in the percentage of HHs using LPG as their primary fuel, from 18.2% to 36.9%. But the census did not capture the significant use of firewood or charcoal as supplementary cooking fuels (known as 'fuel stacking'). And with a 25% rise in Ghana's population over the same 11-year period, the demographic forces driving total energy demand are relentless.

So despite the significant falls in the percentage share of woodfuels in both the national energy mix and in HH cooking, the consumption of energy derived from wood barely changed between 1990 and 2019, according to IEA data (IEA, 2022). And even with the fall in the proportion of HHs using woodfuels as their primary cooking fuel, firewood or charcoal was still the main fuel for 4.53 million HHs in 2021, up from 4.04 million HHs in 2010 (Ghana Statistical Service, 2012, 2022). Woodfuels are also still widely used for institutional and commercial catering, industrial processing and small enterprises such as fish smoking, traditional brewing and shea processing. For thermal applications such as this, woodfuel continues to offer a familiar, accessible and cost-competitive energy option.

So while there is a shift underway in Ghana from bioenergy towards fossil energy, the demand for woodfuel continues to rise.

This growing demand for woodfuel has led to concerns over impacts on tree cover and the security of future supplies. The National Energy Policy (2010) asserts that "the exploitation of biomass for energy purposes results in deforestation" (Ministry of Energy, 2010, p. 26) and the charcoal sector is specifically identified as a "major driver of deforestation" (Ministry of Energy, 2019a, p. x). The National Bioenergy Action Plan (2020-2030) highlights a need for "afforestation programs and improved cookstoves … to curtail or limit potential deforestation threats" linked to woodfuel use (Ministry of Energy, 2019b, p. 45).

But the link between woodfuel production and loss of trees is not straightforward. Woodfuel supply is deeply integrated with the agricultural production system. As population increase brings larger areas under cultivation and reduces fallow periods, more wood is generated from land clearance. The current rate of agricultural expansion is unprecedented in Ghana's history, overrunning many other land cover types, including savannah, woodlands and forests (Ministry of Food and Agriculture, 2021). So the number of trees removed is often dictated more by the requirements of agricultural production than by charcoal production (Amanor et al., 2005). Tree cover in key woodfuel source areas is also reduced by timber harvesting and wild fires (Brobbey et al., 2019).

So it is difficult to quantify the impacts on tree cover specifically linked to woodfuel, because multiple drivers interact and few data exist on the specific causes of forest degradation (Amanor, 2021). There is also minimal information on the extent to which woodfuel is sourced from land which is actively farmed, land previously farmed, fallow land or uncultivated forests.

The Government of Ghana (GoG) has introduced measures to formalise and regularise charcoal production and trade, with the stated aim of making the industry environmentally sustainable (Brobbey, Kyereha, et al., 2021). But without more nuanced understanding and better data, policies that seek to address environmental degradation by controlling the harvesting and trade in woodfuels will have little impact on preserving tree cover. There is a need for better understanding of sector dynamics and the complex drivers of land cover change, especially the interactions between woodfuel extraction, agricultural expansion, logging, fire and urban growth, as the basis for developing sound policies concerning woodfuels.

1.4 Study objective

This analysis of Ghana's woodfuel sector was carried out to, in part, inform investments under the World Bank-funded Ghana Landscape Restoration and Small-Scale Mining Project (GLRSSMP) – see text box.

Ghana Landscape Restoration and Small-Scale Mining Project

The US$103 million, six-year GLRSSMP was approved in August 2021, with a Project Development Objective to "strengthen integrated natural resource management and increase benefits to communities in targeted savannah and cocoa forest landscapes" (World Bank, 2021). The GLRSSMP operates in 28 districts in Ghana's Northern Savannah Zone (NSZ) and central cocoa belt. The activities related to natural resources are coordinated by the Ministry of Environment, Science, Technology and Innovation, whose Environmental Protection Agency also has a partial implementation role, with additional responsibilities delegated to the Forestry Commission and the Ministry of Food and Agriculture. As part of a diverse package of interventions to support sustainable livelihoods and natural resource management, and building on the Government's fuel efficiency goals and AFR100 commitment to restore 2 million hectares (ha) of forest landscape in the NSZ, the GLRSSMP will assist communities in target districts in transitioning to more sustainable systems of woodfuel production, processing and consumption.

The objective of this assessment was *to determine the national woodfuel supply and demand situation in Ghana and to develop interventions for improving the sustainability of the sector.* Though national in scope, the recommendations were to focus especially on the GLRSSMP target areas. The target audience includes the GLRSSMP implementing agencies (especially the Forestry Commission, Environmental Protection Agency and Ministry of Food and Agriculture), Energy Commission, as well as energy practitioners and policymakers more generally.

1.5 Approach

The assessment was carried out by a team of four specialists in bioenergy and wood supply/demand modelling. A country mission took place during January and February 2022 to consult relevant stakeholders, gather data and conduct field visits in the NSZ and cocoa belt. A list of people consulted is in Annex A and a bibliography in Annex B.

A survey of 552 charcoal producers was commissioned through the University for Development Studies (UDS) in Tamale. UDS carried out simultaneous research into woodfuel pricing and units of sale. Woodfuel demand in different sectors was quantified and mapped. Demand data was overlaid on biomass supply, both inside and outside forests. Computer modelling of 'woodsheds' around demand centres enabled hotspots of greatest imbalance between supply and demand to be predicted and mapped. Comparing satellite imagery from 2016 and 2020 also allowed land cover change to be mapped, and the contribution of woodfuel relative to other drivers of tree loss to be quantified. Woodfuel demand pathways were projected to 2030, under both business-as-usual and sector intervention scenarios, to compare their impacts on tree cover. Proposals were made for interventions to address supply/demand imbalances and maximise sustainability in the woodfuels sector, including institutional and policy measures. The full study methodology is outlined in Annex C. The UDS survey results are quoted throughout, with maps and supporting data in Annex D.


On behalf of
Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety
of the Federal Republic of Germany
Forest Landscape Restoration
through a Sustainable
Wood Energy Value Chain Project
THIS IS A RESTORED SITE
No Bush Burning
No Logging
No Cattle Grazing
SOALEPE COMMUNITY
IUCN
giz

02 Woodfuel Value Chains

This section describes how woodfuels are sourced, processed, transported, traded and regulated in Ghana, with pointers to the types of interventions that could help maximise sustainability. A quantitative assessment of woodfuel demand and supply is provided in the chapters that follow.

2.1 Systems of access to wood

Traditional systems of authority remain strong in Ghana. Most areas are ruled by a paramount chief; under him are a number of divisional chiefs; and under these again are caretaker chiefs, known as *Odikro* (Brobbey, Hansen, et al., 2021). Women sometimes share chieftaincy positions with men and are referred to as queen mothers. These customary governance arrangements give chiefs a high degree of control over natural resources. They are the custodians of the land and the gatekeepers to trees, including trees to be harvested for fuel.

Community members may be granted access to trees at no monetary cost. 76% of charcoal producers surveyed for this assessment said that no cash payment was needed (Table 1). When payment was requested, it would typically be made to the chief (12%) or the landowner (10%).

Payment in kind is therefore dominant, with charcoal makers typically required to share 10-20% of their output with the chief or landowner. Migrants from other areas are more likely to be charged a cash fee for access. But monetary payment is also becoming increasingly common for locals. As one chief reported to Brobbey et al. (2021), "We could not distinguish between charcoal for a migrant and that of an indigene, and therefore came up with a 10% levy on charcoal produced by both indigenes and migrants."

Table 1: Do you have to pay someone to make charcoal here?

Region	No payment needed	Yes, payment needed, for kiln located on land of:							Total
		Another farmer	Chief	Family head	Forest Reserve	Government land (except FR)	Own land	Other	
Ashanti	70%	4%	24%	0%	1%	1%	1%	0%	100%
Bono East	85%	3%	11%	1%	0%	0%	0%	0%	100%
Eastern	88%	8%	3%	2%	0%	0%	0%	0%	100%
Savannah	79%	6%	16%	0%	0%	0%	0%	0%	100%
Upper West	54%	40%	0%	0%	0%	0%	5%	1%	100%
Overall average	**76%**	**10%**	**12%**	**0%**	**0%**	**0%**	**1%**	**0%**	**100%**

Source: UDS survey, 2022

Commercial firewood attracts lower access fees than charcoal, if any. GH¢ 5[3] is charged by chiefs in North East Gonja District (Savannah Region) for each truckload of firewood taken out of the area (Mohammed, 2021). Additional fees for traded firewood are usually payable to the District Assembly (see below).

Charcoal revenue has come to fill an important economic and political gap for chiefs, given that most subjects no longer render the kind of services that they used to in the past (Asante, 2019, p. 47). Charcoal (and to a lesser extent firewood) helps sustain chiefs' economic status, which is vital for upholding their power and authority. A study in Savannah Region revealed that almost 92% of respondents cited the traditional authority as the mandated institution responsible for regulating firewood harvesting (Mohammed, 2021). Failure to comply with chiefs' systems and conditions for accessing trees can result in sanctions, arrest or fines (Asante, 2019, p. 23). In Sissala West District (Upper West Region) chiefs impose fines (payable in cash or livestock) on community members who cut live 'economic' trees such as shea (*Vitellaria paradoxa*) and dawadawa (*Parkia biglobosa*) (UDS survey 2022).

Access arrangements controlled by chiefs keep bureaucracy to a minimum and there is reported to be a high rate of compliance, despite the growing threat to these systems from lack of legal backing and diminishing respect for traditional authority, especially in areas of ethnic and cultural diversity, and in areas becoming urbanised (Asante, 2021).

Fallen wood or trees that are dead or fire-damaged can usually be harvested without chiefs' permission, provided that the landowner has consented. Deliberate ringbarking or fire-setting might therefore be a way to circumvent the procedures applicable to live trees (Photo 1).

Photo 1. Tree burned then felled for charcoal on land cleared for farming, Liplime, Sissala West District, Upper West Region

Photo credit: Maxwell Kanyire Nyuor, UDS

3 Exchange rate 7.52 Ghana Cedi (GH¢) per US$, 30th March 2022.

Despite the high level of compliance with traditional arrangements for accessing trees, these systems have not ensured sustainable management of the resource base (Asante, 2019, p. 54). They operate effectively as a means of consolidating authority and generating revenue, rather than as a system that controls environmental degradation. "Where chiefs have established local taskforces, the activities of those task forces have been limited to revenue collection through the enforcement of charcoal fees. ... chiefs, in their present practices, seem to pay little importance to the sustainability of the tree stock" (Agyei, 2020).

Statutory bodies such as the Forestry Commission (FC) have a formal, legal mandate over resource governance and also seek to influence access and management. There is overlap in mandates and the potential for competition between traditional authorities and the FC over revenue from charcoal production (Asante, 2019, p. 49). But traditional authorities - as custodians of the land - are resilient and influential. Irrespective of policies and legislation from state institutions, chiefs' status, property rights and role in resource governance make them more powerful in controlling access. Politico-legal institutions must constantly engage in activities that promote acceptance of their authority by constituents, such as the provision of service (Agyei, 2021). For the FC and other government agencies, the enactment of regulations and collecting of fees does not confer institutional legitimacy; this requires those agencies also to provide meaningful support.

Traditional authorities can turn their power to their further economic advantage. For example, the claims made by the Government regarding charcoal's role in deforestation[4] can be used to justify the imposition of local bans in the name of environmental protection. For example, such a ban was introduced by the Savannah Regional House of Chiefs in May 2021.[5] It was praised by Council of State members from Northern, Upper East and Upper West Regions who said it would "bring an end to the destruction caused [by logging and charcoal burning] in the environment".

In practice, 'bans' simply mean a hike in fees, both formal and informal, not a moratorium on harvesting, so ultimately serve chiefs' and landowners' own interests (Asante, 2019, p. 12). The Savannah Region edict introduced a penalty charge of GH¢ 5 per bag of charcoal by the traditional authorities. In West Gonja (in the same Region) an additional GH¢ 10 per bag charge is now also imposed by the district authorities (UDS survey, 2022). But charcoal production continues. Producers in Bole District in the west of Savannah Region have simply moved deeper into the forested areas, up to 40 km from the nearest main road, to evade the tighter controls of the chiefs and the FC. This has predictably resulted in an increase in prices (UDS survey, 2022). Bans drive production into the shadow economy and increase costs for consumers, but have limited impact on total production when market demand remains unchecked.

2.2 Dynamics of woodfuel production

The preferred tree species for charcoal production are those with higher density, as they burn more slowly (Ministry of Energy, 2019a). The UDS survey revealed that charcoal production in Savannah and Upper West Regions is dominated by just four species, with shea, dawadawa, mahogany (*Khaya spp.*)[6] and rosewood (*Pterocarpus erinaceus*) accounting for 89% of 283 species mentions by producers (Table 2).

In regions further south, there is greater species variety. In Ashanti, while no example was found of shea being used (this being a dryland species), only 33% of mentions were of dawadawa, mahogany and rosewood, and an additional 43 species were named (see Annex D for full species list). The species variety in Bono East is even higher, so although 52% of mentions came from the four leading species, 48 other species were named for charcoal production. The range here is much wider than in the NSZ, perhaps in part due to higher natural diversity and maybe also

4 The Minister for Lands and Natural Resources has described charcoal as a "major driver of deforestation" www.riddimsghana.com/general/charcoal-export-faces-ban-blamed-for-forest-degradation/

5 www.primenewsghana.com/business/chiefs-ban-charcoal-burning-logging-in-savanah-region.html

6 Mahogany in the NSZ refers to *Khava senegalensis*, but the name is applied to a number of other Khaya species. In the Transition Zone it may refer to *K. grandifoliol*a and in the high forest zone to *K. ivorensis*.

Table 2. Mentions of tree species used to make charcoal

Region	Shea		Dawa dawa		Mahogany		Rosewood		Other		Total mentions	
Ashanti	0	*0%*	12	*6%*	14	*7%*	39	*20%*	126	*66%*	191	*100%*
Bono East	40	*11%*	47	*13%*	50	*14%*	50	*14%*	172	*48%*	359	*100%*
Eastern	35	*29%*	24	*20%*	28	*24%*	6	*5%*	26	*22%*	119	*100%*
Savannah	33	*23%*	41	*29%*	30	*21%*	13	*9%*	25	*18%*	142	*100%*
Upper West	59	*42%*	34	*24%*	19	*13%*	23	*16%*	6	*4%*	141	*100%*
Total	**167**	***18%***	**158**	***17%***	**141**	***15%***	**131**	***14%***	**355**	***37%***	**952**	***100%***

Source: UDS survey, 2022. Multiple responses permitted. For breakdown of 'other' see Annex D.

suggesting that the preferred trees are harder to obtain, so producers are prepared to use whatever material is available.

In Kwahu Afram Plains District in Eastern Region, the desired local charcoal trees such as *Danielia oliveri, Milicia spp.* and mahogany have been eliminated and less desirable species such as neem (*Azadirachta indica*) and commercial trees such as shea are used instead (UDS survey, 2022). Research in Ghana's central deciduous zone (around Kumasi) and in the coastal savannah has recorded a significant shift in the tree species used for firewood over the last 20 years, away from commercial timber species and towards fruit and exotic species that would previously have been perceived as lower grade options (Amoah et al., 2015).

Bans on the use of certain species for charcoal are largely ineffective, as it is still permissible to remove trees while opening up land for farming. It was reported in Kintampo South District, for example, that it is prohibited to cut certain trees such as shea and dawadawa in fallow lands, but they may be freely removed from land that is already farmed or due to be cleared for farming (UDS survey, 2022). This opens up the possibility of clear-felling whatever trees remain on the land, if it is done in the name of farm expansion.

In Kwahu Afram Plains South (Eastern Region), farmers report cutting down all trees before cultivating staple crops like yam and maize to maximise sunlight, and because crops grow well on lands where charcoal has been produced because the soil is enriched with nutrients. So "agriculture is influenced positively while the ecosystem is suffering" (UDS survey, 2022). While some farmers generate wood in this way during clearing of their land, others make charcoal in fallow lands and (illegally) in Forest Reserves. In these cases, respondents reported it likely that the primary objective is to extract timber, with charcoal a subsidiary product (ibid.). The producer survey in Bole District (Savannah Region) revealed the use of residues from commercial logging for charcoal production in off-Reserve areas (UDS survey, 2022). In Soalepe, Gonja West, Savannah Region, it was found during a site visit that logs with less than a 9-foot length of red heartwood are discarded by loggers and can be salvaged by charcoal burners free of charge.

2.3 Structure of the value chain

The value chain for subsistence **firewood** follows a pattern familiar across the continent and involves self-collection by users, mainly women and children, for their own domestic cooking. Dead wood or branches are selectively harvested. The value chain for commercial firewood is more complex. Firewood reaches the market via donkey carts, Motor Kings[7] and trucks, usually with three nodes (from collector to trader, trader to wholesaler and wholesaler to customer). The wholesaler is omitted for direct delivery to bulk customers such

7 'Motor King' is the leading brand name of the motorised 3-wheeled vehicles that have become ubiquitous in Ghana for short-distance haulage.

as schools or restaurants. Such a case was found at Balwo-Kayilo in Upper East Region, where members of the Zuregalu Women's Cooperative make direct sales of wood to commercial food outlets in Paga and Navrongo. Haulage distances for firewood tend to be short, as it is not cost-effective to transport firewood over long distances because it is difficult to pack densely and has only half the energy content per kg of charcoal.

The value chain for **charcoal** is more complex and the distance from source to consumer tends to be much greater. The simplified charcoal value chain is summarised in Figure 2.

Figure 2. Simplified representation of charcoal value chain

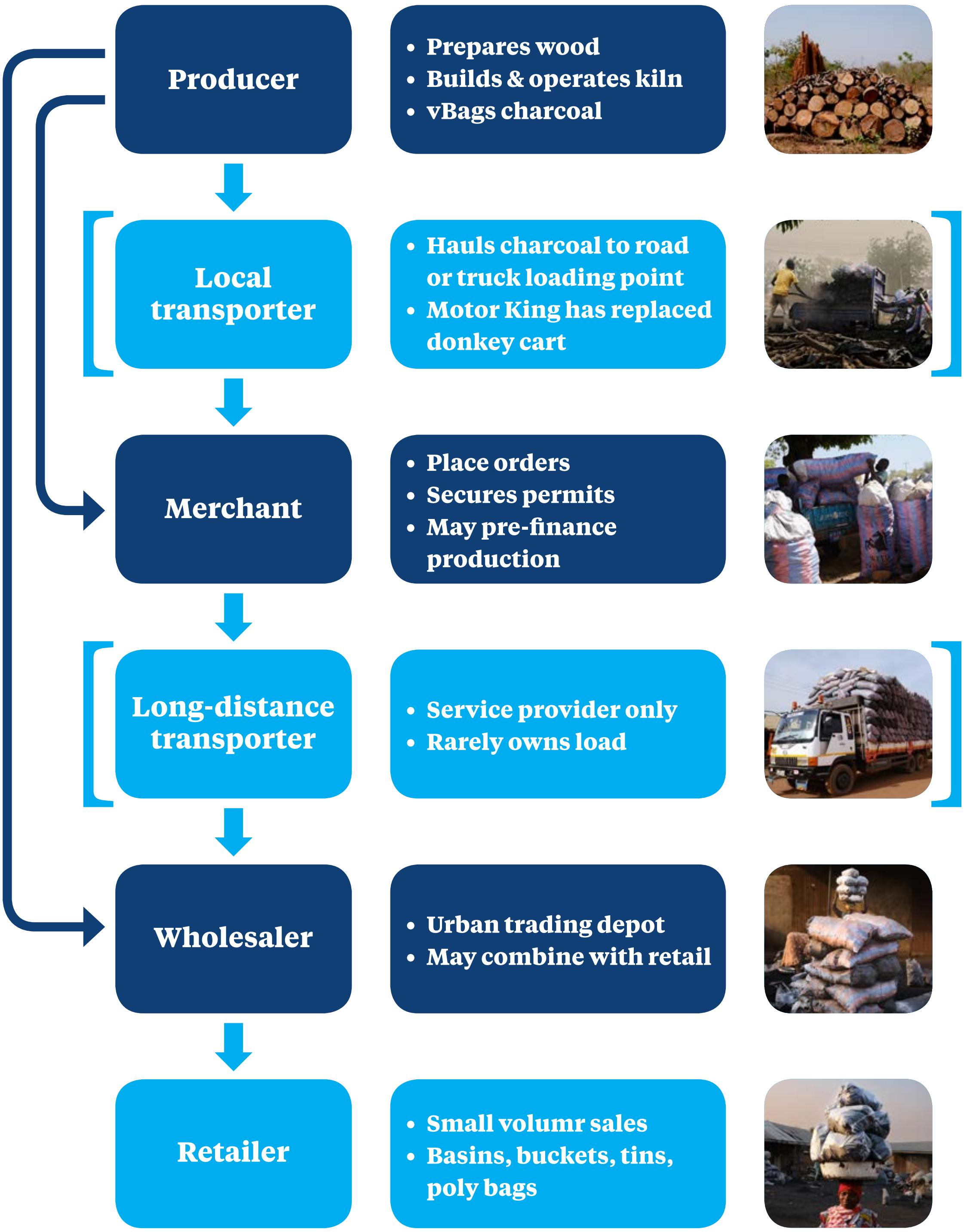


Photo 2. **Charcoal retailer in Tamale, Northern Region**

Transporters are frequently portrayed in the literature as functional actors in the value chain, but in practice they rarely take ownership of the charcoal; they provide a contracted haulage service charged by distance and quantity, paid for by the merchant or wholesaler.

The functional actors are the producers, merchants, wholesalers and retailers. Short profiles are given in the text box below from the February 2022 field visits. There is considerable variety and overlap: larger producers may deal directly with urban wholesalers and cut out the merchant; producers may trade locally at the roadside and sell in small quantities to passing vehicles, rather than to organized merchants; merchants may own urban wholesaling depots rather than selling on to others; and wholesalers may conduct retail sales, by breaking down large sacks into buckets, bowls, tins and plastic bags.

It is sometimes claimed that certain actors in the charcoal value chain use their dominant position to make disproportionate profits. Agyei et al. (2018) observe “a general pattern ... whereby particular groups of actors, notably merchants, wholesalers and transporters, reap the larger share of charcoal profit”. With profits said to be concentrated in the hands of these groups, “the producers and the consumers [are] suffering” (Ministry of Energy, 2019a, p. 120). It is claimed that “merchants utilize producers’ need for credit to dictate the price” and that “the price of charcoal when sold to wholesalers and retailers is also dictated by the merchants” (Agyei et al., 2018). If this was true, then it would endow merchants with a unique degree of control over their own margins, with the ability to dictate both the price they pay and the price at which they sell. In practice they are unlikely to wield such power.

It is certainly the case that merchants frequently pre-finance the fees to chiefs, landowners, chainsaw operators (if used) and labourers (for wood stacking and soil covering). Traders also pay FC and District Assembly fees on transported

The producer: A local man from Soalepe in West Gonja Municipal District has identified the locations of timber offcuts discarded by illegal loggers operating in a nearby Forest Reserve. The loggers discard split or deformed logs and those less than 9 feet long lacking commercial value. Given the risks associated with burning charcoal in the Reserve itself, he contracts a Motor King to bring the wood out to a location close to the main road, where he can pass it off as trees cleared from land being opened up for farming (to evade the 'ban' on charcoal production in Savannah Region). The wood is free and has been partially cross-cut, but he hires a chainsaw operator to finish the task. Transport of the wood costs GH¢ 30 (US$ 4.00) per Motor King load and two loads are sufficient for a small kiln that yields five bags of charcoal, which he sells for GH¢ 25 (US$ 3.30) each. The man has multiple kilns in operation. He enlists the help of two male labourers to build the kilns, as some of the logs are very large. A female relative completes the stacking, covers the wood with grass, softens and packs the soil, and manages the carbonisation process. He sells the charcoal a few hundred metres away to passing vehicles.

The local merchant: Women at Wulugu in North East Region sell charcoal along the main Tamale-Bolgatanga road. They buy it from producers to the east and west, who bring it to them in loose form in contracted Motor Kings. Each load costs GH¢ 350, from which they can fill 10 bags, equating to GH¢ 35 per bag. They sell the bags to passing vehicles at GH¢ 45-50 (US$ 6-6.60). After paying GH¢ 3 for the empty sack, GH¢ 0.5 for filling, GH¢ 0.2 for sewing string, GH¢ 0.5 for sewing and GH¢ 2 for the top 'wrapper', they are left with a profit of GH¢ 4-9 (US$ 0.50-1.20) per bag. The smallest chunks of charcoal are sold to blacksmiths for a little extra income. A Motor King can carry 15-20 bags of charcoal direct to Bolgatanga and cut the women out altogether, so the arrival of this technology has been a mixed blessing.

The wholesaler/retailer: Charcoal dealers (all female) interviewed in Tamale go to the weekly market at Palbe, around 50 km away, to buy their charcoal direct from producers, and rent space on cargo trucks heading back to Tamale in the evening. They pay GH¢ 40 (US$ 5.30) per bag at and sell them in Tamale @ GH¢ 60. (US$ 8) After paying GH¢ 2 to the council in Palbe for a trading ticket, GH¢ 2 to the chief, GH¢ 2 for loading and GH¢ 8 for transport, they are left with a profit of GH¢ 6 (10%) per bag. They also break the bags down into buckets and plastic bags for more profitable retail sale.

The national merchant: A Kia Rhino truck encountered at Jeffisi in Upper West Region had been contracted by a female merchant from Accra to transport a sizeable load of 440 bags to her own trading sites in Ashaiman and Achimoto. She had contracted groups of producers, pre-ordered the charcoal, supplied them with bags and secured the necessary 'community form' and FC Charcoal Conveyance Certificate. She fully controls her consignments right from source to customer. She pays the transporter GH¢ 15 (US$ 2) per bag for the 3-day journey, with an additional GH¢ 1 per bag for loading and GH¢ 2 for offloading.

charcoal, the cost of the transport itself (including the empty bags and the charges for filling, sealing, loading and offloading), as well as informal payments to police and other authorities manning checkpoints.[8] This leaves them financially exposed up to the point where they sell the consignment, and with this level of investment and risk there will naturally be higher rewards. But they do not

8 Police and customs services personnel at checkpoints take informal payments of GH¢ 2-5 per bag. Staff of the police Motor Transport and Traffic Unit also impose informal fines averaging GH¢ 50 per trip (Agyei et al., 2018).

Photo 3. Loose charcoal being offloaded for sorting and bagging at a local merchant's roadside trading site, Wulugu, North East Region

make disproportionate profits per unit, once their costs are deducted. And profiteering would in any case not be possible in such a competitive and price sensitive value chain, where prices are well established and margins are tight. This challenges the popular perception of exploitative merchants.

Actors at all stages are mutually reliant on those either side of them. Retailers, for example, cultivate relations with merchants and wholesalers to ensure frequent supplies and good quality charcoal (Agyei et al., 2021). Wholesalers maintain access to charcoal income through their relations with merchants, retailers and charcoal users, and through access to credit and storage spaces. Transporters with ties to large merchants are able to secure contracts throughout the year. Merchants have access to credit and information on production areas. It is a well-structured and functionally efficient industry, which delivers thousands of tonnes of fuel across the country every day via a highly evolved network, ensuring that stock outages are unheard of.

2.4 Woodfuel prices and economic contribution

As elsewhere in Africa, woodfuels in Ghana are sold by volume, not weight. There have been attempts to classify the most commonly occurring charcoal bags. Nketiah & Asante (2018) identified 'mini', 'maxi' and 'jumbo' bags, with average weights of 38, 54 and 82 kg, respectively. But a different system using numerical classification was encountered during this assessment, with bags of 'size 1' up to 'size 5' observed (though sizes 2 and 3 are said to be uncommon). A sample of size 4 and 5 bags weighed an average of 43 and 65 kg, respectively, which does not correspond with the mini, maxi or jumbo bag weights.

In practice, there is enormous variation in bag sizes used by producers, transporters and wholesalers, and this variation only intensifies when it comes to units of retail (see Figure 3).

If the FC's Charcoal Conveyance Certificate (CCC) was charged per bag, as intended, then it would be

Figure 3. **Various units of charcoal sale**

'Maxi' bags, Dimajan, Upper West Region

'No. 5' bags, Tuna, Savannah Region

Unclassified bags, Disiga, Northern Region

'No. 4' bag, New Apluku, Accra

Metal basin, Wa, Upper West Region

Plastic bucket, Wa, Upper West Region

Metal tin ('olonka'), Nina, Kumasi

Large plastic bags, Tamale, Northern Region

Small plastic bags, Aborfour, Ashanti Region

Photos credits: Mubarick Issahaku, Issah Murtala and Listowel Abugri Anaba, UDS.

logical for traders to opt uniformly for the largest bag sizes (see 2.9 below for further discussion of CCCs). But as this fee has been standardised by the FC for the most common models of lorry, bag size is then irrelevant for CCC costing and seems to be reflect the preferences of particular buyers and sellers. This variety makes price determination quite challenging. The only reliable way to establish prices is to physically weigh a representative sample of whatever package sizes are encountered.

Based on sample weighing in February 2022, the price build-up for charcoal is summarised in Table 3, from the source up to the point of retail in selected cities.

Table 3. **Average charcoal prices from kiln to consumer (February 2022)**

Location	Average charcoal price (GH¢/kg)
Kiln	0.5
Roadside, remote NSZ	0.7
Roadside, main routes to southern markets	1.1
Retail, Wa/Tamale	1.1
Retail, Kumasi	1.6
Retail, Accra	2.4

Source: UDS survey, 2022. See Annex D for details.

Photo 4. **Firewood delivery in MAN 'Albion' truck, Tamale central market, Northern Region**

An average price mark-up for charcoal of 320% has been recorded between producer and retailer (Ministry of Energy, 2019a, p. 115). Research for this assessment found this to hold approximately true for charcoal sold in Accra, with a retail price of GH¢ 2.4 (US$ 0.32) per kg, compared with a price at the kiln of around GH¢ 0.5 (US$ 0.066) per kg - a 380% mark-up.

For firewood, the percentage mark-up from source to consumer tends to be much smaller, as the distances are shorter and fewer nodes are involved. Rural firewood suppliers may also bypass the urban traders and sell direct to end-users. Or a trader will place an order, pay for loading and provide transport, then sell the wood on from their wholesaling site. In Tamale, an 'Albion' truckload (Photo 4) costs a trader GH¢ 2,000 (US$ 266) and contains approximately 72 cubic metres (cbm) of stacked firewood.[9] So the trader effectively pays GH¢ 28/cbm, which is sold on for around GH¢ 34/cbm[10] Assuming a loose-stacked weight of 300 kg/cbm, this gives a price of approximately GH¢ 113 (US$ 15) per tonne for bulk firewood purchases in the NSZ.

The supply of woodfuels generates significant economic flows from consumers to producers, channelling money back through the supply chain from (largely) urban demand centres to rural areas of supply.

Each value chain supports separate sets of rural actors. The supply of firewood for fish smoking, for example, provides a vital year-round source of income for HHs located close to the coast and inland water bodies. A wide range of people are involved in its production, transportation, trading and consumption, including the educated and illiterate, natives, migrants and settlers, and both men and women, young and old (Obiri et al., 2013).

Charcoal production is a particularly important cash contributor to rural livelihoods in source areas. It serves as a gap-filler in slack agricultural seasons and a safety net in case of extraordinary needs. It is the most common strategy for coping with HH shocks such as crop failure, illness and cattle invasion (Hansen, 2021). But in many areas, charcoal making is not a full-time occupation. 94% of charcoal producers interviewed say that they are farmers, 36%

9 Stacked volume of 3 x 4 x 6 m.

10 The Tamale traders sell firewood in units called 'poles', with a quantity purchased at GH¢ 140 sold on to customers for GH¢ 170. The same margin is applied here to the cbm, though traders do not use this measure.

Table 4. Charcoal producer livelihoods, in addition to making charcoal

Region	Farming	Livestock raising	Small business	Mining	Other
Ashanti	114	8	8	0	17
Bono East	186	66	7	0	3
Eastern	65	33	14	1	1
Savannah	69	7	1	0	2
Upper West	83	82	25	0	4
Total	**517**	**196**	**55**	**1**	**27**

Source: UDS survey, 2022

say they keep livestock, 10% run a small business and 5% have other livelihoods (Table 4).

Charcoal may be an important source of seasonal income, but it was the largest source of income for only 29% of the producers interviewed (Table 5). Only in Savannah Region was it the main source of income for more than half (75%) of those surveyed, despite this being a Region where charcoal production is officially 'banned'. This may partly reflect a lack of alternative sources of income in this part of the country.

Table 5. Over the whole year, is charcoal your main source of income?

Region	Yes	No
Ashanti	42%	58%
Bono East	25%	75%
Eastern	0%	100%
Savannah	79%	21%
Upper West	0%	100%
Overall average	**29%**	**71%**

Source: UDS survey, 2022

Even for residents of the Kintampo Forest District, Ghana's primary source area for charcoal (Nketiah & Asante, 2018), the combined income from charcoal production, charcoal trading or charcoal wage labour accounts for an average of only 17% of total income for rural HHs (well behind crops at 46%) (Brobbey et al., 2019). But there are seasonal variations: in another survey in the same area, 27% of HHs with income from charcoal stated that during some periods of the year, charcoal was their 'major' or 'only' source of income (Kiel, 2017), indicating how important this product becomes during the agricultural off-season.

The part-time and informal nature of charcoal-making was confirmed when producers were asked whether they had been contracted by somebody to make their charcoal. Only 25% said that they had been contracted, with the remaining 75% operating independently, suggesting that many are not part of organized commercial arrangements (Table 6). But there is significant disparity: 75% of those interviewed in Upper West Region had been contracted to produce charcoal, perhaps because there is little passing trade in this peripheral part of the country and charcoal is more likely to be made to order.

Table 6. Have you been contracted by someone to produce this charcoal?

Region	Yes	No
Ashanti	35%	65%
Bono East	6%	94%
Eastern	22%	78%
Savannah	1%	99%
Upper West	75%	25%
Overall average	**25%**	**75%**

Source: UDS survey, 2022

When charcoal is being produced on contract, then in 80% of those cases this is being done for a merchant (Table 7).

Table 7. If you have been contracted to produce this charcoal, who by?

Region	Landowner	Merchant	Production coordinator	Other	Total
Ashanti	1	47			**48**
Bono East	7	3			**10**
Eastern	7	4	1	2	**14**
Savannah				1	**1**
Upper West	2	54		6	**62**
Total	**17**	**108**	**1**	**9**	**135**

Source: UDS survey, 2022

2.5 Other supply chain insights from UDS charcoal survey

There is wide variation in the distance walked from the producer's home to the kiln site, with an average of 8 km across the sample, about an hour's walk, but ranging from 0 to 45 km (Table 8). Distances were longest in Ashanti and Eastern Regions (both 12 km), perhaps indicating greater shortage of feedstock or access restrictions compared with Upper West Region (3 km).

Table 8. How far from home have you come to produce charcoal?

Region	Yes	No	Average (km)
Ashanti	1	40	12
Bono East	1	30	5
Eastern	1	45	12
Savannah	1	45	7
Upper West	1	15	3
Average	**1**	**45**	**8**

Source: UDS survey, 2022

76% of all respondents said that they had to walk further to find suitable material than they did in the past (and 100% of the sample in Ashanti), confirming an overall decline in the availability of wood resources (Table 9).

Table 9. Do you need to travel further than before to produce charcoal?

Region	Yes	No
Ashanti	63%	37%
Bono East	69%	31%
Eastern	100%	0%
Savannah	77%	23%
Upper West	93%	7%
Overall average	**76%**	**24%**

Source: UDS survey, 2022

In 91% of cases, the wood was sourced from the immediate vicinity of the kiln (Table 10). This illustrates the versatility of the traditional earth kiln, which can be set up at the location of the wood to minimise haulage distances.

Table 10. Did you get the wood from the same land as the kiln?

Region	Yes	No
Ashanti	90%	10%
Bono East	99%	1%
Eastern	79%	21%
Savannah	86%	14%
Upper West	90%	10%
Overall average	**91%**	**9%**

Source: UDS survey, 2022

In the few cases where the wood had been brought to the site from elsewhere, this was invariably from land belonging to another farmer, to the producer themselves or to the chief (Table 11). Only in about 1% of cases surveyed did the producer admit to using wood taken from a Forest Reserve.

In 40% of cases, the land on which the kiln was built was said to belong to the area chief, with a lower percentage (35%) building the kiln on their own land or their family's land (Table 12). This confirms the importance of chiefs in granting access. 79% of kilns in Savannah Region were on chiefs' land, perhaps reflecting the recent ban that the chiefs themselves imposed in that region, so bringing charcoal production more closely under their own control. There was no example in Upper West of a kiln on a chief's land. The chieftaincy system is said to be relatively weak in that region.

Table 11. If not from the same land, where did you get the wood?

Region	Own land	Family head	Chief	Another farmer	Government land (except FR)	Forest Resrve	Total
Ashanti	4	0	0	9	6	2	0
Bono East	0	0	0	1	0	0	0
Eastern	0	0	7	8	0	0	0
Savannah	0	1	8	3	2	3	0
Upper West	7	3	0	8	5	2	0
Grand Total	**11**	**4**	**15**	**29**	**13**	**7**	**0**

Source: UDS survey, 2022

Table 12. Who owns the land on which the kiln is located?

Region	Chief	Own land	Another farmer	Family head	Government land (except FR)	Forest Resrve	Other	Total
Ashanti	59%	31%	4%	2%	2%	1%	0%	100%
Bono East	29%	31%	24%	12%	5%	0%	0%	100%
Eastern	37%	26%	28%	3%	0%	4%	1%	100%
Savannah	79%	0%	8%	4%	7%	0%	1%	100%
Upper West	0%	41%	45%	13%	0%	0%	1%	100%
Grand Total	**40%**	**28%**	**21%**	**7%**	**3%**	**1%**	**1%**	**100%**

Source: UDS survey, 2022

Around half (53%) of the surveyed charcoal producers reported sourcing some of their wood from land being cleared for farming, 29% from land already farmed and 20% from fallow land, which shows the significance of the interaction with agriculture (Table 13). Still, 37% sourced wood from forested land that had never been farmed, and this rose to 65% and 69% of the producers in Savannah and Upper West Regions, respectively.

74% of producers said they could collect wood for charcoal making without obtaining authorisation. When such authorisation is required, it is generally obtained from the chief or the landowner, except in Upper West Region, where chiefs do not feature and permission comes mainly from the landowner or family head (Table 14). It seems that sourcing the wood is not contentious and generally requires no special permission, though the same may not be said for the process of conversion to charcoal.

Wood sourcing practices differ widely across the sampled areas. In Savannah and Upper West Regions, more than 60% of charcoal producers report sourcing wood from trees damaged by fire, compared with 11% or fewer in the other regions (Table 15). Clearly fire plays an important role in the charcoal supply chain in the NSZ, whether deliberately set to bring trees down or passing uncontrolled through an area.

Table 13. What is the land use where the wood came from?

Region	Land already farmed	Land being cleared for farming	Fallow land	Forest Reserve	Forested land never farmed (except FR)
Ashanti	27%	62%	9%	4%	47%
Bono East	34%	51%	18%	0%	19%
Eastern	24%	50%	31%	6%	1%
Savannah	18%	27%	15%	3%	65%
Upper West	37%	69%	37%	0%	69%
Total	**29%**	**53%**	**20%**	**2%**	**37%**

Source: UDS survey, 2022. Multiple responses permitted.

Table 14. Did you need to get authorisation from anyone to get the wood for making charcoal?

Region	No authorisation needed	Yes, authorisation needed from:				
		Another farmer	Chief	Family head	Forest Reserve	Government land (except FR)
Ashanti	86%	5%	7%	0%	0%	4%
Bono East	65%	14%	18%	3%	0%	1%
Eastern	70%	13%	15%	1%	0%	0%
Savannah	87%	6%	9%	0%	0%	1%
Upper West	67%	2%	19%	13%	2%	2%
Overall average	**74%**	**9%**	**14%**	**3%**	**0%**	**2%**

Source: UDS survey, 2022. Multiple responses permitted.

Table 15. How did you get the wood to make the charcoal?

Region	Tree damaged by fire and cut by charcoal producer	I cut the tree myself	Tree already cut by a farmer clearing farm	Tree cut by contractor
Ashanti	11%	42%	17%	50%
Bono East	8%	88%	21%	0%
Eastern	1%	68%	12%	0%
Savannah	61%	60%	29%	11%
Upper West	65%	96%	40%	10%
Overall average	**23%**	**72%**	**22%**	**16%**

Source: UDS survey, 2022. Multiple responses permitted.

Charcoal producers generally cut the trees themselves, except in Ashanti Region, where only 42% cut their own trees and it is more common to hire a chainsaw operator. Use of contracted chainsaw operators is much rarer in the other regions surveyed.

Despite a majority of producers not having been formally contracted to produce charcoal, it is clear that most of them still have a clear plan for selling the output. They usually sell to a merchant at a consolidated collection point, or direct from the kiln itself (Table 16). Most producers do not rely on roadside sales to passing traffic, although this remains the third most common practice. A few producers sell direct to their own customers, especially in Upper West Region, perhaps because few traders come spontaneously to this marginal region.

Unsurprisingly, given the current ban, a majority of producers in Savannah Region (64%) report being hassled while making charcoal (Table 17). In that region, the FC, the Assemblyman and Chief are the main source of aggravation. Only 8% of producers in Ashanti Region report being hassled, perhaps indicating less stigma associated with charcoal making in that region.

Table 16. Who will buy the charcoal from this kiln?

Region	Merchant, who will collect at kiln site	Merchant, after bags are carried to a central place	To nearby roadside, for sale to passing traffic	Direct to my own customers in town	Other
Ashanti	67%	59%	5%	7%	0%
Bono East	69%	58%	21%	4%	1%
Eastern	42%	33%	28%	6%	3%
Savannah	63%	79%	54%	16%	0%
Upper West	0%	76%	100%	43%	1%
Overall average	**54%**	**60%**	**34%**	**12%**	**1%**

Source: UDS survey, 2022. Multiple responses permitted.

Table 17. Do you face any hassle while making charcoal?

Region	Yes	No	Total	If yes, from whom?					
				Chief	Land owner	Family head	Assembly-man	Forestry Commission	Other
Ashanti	8%	92%	100%		1			1	
Bono East	27%	73%	100%	3	2			6	1
Eastern	42%	58%	100%	1	3				4
Savannah	63%	37%	100%	1	2			2	
Upper West	34%	66%	100%	8	2		9	10	
Overall average	**30%**	**70%**	**100%**	**14**	**10**		**9**	**19**	**5**

Source: UDS survey, 2022

2.6 Ethnicity

Charcoal production was historically dominated by people of the Sissala ethnic group from Upper West Region, who moved from village to village to produce charcoal under arrangements with the local chief (Agyei et al., 2018). Charcoal even became known as 'Sissala cocoa' according to anecdotal reports from Kintampo South (UDS survey, 2022). Their dominance seems to have begun waning in the 1990s as other ethnic groups, including the Dagaati, Frafra, Moosi, Konkomba, Grushi, Mamprusi, Twokosi and Bono also began to produce charcoal on an itinerant basis, in response to the growing market opportunity from the cities in the south. These specialised producers migrated from their home areas with the primary purpose of producing charcoal.

As the charcoal business boomed it also became an attractive opportunity for indigenous residents in many areas, especially in the Transition Zone and the NSZ. In some areas it is also said that a move into charcoal-making was spurred by the declining returns from agriculture caused by the arrival of Fulani herdsmen and their free-roaming livestock (UDS survey, Atebudu Amantin District, 2022). The detrimental impact of livestock on yields from agriculture was also reported by charcoal producers in West Gonja District in Savannah Region, one of whom stated that "the presence of the Fulani herdsmen devastated us; their cattle ravaged our crops every time we planted; we used to be self-sufficient with the proceeds from our farms, but now we can't even boast of a bag of corn or a tuber of yam; this is what drove us into charcoal production" (UDS survey, 2022).

People of all ethnicities are now involved in charcoal production, including both indigenous residents and specialist migrants. In fact locals now dominate - at least two thirds of producers surveyed originated from the community where their kiln was located, and in Upper West Region, 100% of producers surveyed in Sissala West District were indigenous to the area. Migrants accounted for up to 36% of producers interviewed in some of the other regions surveyed, but not more than this (Table 18). Charcoal is no longer a migrant-dominated enterprise and is now firmly indigenised across all regions where it takes place.

Table 18. Is the producer from the local community?

Region	Yes	No	Total
Ashanti	71%	29%	100%
Bono East	93%	7%	100%
Eastern	65%	35%	100%
Savannah	64%	36%	100%
Upper West	100%	0%	100%
Overall average	**81%**	**19%**	**100%**

Source: UDS survey, 2022

But while charcoal production is no longer the exclusive domain of the Sissala people, Sissala women have remained dominant in wholesaling and retailing.

There can be animosity between resident producers and in-migrants, especially in areas that have only recently opened up for large-scale charcoal production. In Bole District (Savannah Region), for example, the main commercial charcoal producers are the Sissalas, Dagaabas and Brifors from Upper West Region, and Ligbis from Côte d'Ivoire (UDS survey, 2022). While these non-native producers reportedly have good relations with the local chiefs, Assemblymen and the Area Council, and contribute significant revenue to the area, they are said to be resented and harassed by the indigenous Gonja people, who also produce charcoal.

But in areas further south, where migrant charcoal makers have lived and intermixed for several decades, relations seem to be better. In Mampong Municipal (Ashanti Region), for example, some migrant charcoal producers have lived in the community for so long that they have "become like family members" and they are "well-respected people due to the fact that they contribute immensely towards the development of the various communities within the district" (UDS survey, 2022). In Sekyere Afram Plains District, the "authorities regard charcoal producers with respect and value them highly because they contribute significantly to the district's overall growth". "The land used for charcoal production is held by the Kumawu area's paramount chief, who has caretakers supervising all charcoal manufacturing activities in the area. Conversations with the caretakers revealed that they have excellent relationships with the charcoal producers in the area" (ibid.). Charcoal markers in Kwahu Afram Plains South are "hailed in the community" for the tradition of giving two bags out of every ten produced to the local chief and providing an "essential means of generating money for chiefs and the government" (ibid.).

The charcoal production belt is moving progressively northwards. Output appears to be rising in Transition Zone districts, such as Atebubu Amantin and Sene West, due to a combination of high market demand, lack of alternative youth employment and the risks associated with farming due to repeated incursions by Fulani livestock (UDS survey, 2022). Kintampo is currently a major source area and charcoal provides the main source of income for many community members and in-migrants such as Sissalas, Komkombas, Dagaabas and Dagombas (ibid.). Meanwhile in Mampong Municipal (Ashanti Region) the heyday of charcoal making is said to be over as production moves to better stocked areas and most of the outsiders who originally introduced charcoal making have migrated away (ibid.).

It may be that in the Transition Zone, where charcoal has been produced at large scale since the 1970s, the tradition of ethnic mixing between locals and migrant charcoal makers is now long-standing and non-contentious. Meanwhile in the charcoal 'frontier' in the country's northwest, local people still resent the intrusion of outsiders in the relatively young and lucrative charcoal trade.

In contrast with charcoal production, commercial firewood harvesting seems to have no particular ethnic orientation. A study in Savannah Region suggests it is mainly carried out by the poorest people in society with the lowest levels of literacy and few other livelihood options (Mohammed, 2021). The stratification is more likely to be socio-economic than ethnic.

2.7 Seasonality

Demand for charcoal remains approximately constant all year round, as Ghana does not experience a cold season when requirements might spike for indoor heating. Nketiah et al. (2021) analysed CCC statistics and confirm that charcoal transport volumes are more or less stable throughout the year. So although there may be some felling and stockpiling of wood immediately before the rains (Agyei et al., 2018), total output is approximately constant year-round.

This runs counter to the common narrative as it has long been held that charcoal production is minimal during the rainy season (Nketiah & Asante, 2018). Seasonal producers are said to return to farm work, production is constrained by wet wood and tougher working conditions,

Photo 5. **Grass packed around a charcoal kiln, Soladje, Sekyere Afram Plains, Ashanti Region**

Photo credit: Akuoko Asare Nyantakyi, UDS

and vehicles struggle to access production sites. But it was reported by producers in the NSZ that the ground is hard in the dry season and the soil not easily heaped to make kilns, so it must be pre-softened with scarce water. There is also a lack of grass to pack around the wood for igniting the charge. This makes the work harder and acts as a deterrent to production.

The reality is that different types of producers in different regions may be involved at different seasons. Brobbey et al. (2021) found that high-income HHs tend to produce charcoal to supplement their income during the rainy season (September to October) when charcoal prices rise due to transport challenges, while low-income HHs produce charcoal during the slack agricultural season (November to February) when they lack other sources of income, or these other sources are not sufficient. The degree of seasonality also varies by region. 94% of charcoal producers surveyed in Savannah Region and 82% in Upper West Region reported low output in the dry season, with many mentioning the hardness of the ground as a factor, whereas 96% in Savannah and 86% in Upper West reported high output in the rainy season. In Ashanti and Eastern Region, a more balanced level of production was recorded between the seasons. 77% in both regions said they had high output in the rainy season, while 70% in Ashanti and 67% in Bono East claimed high output for the rainy season (Table 19).

Table 19. Charcoal production by season, as reported by producers

Region	Rainy season			Dry season		
	High	Low	No production	High	Low	No production
Ashanti	77%	23%	0%	70%	30%	0%
Bono East	77%	20%	3%	19%	77%	4%
Eastern	68%	32%	0%	67%	33%	0%
Savannah	96%	4%	0%	3%	94%	3%
Upper West	86%	14%	0%	14%	82%	4%
Overall average	**79%**	**19%**	**1%**	**35%**	**63%**	**2%**

Source: UDS survey, 2022

As production becomes easier or more difficult, as it moves between regions and as different groups of people come in and out of production, prices inevitably fluctuate. There are typically price peaks during the rainiest periods (due to access challenges) and during the very driest periods (due to hard ground and scarcity of grass), with retail prices up to 50% higher at these times (Agyei et al., 2018).

Price variation in firewood is less complex. Access is easier in the dry season and more difficult in the wet season, resulting in a single seasonal spike in the wet season, when sellers in Savannah Region charge between 7% and 19% more (Mohammed, 2021, p. 66). Firewood prices are also higher when schools are in session than when they are closed, due to higher demand from school feeding programs.

2.8 Gender

Women dominate the harvesting of firewood, not only in the traditional domain of fuel for domestic cooking, but also for commercial firewood trade (Mohammed, 2021).

Along the charcoal commodity chain there is clear gender segregation, with women dominating all nodes except production and transport (Agyei et al., 2018). This is attributed to the Ghanaian norm of trade being a female domain, as well as the physical strength required to carry out particular activities. Men generally fell the trees, stack the logs, construct the kiln, load bags on trucks and transport them to market. 90% of the transport vehicles are owned by men (ibid.). Women assist in kiln management, charcoal bagging and bag stitching.

Gender norms are changing, however, as women are increasingly becoming involved in production too (Agyei et al., 2018). At sites observed during field research, women played an integral role alongside men in all but the heaviest manual operations and were seen building up the base layer of small logs on which the heavier logs would be positioned, cutting and heaping grass on the wood, piling soil on the charge and managing the charcoaling process itself, over a period of several days (see Photo 6).

Photo 6. **Woman managing charcoal kiln, Soalepe, West Gonja Municipality, Savannah Region**

2.9 Regulatory environment

Ghana's woodfuel sector is subject to a variety of state regulation by the EC, Environmental Protection Agency (EPA), FC and District Assemblies.

2.9.1 Energy Commission regulations

Under the Renewable Energy Act (2011), the EC is mandated to issue licences for the production, transport, storage and supply of firewood and charcoal. The licensing requirements are spelled out in a Licence Manual that accompanies the Act (Energy Commission, 2012b):

a) Bulk Charcoal Production Licence for those wishing to produce more than 100 t p.a.

b) Bulk Charcoal Transportation Licence to authorise the use of registered vehicles for transportation of charcoal.

c) Charcoal Wholesale Storage Licence for storage of charcoal in commercial quantities for local sale.

d) Charcoal Export Licence.

e) Charcoal Export Permit additionally required for each shipment.

No licensing arrangements for firewood have yet been elaborated.

Of the licences introduced by the EC in 2011, only the Charcoal Export Licence and the Charcoal Export Permit have so far been operationalised. The requirement for a Production Licence has been relaxed to apply only to charcoal intended for export.[11] The procedures for acquiring a Bulk Transportation Licence and Wholesale Storage Licence have not been elaborated so cannot be enforced.

2.9.2 EPA regulations

A permit from the EPA is said to be required before felling any tree, according to the Agency's interpretation of Regulation 1(2) of the Environmental Assessment Regulations (1999), which applies to "any undertaking which … is likely to have adverse effect on the environment".[12] Woodfuels industry players are ignorant of this requirement and others claim it is being interpreted to apply only to amenity trees in urban areas and around homes.

2.9.3 Forestry Commission regulations

Under the Forest Ordinance of 1927, ownership of all forest products within reserved forests is vested in the government. Traditional owners have no right of access except through a permit from the Forest Services Division of the FC, which may allow the extraction of dead wood, logging residues, deformed plantation material and residue, and species of no timber value (Obiri et al., 2014). In practice, however, the exploitation of non-timber forest products - including woodfuels - is poorly regulated. Woodfuel resources are often regarded as free common goods that can be collected anytime, anywhere for domestic use (ibid.).

Legal controls also exist for tree felling 'off-reserve', although these are not specific to woodfuels. They fall under the 'small-scale timber rights' set out in the Timber Resource Management and Legality Licensing Regulations (2017). Such rights are applied for at district level via a team comprising members of the District Assembly and the Traditional Council, the District Forest Officer and the relevant landowner(s). But the permit requirement exists on paper only, and is not actually enforced on the ground (Hansen, 2021). This may reflect insufficient FC administrative capacity at the rural locations where woodfuel is being harvested, or the fact that obtaining fuel may not be the principal reason for felling a tree if it is being removed for farm expansion or timber production, or has been killed by fire.

The permit most frequently acquired in the woodfuel value chain is the CCC, which is issued by the FC. A CCC is required by long-distance transporters carrying a nominal minimum of around 100 bags of charcoal. Smaller loads, loads on other types of vehicle and loads moving locally or within districts are not subject to any restrictions. Prior to 2015, when the CCC was introduced, producers and traders operated in fear of forestry, police and other government staff, whereas they now have a form of licence that legitimises the charcoal trade (Agyei, 2021).

Applications for the CCC are made either at the FC office in the Forest District where the charcoal was made or at the first FC-manned checkpoint encountered *en route* to market. The system is not standardised, but a 'community paper' issued by the chief and endorsed by the area Assemblyman is usually required, to confirm that the production was locally approved.

The CCC is nominally priced at GH¢ 0.8 (US$ 0.11) per 'mini' bag and GH¢ 1.6 (US$ 0.21) per 'maxi' bag, assumed to contain 25 and 50 kg of charcoal, respectively. In practice, the fee is standardised for various common truck types to simplify enforcement, and there is no physical count of the number of bags actually being carried. This is a source of error. The Kia 'Rhino', for example is assumed for CCC costing purposes to carry 400 bags, whereas a randomly encountered lorry at Jeffisi in Sissala West District was carrying 440 bags (Photo 7).

Taking into account these loading under-estimates, together with other limitations such as an absence of checkpoints on minor roads and CCC exemptions for loads of less than 100 bags, there is significant under-recording of charcoal movement in the CCC system. Nketiah and Asante (2018) estimate that only 47% of transported charcoal is captured by CCCs. But as they only compared the official records with their observations of charcoal-specific trucks carrying large quantities of bags, their under-estimate did not consider the additional quantities being conveyed in smaller loads exempt from the CCC requirement. Official FC statistics recorded 155,908 t of charcoal transported with CCCs in 2021, compared with

11 See www.energycom.gov.gh/licensing/licensing-renewable-energy-sector

12 www.ghanaweb.com/GhanaHomePage/NewsArchive/It-s-a-crime-to-fell-a-tree-without-permit-EPA-772443

Photo 7. Kia Rhino bound for Accra at Jeffisi, Sissala West District, Upper West Region

total national consumption estimated at 928,811 t under this study (see section 6 below). So the CCCs may be capturing only 17% of the charcoal being transported, much less than Nketiah and Asante's 47% estimate.

The FC is losing additional revenue because of incorrect assumptions about bag weights and truck loading. First, the latest (2021) CCC statistics record that 99.7% of all charcoal bags are of the smallest 'mini' size, which is certainly not the case. Second, average weights of mini and maxi bags are 37.9 and 53.8 kg, respectively, not the 25 and 50 kg assumed for official calculations (Nketiah & Asante, 2018). So for every 'mini bag' recorded on the CCCs, the quantity of charcoal being transported is being under-reported by 34%, and for each 'maxi bag' by 7%. Third, the FC's adoption of standardised truck capacity estimates that do not reflect actual loading, means that the payment per bag averages just GH¢ 0.63 (US$ 0.08), rather than the intended GH¢ 0.8 (US$ 0.11).[13]

So the CCC system not only fails to capture an estimated 83% of the charcoal being transported to consumers, it also under-collects revenue on those charcoal shipments that are issued with CCCs. CCCs function mainly as a measure to generate revenues from the sector (Hansen, 2021). If this is their primary value, then the significant amount of uncollected Government revenue should be of concern and amounts to an estimated GH¢ 24.7 million (US$ 3.3 million) per annum.[14]

2.9.4 District Assembly regulations

The 2016 Local Government Act allows District Assemblies to charge a fee for the transport of

13 The rate applied is GH¢ 120 for a Kia truck or vehicle of related size (nominal load 200 mini-bags), GH¢ 250 for a single-axle cargo truck, including Kia Rhino (nominal load 400 bags) and GH¢ 400 for a double-axle cargo truck or articulated vehicle (nominal load 600 bags). This gives an average charge of GH¢ 0.63 per bag, compared with GH¢ 0.8 that would be separately chargeable for individual 'mini' bags.

14 83% of GH¢ 32/t, on total annual consumption of 928,811 t.

woodfuels out of their district. For charcoal, this fee varies widely from GH¢ 0.50 (US$ 0.066) per bag in Kintampo Forest District (Brobbey, Hansen, et al., 2021) to GH¢ 2 (US$ 0.27) in Balwo-Kayilo in Upper East Region, to as much as GH¢ 8 (US$ 1.06) in Atebubu Amantin in Bono East Region and GH¢ 10 in (US$ 1.33) West Gonja District, Savannah Region (UDS survey, 2022). Since the levies are imposed per bag, irrespective of size, using larger bags tends to be financially advantageous (Ministry of Energy, 2019a). As with the CCC, the charge is standardised in some districts for the most common truck sizes. District Assemblies sampled in 2019 charged GH¢ 30 (US$ 4) per Kia, GH¢ 40 (US$ 5.30) per Rhino single-axle, GH¢ 60 (US$ 8) per Rhino double-axle and GH¢ 120 (US$ 16) per trailer (Agyei, 2020). The fee collection rate by District Assemblies has been estimated at around 45% (Ministry of Energy, 2019a, p. 129), suggesting a further significant loss of potential government revenue. This may be an over-estimate as the cited survey covered only larger-scale producers.

Some districts also charge a fee for firewood transport, one example at Balwo-Kayilo (Upper East Region) being GH¢ 5 (US$ 0.66) per donkey cart or GH¢ 10 (US$ 1.33) per Motor King, and in North East Gonja (Savannah Region) the district fee for firewood is GH¢ 10 per truckload (Mohammed, 2021).

2.10 Implications for further regulation

The practical experience of most people involved in extracting woodfuel is that they can harvest trees without reference to central government agencies, despite the regulations of the EC, EPA and FC. Practical control over harvesting is decentralised to traditional authorities. As previously explained, this system is effective in consolidating chiefs' power and raising revenue, but does not ensure a sustainable rate of exploitation.

It is worth giving some context for the current approach to regulation, which has its origins in a deforestation narrative. Policy documents on woodfuels in Ghana, such as the Strategic National Energy Plan (Energy Commission, 2019), tend to present a scenario of deforestation and degradation linked to woodfuels that requires robust intervention. The GoG reports that 90% of woodfuels originate from natural forests and 10% from wood waste (Energy Commission, 2012a). By portraying woodfuels (and especially charcoal) as a product of natural forests, and by not making any distinction between loss of trees (degradation) and loss of forest cover (deforestation), the logical policy reaction to protect natural forests is to tightly control charcoal production. But the conventional narrative takes no account of wood that is a by-product of forest clearing for farming or that comes from forested fallow lands managed by farmers, as they subject them to alternating cycles of cut and regeneration (Amanor, 2021). It also leaves no room for wood harvested from areas not classified as forest at all.

Ghana's Nationally Appropriate Mitigation Actions (NAMA) report on charcoal production conveys a picture of rapid deforestation in which the country's total forest cover may be lost in the next 40 years (UNDP, 2015). This indeed may be the unfortunate case, but the NAMA study draws a direct causal linkage to charcoal that is less plausible. The report does not differentiate between the very different dynamics driving the rapid loss of high forest and the more gradual processes of degradation underway in the areas under Guinea savannah woodland, from which most charcoal is sourced.

Yet the deforestation narrative remains strong. A recent area-specific study in Bono East Region concludes that if charcoal production continues at its current rate, then the quantity of above-ground biomass (AGB) will be reduced to 46% of 2021 levels by 2035, and to 6% by 2045 (Lemke, 2021, p. 38). But if charcoal production was halted, would that biomass loss be averted? This is unlikely, as biomass removals are driven by factors other than woodfuel extraction; and the fact that trees are converted to charcoal does not necessarily mean that they were felled specifically and exclusively for that purpose.

15 www.ghanaweb.com/GhanaHomePage/business/The-National-Energy-Policy-2020-is-completed-Akufo-Addo-1200355

So woodfuels are rooted in a narrative that links extraction with deforestation. The woodfuels industry is characterised as unsustainable, polluting, wasteful and exploitative. And it is widely perceived that a combination of technology and further regulation will transform it into a modern, sustainable and productive economic sector. However, this narrative is poorly supported by evidence and does not take into account the multiple ways that charcoal is produced in woodlands, farms and fallows (Hansen, 2021).

The EC is currently drafting new Woodfuel Regulations, pending the publication of the revised National Energy Policy[15] that was awaiting Cabinet approval at the time of this study. The new Regulations are intended "to ensure the enforcement of sustainable management of biomass resources predominantly used as fuel for cooking and heating" (Energy Commission, 2019). The vision is clearly to achieve full government control of the woodfuel value chain, from the tree to the final consumer, through a holistic chain-of-custody approach and a fully tracked commodity chain (Zormelo, 2018). Charcoal producers may be required to use certain kiln technologies that are approved by the Ghana Standards Authority.

Production from woodlots is expected to form the basis for the creation of this new state-controlled value chain that is focused on defining legal charcoal and criminalising the trade of charcoal outside that chain. The transportation and trade in charcoal will be controlled through a system of new permits and licences. Woodlot-produced charcoal will be certified as sustainable and woodfuel from woodlands, farms and fallows as not sustainable, and subject to higher rates of taxation. This will brand all charcoal that is a by-product of farming as unsustainable, irrespective of the principal motivation for the clearance and the degree of regeneration on farms and preservation of trees on the farmed land. Perversely, a large commercial farmer who clears a wooded environment with mechanical equipment and plants a monoculture eucalyptus plantation would be certified as producing a sustainable product (Amanor, 2021).

A policy of control and containment of the woodfuels sector as a tool to reduce the rate of deforestation is founded on questionable assumptions about the complex interplay of drivers of tree loss. Successfully controlling woodfuel extraction would have only a limited effect on unsustainable removals.

Whatever the justification and intent, tight regulation is also unrealistic, based on evidence from other countries and from the GoG's own limited success in enforcing the relatively straightforward rules that already exist. It is already proving difficult to regulate charcoal conveyance and charcoal export, with estimated capture rates of 17% and 7%, respectively. The challenges in enforcing even these relatively simple measures on the bulk movement of charcoal via major transport corridors are a pointer to the far greater challenge of enforcing a wide-ranging set of regulations through the entire woodfuel value chain. Indeed, legislation already exists to control tree felling for woodfuels, but is not enforced by the FC, the EC or the EPA. The EC has also largely failed to implement the licensing frameworks mandated by the Renewable Energy Act (2011). There is simply not the manpower, capacity or incentive for local staff to effect the even tighter controls now under development. Any credible regulation must be enforceable with the available human, financial and operational resources of the responsible state agency.

If the costs of compliance are higher than the costs of evasion, then evidence from the systems for CCCs and export permits suggests that evasion by industry players becomes the norm. New regulations then serve only to add new costs, which will be passed on to consumers. This has wider economic and political ramifications, and impacts especially upon the urban poor, who depend disproportionately on purchased woodfuels and spend the highest share of their income on energy. So new regulations risk adding costs and bureaucracy, while not contributing to the stated goal of ensuring sustainable resource management. Efforts to regulate the industry more tightly could have the opposite of the desired effect and push woodfuels further outside the regulatory environment, while penalising consumers with higher energy costs.

If the GoG presses ahead with more stringent rules, it will fall upon the merchants to demonstrate compliance and cover the costs, as they are the only actors with the requisite capacity and financial resources to navigate new permitting processes. Low-income rural producers and small-scale retailers at the two extremities of the value chain will be unable to meet the requirements of new operating rules, due to the costs, protocols and connections required, so may be further marginalised and disempowered. There is therefore a risk that new regulations with the stated goal of controlling the woodfuel sector will inadvertently consolidate power in the hands of merchants, as they have the connections and financial capacity to demonstrate compliance on behalf of the poor (see Tanzania example in text box).

How woodfuel regulation can disenfranchise the poor

A new forestry regulation was introduced in Tanzania in 2019, known as Government Notice 417. It requires village authorities to secure central government approval for their village forest management plans and for charcoal traders to apply for annual purchasing quotas through a harvesting committee chaired by the District Commissioner, a central government appointee. By replacing a community-managed system for approving forest management plans, determining quotas and issuing harvesting permits, GN417 has led to elite capture of the commercial opportunity (www.ippmedia.com/en/news/forest-stakeholders-concerned-over-government-notice-417). Village-based charcoal producers are now subject to an oligopoly in which a small number of pre-approved dealers dictate the volume of their orders and set the prices, while producers are not legally permitted to sell elsewhere so have lost their power to negotiate on price and quantity.

03 Woodfuel Demand for Cooking

3.1 Introduction

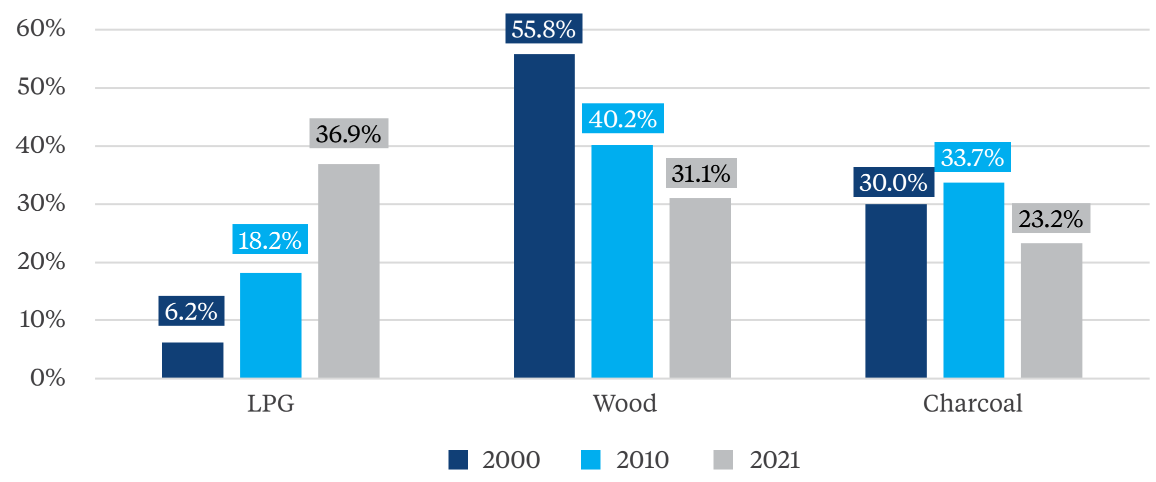
While the previous chapter described woodfuel value chains and the regulatory environment, this chapter quantifies woodfuel demand. The vast majority of woodfuel consumed in Ghana is used for cooking. The scale of this demand is a factor of the number of HHs for which firewood or charcoal is a primary or supplementary cooking fuel, in both rural and urban areas, the types of cooking appliances used by HHs in different fuel combination categories and their respective levels of consumption. Taking these together gives a figure for total national woodfuel demand for cooking.[16] Distributing this demand using high resolution demographic data on rural and urban HHs allows total woodfuel consumption to be mapped.

3.2 Woodfuel consumption for HH cooking

3.2.1 Primary fuels

LPG has come to replace firewood as the dominant cooking fuel in Ghana, with 36.9% of households now using it as their main cooking fuel, according to the latest census (Figure 4). LPG is especially important in Greater Accra, where it is now the main fuel for 70% of the urban population, and in Ashanti, Central, Eastern, Western and Volta Regions, where about half of the urban population use LPG as their main fuel. Firewood still dominates in rural areas, though LPG has seen rapid adoption here too. The share of HHs using charcoal as their primary cooking fuel has seen a significant drop in recent years.

Figure 4. Primary cooking fuel evolution in Ghana (2000, 2010 and 2021)



Sources: (Ghana Statistical Service, 2005, 2012, 2022)

16 The woodfuel required for commercial catering in hotels, restaurants and street food outlets is accounted for in the overall cooking fuel estimates, to avoid double counting of meals taken outside the home

While the move away from woodfuels may seem significant, it is important to note that Ghana's population is growing at an annual rate of 2.1% (Ghana Statistical Service, 2021a), so total demand continues to rise. Despite a percentage drop, the absolute number of HHs using firewood as their main fuel increased by 18% between 2010 and 2021, and the absolute number relying primarily on charcoal increased by 5%, to reach 2.6 million and 1.9 million HHs, respectively (Table 20). The use of electricity for cooking remains marginal, even in urban areas, with less than 1% of HHs relying on it at present. Other marginal fuels include crop residues and kerosene, with less than 1% of the primary fuel mix.

3.2.2 Secondary fuels and fuel stacking

The relative decline in the use of firewood and charcoal as primary cooking fuels conceals the important dynamic of 'fuel stacking'. Socio-economic development tends to lead to the stacking of multiple fuels and stoves, rather than the replacement of traditional fuels by modern appliances (van der Kroon et al., 2013). Understanding fuel stacking is important, not only for determining overall energy demand, but also for designing effective interventions in the cooking sector. Despite its significance, fuel stacking is often disregarded in government surveys and data on the phenomenon is limited.

According to a recent survey of 7,251 HHs in Ghana, 47% of those using LPG as their primary fuel also use a charcoal stove (Kintampo Health Research Centre & Columbia World Projects, 2021). Using cooking time as a proxy for fuel consumption, the results from that survey show that HHs using charcoal as a secondary fuel consume about 10% as much as those using charcoal alone. This

Table 20. Primary cooking fuel, urban and rural households (2021)

Region	Firewood		Charcoal		LPG		Electricity	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Ahafo	22,381	56,688	22,834	6,070	25,194	6,088	219	108
Ashanti	69,037	287,835	300,753	115,294	470,931	108,147	6,068	1,613
Bono	54,730	86,956	45,553	9,689	75,503	13,196	822	229
Bono East	43,140	95,609	63,841	13,887	41,600	6,628	254	87
Central	45,655	173,180	161,592	77,726	245,766	65,472	1,297	561
Eastern	58,628	224,143	148,126	85,656	219,750	75,390	2,171	884
Greater Accra	13,417	22,799	312,544	36,722	1,102,235	55,524	9,585	531
North East	23,612	66,152	8,925	1,929	3,712	867	140	55
Northern	91,644	187,285	77,268	6,885	41,477	3,902	2,621	545
Oti	23,344	86,581	23,618	13,961	10,364	7,416	100	53
Savannah	14,858	76,911	18,772	6,649	4,874	894	148	93
Upper East	16,566	142,876	26,418	14,587	26,237	10,102	138	117
Upper West	8,153	109,079	29,978	10,233	17,940	4,787	278	100
Volta	23,110	140,730	71,115	69,942	109,498	56,094	252	114
Western	28,535	157,903	84,574	42,984	176,646	57,377	1,865	826
Western N	21,060	122,340	20,709	13,937	26,982	15,731	297	307
Total	**557,870**	**2,037,067**	**1,416,620**	**526,151**	**2,598,709**	**487,615**	**26,255**	**6,223**

Source: (Ghana Statistical Service, 2022) recorded decrease in charcoal use is surprisingly high compared to other countries. In Tanzania, the adoption of LPG led to a reduction in charcoal consumption of only 27% (Alem et al., 2017). In Kenya, HHs using LPG as their primary fuel still use, on average, 42% of the amount of charcoal used by HHs that depend on charcoal as their primary fuel (EED Advisory & SEI, 2019). So in the calculation of woodfuel demand for this study, an assumed 90% decrease in charcoal consumption for HHs using LPG as their primary fuel is a conservative estimate. The important point is that the use of firewood or charcoal as supplementary fuels continues, even with the rapid uptake of LPG as a primary fuel.

Further research on fuel stacking is needed to better understand its impact, as it has the potential to partially offset the gains achieved by switching to a different primary cooking fuel.

3.2.3 Efficiency and market share of different stoves

The type of cooking stove also has a significant influence on the quantity of firewood or charcoal consumed. Several tests are available to estimate the annual woodfuel consumption per adult-equivalent for a given stove type, of which the most reliable is the Kitchen Performance Test (KPT).[17]

A review of relevant literature (Amoah et al., 2015; Kemausuor et al., 2016; Quaye & Stosch, 2008) and validated Ghanaian carbon finance projects (by Toyola and Cookmate) provided KPT data with which to estimate the average woodfuel consumption per capita for different fuels and different stoves (as summarised in Table 21).

Using data from the Ghana Living Standards Survey, the share of HHs in each region with charcoal as their primary cooking fuel using improved cookstoves (ICS) can be estimated (Figure 5). There is wide variation between regions on the uptake of ICS, and an overall low penetration rate considering the share of HHs using charcoal as a primary fuel.

3.2.4 Total woodfuel consumption for cooking

By combining the primary and secondary fuel used for cooking with the share of HHs using an ICS with charcoal, and applying the average annual consumption for each type of stove, it is possible to estimate total annual woodfuel demand for cooking. This is summarised by region in Table 22.

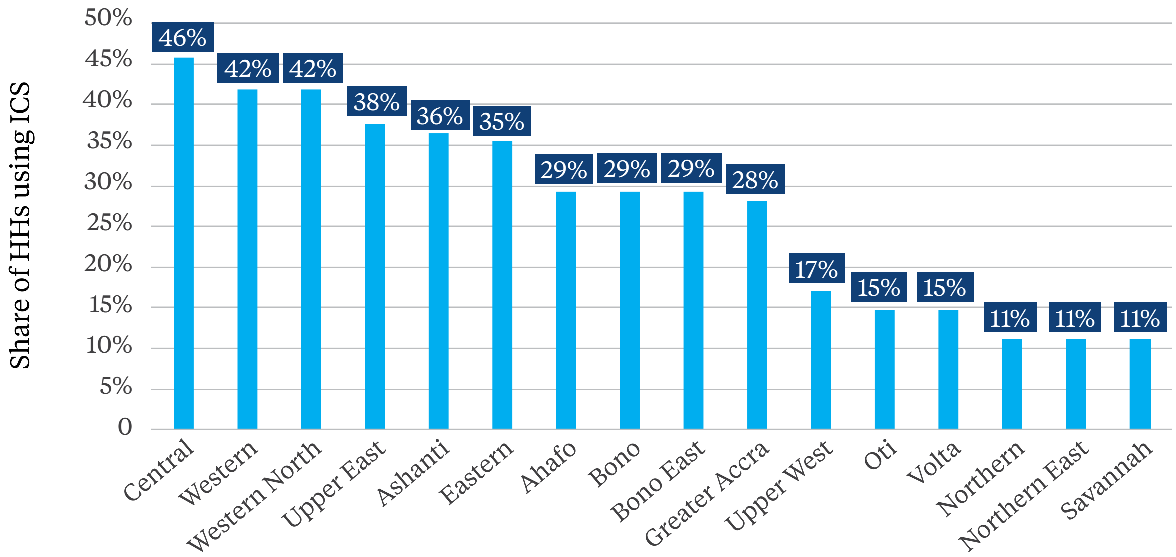
Table 21. Average per capita fuel consumption using different types of cookstoves

Fuel	Stove	Fuel consumption (t wood-equivalent/yr)	
		per HH	per capita
Charcoal	Traditional metal stove	3.60	0.69
	Improved (Gyapa) stove	2.39	0.55
Firewood	3-stone fire	5.96	0.62

Note:A user of firewood on a 3-stone fire uses less wood than a user of charcoal with a traditional metal stove. This is because the production of 1 kg of charcoal requires about 6 kg of wood, yet the fuel has only around double the calorific value of firewood. So while the process of cooking with charcoal is more efficient than cooking with firewood, there are significant energy losses in the production of the fuel.

17 www.cleancooking.org/binary-data/DOCUMENT/file/000/000/604-1.pdf

Figure 5. Share of HHs with charcoal as main fuel using improved cookstoves, by region



Source: (Ghana Statistical Service, 2017)

Table 22. Annual woodfuel consumption for cooking, urban and rural HHs (2021)

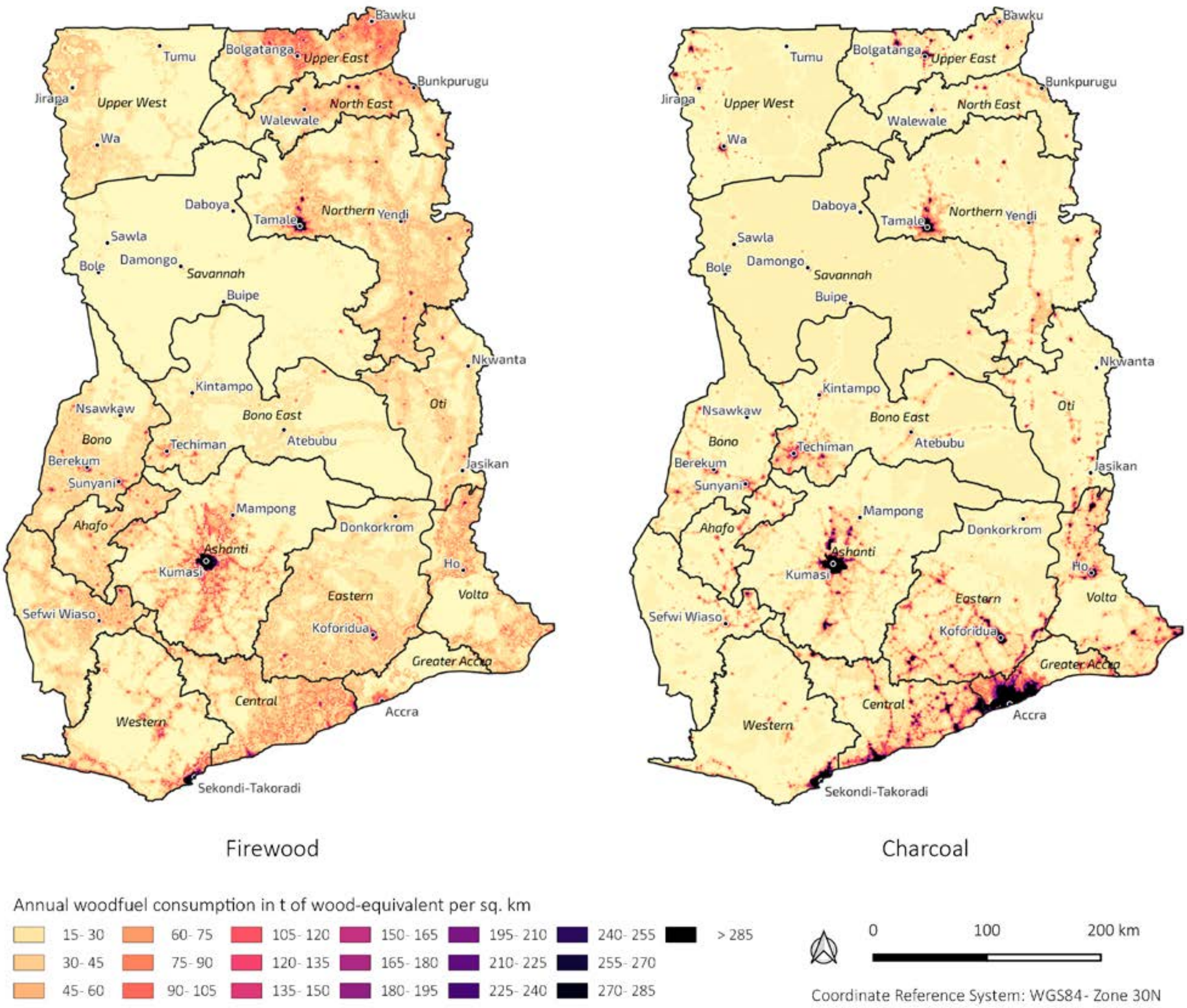
Region	Firewood (t/yr)			Charcoal (t/yr in wood-equivalent)		
	Urban	Rural	Total	Urban	Rural	Total
Ahafo	48,750	140,341	189,091	61,298	30,907	92,204
Ashanti	159,948	670,135	830,083	749,577	351,455	1,101,031
Bono	123,134	226,697	349,831	132,752	51,343	184,096
Bono East	104,609	277,121	381,730	179,347	71,601	250,948
Central	99,900	384,506	484,406	378,803	215,108	593,911
Eastern	121,458	485,496	606,954	345,506	245,652	591,158
Greater Accra	36,215	54,351	90,566	761,975	99,558	861,532
North East	82,948	261,284	344,232	47,345	36,899	84,245
Northern	266,943	701,794	968,737	289,398	105,154	394,552
Oti	58,450	241,046	299,497	73,271	68,863	142,135
Savannah	41,711	245,686	287,397	63,495	49,992	113,488
Upper East	46,276	460,133	506,410	84,514	96,192	180,706
Upper West	20,820	349,048	369,868	83,665	73,305	156,970
Volta	49,063	304,185	353,248	175,183	200,713	375,896
Western	59,892	340,301	400,193	199,355	132,183	331,538
Western N	45,083	292,091	337,174	53,850	64,604	118,454
Total	**1,365,199**	**5,434,215**	**6,799,414**	**3,679,334**	**1,893,529**	**5,572,863**

Source: (Ghana Statistical Service, 2022)

The results give total annual firewood demand for cooking of **6,799,414 t of firewood** and **928,811 t of charcoal** (which equates to **5,572,863 t of wood**, before conversion to charcoal). This gives total demand in wood-equivalent of **12,372,277 t** p.a. The charcoal estimate is consistent with another recent study that estimated that Ghana produces 1.1 million t of charcoal annually (Hansen, 2021).

The spatial distribution of this woodfuel demand is mapped in Figure 6 below. The demand for charcoal is highly concentrated in urban centres and especially in the coastal cities.

Figure 6. **Spatial distribution of firewood and charcoal demand for cooking (wood-equivalent)**



3.3 Woodfuel demand for institutional catering

The woodfuel required for mass catering in institutions is already accounted for in the cooking fuel estimates, to avoid double counting of meals taken outside the home. But the requirements of institutions are still worth quantifying separately to establish the significance of their energy requirements and the potential for intervention in this sub-sector.

There are a variety of institutional settings in which woodfuel is consumed for cooking, of which educational institutions are by far the most important. Almost 8.3 million students are enrolled in state-run or private schools, Training and Vocational Education and Training Institutions (TVETs), Colleges of Agriculture, Colleges of Education, Nursing, Midwifery & Health Training Colleges, specialised professional teaching institutions and universities and polytechnics.[18]

Firewood consumption is a factor of the percentage of day, boarding and mixed institutions in each category, the percentages offering catering services, the percentages using firewood and the quantities of firewood required for day and boarding students. The net result is annual firewood demand for institutional catering of around **777,000 t**, as summarised in Table 23. This represents around 6% of total national wood demand for cooking, so is not insigifnicant. There is additional demand (not quantified) from prisons, hospitals, military installations and other institutions where mass catering takes place, though this will be much lower than the educational institutions.

3.4 Woodfuel demand for commercial catering

As with institutional use, the woodfuel required for commercial catering in hotels, restaurants and street food outlets is already accounted for in the overall cooking fuel estimates, to avoid double counting of meals taken outside the home. But it is still useful to estimate the demands of commercial catering to gauge its significance and potentially to direct demand-side interventions.

It is reported that an average of 17.4% of Ghanaians' HH food budget is spent on catering services or prepared meals (Ghana Statistical Service, 2017, p. 211). Expenditure cannot be translated directly to

Table 23. Firewood consumption by educational institutions

Type of institution	Total firewood consumption (t/yr)
Primary Schools	546,176
Junior High Schools	28,293
Senior High Schools	164,691
TVETs	10,309
Colleges of Agriculture	231
Colleges of Education	14,855
Nursing, Midwifery & Health Training Colleges	8,399
Specialised/Professional Teaching Institutions	77
Technical Universities & Polytechnics	783
Universities & Colleges	3,595
Total	**777,409**

18 moe.gov.gh/emis

an equivalent in energy terms, as restaurant food is more expensive than food cooked at home. Taking a global average figure, the cost of the food is likely to be around 30% of the total cost of commercially prepared food.[19] Assuming that average cooking efficiency is similar to home-cooked food, then the energy needed to cook that food will also be around 30% of the total, which is 5.2%.

The total fuel consumed for commercial catering is therefore estimated at **643,400 t** of wood p.a. (5.2% of 12,372,277 t). This makes it similar in scale to the institutional catering sector.

Photo 8. **Commercial vendor of koko (millet porridge) in Tamale, Northern Region**

19 smallbusiness.chron.com/common-food-labor-cost-percentages-14700.html

04 Woodfuel Demand for Industrial Uses

Woodfuel is used to provide heat in a variety of industries, both formal and informal. Those considered here are traditional brewing, fish smoking, shea processing, gari production,[20] rice parboiling and palm oil production. Women play a pivotal role in these industries and their engagement and involvement in any interventions to reduce fuel consumption or otherwise upgrade processes will be vital.

4.1.1 Traditional brewing

Firewood is used for the preparation of various types of traditional alcoholic beverages. These fall into two categories: local beer made from fermented millet, sorghum or maize, known as *pito*, and distilled spirit produced from the sap of palm trees or sugar cane water, known as *akpeteshie*. Both have regional variants, but the production processes within each category are similar.

Average annual consumption of alcohol in Ghana is 2.7 litres (l) per person aged 15 or over (WHO, 2018). 57.1% of this is drunk in the form of traditional brews, representing average consumption of 1.54 l/person/yr. The population aged 15 or over is 19,942,000 (Ghana Statistical Service, 2021b), giving total annual consumption of alcohol via traditional brews of 30,744,000 l. Assuming this is split equally between *pito* and *akpeteshie*, and assuming alcohol content of 3% and 45%, respectively (Akyeampong, 1996; FAO, 2012), total annual consumption is around 512 million l of *pito* and 34 million l of *akpeteshie*.

It requires 1.37 kg of firewood to produce 1 litre of *pito* (Owusu-Takyi et al., 2013) and 6.5 kg of firewood to produce 1 litre of distilled spirit (Ohimain, 2012). The annual firewood requirement is therefore 702,000 t for *pito* and 222,000 t for *akpeteshie*, for a total of **924,000 t**. As variants of both drinks are produced across the whole country, but with a bias towards rural and peri-urban areas, this firewood demand is assumed for modelling purposes to be distributed evenly in areas of population density between 50 and 1,500 persons per sq. km.

4.1.2 Fish smoking

Ghana has a large and commercially significant fisheries sector based on both marine and inland stocks. A significant portion of the catch is smoked, mainly for domestic consumption. Fish smoking is generally carried out using firewood in basic 'chorkor' kilns, a technology introduced by the FAO in the late 1960s (Kwarteng et al., 2016). The process of generating smoke is not only unhealthy, but is also inherently inefficient, as it requires the incomplete combustion of the wood to generate the smoke. Efforts to introduce more efficient smokers such as the 'Morrison', 'Frismo' and 'Ahotor' have faced challenges, and the chorkor still dominates. Recent technological interventions have focussed instead on the reduction of carcinogenic polycyclic aromatic hydrocarbons in the smoked fish, to make them safer for human consumption (Coastal Resources Center, 2021).

The calculations to derive the firewood requirements for fish smoking are summarised in Table 24. The total estimated requirement is just over **225,000 t** of wood p.a. For modelling purposes, the 88,549 t/yr for smoking the marine

20 Gari is roasted, fermented cassava and one of Ghana's staple foods.

Photo 9. Pito brewing in Wa, Upper West Region

catch is assumed to be distributed evenly along the Atlantic coast, within 1 km of the sea, while the 136,555 t/yr for smoking the inland catch is assumed to be concentrated within 1 km of the margins of all significant inland lakes and waterways.

Table 24. Firewood requirements for fish smoking

	Marine	Inland	Source
Total catch, 2019 (t, live weight)	445,351		(FAO, 2022)
Split between marine and inland (t, live weight)	66%	34%	(Fisheries Commission, 2011).
	291,885	153,465	
Minus exports	(173,748)		(FAO, 2022). Smoked exports <70 t/yr (Asiedu et al., 2018).
Balance consumed locally (t/yr)	118,137	153,465	
Quantity smoked (t/yr)	72.4%	85.9%	72.4% of marine catch smoked (Dovlo et al., 2016)). 80% of total catch smoked (Samey, 2015, p. 20).
	85,472	131,810	
Firewood required for smoking (kg/kg fresh fish)	1.036	1.036	(Kwarteng, n.d.) Assumes chorkor kiln.
Total firewood requirement (t/yr)	**88,549**	**136,555**	**225,104 Grand Total**

Table 25. Firewood demand for shea processing

Shea nut production (t/yr)	End market	Firewood required per kg of kernel[21] (kg)	Total firewood required (t/yr)
25,000	Kernel exported for industrial processing	0	-
50,000	In-country industrialised processing for export	0.65	32,500
7,000	Hand-crafted shea butter for export	1.47	10,290
12,012	Processed for local consumption	1.47	17,658
94,012			**60,448**

Source: (Technoserve, 2018)

4.1.3 Shea processing

The fruit of the shea tree is processed into shea butter that is used in a variety of foodstuffs, cosmetics and pharmaceuticals. Firewood is used both for roasting the nuts (0.65 kg per kg of kernel) and for boiling the butter emulsion (1.47 kg per kg of kernel) (Mohammed & Heijndermans, 2013; Technoserve, 2018). A study commissioned by USAID quantified annual shea nut output at 94,012 t p.a., giving total firewood demand of **60,448 t/yr**, as shown in Table 25. Shea production is concentrated in the NSZ, so for modelling purposes the calculated demand is considered to be confined to the five northern regions, where it is distributed across all settlements located in the savannah ecological region.

4.1.4 Gari production

21,811,661 t of cassava was grown in Ghana in 2020 (FAOSTAT), of which 12.75% (2,780,987 t) is estimated to have been processed into gari (Kleih et al., 2013). With a conversion from fresh cassava to gari of 18.75% and a firewood requirement of 0.85 kg per kg of gari (Kemausuor et al., 2015), the total annual firewood used for gari processing is estimated at **443,000 t**. For modelling purposes, this demand is assumed to be distributed across the rural areas of each region, in proportion to their share of national cassava output, using data from the Ministry of Food and Agriculture (2019).

4.1.5 Rice parboiling

Rice is parboiled in some regions of Ghana to facilitate milling and reduce breakages. The process involves soaking the paddy in hot water for 10 to 24 hours and then steam-heating it until gelatinized, before drying and milling. Firewood is used for both the soaking and steaming phases. Parboiling takes place in the five northern regions, Oti and Volta, where lower post-harvest humidity levels would otherwise result in higher percentages of broken rice from milling (Ayamdoo et al., 2013; Kula & Dormon, 2009).

Ghana produced 973,000 t of rice in 2020 (FAOSTAT), of which an estimated 46% (447,580 t) is parboiled (Tomlins et al., 2005). 0.99 kg of firewood is required to parboil 1 kg of rice, using medium-sized vessels (Kwofie et al., 2016), giving a total annual firewood requirement of **442,000 t**. For modelling purposes, this demand is assumed to be spread across the rural areas of the five northern regions plus Oti and Volta.

4.1.6 Palm oil production

Heat is required for the softening and cleansing of palm oil fresh fruit bunches (FFB) before the oil is extracted. The FFBs are either cooked in boiling water or sterilised using steam. The use of firewood is restricted to artisanal processors (using oil drums and open fires) and small-scale

21 The quoted study seems to use the term ‘kernel’ interchangeably with ‘nut’, although the kernel is technically the core of the nut, after the shell has been removed. But as this description is maintained in the firewood consumption figures, it is assumed that this is an oversight and that ‘nut’ was the intended term.

industrial processors (using steam boilers). Ghana's large, estate-based processors use solid oil palm residues for generating process steam, and do not consume any firewood. They also process large quantities of FFB from contracted out-growers, which goes through the same factories and also uses no firewood. So it is the artisanal and small-scale industrial processing that is of interest for this assessment.

Ghana produced 2,471,605 t of oil palm FFB in 2020 (FAOSTAT). 62% of the land under oil palm is owned by smallholders or under wild groves for FFB processing at home or at small processing facilities, while 38% is under estates or out-growers processing centrally (Ofosu-Budu & Sarpong, 2013, pp. 362–363; Preferred by Nature, 2017). Yields of FFB per hectare are three times higher for smallholders than wild groves, and three times higher again for estates and their out-growers (Ofosu-Budu & Sarpong, 2013). So it can be calculated that the annual combined output from wild groves and smallholders is around 653,300 t of FFB.

It is reported that 66.8% of farmers with oil palms have their FFBs processed elsewhere (Ghana Statistical Service, 2017, p. 169). This includes all the out-growers for the estates plus some smallholders who sell their crop to small-scale industrial processors. Calculations reveal that around 345,400 t of smallholder or wild-harvested FFB must be processed by small-scale steam installations, while 307,800 t is processed on-farm using the drum boiling method.

The fuel requirement for processing using a small-scale industrial boiler has been measured as 0.00251 m3 of firewood per kg of FFB (FAO, 2005). Adopting an FAO global standard for firewood density of 725 kg/cu.m.,[22] this implies a requirement of 1.82 kg of firewood per kg of FFB. The total firewood requirement for 345,400 t of factory-processed FFB is therefore 629,000 t p.a. Data are lacking on the energy requirement for the artisanal drum boiling method. As an approximation, it is assumed that the process is similar in energy terms to the pre-treatment and cleaning of shea nuts, which requires 0.65 kg of firewood w/w (Technoserve, 2018). Given that the fruit comprises 66% of the FFB, by weight (Aziz et al., 2015), the artisanal processing of 307,800 t of FFB using the drum boiling method requires 132,000 t of firewood p.a. This gives total firewood demand of 761,000 t p.a. for both processing streams.

But due to the cost of firewood, it is well documented that a variety of wastes and residues are blended with wood for the processing of FFB, including solid oil palm residues, bamboo, tyres, plastics and other wastes (Osei-Amponsah et al., 2012). Assuming that firewood accounts for 50% of the fuel blend, then the total annual firewood requirement for oil palm processing is approximately **380,000 t**. In the demand model, this is assumed to be spread across the rural areas of the southern regions only.

While this figure is likely to be of the correct order of magnitude, there is a high degree of uncertainty over the exact quantity of firewood required for palm oil processing. There is a need for more accurate empirical assessment of the quantities of FFB being processed in different ways, the energy requirements of each method and the percentage contribution of firewood compared with other fuels.

4.1.7 Other (agro-)industrial woodfuel demand

Other potential agro-industrial processes requiring woodfuel are the production of groundnut paste, groundnut oil and cassava chips. These are not thought to be nationally significant, but merit further investigation. The thermal energy requirements of industrial cocoa processors are supplied from their own residues, mainly shells. Timber processing companies are understood to use their own offcuts and other wood residues to generate process heat.

Efforts were made to identify additional industries where woodfuel is consumed. It had been hoped that government records of steam boilers would facilitate the identification of industrial consumers, as all industrial boilers in Ghana are required to undergo annual safety inspections by 21 companies licensed by the Department of

22 www.fao.org/3/AD353E/AD353e12.htm

Factories Inspectorate (DFI). But the DFI does not maintain consolidated records of boilers and the boiler inspection template used by its licensed inspectors gathers no information on the fuel used. An interview with the DFI's Deputy Chief Inspector revealed that the larger boilers (found at breweries, food processors, producers of cocoa powder and cocoa liquor, fruit juice processors and soft drink manufacturers) are usually fuelled with residual fuel oil or diesel. There may be boiler systems using woodfuel in the textiles sector (e.g., for dyeing fabric) and potentially in food processing businesses, but no data are available. This is another area requiring further research.

4.1.8 Summary of industrial firewood demand

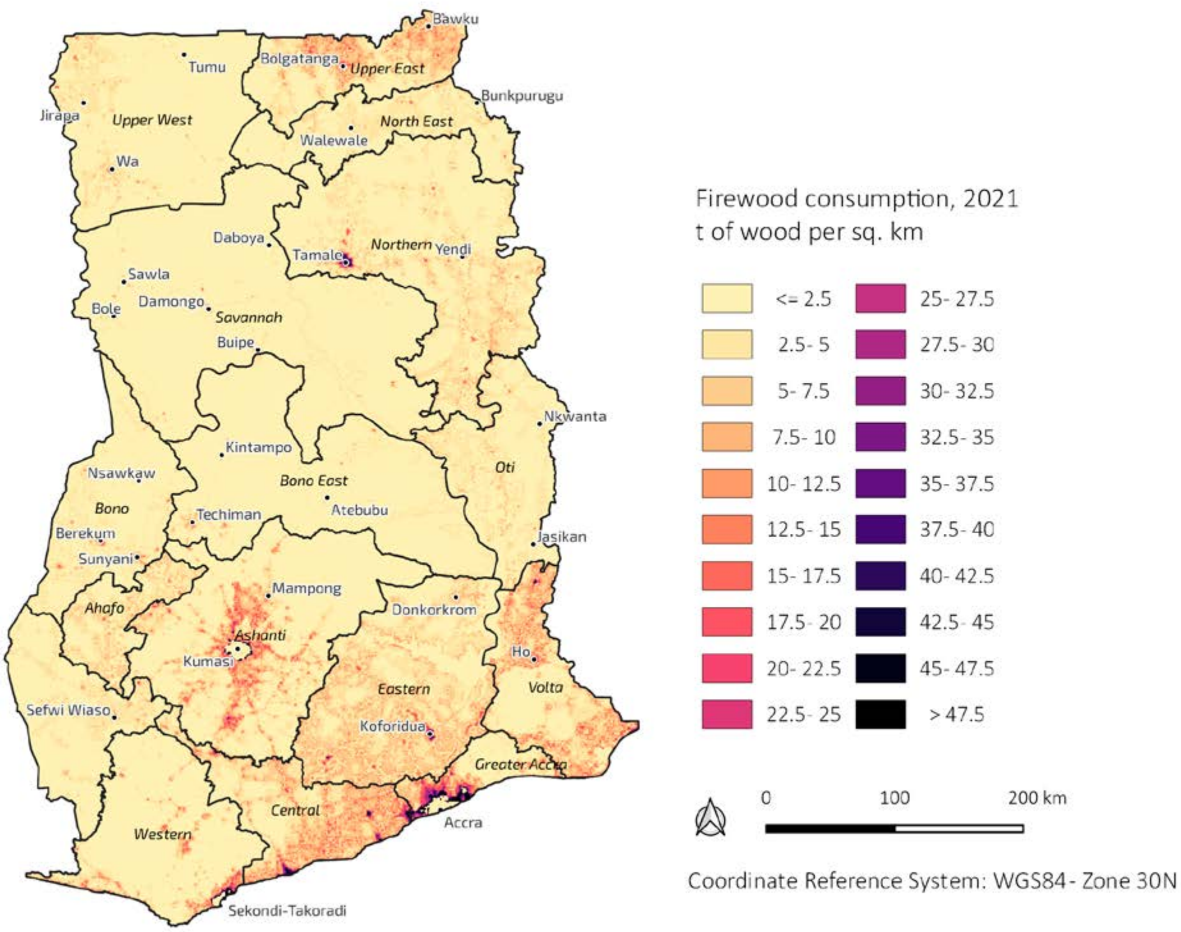
The combined firewood requirement for traditional brewing, fish smoking, shea processing, palm oil processing, gari production and rice parboiling is **2,474,448 t** p.a., as summarised in Table 26. This is spatially distributed as shown in Figure 7.

Table 26. Summary of industrial firewood demand

Industry	Firewood consumption (t/yr)
Brewing	924,000
Fish smoking	225,000
Shea processing	60,448
Gari processing	443,000
Rice parboiling	442,000
Palm oil processing	380,000
Total	**2,474,448**

Source: UDS survey, 2022

Figure 7. Distribution of industrial firewood consumption (2021)



05 Charcoal Export

Exports of charcoal from Ghana must be added to the domestic demand to calculate total woodfuel demand for all purposes.

The export of charcoal requires a licence from the Energy Commission (EC), which is obtained via a procedure set out on the EC website.[23] Applicants must provide various documentation and pay a fee of US$ 1,000 per year. They must also obtain permission from the EPA. Nine companies have been approved to date, with a combined annual export quota of 7,340 t.[24] These licence holders must secure a separate permit for each shipment, with additional fees payable of US$ 4/t (Energy Commission, 2012b). Official statistics record average charcoal exports of only 537 t/yr for the 5-year period 2016-2020 (Energy Commission, 2021),[25] no doubt in part because of this bureaucratic and expensive process.

The official export figure is only a fraction of the 8,400 t of charcoal p.a. recorded as imports from Ghana by receiving countries over the same period through the UN Comtrade system.[26] 89% of those imports were to five countries: the United Arab Emirates, Saudi Arabia, Turkey, Kuwait and Oman. Assuming the Comtrade figures are broadly reliable, **93% of exports are not captured by the official figures.** But **8,400 t (50,400 t in wood-equivalent)** p.a. is still a relatively insignificant quantity compared with Ghana's domestic consumption of charcoal, even if the number is inaccurate by a considerable degree.

Overland charcoal export was also investigated by visiting border crossings to Burkina Faso, where it was possible to determine from observation and from staff of the Ghana Revenue Authority and Ghana Immigration Service that large-scale export over the northern border does not take place. There may be small quantities of charcoal taken short distance into Burkina Faso (e.g., to the town of Leo) by donkey cart or 'Motor King' trikes, bypassing the official crossings, but these quantities are negligible. There is also thought to be little or no east-west export of woodfuel to Côte d'Ivoire and Togo.

A ban on charcoal export has been touted recently by the Minister for Lands and Natural Resources to prevent the "huge toll on the nation's forest resources".[27] A ban might restore some government control over an export trade that currently goes largely unrecorded, but as the export quantities are relatively small, it would not have a measurable impact on total demand.

23 www.energycom.gov.gh/files/Charcoal%20Export%20Licence%20Requirements.pdf

24 energycom.gov.gh/regnew/index.php/Energy/loadRegister/Charcoal%20Export%20License%20Holders

25 Average recorded charcoal exports for 2016-2020 were 0.434 ktoe p.a. in energy terms, which converts to 557 t using the energy content of 32.6 GJ/t applied elsewhere in the same document.

26 comtrade.un.org/data searching for imports from Ghana with HS code 440290 'Wood; charcoal of wood other than bamboo (including shell or nut charcoal), whether or not agglomerated.'

27 www.ghanabusinessnews.com/2021/11/18/government-contemplates-ban-on-charcoal-export-minister

06

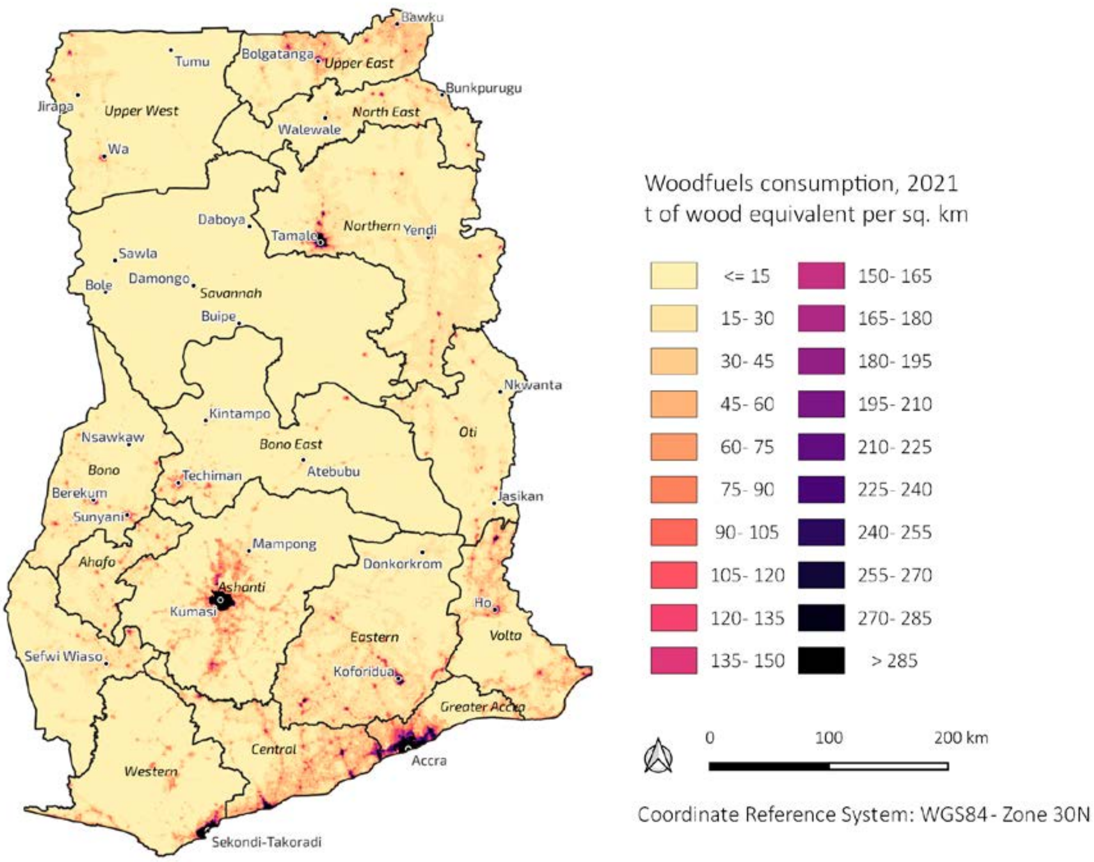
Total Woodfuel Demand

Combining the demands for cooking, industrial uses and export, total national woodfuel demand is **14,897,125 t p.a.** in wood-equivalent, as summarised in Table 27. The spatial distribution of this demand is mapped in Figure 8.

Table 27. Summary of total national woodfuel demand

Sector		Fuel	Quantity (t/yr, wood-equivalent)
Cooking		Firewood	6,799,414
		Charcoal	5,572,863
Industry	Brewing	Firewood	924,000
	Fish smoking		225,000
	Shea processing		60,448
	Gari processing		443,000
	Rice parboiling		442,000
	Palm oil processing		380,000
Exports		Charcoal	50,400
		Total	**14,897,125**

Figure 8. Distribution of total woodfuel consumption for cooking, industry and exports



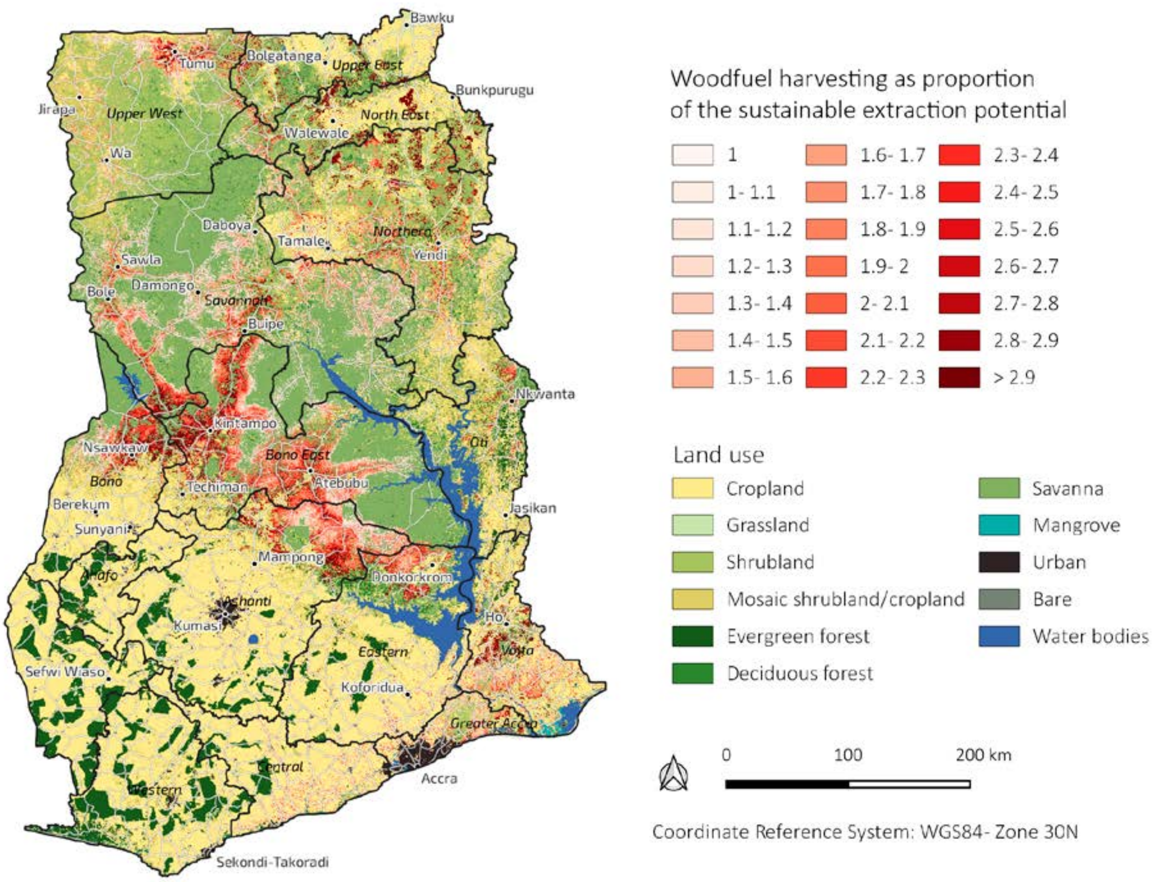
07 Impacts of woodfuels on tree cover

7.1 Current pressure on tree cover from woodfuels

Based on the supply-demand modelling process described in Annex C, it is estimated that of the total wood demand of 14,897,125 t per year, 2,279,958 t (15%) is being harvested in excess of the mean annual increment (MAI); that is, beyond the sustainable extraction potential.

Figure 9 below indicates the areas where pressure from wood extraction for woodfuels exceeds sustainable harvesting levels. The hotspots from this modelling match those flagged by previous studies, with the Kintampo and Atebubu areas being the areas of most significant pressure on tree cover.[28] Additional areas further north in the NSZ are also coming under increasing pressure, notably parts of Upper West Region (near Tumu), Upper East Region and southern parts of Savannah Region.

Figure 9. Woodfuels pressure map, indicating areas of unsustainable harvesting (2021)



28 It is no coincidence that Kintampo-Atebubu is one of the two priority landscapes for GIZ's Forest Landscape Restoration project.

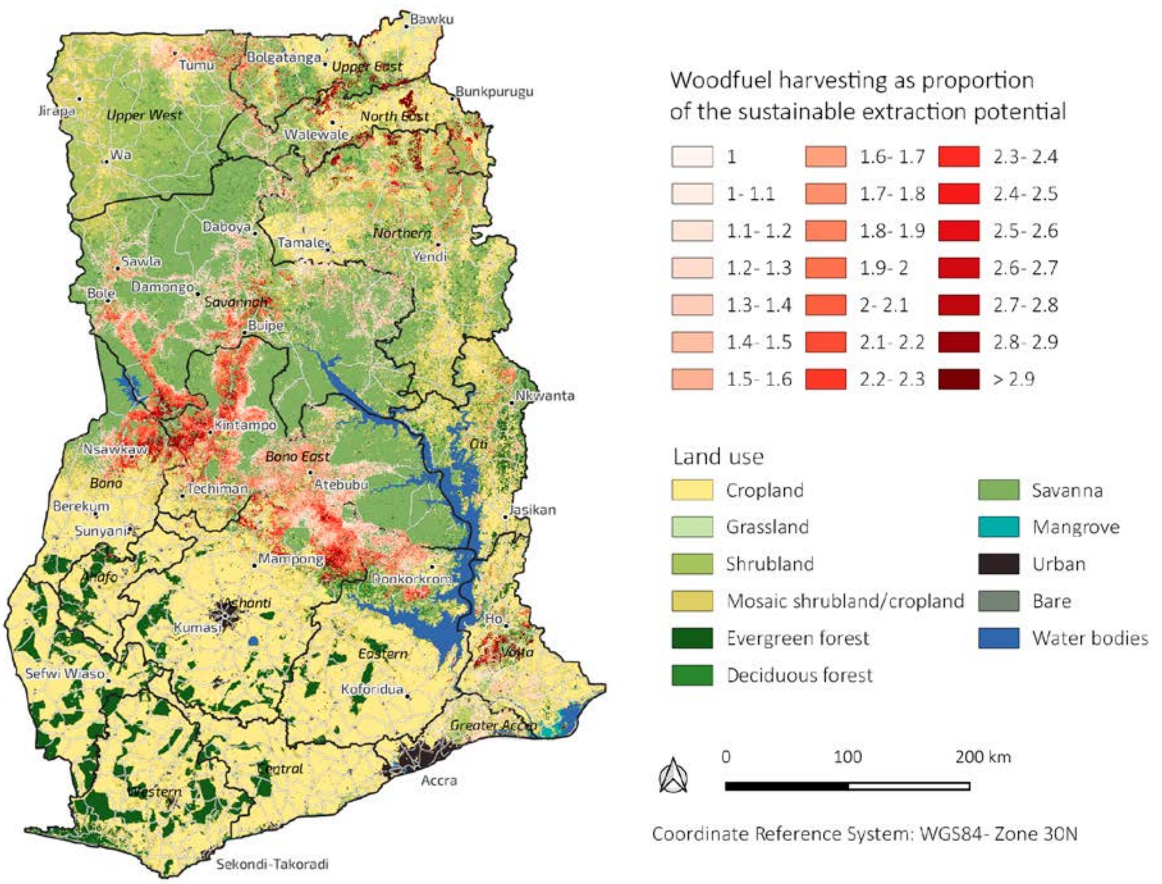
The situation is very different for firewood and charcoal, however. While only 15% of all woodfuel is being harvested in excess of the MAI, the amount of wood overharvested for charcoal is estimated at 1,531,489 t p.a., corresponding to 27% of the total charcoal consumed.

Woodfuels, and more specifically charcoal, are adding to the pressure on Ghana's tree cover, especially in the savannah areas. Wood collection patterns are highly integrated with other landscape dynamics, however. In most cases, the residues of farm clearing can generate significant amounts of biomass that can be used as woodfuel in preference to direct harvesting on forested land. To account for the woodfuel supply generated by such land cover change, the biomass stock in areas of forested land use[29] converted each year to cropland or grassland may be deducted from the woodfuel demand. Between 2018 and 2019, the conversion of forested land use to agricultural use or grassland may have generated 440,743 t of wood.

This additional analysis does not suggest a significant reduction in the amount of wood overharvested for fuel (see Figure 10), with the over-harvesting figure still 2,225,983 t annually. Most of the reduction is achieved in the southern part of the country, with only a few locations in the NSZ around Tumu and Wa.

While land cover change is a significant phenomenon, the land cover time series analysis suggests that most of it takes place in the southern part of the country, where the pressure of woodfuel extraction relative to the MAI is generally much lower than it is in the northern regions. So the relatively small decrease in the quantity overharvested, once land cover is taken into account, can be explained by the high concentration of commercial woodfuel extraction in specific hotspots.

Figure 10. Woodfuels pressure map indicating areas of unsustainable harvesting after accounting for land cover change



29 The forest land uses are evergreen and deciduous forests, savannah and shrubland.

Photo 10. Charcoal for sale in farmland near Tumu, Upper West Region

7.2 Pressure on tree cover under future woodfuel demand scenarios

Between 2021 and 2030, the population of Ghana is expected to grow by 19% (United Nations, 2019). Population growth is the 'elephant in the room' and will massively increase woodfuel demand, offsetting whatever gains are achieved from active interventions in the sector.

Given the high contribution of charcoal to the overall consumption of wood for fuel, targeting a reduction in charcoal consumption in urban centres could also have a significant impact on demand, and thus on wood harvesting levels. Similarly, a reduction in consumption of firewood in the identified deficit areas could significantly contribute to improving the sustainability of the sector.

Woodfuel demand projections have been made to 2030 under two scenarios, one assuming a continuation of the current situation ('business as usual', BAU) and the other with selected interventions to promote fuel switching and efficiency improvements. The assumptions under the two scenarios are summarised in Table 28. The GLRSSMP could help promote the charcoaling efficiency improvement under the intervention scenario, while the demand-side changes would fall more under the EC and other agencies.

The results of this modelling show that demand for woodfuel might grow by 2,142,382 t p.a. (14%) by 2030 under the BAU scenario, while the stated interventions may reduce this by 3,235,657 t (-19%) against the BAU projection, and by 1,093,276 t (-7%) against current demand, as presented in Table 29. Growth in demand is expected to be especially strong for commercial fuels like charcoal and for firewood used by industries. As seen in the previous section, these fuels are generally harvested in more concentrated areas, which may lead to an increased pressure on tree cover.

Table 28. Scenarios for future evolution of woodfuel demand

Key parameters		Current situation	2030 BAU	2030 with interventions
HHs using LPG as main cooking fuel	Urban	57%	60%	70%
	Rural	16%	17.5%	27.5%
HHs using charcoal as main cooking fuel	Urban	31%	32.5%	25%
	Rural	17%	22.5%	20%
HHs using firewood as main cooking fuel	Urban	12%	7.5%	5%
	Rural	67%	60%	52.5%
Share of charcoal HHs using improved cookstoves		32%	35%	50%
Average charcoal kiln efficiency		16.7%	16.7%	18.3%
Efficiency gains in industrial firewood use		/	/	10%

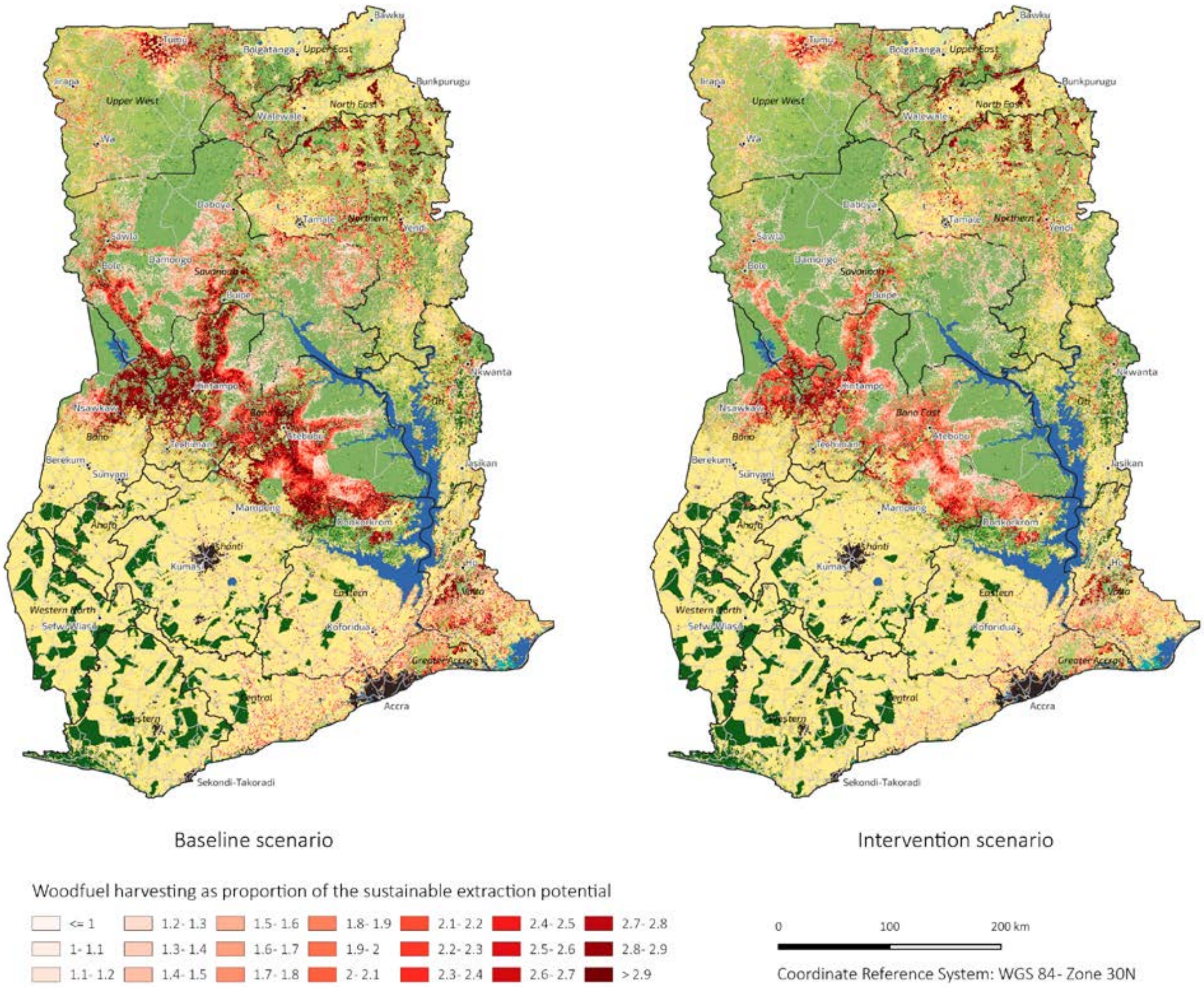
Table 28. Scenarios for future evolution of woodfuel demand

Sector		Fuel	Current situation	2030 BAU	2030 with interventions
Cooking		Firewood	6,799,414	6,923,425	5,955,726
		Charcoal	5,572,863	7,111,290	5,138,771
Industry	Brewing	Firewood	924,000	1,103,219	992,897
	Fish smoking		225,000	268,641	241,777
	Shea processing		60,448	72,172	64,955
	Gari processing		443,000	453,705	408,334
	Rice parboiling		442,000	528,924	476,032
	Palm oil processing		380,000	527,730	474,957
Exports		Charcoal	50,400	50,400	50,400
		Total	**14,897,125**	**17,039,507**	**13,803,850**

Overlaying the projected woodfuel demand in 2030 onto the current potential biomass supply shows that the level of non-sustainable harvesting may significantly increase in the BAU scenario (rising 59% from the current 2,279,958 t to 3,624,104 t in 2030). With the interventions described, the level of unsustainable harvesting can be reduced to 1,842,237 t, which represents a decrease of 19% compared to the current situation and, more importantly, a reduction of 49% compared to the BAU projection (Figure 11).

While this study is thought to be the first to have compared supply and demand for woodfuel in Ghana using modern techniques, and to have attempted to quantify tree loss associated with woodfuel use, there is a pressing need for much better data. Information is particularly weak on biomass stocking and MAIs on land outside forests, and on the dynamics of land cover change over time. Securing better data, especially on the supply-side, would improve the accuracy of the supply/demand analysis, while more accurate and consistent time series data on land cover would greatly improve the understanding of the drivers of tree loss.

Figure 11. **Woodfuel pressure maps for 2030, projected under BAU and intervention scenarios**



08 Intervention Options

This final chapter sets out four types of interventions that could make woodfuel value chains more sustainable, including measures to boost biomass supply, improve efficiency in charcoal production and fuel use, promote fuel-switching and strengthen the enabling framework. Population growth is the 'elephant in the room' and will massively increase woodfuel demand, offsetting whatever gains are achieved from these additional measures.

Containing population growth would be the single most effective way to counter rising woodfuel demand and reduce rates of tree loss, because of its direct link to the expansion of farmland in the absence of significant improvements in agricultural productivity.

The role of women in domestic, commercial and institutional cooking cannot be understated, and should be appropriately reflected in any measures to promote greater efficiency or fuel switching. During the design and implementation of the suggested measures, the issue of gender will therefore be important in ensuring appropriate and equitable delivery. The team who carried out this assignment did not include a gender specialist and cannot claim expertise in this field, making it especially important that additional consideration is given to gender mainstreaming in activity design and operationalisation. This is already known to be an important principle within the GLRSSMP.

8.1 Increasing production of woody biomass

Interventions are first recommended to enhance the supply of biomass for woodfuels, focussing on the forest pressure hotspots identified by the supply/demand modelling.

8.1.1 Assisted natural regeneration

Assisted natural regeneration (ANR) is a flexible approach to reforestation based on natural regeneration from seedlings, sprouts and stumps, with the possibility of additional (enrichment) planting to enhance degraded stocks. In dryland environments in particular, ANR can be a more cost-effective way to restore tree cover in the landscape than planting new trees, as it relies on indigenous species that are adapted to local ecological conditions and need no special management. Unlike high forest trees, species in the NSZ are robust, resilient and adapted to a forest ecotone that is constantly disrupted by wild fires (Amanor, 2021). This results in species that are well adapted to bush fallowing and respond to cutting by regenerating through coppice. Coppice from existing root stocks and stumps provides much faster regeneration than seeds.

If degraded land is left to recover, then tree cover will eventually come back through natural regeneration. This is well illustrated by an aerial view of a Forest Reserve in Upper East Region that has been heavily harvested for commercial firewood (Photo 11). Provided that encroachment for farming is prevented, there is strong potential for ANR at sites like this.

Photo 11. **Remnant stumps after firewood harvesting, Gia Forest Reserve, Kasena-Nankana Municipal District, Upper East Region**

Photo 12. **Fire break to facilitate ANR, Soalepe, West Gonja Municipality, Savannah Region**

For maximum effectiveness, ANR requires the exclusion of fire and grazing, at least until tree stands have recovered to a level where they can withstand these pressures. Photo 12 illustrates how simple firebreaks can protect forest areas and facilitate regrowth.

World Vision has already promoted ANR in Upper East Region. Research in five targeted communities recorded average firewood harvests of 48 t/ha/yr, against 29 t/ha/yr from unmanaged forests, as a result of active pruning and management of tree regrowth, reduction in bushfires and no indiscriminate cutting of trees (Amedi & Akunyagra, 2021).

Efforts are underway elsewhere in the NSZ and the Transition Zone to support ANR under the GIZ-managed Forest Landscape Restoration project, which operates in ten communities in the Mole and Kintampo-Atebubu landscapes.[30] If wildfires can be contained, through physical measures, awareness-raising and community-based firefighting systems, then there is considerable scope for interventions to boost growth rates – such as active management of regrowth and enrichment planting in degraded woodlands.

It is recommended that ANR is promoted in the GLRSSMP as a forest landscape restoration strategy, incorporating fire control measures and enrichment planting to boost natural biomass stocks.

8.1.2 Agroforestry

Agroforestry integrates multi-purpose trees in a mixed farming system. An example from Sunyani District shows how this can be used to enhance the supply of woodfuel.

Research conducted in Sunyani revealed that almost 80% of HHs in this part of the country were already buying firewood by the late 2000s (Amua, 2011), indicating local shortage of fuel as people could no longer self-collect. The area is relatively rich in biomass compared with the NSZ, but it is mostly locked up in privately owned trees. Despite the scarcity of accessible woodfuel, landowners did not plant trees for the specific purpose of producing energy. They instead purchased woodfuel from alternative locations (such as Kintampo) and put their own land to more economically attractive uses (mainly growing crops). But it is notable that they also integrated trees from which firewood could be obtained in their farming systems.

Agroforestry practices observed included the modified taungya system, woodlots (for building poles), bee keeping, alley farming, fruit trees, green fences, trees on cropped land and residual indigenous trees, with diverse reasons given including providing shade, medicine, fodder and firewood, and improving soils. The researcher recommended further promoting live fencing, home gardens and intercropping of trees on farmland, from which fuel is a by-product. The result can be a diverse and resilient landscape under integrated agroforestry configurations (see Photo 13). For poor HHs especially, extra income from agroforestry can help improve economic resilience.

The NSZ requires context-appropriate agroforestry techniques that are adapted to low rainfall, extended drought, fire risk, encroaching livestock and termite damage, among other threats. Live fencing is often an important first step to exclude grazing animals and provide a windbreak to reduce evapotranspiration. A mango plantation visited in Zugu near Tamale was protected with a living fence of neem (*Azadirachta indica*) which had been pruned for firewood (Photo 14). The trees in highest demand from farmers - according to a commercial tree nursery owner in Tamale - are mango and cashew. The owner reports that people "need to plant around their homes and then they will take care of it; with group planting nobody really owns it."

A smallholder farmer's priority is generally to produce enough food to sustain their families and reforestation schemes should therefore focus on integrated systems that boost food production (Appiah et al., 2015). Agroforestry is ideally suited to meeting these combined needs.

30 See www.giz.de/en/worldwide/90315.html

Photo 13. **Mixed crop/tree landscape in cocoa belt at Boankra, Ejisu Municipal, Ashanti Region**

Photo 14. **Live neem fencing around a mango plantation, Zugu, Kumbungu District, Northern Region**

An intensive program of support for agroforestry is recommended in the GLRSSMP, integrating multi-use tree and shrub species on farms, along boundaries and around homes, from which wood for fuel will be continuously regenerated.

A potential channel for promoting agroforestry is the Ghana Federation of Forest and Farm Producers (GhaFFaP), an umbrella organization for Forest and Farm Producer Organisations (FFPOs) drawn from the Savannah, Transition and Forest ecological zones. GhaFFaP has a membership of more than 1 million representing 12 FFPOs (GhaFFaP, 2020) and actively promotes mixed land use systems that provide food, fodder, fuel and multiple additional outputs. The systems should always be farmer-led, demand-driven and include an element of cost-sharing, and not based on handouts and prescribed, standardised approaches.

A GhaFFaP model HH visited in Upper East Region has become self-sufficient in firewood from their own land, through intensive multi-purpose agroforestry (Photo 15).

8.1.3 Energy woodlots

A key woodfuel policy intervention promoted by the GoG on the supply side entails the transformation of energy production to woodlots, with the aim of alleviating pressure on natural forests. Ghana's Nationally Determined Contribution to the Paris Agreement on climate change includes a target of establishing 428,000 ha of woodlots for charcoal production by 2030. The establishment of community woodlots for charcoal production is also one of the planned mechanisms for generating woody biomass in the GLRSSMP.

This approach to forest protection and supply-side enhancement raises a number of questions. First, there is an assumption that Ghanaian consumers will be prepared to use plantation-grown wood as

Photo 15. Model agroforestry farm in Namdam District, Upper East Region

an alternative to natural hardwoods for firewood and charcoal. But there is no evidence of such interest in the market, given the continued availability of naturally occurring trees. Second, there is an assumption that a switch to plantation-grown woodfuel will avert the felling of trees in the natural landscape. But this assumes that woodfuel extraction is the primary driver of tree loss, whereas the reality is more complex and the contributions of agriculture, fire, timber extraction and grazing must also be considered. Third, the commercial viability of energy woodlots is in doubt. As the FC itself has concluded, "community woodlot schemes ... have a questionable record elsewhere, and the proposition would need further substantiation" (Forestry Commission, 2010).

Optimistic financial models may indicate a positive return from investments in woodlots for woodfuel. But it is unlikely that these results can be achieved in practice. One recent analysis indicates a Net Present Value (NPV) of US$ 1,884 per ha and an Internal Rate of Return (IRR) of 56% from a *Senna siamea* woodlot managed for charcoal production over 20 years and five coppicing cycles (Lemke, 2020). But this assumes highly ambitious wood yields (128.5 t/ha, air dry, per cycle), no failures after the first year, 30% efficiency in charcoal production (almost double what is currently achieved) and an optimal road-side price for charcoal in small bag sizes (with no allowance for the added costs of transport and handling from the kiln site). The land on which the trees are grown is not costed and alternative land uses (such as farming or other forestry configurations) are not compared.

A financial model was developed for this assessment using the same labour inputs and costs as Lemke (2020) for woodlot establishment, maintenance and harvesting, and a more favourable discount rate of 10% (vs. Lemke's 22%). But the price of seedlings was raised from GH¢ 1.0 to GH¢ 1.2 (to include transport to the planting site) and a lower wood yield of 114.9 t/ha (air dry) after four years was adopted, based on trials at Kumasi (Mainoo & Ulzen-Appiah, 1996).[31] This will still exceed real-world performance, but represents a best-case outcome. The wood yield from the Kumasi trials was adjusted downwards by 35% for the drier landscape of the NSZ, based on default values for national greenhouse gas inventories (IPCC, 2019, p. 39).[32] The same four coppicing cycles over 20 years were assumed.

Three scenarios were then run for the Cocoa Belt and the NSZ, with different assumptions for tree mortality rates, carbonisation efficiencies and charcoal prices. The results are summarised in Table 30.

Table 30. Financial modelling of Senna siamea woodlot for charcoal production

Variable	Base case	Improved case	Optimised case
Mortality rate per cycle	20%	10%	5%
Carbonisation efficiency	16%	20%	24%
Charcoal sale price (GH¢/kg)	0.48	0.52	0.57
Cocoa Belt			
IRR	12%	24%	33%
NPV (US$ per ha)	90	995	2,010
Northern Savannah Zone			
IRR	-3%	11%	20%
NPV (US$ per ha)	-501	86	748

Source: Authors' model adapted from Lemke (2020). See Annex F for details and sources.

31 The yield in the Kumasi trials was 86.2 t dry matter (dm)/ha, equivalent to 114.9 t/ha air-dry at 25% moisture content.

32 The IPCC Guidelines have reference figures for eucalyptus in Africa (but not for S. siamea), with AGB yields of 20 t dry matter (dm)/ha/yr for Tropical Moist zones and 13 t dm/ha/yr for Tropical Dry zones (< 1,000 mm rainfall p.a.). Placing Kumasi in the former and the NSZ in the latter, a 35% yield reduction is modelled for woodfuel plantations in the NSZ compared with the Cocoa Belt.

The modelling results indicate that woodlots for charcoal in the NSZ have a negative NPV under the most realistic (BAU) scenario. The prospects look more promising for the Improved and Optimised cases, although the input assumptions are highly optimistic[33] and the returns from an energy woodlot are not compared with other land uses. The evidence from observed farmer practice is that setting aside potential agricultural land to grow trees purely for energy is not considered rational. Efforts have been made to improve economic returns by introducing intercropping during the first one to two years of woodlot establishment, under a modified taungya system. While this approach may deliver better economic returns on paper, because early year expenditures can be offset by revenue from crop sales, access and benefit sharing from such systems is complex to manage and farmers may have little motivation to look after the trees when they will be prevented from growing more crops once the trees have reached a certain size.

Unfavourable economic prospects are a key reason why dedicated energy woodlots have a poor track record of adoption and survival. For example, Ghana's ELCIR+ project (Engaging Local Communities in REDD+/Enhancing Carbon Stocks), under the World Bank-funded Forest Investment Program, had reached only 11.5% of its plantation establishment target of 6,200 ha by the time of its mid-term review in January 2018 (Schwöppe & Wojewska, 2018). It was found that the low financial benefits and high costs of woodlot establishment and maintenance, compared with more profitable land uses, deterred communities and individuals from engaging. Tree planting activities compete for land with food crops and cash crops, predominantly cashew farming in the ELCIR+ case. Those woodlots that were established were mainly on private land. Communal projects have higher management demands and create a risk of elite capture and uncertain distribution of benefits (ibid.).

Photo 16 shows a woodlot of *S. siamea* established near Tamale in 2014 with support from an international NGO, with free seedlings and a package of fencing, water pump, piping and elevated storage tank (all since removed). The woodlot was allocated to a women's group to provide a source of fuel for processing shea butter. Tree survival today is around 50% and growth rates are variable but generally very poor. There is evidence of one round of rudimentary harvesting and coppicing from some stumps. The land has recently been surveyed and beacons have been installed for sub-division, making the future of the site unclear. It is evident that this has not been a well-supported initiative at community level and would not have generated a positive return for an investor.

There are social as well as economic barriers to energy woodlots. An alternative charcoal value chain based on woodlots rather than natural trees needs clients for farmed charcoal, who are prepared to switch over to these new sources. Since charcoal production is largely a product of natural forests and not farms, this presupposes a significant shift in production from woodcutters to farmers, or the conversion of woodcutters to farmers. Where woodcutters would acquire land and skills in plantation cultivation is something that needs to be addressed. As is the logic of why farmers would be interested in converting production from crops to charcoal, or where they would acquire the necessary skills for burning charcoal (Amanor, 2021).

Woodlots also provide a highly visible transformation of the land, which - once established - is difficult for others to challenge and claim rights over (ibid.). Smallholder farmers might therefore see establishing woodlots as a way of securing rights to land, particularly when seedlings are freely provided as an inducement, while not actually having any real interest. The expansion of woodlots results in difficulties in accessing land for the most vulnerable and poor farmers, including migrant farmers and women (ibid.). There is therefore a risk that energy woodlot establishment on a large scale may worsen existing processes of dispossession of vulnerable groups from access to agricultural lands (Hansen, 2021). Besides intensifying social inequality, the

33 The labour inputs from Lemke (2020) give establishment costs of US$ 984/ha and annual maintenance costs of US$ 36-88/ha, whereas the FC budgets US$ 1,500/ha for establishment and US$ 600/ha/yr for maintenance in its national plantation strategy (Forestry Commission, 2015).

Photo 16. Senna siamea woodlot, Zugu, Kumbungu District, Northern Region

expansion of land under plantations also disrupts existing bush fallowing systems, shortens fallow periods and reduces biodiversity (Amanor, 2021).

Proposals to develop energy woodlots seem to be based on an incomplete understanding of the complex context in which charcoal is produced, failure to reference the unsatisfactory experiences from previous woodlot establishment in the Transition Zone and the NSZ, insufficient clarity over who is to be involved in new woodlot establishment, their motivations for investing land, time, money and labour, and the potential impacts on the poorest and most vulnerable.

Woodlots for the dedicated purpose of generating woodfuel are not recommended as an intervention strategy.

Rather than seeing woodfuels as a resource to be produced, managed and used in isolation, there is a need for landscape-wide approaches that consider these fuels in the context of rural livelihoods and integrated natural resource management, with woodfuel provision being one of a range of environmental services. ANR and agroforestry are founded on this more integrated perspective.

8.2 Improve charcoal production techniques

Most charcoal in Ghana is produced in traditional earth-mound kilns. At efficiency rates typically between 15 and 20%, at least 6 kg of air-dried wood is required to produce 1 kg of charcoal. So these kilns convert 90-100 megajoules (MJ) in the wood to only around 30 MJ in the charcoal.

Improving the efficiency of the carbonisation process has the potential to improve the energy balance, reduce greenhouse gas emissions, improve charcoal quality (hence price) and save time for producers. Options range from adapting the construction and management of earth kilns to using metal or brick kilns, to using industrial charcoal retorts that co-generate heat and electricity (Schure et al., 2021). But despite many efforts to introduce improved kiln technology in Sub-Saharan Africa, uptake remains low due to the relatively high investment costs of stationary or industrial options, a lack of training among charcoal producers, the inappropriateness of some kiln techniques for local contexts and a lack of institutional frameworks to promote more efficient carbonisation practices (Schure et al., 2019).

The same limitations hold true for Ghana, where a variety of improved carbonisation methods have been tried, tested and demonstrated since the 1980s, including the Tropical Development Research Institute kiln, the Ghana mini metal kiln, the Missouri kiln, the Subri clay-metal kiln, the Casamance kiln and various brick kilns (Ministry of Energy, 2019a). Promotion of these technologies has encountered constraints that include high cost, lack of start-up and working capital, and absence of adequate skills for effective management. Brick kilns are further limited by the fact that they are immobile, while most charcoal producers follow the wood. In many cases, the supposed efficiency gain is only marginal. The EC is developing Woodfuel Regulations "in which the need to undertake charcoal production using efficient production technologies is emphasised" (Ministry of Energy, 2019b). But options for upgrading the process with new technology are very limited, given these constraints.

There are instead ways to improve the performance of traditional earth kilns at no cost to users, focussing on raising knowledge and skills rather than introducing new hardware. Producers consider the traditional earth mound method more versatile, and a valuable legacy handed down to them by their forebears. Techniques to improve this technology include pre-drying the wood to less than 20% moisture content, separating the wood by species, stacking systematically according to diameter (starting with the smallest pieces, then medium wood in the first third of the kiln, followed by wood of large diameter in the second third, then topped with twigs), tightly stacking the wood but in a way that still leaves space for air to circulate and properly covering the wood with leaves or grass before adding soil (Schure et al., 2021). It is vital to watch the kiln carefully during all phases of carbonisation and address any cracks immediately. The cooling period should be at least two days and water should not be used to cool the charcoal.

The adoption of such techniques improved yields from traditional kilns from 16% to 22% in a project in Cameroon, and from 15% to 22% in a project in Kenya, with the latter also predicted to reduce emissions of carbon monoxide, carbon dioxide and methane by 40%, 49% and 44%, respectively (Schure et al., 2021). The carbonisation process can also be faster and can produce charcoal with fewer impurities.

A program is recommended to promote improvements to basic earth kilns for charcoal making through grassroots training, exchange and practical learning, working with charcoal producers themselves and sharing hands-on experiences from within Ghana and elsewhere.

The necessary skills can be introduced through peer-to-peer skills enhancement from respected and experienced charcoal makers. Uptake can be promoted through a participatory 'train-the-trainers' format, in which producers can experience for themselves the benefits of new methods and can then share what they have learned with fellow producers.

8.3 Supporting cleaner and more efficient woodfuel use

8.3.1 Improved HH stoves

Ghana's first improved charcoal stove, the 'Ahibenso', was introduced in 1989 with support from World Bank ESMAP, and was reportedly about twice as efficient as the traditional 'coal pot' (Ahiekpor & Bensah, 2019). But users complained about the stove's durability and cost (UNDP, 2012). There were also initiatives by the Council for

Scientific and Industrial Research and the Volta River Authority to promote improved HH firewood stoves, though little is known about their impact.

In 2002, Enterprise Works/VITA launched a local version of the highly successful Kenya Ceramic Jiko called the 'Gyapa', with funding from USAID and the Shell Foundation (see Photo 17). The design was widely taken up and at least 600,000 units had been sold by 2014 (Ahiekpor et al., 2014), though more recent data are unavailable as much of the production has moved into the informal sector. A number of carbon finance projects have supported Ghanaian stove producers, some promoting the Gyapa and others disseminating alternative charcoal stoves such as CookClean's 'CookMate'.[34]

With support from the Clean Cooking Alliance (formerly the Global Alliance for Clean Cookstoves) and others, the Ghana Alliance for Clean Cookstoves (GHACCO) was formed in 2012 to bring stakeholders together with the aim of disseminating five million improved cookstoves by 2020 (Ahiekpor et al., 2014). SNV was an active player and commissioned a series of detailed technical and commercial studies on household energy and hosted the GHACCO secretariat.

The main stove producers have historically been Relief International, Toyola, Man & Man and CookClean. Most products have been artisanal or produced in quite basic manufacturing facilities. A lack of technical standards, quality control and effective testing and monitoring mechanisms has resulted in poor performance and low durability (UNDP, 2015). Many of the programs to promote improved cookstoves have under-performed due to inconsistent quality, high cost and supply-driven approaches that pay insufficient attention to consumer needs and preferences, and to the long-term financing and business growth of the companies involved (Energy Commission, 2012a).

Following a period of significant interest and investment from around 2000 to 2015, the improved cookstove sector seems to have seen a drop in external support and has plateaued, with limited evidence of recent innovation. A renewed national effort is required to revitalise the sector and launch innovative new products, now that the Gyapa is ubiquitously available.

The GoG is developing a National Clean Cooking Strategy, with support from the World Bank, to guide the roll out of program for deployment of the clean cooking solutions. In 2020, it commenced the deployment of 500,000 HH cookstoves. This will increase the availability of improved charcoal cookstoves in the Ghanaian market but is not yet of sufficient scale to make a major impact. The World Bank is also supporting a pilot project with Eni

Photo 17. Traditional coal pot and improved Gyapa charcoal stove, Tamale, Northern Region

34 www.cookclean.net

Ghana to assess the most suitable improved stoves and production and distribution approaches in ten coastal communities in the Western Region, leading to a larger two-year program.

The commercial opportunity for improved cookstoves could be very significant. The latest census found that 1.94 million HHs use charcoal as their main source of fuel for cooking. Assuming these HHs have at least one stove with an average lifetime of three years, and not accounting for use of charcoal as a secondary or tertiary fuel, there may be demand for at least 650,000 improved charcoal stoves per annum. The latest sales figures available suggest that 275,000 improved charcoal stoves were produced in 2015 (SNV Ghana, 2017). Less than half the potential market is therefore served with improved stoves, unless there has been a recent dramatic unreported uplift in sales. There will also be significant (but unquantified) demand for improved cookstoves from restaurants, street food vendors and other commercial catering establishments.

The Clean Cooking Alliance recently commissioned a consumer segmentation study in Ghana, which used machine learning techniques to classify and locate 5.7 million HHs most likely to purchase improved stoves (Fraym, 2021).[35] This market estimate is certainly on the high side as there are only 4.53 million HHs for which woodfuels are the primary cooking fuel (Ghana Statistical Service, 2022). But the study's novel methodology could be applied to more accurate market research using more conservative screening parameters.

The Gyapa-type stove design is now almost 40 years old. In other emerging economies in Africa, the mass production of more refined, factory-made appliances has been proving successful, now frequently promoted on a par with LPG stoves, electric cookers and other aspirational HH durables. The market is evolving and becoming more sophisticated and there is an opportunity in Ghana to promote the next generation of high-performance products that offer consumers status, pride and prestige, as well as fuel-savings and emissions reductions (see Photo 18 for examples).

A more ambitious and scaled-up national program to promote high-tier charcoal stoves for households and commercial catering is recommended.

The distribution network for improved cookstoves is still poorly developed in Ghana, especially in rural areas. Profit margins on stoves are generally low, providing limited financial leeway for investments in marketing and expansion of the distribution. Cookstove companies need financing

Photo 17. High performance charcoal stoves mass-produced by BURN and Envirofit

Source: www.burnstoves.com ; www.envirofit.org

35 1.3m 'Urban Early Adopters' and 1.4m 'Peri-urban & Rural Early Adopters', considered most likely to afford clean cookstoves, plus 1.4m 'Secondary Followers' who may be able to afford lower-cost clean cookstoves or higher-cost products with financing, and 1.2m 'Secondary Followers' who may be able to afford lower-cost clean cookstoves.

in the form of working capital to be able to invest in the distribution system (Hellpap, 2020). Additional support to marketing efforts can significantly increase the demand for improved stoves, provided that an adequate range of products of good quality is available and the necessary sales structures are in place (ibid.).

Offering microloans to HHs or catering enterprises for purchasing improved stoves could increase adoption, but the administrative cost of handling such loans is high. Subsidising stoves is more straightforward but can lead to market distortions and is not recommended. Manufacturers should instead be supported in technology development to better meet the expectations of customers through consumer preference and market intelligence studies, capacity development, challenge funds and investments in new production technologies and processes. A key challenge will be to give all eligible companies equal access to opportunities for support.

The proposed program should be led by the private sector using aspirational commercial messaging, but the endorsement and support of the EC, FC and Ministry of Health would be beneficial for associating the products with a healthier and more sustainable lifestyle.

A draft regulation on cookstoves standard and labelling has been prepared by the EC. The purpose of the regulation is to enforce minimum performance requirement and appropriate labelling for biomass cookstoves. Manufacturers are expected to meet a minimum performance requirement of 20% thermal efficiency and a safety score of 70 (Ministry of Energy, 2019a).

The standard-setting process for cookstoves should be completed and quality labelling should be introduced via the Ghana Standards Authority in a way that is streamlined and cost-effective for manufacturers and importers.

Enforcement will be essential and may require significant resources, as most stoves are sold through the informal sector.

Import duties and VAT should be removed for cookstoves to enable high-performance products to compete with artisanal stoves from the informal sector.

8.3.2 Institutional catering improvement

The majority of kitchens in educational institutions, especially at secondary level and below, use firewood as their main source of cooking energy, often in traditional, inefficient hearths that are wasteful and polluting, and which are likely to negatively affect the taste and nutritional quality of the food. Cooks are exposed to harmful smoke that can cause respiratory infections, pulmonary diseases, cataracts, lung cancer and heart-related diseases (Ahiekpor & Bensah, 2019).

The situation is particularly poor in primary schools. The GoG has been implementing the National School Feeding Program (NSFP) since 2005 to provide a hot meal to pupils each day. By the end of 2019, 2,939,555 pupils in 9,162 schools were benefiting. The NSFP has resulted in the construction of kitchens within or close to beneficiary schools, many of which are makeshift structures with equipment left at the mercy of the weather (Ahiekpor & Bensah, 2019). In 2018 the GSFP was paying feeding provides GH¢ 0.80 per day per pupil served. A survey in Greater Accra revealed that they spend anything from 17% to 69% of this on cooking fuel (GHACCO, 2018).

While the National Clean Cooking Strategy will increase the availability of improved charcoal cookstoves for HH use, it is not significantly improving the low penetration and adoption of improved institutional stoves (Acheampong et al., 2021). This is a sector in need of more attention. It is also a sector with significant impact potential. Institutions purchase their firewood, so they have an economic incentive to invest in stoves that save energy in a way that does not apply to HHs freely gathering their own fuel. Institutions also have a duty of care to provide well cooked food and a safe and healthy working environment for staff. In promoting themselves to prospective students and their parents, some educational institutions (especially in the private sector) have an added incentive to showcase clean, modern and efficiently managed kitchens to boost their enrolment. There is both a need and an opportunity to support the dissemination of improved cooking systems in institutions.

Sporadic efforts have been made to introduce improved cooking systems in schools. NGOs, research institutions, private companies and artisans have been promoting various types of improved institutional cookstoves in schools, especially at the Senior High School level, sometimes with funding from international organizations such as UNDP (Ahiekpor & Bensah, 2019). The NGO New Energy implemented a kitchen improvement project in 25 schools in Tamale in 2009/2010. The Integrated School Project on Clean Cooking Energy (INSPOCCE) of World Education Inc was launched in 2015 and was followed by the INSPOCCE School Kitchen Improvement Project (ISKIP) from 2019. ISKIP supports the upgrading of kitchens in NSFP-supported schools.

Results from stove upgrades in ten ISKIP schools reveal the potential for significant fuel savings, reduction or elimination of smoke and ash, a cleaner environment and cooler kitchens, although some respondents noted that the new stoves cooked more slowly (Ahiekpor & Bensah, 2019). In the ten schools supported, average spend on energy per pupil per day was GH¢ 0.73. The introduction of Envirofit fuel-saving stoves led to an average 77% reduction in consumption of fuel for selected dishes. Even assuming a more conservative saving of 30% (as a controlled trial is not necessarily representative), a school previously using an open fire could save GH¢ 0.22 per pupil per day on firewood purchase. So for every 250 pupils (who could be catered for with one new stove), daily savings would be GH¢ 55 (US$ 7.30) and the payback time for a stove costing US$ 2,000 would be nine months. While this does not consider the cost of borrowing the money for the stove(s), upgrading the kitchen structure or training staff, it gives an indication of the economic case for upgrading institutional cooking systems. Cheaper local stoves are also available (e.g., ORGIIS in Paga quoted GH¢ 5,000 for a 'size 40' brick stove that could feed 200 pupils, less than half the cost per pupil of the imported Envirofit option, though with likely performance and durability trade-offs).

A program is proposed to upgrade catering in institutions, with a range of technologies for day schools (where one meal is cooked per day) and boarding institutions (which cook more meals so benefits will be greater).

This should include a comprehensive package of awareness-raising and training for school administrators, canteen managers and cooks, alongside marketing and promotion of clean cooking technology. The cost of improved cookstoves can be a major barrier to adoption, so a credit scheme would also be required.

8.4 Promoting alternative energy sources

8.4.1 LPG

Government policy

A growing number of countries in Sub-Saharan Africa have ambitious plans for scaling up the use of LPG as cooking fuel, to improve access to modern energy in line with the targets of Sustainable Development Goal 7 and Sustainable Energy for All, to support economic development, to contribute to forest protection and to reduce the health burden from indoor air pollution (Bruce et al., 2017). Ghana is one of these countries and the GoG has promoted LPG since the late 1980s, with strategies at different times including free distribution of cylinders, subsidies for the gas, a nationwide network of refill facilities and – most recently – a Cylinder Recirculation Model (Bawakyillenuo, 2020). The National LPG Promotion Policy has a target for LPG to be the main cooking fuel in 50% of HHs by 2030 (Ministry of Energy, 2017),[36] up from 36.9% in 2021.

The fact that LPG is a fossil fuel inevitably raises questions about its environmental credentials. But it has a lower Carbon-to-Hydrogen ratio than most

36 This is a pushback from the National Energy Policy (2010), which aimed to reach this milestone by 2015.

other hydrocarbons, combusts efficiently and completely (largely regardless of user operating factors) and places no burden on forest resources. The net effect is similar CO2 emissions to advanced biomass stoves using partly renewable resources, as well as lower emissions of black carbon and other short-lived pollutants (Bruce et al., 2017).

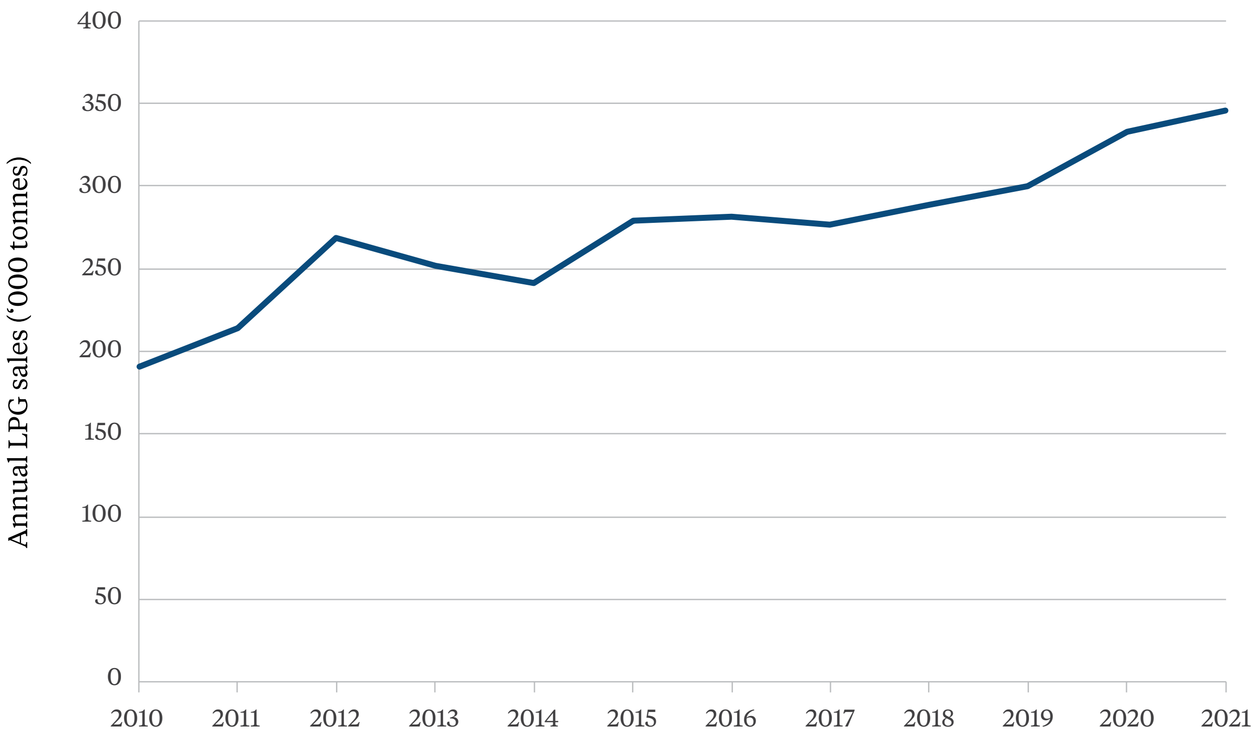
Ghana's Ministry of Energy and the National Petroleum Authority (NPA) initiated the Rural LPG Promotion Program in 2013 (Ministry of Energy, 2021). This included distribution of free cylinders and stoves in low access rural areas and the setting up of cylinder refill outlets in beneficiary districts (see Photo 19).

The consumption of LPG in Ghana has been rising steadily, from 45,000 t in 2000 to 190,000 t in 2010 and 354,000 t in 2021 (National Petroleum Authority, 2022; SNV Ghana, 2017), distributed through 723 refilling plants (of which 693 were operational at the end of 2021). This corresponds with an increase in the percentage of HHs using LPG as their main cooking fuel, which had reached 18.2% in 2010 and doubled to 36.9% by 2021 (Ghana Statistical Service, 2022) (see Figure 12). Even taking population growth into account, LPG consumption rose on a *per capita* basis from 7.8 kg p.a. in 2010 to 11.2 kg p.a. in 2021.

Despite achieving a significant increase in LPG adoption, the refill model is said to have contributed to a growing number of serious, often fatal, safety accidents. It also entails high investment risk for private sector-led market growth (GLPGP, 2018). The use of LPG as a cooking fuel has remained skewed towards urban centres and higher income households. Supply is also highly concentrated in the south, with only 4% of refilling plants in the northern regions. During the research for this study, it transpired that Wa (capital of Upper West Region) had had no LPG for more than two months. The regional breakdown in consumption has hardly changed for the last decade, with Greater Accra averaging 32% of the total from 2011 to 2021.

Photo 19. **LPG refilling station, Tamale, Northern Region**

Figure 12. **Annual LPG sales in Ghana, 2010-2021**



Source: (National Petroleum Authority, 2022)

The GoG's approach has therefore recently changed. Under the National LPG Promotion Program (NLPGPP), the cylinder refill model is being replaced by the Cylinder Recirculation Model (CRM). LPG cylinders will be owned by bottling plants companies or oil marketing companies, rather than users, and will be filled in bulk at a centralised plant and distributed through designated exchange points. Government is of the view that changing to the CRM will remove some of the barriers to accessing LPG, and is also motivated by issues of public safety associated with the current value chain (GLPGP, 2018; Ministry of Energy, 2021).

The NLPGPP targets the adoption of LPG by 2 million HHs, 20,000 commercial caterers and 1,000 public institutions, among others. At least 520 cylinder exchange points will be supported (two per district). The program will provide subsidised 3 kg cylinders, stoves and accessories for domestic users, 14.5 kg cylinders and accessories for commercial caterers, and 1,000 l tanks and ancillary equipment for institutions, with estimated equipment subsidies of GH¢ 372 (US$ 49), GH¢ 57,300 (US$ 7,600) and GH¢ 1,600 (US$ 210) per user, respectively.[37]

Cooking cost comparison

The cost of LPG is key. Research conducted recently in Tanzania found that affordability was the most frequently cited reason for the selection of HHs' main cooking fuel (Doggart et al., 2020). The World Bank (2011) similarly concludes that the two main determinants of a decision to use LPG are HH income and fuel prices (World Bank, 2011). The tipping point between the cost of using charcoal and the cost of using LPG is therefore an important determinant of the pace at which users will switch to LPG as their primary cooking fuel.

A 2018 study on fuel pricing in Ghana revealed LPG to be 20% cheaper for HH cooking than charcoal (GLPGP, 2018). But other analyses do not share

37 Additional support to industries and vehicle owners is not detailed here.

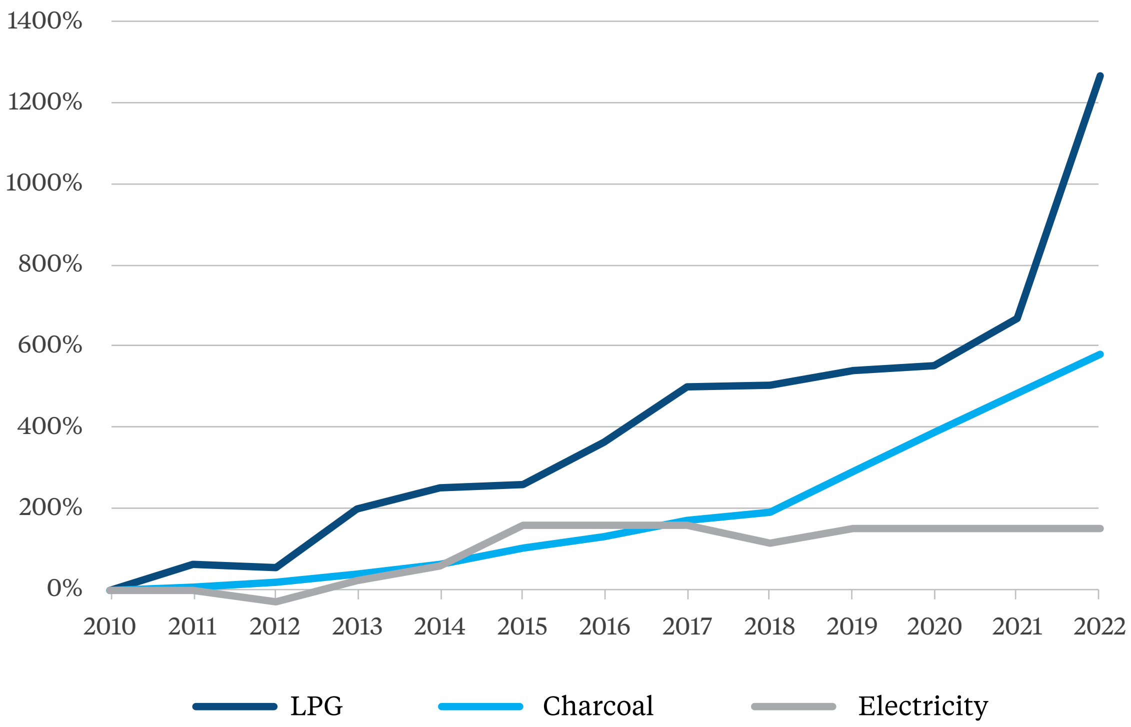
that conclusion. Research one year later found that cooking with charcoal, LPG or electricity with the predominant stove type for each fuel would be almost identical in cost for HHs in urban areas (Hellpap, 2020). The GLPGP 2018 analysis applied thermal efficiency figures that could be seen to have favoured LPG. It also assumed an unusually high charcoal price of GHS 1.61/kg, which would only apply to the smallest unit of retail sale (e.g., plastic bag), whereas purchase by the sack would have been about half as much,[38] and more directly comparable with the habits of a potential LPG user.

There has also been a steep rise in the price of LPG in Ghana since the GLPGP analysis. Figure 13 shows the 12-year price trends of LPG, charcoal and electricity.

As the chart indicates, the price of LPG has been rising considerably more quickly than the price of charcoal and electricity, and is now at least 12 times more expensive in GH¢ terms than it was 12 years ago. The rise has been especially steep since late 2021. The effect of this most recent increase on HH energy choice will not have been captured by the national census, which was conducted in June 2021, and which still showed a strong upwards trend in LPG adoption.

Hellpap (2020) concluded that if the LPG price was to increase even moderately, the price difference to cooking with a highly energy-efficient charcoal stove would become significant. And indeed, looking again at the GLPGP (2018) cooking cost comparison, a modest change in the efficiency

Figure 12. **Annual LPG sales in Ghana, 2010-2021**



Note: Chart indicates percentage increase against 2010 price in GH¢/kg for LPG and charcoal, and GH¢/kWh for electricity (based on 300 kWh/month consumption). Unadjusted for inflation.

Sources: 2010-2018 data from (Ministry of Energy, 2019b).

2019-2022 retailer LPG prices from www.npa.gov.gh/download-media/industry-data/indicative-prices

2019-2022 electricity tariff from www.ecggh.com/index.php/customer-service/services/current-tariff#

2022 charcoal price from UDS survey for this assessment for bag purchase in Accra, assuming straight-line growth since 2018.

38 The average charcoal retail price in 2018 was GHS 0.82/kg, based on the 'maxi' bag (assumed 53.8 kg) priced at GHS 43.9 (Ministry of Energy, 2019a, p. 111).

Table 31. Cooking cost comparison for selected fuels (Feb/March 2022)

Cooking fuel	Net calorific value (MJ/kg)	Current fuel price (GH¢/kg)	Stove thermal efficiency	Energy cost (GH¢/HH/day)
LPG	47.3	11.48	48.0%	12.3
Charcoal	29.5	2.36	24.5%	7.9
Electricity	3.6 MJ/kWh	GH¢ 0.654/kWh	58.0%	7.6
Firewood	15.6	0.23	17.3%	2.1

Note: Costs based on delivery of 24.3 MJ to the pot as the assumed daily HH requirement (GLPGP, 2018).

Sources: LPG price (16-31 March 2022) from: www.npa.gov.gh/download-media/industry-data/indicative-prices

Charcoal price from UDS survey (Annex D). Firewood price from Tamale market, multiplied by 2.1 for Accra to match price uplift of charcoal.

Firewood efficiency: Average of cold, hot and simmer phases for shielded fire: digitalcommons.mtu.edu/cgi/viewcontent.cgi?article=1512&context=etds

Charcoal efficiency: Average of low-power and high-power phases for Gyapa equivalent: stoves.bioenergylists.org/files/er120-1biomass.pdf

LPG efficiency: www.ijert.org/download/4305/performance-of-lpg-cooking-stove-using-different-design-of-burner-heads

Electricity efficiency: Average of 74% optimal and 42% if pot smaller than ring: www.aceee.org/files/proceedings/2014/data/papers/9-702.pdf

assumptions and an update to 2022 fuel prices has switched the cost advantage significantly in favour of charcoal (Table 31). This updated comparison also brings electricity into a much more competitive position, though a tariff increase is expected shortly.[39]

This change in the cooking cost balance will naturally be of some concern to the GoG. Modelling has suggested that for every 10% increase in the end-user price of LPG, there will be a decrease in forecasted LPG use of roughly 5% against the rate otherwise expected from improved availability and preference-affecting measures (GLPGP, 2018). LPG prices have risen (and will continue to rise) much more than this, due to the combined effects of global pressure on fossil fuel prices, a 26% fall in the value of the Ghana currency against the US dollar between March 2021 and March 2022 (from 5.7 to 7.1)[40] and an inflation rate that had reached 15.7% p.a. by early April.[41]

Given consumers' sensitivity to price differentials when it comes to fuel choice, these significant cost pressures clearly make the GoG's 2030 policy goal much harder to achieve. There may be some room to manoeuvre if the government is willing to consider a program of carefully targeted subsidy and other proactive interventions.

LPG pricing

Ghana employs a form of semi-regulated LPG pricing. The unit margins at each node in the supply chain are predetermined by regulation. Maximum prices are revised regularly by each marketer, according to a national LPG price build-up formula (GLPGP, 2018). The current price build-up specifies a maximum ex-pump price of GH¢ 12.22 per kg (Table 32). The average charged at the refill stations from 16th to 31st March 2022 was a little lower at GH¢ 11.48 per kg,[42] perhaps due to the use of old stocks acquired at a cheaper price.

As Ghana's petroleum pricing policy is underpinned by the principle of full-cost recovery, some of the cost elements may rise still further. The Ministry of Energy is in the process of obtaining Cabinet approval for a doubling of the LPG Promotion Margin from GH¢ 0.05 to GH¢ 0.10 per kg, to help fund the NLPGPP. This may require some other taxes and margins to be reduced, if there is to be a zero net-effect on consumer prices.

39 The electricity tariff has been unchanged since October 2019, but the Electricity Company of Ghana has tabled a proposed tariff revision with the Public Utility Regulatory Commission, so a rise is imminent.

40 www.xe.com/currencycharts/?from=US$&to=GHS&view=1Y

41 www.tradingeconomics.com/ghana/inflation-cpi

42 www.npa.gov.gh/download-media/industry-data/indicative-prices

Table 32. Price build-up for LPG, effective 15th March 2022

Cost item	Cost (GH¢/kg)
Ex-refinery price	10.64
Energy debt recovery levy	0.41
Price stabilisation and recovery levy	0.14
Energy sector recovery levy	0.18
Special petroleum tax	0.48
Ex-depot	11.85
Unified Petroleum Price Fund	0.27
LPG filling plant/premix/MGO local admin costs	0.048
Distribution compensation/promotion margin	0.05
Firewood	15.6
Indicative maximum price (ex-pump)	**GH¢ 12.22 (US$ 1.60)**

Source: www.npa.gov.gh/download-media/industry-data/pbu-template

Intervention options

Given the current upward pressures on LPG prices, some form of financial support to consumers will be required if the rise in LPG use is to be sustained and the GoG is to stay on track to meets its 2030 adoption target.

A comprehensive reassessment of LPG pricing and promotion is proposed, including review of the price build-up formula, potential subsidy for the gas, subsidy and/or credit for cylinders and stoves, and ways to encourage pay-as-you-go systems.

a) **Price review.** It may be feasible to waive certain taxes on LPG to reduce the price to consumers. This has risks, as it could reduce the unit margins, and thus the profitability, of the firms in the supply chain, rendering them less bankable and less capable of investing in growth and maintaining safety. Any price decrease via regulation must therefore consider the extent to which industry profitability can be sustained at an adequate level, whether through major increases in the volume of LPG handled per company, or through improvements in efficiency (such as from economies of scale) (GLPGP, 2018).

b) **Targeted gas subsidy:** The GoG will not provide a blanket subsidy for LPG. This was tried previously and the subsidies had reached US$ 276 million in 2011, but were removed in 2013 to address a national budget shortfall (SNV Ghana, 2017). Subsidies can also be exploited by those who are not meant to receive them and create market distortions, which in Ghana led to an unintended boom in vehicular LPG use (GLPGP, 2018). To avoid this, Brazil and the Dominican Republic have moved away from price subsidies to LPG vouchers for poor families (World Bank, 2011). Other countries target subsidies to the poor using technologies such as digital ID cards, electronic bank accounts, integrated national LPG user databases and mobile phones (Bruce et al., 2017). In India, LPG subsidies are no longer applied at the point of sale, but rather deposited into the bank accounts of qualifying HHs. This allows all LPG to be sold in the market at international prices, which has greatly reduced the leakage that often accompanies subsidy at point of sale, in which much fuel was diverted to non-HH uses (ibid.). Should the GoG determine that an LPG subsidy to benefit the poorest is desirable, it can apply the learnings from other countries to deliver this in a way that minimizes the risks of elite capture and other unintended consequences.

c) **Subsidy or credit for cylinders and/or stoves:** The CRM is expected to include payment mechanisms that will allow first-time users to access LPG without paying for the full cost of cylinders, which will be owned by the LPG marketing companies. But the cost of the stove and other accessories to accompany the cylinder is still likely to be a barrier to adoption by lower income HHs for whom charcoal is currently the primary cooking fuel. A credit scheme should be considered for a pre-approved range of quality-assured stoves, regulators and fittings, which offsets the cost for specific targeted groups and which could be paid back through regular instalments or through price top-ups when cylinders are exchanged. Targeting the simplest single burner that screws directly into the cylinder would help keep such a program as cheap and streamlined as possible. The burner and a pot stand could be bundled with the cylinders under a single credit mechanism.

d) **Pay-as-you-go systems:** The system of exchanging empty cylinders for full ones presents further barriers to lower income users, who may not be able to afford the upfront cost of a full cylinder of gas. Ghana's current system of refill stations conveniently permits users to pay for partial refills, which is popular with users unable to afford a full top-up. The CRM will unfortunately end this possibility. But an option for small volume purchasing could still be retained using emerging pay-as-you-go (PAYG) technology. This allows HHs to take possession of a full cylinder but only pay for the gas as they need it, to match their cash availability. Once the prepayment is used up and the units are consumed, access to the gas automatically shuts off. The PAYG system works with a 'smart valve' controlled by a pre-paid meter system with remote monitoring of fuel consumption. PAYG is typically combined with mobile payments and wireless data transmission. PAYG models for LPG have been piloted in East Africa by companies such as BBOX, Envirofit, KopaGas and PayGo Energy. The cost of the pre-paid meter system, including the valve, is currently EUR 30-50, resulting in increased per-kg gas prices (Hellpap, 2020). In markets with regulated pricing, like Ghana, this limits the opportunity for PAYG companies to compete with traditional LPG companies serving the same market. But those traditional companies could potentially use PAYG cylinders to win new customers, who could later switch to the traditional cylinder of the same brand. In this case, subsidising at least part of the cost could make sense for building the customer base for LPG. But the prospects for introducing a PAYG model in Ghana are limited by the regulation of prices, which allows little or no profit margin for these more expensive systems. The same pricing limitation applies to a commercial cylinder delivery service, which would be another mechanism to boost LPG adoption. As long as the consumer price of LPG is regulated, any extra costs will eliminate profit margins and prevent innovation. On the other hand, if those restrictions were removed, higher gas prices would then hit existing consumers. But the net benefit in terms of opening up to innovations like PAYG and cylinder delivery could still outweigh the drawbacks, particularly if combined with carefully targeted subsidy to the poorest LPG consumers. It is recommended that serious consideration is given to deregulating LPG pricing, to encourage innovations such as PAYG and cylinder distribution.

8.4.2 Electricity

82.8% of Ghanaian HHs had access to electricity in 2020 (Energy Commission, 2021), one of the highest rates in Africa. But just 0.4% of HHs (32,500) used electricity as their primary source of energy for cooking in 2021, only a small rise from 29,800 HHs recorded in 2010 (Ghana Statistical Service, 2012, 2022). If secondary or tertiary use is also considered, then 1.8% of HHs may have electricity as part of their cooking energy mix, usually for powering a rice cooker (Kintampo Health Research Centre & Columbia World Projects, 2021).

This limited adoption of electricity for cooking has been entirely consumer-driven, with no Government support. Ghana has no policy targets for 'e-cooking' and it has not been promoted in any way. There could be significant untapped potential. Consumer research has found that Ghanaian consumers value the convenience, time savings and elimination of indoor pollution associated with e-cooking (Bawakyillenuo et al., 2021). And with LPG facing a challenging economic environment, the cooking cost comparison currently appears to favour electricity.

The development of more efficient induction hobs, electric pressure cookers and off-grid electric stoves (such as the solar-powered Pesitho ECOCA[43]) are making e-cooking appliances increasingly user-friendly and efficient. There is also a growing demand in Ghana for new and second-hand electric appliances such as kettles, blenders, water heaters, bread toasters and deep fryers (Bawakyillenuo et al., 2021).

It would therefore be appropriate for the GoG to give more serious consideration to electricity as a cooking energy option for HHs or businesses who have the financial capacity to migrate from woodfuels (or even LPG), albeit noting that 58% of Ghana's electricity is currently generated from oil or gas (IEA, 2022), so this is not an environmentally benign option.

Constraints to wider uptake include the lack of Government policy and actions, the cost and unreliability of electricity, the cost of the appliance and fears around safety (Bawakyillenuo et al., 2021).

It is recommended that the GoG formulates a national e-cooking strategy and plan; offers fiscal incentives to manufacturers and importers of electric cooking appliances; introduces promotional programs targeting tasks and appliances suited to e-cooking; and invests further in grid extension, densification and stabilisation.

Details are provided below:

- **Formulate a national e-cooking strategy and plan.** The GLPGP and Ghana Country Action Plan for Clean Cooking have targeted LPG and biomass, but there is no equivalent policy with targets and an action plan for e-cooking. There is a wealth of experience from other countries in the development of such policies and plans, which Ghana can adapt.

- **Offer fiscal incentives to manufacturers and importers.** Measures such as tax exemptions, lower import duties and subsidies on imported electrical cooking appliances could boost uptake.

- **Introduce promotional programs targeting tasks and appliances well suited to e-cooking.** Electric rice cookers should be promoted (especially as many can also cook other foods), as should electric pressure cookers (EPCs). These are airtight vessels in which the steam produced from the boiling liquid raises the internal pressure and permits the cooking temperature to rise above 100°C. The higher temperature and pressure reduce cooking time by up to 70% compared to conventional boiling. EPCs allow the heat input to be regulated with a thermostat to keep temperature and pressure stable, which reduces power consumption and increases

43 www.pesitho.com/the-ecoca-new/

efficiency compared with stove-top versions. The main barriers to EPC adoption are unreliable power supply, the need to change cooking habits (as the food is not visible), risk of accidents through careless opening (though newer models have safety features to prevent this), general consumer safety concerns and high cost (Hellpap, 2020). Rice cookers and EPCs could be promoted with micro-loans or possibly subsidies.

- **Invest in grid extension, densification and stabilisation.** As long as the electricity supply is unstable, only a small number of HHs will use electricity as their main cooking fuel. Most will practise fuel stacking in which e-cooking plays a minor role. To really encourage e-cooking at scale, there is a need for additional power generation and extension, densification and stabilization of the grid, to improve access and reliability of the power supply (Hellpap, 2020). These are not quick solutions, but they will need to be part of any serious strategy to promote the large-scale uptake of e-cooking.

8.5 Strengthening the enabling framework for sustainable woodfuels

8.5.1 Data gathering and dissemination

Despite woodfuels being a prominent source of energy for Ghana and the country's main cooking fuel, there is a lack of reliable and regularly updated information on consumption patterns, the dynamics of woodfuel extraction from the landscape and the sector's economic significance in both direct and indirect terms (e.g., through avoided fuel imports). Basic information on trade volumes and prices is no longer gathered, since the Ministry of Energy suspended its monthly charcoal price surveys in 2014.[44] There is limited information on production volumes and magnitudes of resource flows, upon which sustainable development of the industry could be based (Obiri et al., 2014). There is an overall lack of data on which to base sound planning and policymaking, and where such data exists it is often in the grey literature, vested in research programs led by academics, NGOs and consultants.

It is recommended that woodfuel market surveys are re-introduced in expanded form by the EC, on at least a bi-annual basis, to provide up to date information on price build-ups through the value chain.

Given that units of production and sale for firewood and charcoal are variable and volume-based, this should include fuel weighing alongside price recording. For firewood it is important also to measure moisture content, to facilitate weight-to-volume conversions. Fuel weighing can be laborious and time consuming, so these market surveys will require commensurate allocation of resources and manpower within the EC.

Further research on fuel stacking is needed to better understand its impact, as it has the potential to partially offset the gains achieved by switching to clean cooking fuels.

Surveys of HH energy dynamics by the EC are recommended, to establish the prevalence and impact of the fuel stacking phenomenon. Questions on secondary and tertiary cooking fuels should be introduced in all official Government surveys, including the next Ghana Living Standard Survey and future national censuses.

The quantity of charcoal flows both within and between districts should be better monitored, which would be feasible with improved application of the FC's existing CCC system (see below).

Data on biomass stocking and MAI is scant and unreliable outside forests, especially in areas of sparse canopy cover such as the NSZ. This has been a perennial problem for supply/demand

44 www.energycom.gov.gh/planning/data-center/charcoal-tracking-in-ghana

modelling in many developing countries, and can lead to under-estimation of supply and unduly pessimistic assessments of pressure on tree resources attributable to woodfuel consumption.

The FC should undertake a thorough empirical assessment of biomass stocking and mean annual increments from trees outside forests, especially in the drier northern regions, to improve the quality and accuracy of supply-side data for assessing impacts of demand for woodfuel and other tree products.

Despite useful snapshots of land use and land cover (LULC) at discrete points in time,[45] there is no time series data on LULC changes that has been ground-truthed in Ghana, hence scant knowledge of the drivers of those changes and their relative contributions. Imagery and classification algorithms are not made available to the public, except as JPG images. There are several government-managed remote sensing agencies who seem to perform overlapping functions.

It is recommended that GoG identifies which agency has primary responsibility for monitoring LULC and supports that agency to publish regularly updated, satellite-derived LULC data.

This should be ground-truthed for Ghana and ideally updated annually using consistent classification algorithms, at the highest available resolution, to facilitate time series comparison.

Raster datasets and classification methodologies should be open source and made available online, to facilitate a cooperative effort by researchers and academics to support the Government in identifying key trends and issues that need to be addressed.

8.5.2 Institutional coordination

The disjointed and inconsistent availability of data on woodfuels arises in part from lack of clarity over institutional roles and responsibilities. As the GoG has itself pointed out, there is weak collaboration and institutional linkages among the relevant institutions in the implementation and management of woodfuel-related programs. This has the potential to worsen the challenges facing the charcoal industry (Ministry of Energy, 2019a).

The main agencies with mandates that impinge on woodfuels are the EC, FC, EPA and Ministry of Food and Agriculture (MoFA). There is duplication and lack of clarity on their respective roles. For example, the FC and EPA both have regulations designed to control the felling of trees, making it unclear which rules take precedence. Traditional authorities have their own controls on tree felling, but it is unclear whether formal state regulations are an addition or an alternative to those controls. Trees can be cleared in the name of farming with little or no restriction, but not if the stated aim is to produce woodfuel, so the role of MoFA seems fundamental to efforts to manage wood resources more sustainably; yet MoFA has been minimally involved in dialogue around woodfuels as a product of farm clearing. The EC has a mandate under the Renewable Energy Act to issue licences for the production, transport, storage and supply of woodfuels, but has no decentralised capacity to enforce these licensing requirements. The FC has an overlapping mandate to ensure the sustainable management of trees, forests and forest products, but it is unclear how this relates to the EC's licensing mandate, especially for charcoal production. The EC plans to specify approved wood carbonisation technologies in the Woodfuel Regulations under development, but once the charcoal is bagged, it reverts to the FC to issue movement permits under the CCC system. If the charcoal is destined for export, then it comes back to the EC and the EPA for licensing and permitting. The situation is confusing and enforcement is patchy.

The role of traditional authorities is also key. They have a preeminent function in managing access to land and resources at the local level.

45 See this 2019 analysis, for example: ghana-national-landuse.knust.ourecosystem.com/interface/

GoG should provide greater clarity on the respective mandates of central government agencies, traditional authorities and district assemblies concerning policymaking, regulatory development, law enforcement, revenue collection, research and data gathering and dissemination relating to woodfuels, with a focus on commercially traded fuel (not subsistence firewood).

It is especially important that formal state institutions with an interest in woodfuel should acknowledge the role of traditional authorities and align with these structures when formulating development strategies, management priorities and interventions in woodfuel value chains.

The FC should collaborate more closely with district assemblies and traditional authorities to promote a more consistent approach to accessing land and trees for woodfuel.

It is unrealistic to expect government ministries to control charcoal production through a centrally administered permitting system. Systems to manage commercial woodfuel production should be embedded in existing customary arrangements.

District-level charcoal forums have been piloted by the Danish-funded AX project and by GIZ's Forest Landscape Restoration project.

District-level charcoal forums should be more widely supported across the main charcoal-producing districts under the GLRSSMP.

8.5.3 Regulatory rationalisation

Ghana has had numerous policies and plans that relate to the woodfuels sector. The National Energy Policy (2010), the Renewable Energy Law (2011), the Strategic National Energy Plans (2006-2020 and 2020-2030), the Sustainable Energy for All Action Plan (2012), the Renewable Energy Master Plan (2019) and the National Bioenergy Action Plan (2020-2030) are prominent examples. Relevant supply-side policies and plans include the Forestry and Wildlife Policy (2012), Forestry Development Master Plans (1996-2020 and 2016-2036) and the National Forest Plantation Development Program (2016-2040), along with discrete initiatives such as the Forest Investment Program (2012), the Dedicated Grant Mechanism for Local Communities (2017-2021) and the GLRSSMP.

These policies, plans and programs have included ambitious targets for significantly increasing wood production, improving efficiencies in processing and end-use, and phasing out woodfuels. But although it has been observed that energy sector policies demonstrate good alignment and intent with the sustainable management of the forestry sector and the sustainable production and utilisation of woodfuel, "not much can be said about the implementation measures proposed towards their achievement" (Ministry of Energy, 2019a). Targets have not been accompanied by realistic and well-resourced implementation pathways.

When targets have not been met, there has been a tendency to restate them with a deferred deadline. For example, The National Energy Policy (2010) set a goal for 50% of HHs to have access to LPG by 2015. In 2012, the EC revised this to 2020. Assessing national progress to 2017, the National LPG Promotion Policy then set a new target year of 2030 (GLPGP, 2018). This is now under threat, for the reasons outlined above.

As previously explained, Government policies in the energy and forestry sectors are built on the premise that woodfuels are an unsustainable threat to the environment. From this starting point, they share a common narrative of control and containment, justified by sustainability concerns that establish a direct link between charcoal production and deforestation. But – as this report has discussed extensively - the relationship between woodfuel extraction and deforestation is poorly supported by evidence and gives insufficient attention to agricultural production on the same lands (Hansen, 2021). This means that measures to contain and control woodfuel are unlikely to have any noticeable impact on deforestation rates.

An approach based on containment and control is also unrealistic. The GoG itself has expressed frustration at the limited impact of enforcement, and the Ministry of Energy has stated that the EC "must, as a matter of urgency, galvanize the necessary stakeholder support and resources in order to actively implement the strategies as captured in the charcoal/woodfuel-related policy documents" (Ministry of Energy, 2019a). But while it is certainly the case that stated goals are not being met, it is unrealistic to expect that sufficient additional resources will now be forthcoming to enable the EC to achieve them. Yet the push continues for ever tighter regulation. The Ministry of Energy believes that "challenges within the charcoal export sector calls for increased regulatory oversight ... to streamline the charcoal trade" (Ministry of Energy, 2019a).

The view has already been expressed in this report that many of the existing regulations pertaining to woodfuels are unenforceable, making the idea of additional regulations inappropriate at this time. New measures also run the risk of harming those who rely on charcoal for their livelihood, without necessarily delivering the outcomes they set out to deliver (Hansen, 2021). Rather than repeating previous policy targets and recommending the same actions, there is an opportunity to consider alternative approaches and more realistic target-setting that is better aligned with the Government's implementation capacity. There is a particular need to review what is realistic and achievable in terms of policy and regulation, and the extent to which government should be taking a facilitatory and supporting role, rather than seeking only to control and regulate.

Instead of introducing new woodfuel regulations that cannot realistically be enforced, the GoG should conduct an inter-agency review of all rules pertaining to woodfuels to critically appraise their workability and realism, revoking those that are unenforceable and streamlining the remaining regulations to a reduced set of implementable measures.

It would be preferable to have a majority of value chain actors complying with light-touch regulation, than to continue with a stringent regulatory regime with which only a small fraction of actors can (or choose to) comply.

There is a need to enforce the agreed set of regulations with greater consistency. This should especially include CCCs and charcoal export permits, neither of which is functioning effectively. The CCC system should be extended to cover all charcoal transport, not only large loads, and should be implemented in a more effective and consistent way in all regions. The management of the licensing system for charcoal exports requires simplification, merging the need for a licence plus permit into a single authorisation, and making the requirements easier to achieve.

Annexes

ANNEX A: PEOPLE CONSULTED

Name	Designation	Organization
Government of Ghana		
Edith Abruquah	Director of Ops. (Natural Forests)	Forest Service Division, Forestry Commission
Dinah Fiate	Ops. Manager (Natural Forests)	
Yaw Kwakye	Ops. Manager (Natural Forests)	
Kwame Agyei	Plantations Manager	
Bernard Tab`il	Regional Manager, N Region	
Nsiah Ahmed Bempah	Regional Manager, NE Region	
Muntala Alhassan	Range Manager, Kambega Scarp West, NE Region	
Mohammed Yakubu	Head of GIS and Mapping	Resource Management Support Centre, Kumasi
Isaac Acquah	GLRSSMP Coordinator	Environmental Protection Agency
Kingsley Amoako	Deputy Director, Crop Services	Ministry of Food & Agriculture
Asher Nkegbe	Head of GLRSSMP Regional Technical Coordination Office, Savannah (Bolgatanga)	
Samuel Fordjuor	Extension worker, Boankra, Ejisu Municipal	
Paulinus Terbobri	Snr. Research Manager	Shea Unit, COCOBOD
William Amaning	Snr. Research Officer	
Priscilla Boama-Wiafe	Snr. Research Officer	
Lydia Amakwa	Research Assistant	
Emmanuel Nii Tackie-Otoo	Executive Director	Cocoa Health & Extension Division, COCOBOD
Faruk Kwansah Nyame	Acting Deputy Director	
Julius Nkansah-Nyarko	Head of Bioenergy	Energy Commission
Bernice Nortey	Bioenergy Officer	
Felix Koranting	Policy & Planning Division	
Beatrice Obiri	Principal Research Scientist	Forestry Research Institute of Ghana, Kumasi
John Kingsley Armah	Dep. Chief Inspector of Factories	Dept. of Factories Inspectorate
Anthony Krakah	Head, Industrial Statistics	Ghana Statistical Service
Rosalind Quartey	Assistant Director (Cartography)	
Mr Danso	2nd in command, Paga border	Ghana Revenue Authority
Jeremy	2nd in command, Tumu border	Ghana Immigration Service

Name	Designation	Organization
Lawrence Brobbey	PhD fellow	Kwame Nkrumah University of Science & Technology, Kumasi
Frank Agyei	PhD fellow	
NGOs		
Cisco Aust	Project Manager, FLR through a Sustainable Wood Energy Value Chain	GIZ
Margarita Lopez	Charcoal assurance consultant	IUCN NL
Daryl Bosu	Deputy National Director, Operations	A Rocha
Nina Agyemang	Project Officer	
Isaac Ntori	Project Officer, Mole landscape	
Joseph Asante	Project Manager, Kintampo-Atebubu landscape	Tropenbos
Samuel Ali	Project Officer	
Emmanuel Kwarteng	Market & Private Sector Specialist	DevWorks / USAID Ghana Fisheries Recovery Activity
Okua Okyere Nyako	Value Chain Specialist	
Julius Awaregya	Coordinator	Organization for Indigenous Initiatives & Sustainability (ORGIIS), Paga
Ataasu Christopher	Field Officer	
Mark Kebo Akparibo	Secretary to National Exec. Committee	Ghana Federation of Forest & Farm Producers
Boniface Nyewei	ex-SNV Local Capacity Builder	Independent, Tumu
Rapheal Ali Yenbapono	Manager	Tuna Women Development Program
Private sector		
Amin Sulley	CEO	Zaacoal, Accra
Faiza Taimako	CEO	RAINcorp, Tamale
Rabia tu Abukari	CEO	Maltiti A Enterprise, Tamale
Senyo Kpelly	Finance Director	Eco-Restore, Tamale
Other		
Maclean Oyeh	REDD+ consultant	World Bank
David Daitz	Wildfire consultant	
Rabia tu Abukari	CEO	Maltiti A Enterprise, Tamale
Women's group committees and members		Zuregalu Group, Balwo-Kayilo, Paga, Upper East Region
		Handi Group, Tuna, Savannah Region
Charcoal producers, transporters & traders; LPG retailers; stove retailers; commercial caterers		Northern regions plus Babatokuma, Kintampo North District
Cocoa farmers and agricultural extension officer		Boankra, Ejisu Municipal District

ANNEX B REFERENCES

Acheampong, E., Ahiekpor, J. C., & Lukumanu, M. A. (2021). *Rural Clean Cooking Project Baseline Report* (p. 25). Eni Ghana and The World Bank Partnership.

Acquah, S. B., Oduro, K. A., & Obiri, D. B. (2015). *Silvicultural prescriptions for management of woodfuel species* (p. 29). CSIR-Forestry Research Institute of Ghana.

Agyei, F. K. (2020). *Study on the Wood Energy Value Chain in Four Communities, Ghana.* for GIZ German Development Cooperation.

Agyei, F. K. (2021, November 23). *Forestry officials don't have any land or rights here: Authority of politico-legal institutions along Ghana's charcoal commodity chain.* Sustainable Woodfuel Value Chains in Africa: Governance, Social, Economic and Ecological Dimensions, Kumasi, Ghana.

Agyei, F. K., Acheamponga, E., & Hansen, C. P. (2021). Who profits from charcoal production and trade in Ghana? *Access and Exclusion along the Charcoal Commodity Chain in Ghana* (AX) Research Project, 4.

Agyei, F. K., Hansen, C. P., & Acheampong, E. (2018). Profit and profit distribution along Ghana's charcoal commodity chain. *Energy for Sustainable Development, 47,* 62–74. https://doi.org/10.1016/j.esd.2018.09.002

Ahiekpor, J. C., & Bensah, E. C. (2019). *Integrated School Project on Clean Cooking Energy (INSPOCCE) School Kitchen Improvement Project (ISKIP): An Endline Report.* Centre for Energy, Environment and Sustainable Development for World Education, Inc.

Ahiekpor, J. C., Ribeiro, J. X. F., Rockson, M. A. D., Bensah, E., & Antwi, E. (2014). *National Mapping of Stakeholders in the Clean Cook Stove Value Chain in Ghana.* Centre for Energy, Environment and Sustainable Development.

Akyeampong, E. (1996). What's in a Drink? Class Struggle, Popular Culture and the Politics of Akpeteshie (Local Gin) in Ghana, 1930–67. *The Journal of African History, 37*(2), 215–236. https://doi.org/10.1017/S0021853700035209

Alem, Y., Ruhinduka, R., & Berck, P. (2017). *Liquidity constraint, LPG stoves and charcoal consumption in Tanzania* (Policy brief 89410). International Growth Centre.

Amanor, K. (2021). Policy Frameworks for Plantation Models of Charcoal Production in Ghana: Evidence-based approaches and equity. *Access and Exclusion along the Charcoal Commodity Chain in Ghana (AX) Research Project, 5.*

Amanor, K., Osei, E., & Gyampoh, K. (2005). Charcoal Burning in the Kintampo Districts: Policies, Environment and Livelihoods Issues. *Workshop Proceedings,* 28.

Amedi, M., & Akunyagra, E. A. (2021, November 23). *World Vision Farmer Managed Natural Regeneration (FMNR) Approach—A Catalyst for Sustainable Wood Fuel production in Ghana.* Sustainable Woodfuel Value Chains in Africa: Governance, Social, Economic and Ecological Dimensions, Kumasi, Ghana.

Amoah, M., Marfo, O., & Ohene, M. (2015). Firewood consumption pattern, availability and coping strategies adopted to mitigate firewood scarcity: A case of rural households in Ghana. *Forests, Trees and Livelihoods, 24*(3), 202–218. https://doi.org/10.1080/14728028.2015.1052854

Amua, N. E. E. H. (2011). *The potential of agroforestry In fuelwood production for domestic and income generation activities* [MSc these in Agroforestry]. Kwame Nkrumah University of Science and Technology.

Anderson, D., & Fishwick, R. (1984). *Fuelwood consumption and deforestation in African countries.* World Bank.

Appiah, M., Fagg, M., & Pappinen, A. (2015). A Review of Reforestation Approaches in Ghana: Sustainability and Genuine Local Participation Lessons for Implementing REDD+ Activities. *European Journal of Scientific Research,* 131(1), 31.

Arnold, M., Köhlin, G., & Persson, R. (2006). Woodfuels, livelihoods, and policy interventions: Changing Perspectives. *World Development, 34*(3), 596–611. https://doi.org/10.1016/j.worlddev.2005.08.008

Arnold, M., Köhlin, G., Persson, R., & Shepherd, G. (2003). *Fuelwood Revisited: What Has Changed in the Last Decade?* Center for International Forestry Research; JSTOR. www.jstor.org/stable/resrep02182

Asante, J. (2019). *Community-based governance arrangements for charcoal production in the Atebubu-Amantin District* [MPhil thesis]. Department of Silviculture and Forest Management, Kwame Nkrumah University of Science and Technology.

Asante, J. (2021, November 23). *Community-Based Governance Arrangements for Charcoal Production in Ghana.* Sustainable Woodfuel Value Chains in Africa: Governance, Social, Economic and Ecological Dimensions, Kumasi, Ghana.

Asiedu, B., Failler, P., & Beygens, Y. (2018). Ensuring food security: An analysis of the industrial smoking fishery sector of Ghana. *Agriculture & Food Security, 7*(1), 38. https://doi.org/10.1186/s40066-018-0187-z

Ayamdoo, J. A., Demuyakor, B., Dogbe, W., & Owusu, R. (2013). Parboiling Of Paddy Rice, The Science And Perceptions Of It As Practiced In Northern Ghana. *International Journal of Scientific & Technology Research, 2*(4).

Aziz, M., Oda, T., & Kashiwagi, T. (2015). Design and Analysis of Energy-Efficient Integrated Crude Palm Oil and Palm Kernel Oil Processes. *Journal of the Japan Institute of Energy, 94*(1), 143–150. https://doi.org/10.3775/jie.94.143

Bailis, R., Drigo, R., Ghilardi, A., & Masera, O. (2015). The carbon footprint of traditional woodfuels. *Nature Climate Change, 5*(3), 266–272. https://doi.org/10.1038/nclimate2491

Bailis, R., Ezzati, & Kammen, D. (2005). Bailis, R., Ezzati, M. and Kammen, D. M. (2005) "Mortality and greenhouse gas impacts of biomass and petroleum energy futures in Africa", 308, Science, 98 – 103. *Science, 308,* 98–103.

Bawakyillenuo, S. (2020). Energy Safety Nets: Ghana Case Study. Sustainable Energy for All.

Bawakyillenuo, S., Crentsil, A. O., Agbelie, I. K., & Danquah, S. K. (2021). *Energy for cooking in Ghana: Analysis of Stakeholder Net-Mapping Exercise.* Institute of Statistical, Social and Economic Research (ISSER), University of Ghana for Modern Energy Cooking Services (MECS) project. https://mecs.org.uk/wp-content/uploads/2021/08/Energy-for-cooking-in-Ghana-Analysis-of-Stakeholder-Net-Mapping-Exercise.pdf

Bradley, P. N., & Campbell, B. M. (1998). Who Plugged the Gap? Re-Examining The Woodfuel Crisis in Zimbabwe. *Energy & Environment, 9*(3), 235–255. https://doi.org/10.1177/0958305X9800900302

Brobbey, L. K., Hansen, C. P., & Kyereh, B. (2021). The dynamics of property and other mechanisms of access: The case of charcoal production and trade in Ghana. *Land Use Policy, 101,* 105152. https://doi.org/10.1016/j.landusepol.2020.105152

Brobbey, L. K., Hansen, C. P., Kyereh, B., & Pouliot, M. (2019). The economic importance of charcoal to rural livelihoods: Evidence from a key charcoal-producing area in Ghana. *Forest Policy and Economics, 101,* 19–31. https://doi.org/10.1016/j.forpol.2019.01.013

Brobbey, L. K., Kyereha, B., & Hansen, C. P. (2021). Charcoal: An important source of household income in the forest savannah transition zone of Ghana. *Access and Exclusion along the Charcoal Commodity Chain in Ghana (AX) Research Project, 3.*

Bruce, N. G., Aunan, K., & Rehfuess, E. A. (2017). *Liquefied Petroleum Gas as a Clean Cooking Fuel for Developing Countries: Implications for Climate, Forests, and Affordability* (p. 44). KfW Development Bank. https://www.kfw-entwicklungsbank.de/PDF/Download-Center/Materialien/2017_Nr.7_CleanCooking_Lang.pdf

Cline-Cole, R. A., Main, H. A. C., & Nichol, J. E. (1990). On fuelwood consumption, population dynamics and deforestation in Africa. *World Development, 18*(4), 513–527. https://doi.org/10.1016/0305-750X(90)90068-9

Coastal Resources Center. (2021). *Final Report, 2014 -2021. USAID/Ghana Sustainable Fisheries Management Project* (GH2014_PGM357_CRC; p. 143). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island. https://www.crc.uri.edu/download/GH2014_PGM357_CRC_FIN508.pdf

Doggart, N., Ruhinduka, R., Meshack, C. K., Ishengoma, R. C., Morgan-Brown, T., Abdallah, J. M., Spracklen, D. V., & Sallu, S. M. (2020). The influence of energy policy on charcoal consumption in urban households in Tanzania. *Energy for Sustainable Development, 57,* 200–213. https://doi.org/10.1016/j.esd.2020.06.002

Dovlo, E., Amador, K., & Nkrumah, B. (2016). *Report on the 2016 Ghana Marine Canoe Frame Survey* (No. 36; Information Report). Ministry of Fisheries and Aquaculture Development. https://www.crc.uri.edu/download/Final-2016-Canoe-Frame-Survey-Report.pdf

Eckholm, E. P. (1975). *The other energy crisis: Firewood.* Worldwatch Institute.

EED Advisory & SEI. (2019). *Kenya Household Cooking Sector Study. Assessment of the Supply and Demand of Cooking Solutions at the Household Level.* EED Advisory and Stockholm Environment Institute for Kenya Ministry of Energy.

Energy Commission. (2012a). *Sustainable Energy for All Acceleration Framework—Ghana Situational Analysis Report.* Sustainable Energy for All. https://www.seforall.org/sites/default/files/Ghana_RAGA_EN_Released.pdf

Energy Commission. (2012b). *Licence Manual for Service Providers in the Renewable Energy Industry.* http://www.energycom.gov.gh/files/RE%20LICENCE%20MANUAL.pdf

Energy Commission. (2019). *Strategic National Energy Plan (SNEP 2030) Final Draft. Volume One. Energy Demand Projections for the Economy of Ghana.* http://energycom.gov.gh/files/SNEP%20Demand%20Oct2019_SNEP2030_Final.pdf

Energy Commission. (2021). *National Energy Statistics. 2021 Edition.* http://www.energycom.gov.gh/files/2021%20published%20Energy%20Statistics.pdf

ESA. (2019, December 6). *New biomass map to take stock of the world's carbon.* European Space Agency. https://www.esa.int/Applications/Observing_the_Earth/Space_for_our_climate/New_biomass_map_to_take_stock_of_the_world_s_carbon

FAO. (2004). *Unified Bioenergy Terminology—UBET*. Food & Agriculture Organisation of the United Nations. http://www.fao.org/3/j4504e/j4504e.pdf

FAO. (2005). *Technical coefficients for utilization in the preparation of investment projects in the fields of agro-industries and post-harvest.* Food & Agriculture Organisation of the United Nations. https://www.fao.org/fileadmin/user_upload/inpho/docs/Technical_coefficients.pdf

FAO. (2012). *West African food composition table = Table de composition des aliments d'Afrique de l'Ouest.* Food and Agriculture Organization of the United Nations. https://www.fao.org/3/i2698b/i2698b00.pdf

FAO. (2022). *Fisheries and Aquaculture* [Global production by production source Quantity (1950 - 2019)]. https://www.fao.org/fishery/statistics-query/en/global_production/global_production_quantity

Fisheries Commission. (2011). *Republic of Ghana Fisheries and Aquaculture Sector Development Plan 2011-2016.* http://rhody.crc.uri.edu/gfa/wp-content/uploads/sites/10/2018/04/Ghana-Fisheries-and-Aquaculture-Sector-Development-Plan-2011-2016.pdf

Fleming, S. (2021, October 5). *7 billion 'extra' trees have been discovered in Africa—Part of the continent's ongoing efforts to restore and reforest the land.* World Economic Forum. https://www.weforum.org/agenda/2021/10/7-billion-trees-discovered-africa-deforestation/

Forestry Commission. (2010). *Readiness Preparation Proposal Ghana. Submitted to Forest Carbon Partnership Facility (FCPF).* https://www.forestcarbonpartnership.org/system/files/documents/Final_version_Ghana_R-PP_with_disclaimer_21810.pdf

Forestry Commission. (2015). *Ghana Forest Plantation Strategy 2016-2040.*

Frankel, G. (1984, December 6). Shortage of Firewood Reaching Crisis Level In the Third World. *Washington Post.* https://www.washingtonpost.com/archive/politics/1984/12/06/shortage-of-firewood-reaching-crisis-level-in-the-third-world/cac9a6a7-2adf-4161-9cee-c9a0c90cf327/

Fraym. (2021). *Ghana Consumer Segmentation.* Clean Cooking Alliance. https://cleancooking.org/wp-content/uploads/2021/08/Ghana-Consumer-Segmentation-Fraym-for-Clean-Cooking-Alliance.pdf

GHACCO. (2018). *Final Report of the Healthy Cooking Project: Pitch for a Feasibility and Acceptability Survey* (p. 56). Ghana Alliance for Clean Cookstoves.

GhaFFaP. (2020). *GhaFFap Agenda 2030 flyer.* Ghana Federation of Forest and Farm Producers.

Ghana Statistical Service. (2005). *2000 Population & Housing Census. Summary Report of Final Results.* https://www2.statsghana.gov.gh/nada/index.php/catalog/3

Ghana Statistical Service. (2012). *2010 Population & Housing Census. Summary Report of Final Results.* https://www.statsghana.gov.gh/gssmain/storage/img/marqueeupdater/Census2010_Summary_report_of_final_results.pdf

Ghana Statistical Service. (2017). *Ghana Livings Standards Survey 7—Main Report.*

Ghana Statistical Service. (2021a). *2021 Population and Housing Census General Report, Vol 3A* [Population of Regions and Districts]. Ghana Statistical Service. https://census2021.statsghana.gov.gh/gssmain/fileUpload/reportthemelist/2021%20PHC%20General%20Report%20Vol%203A_Population%20of%20Regions%20and%20Districts_181121.pdf

Ghana Statistical Service. (2021b). *2021 Population and Housing Census General Report, Vol 3B* [Age & Sex Profile]. Ghana Statistical Service. https://census2021.statsghana.gov.gh/gssmain/fileUpload/reportthemelist/2021%20PHC%20General%20Report%20Vol%203A_Population%20of%20Regions%20and%20Districts_181121.pdf

Ghana Statistical Service. (2022). *2021 Population and Housing Census General Report, Vol 3K* [Housing Characteristics]. Ghana Statistical Service. https://census2021.statsghana.gov.gh/gssmain/fileUpload/reportthemesub/Volume%203K_Housing%20Characteristics_240222.pdf

Ghilardi, A., Tarter, A., & Bailis, R. (2018). Potential environmental benefits from woodfuel transitions in Haiti: Geospatial scenarios to 2027. *Environmental Research Letters, 13*(3), 035007. https://doi.org/10.1088/1748-9326/aaa846

GLPGP. (2018). *National Feasibility Assessment: LPG for Clean Cooking in Ghana.* The Global LPG Partnership.

Hansen, C. P. (2021). Charcoal production and trade in Ghana: An overview of the outputs of the AX project. *Access and Exclusion along the Charcoal Commodity Chain in Ghana (AX) Research Project, 3.*

Hellpap, C. (2020). *Desktop Analysis of the Cooking Sector in Ghana* (p. 28). iiDevelopment.

IEA. (2022). *World Energy Balances.* International Energy Agency, Data & Statistics. https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances

IPCC. (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Chapter 4 Forest Land.* The Intergovernmental Panel on Climate Change. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch04_Forest%20Land.pdf

Kemausuor, F., Addo, A., & Darkwah, L. (2015). Technical and Socioeconomic Potential of Biogas from Cassava Waste in Ghana. *Biotechnology Research International, 2015,* 1–10. https://doi.org/10.1155/2015/828576

Kemausuor, F., Bolwig, S., & Miller, S. (2016). Modelling the socio-economic impacts of modern bioenergy in rural communities in Ghana. *Sustainable Energy Technologies and Assessments, 14,* 9–20. https://doi.org/10.1016/j.seta.2016.01.007

Kiel, M. L. (2017). *Charcoal's contribution to rural income—A livelihood study from Brong-Ahafo region, Ghana* [Master's thesis]. Department of Food and Resource Economics.

Kintampo Health Research Centre & Columbia World Projects. (2021). *Ghana Energy Use Survey Summary for Policymakers.* Kintampo Health Research Centre and Columbia World Projects.

Kleih, U., Phillips, D., Wordey, M. T., & Komlaga, G. (2013). *Cassava Market and Value Chain Analysis Ghana Case Study* (p. 66). University of Greenwich, UK; Food Research Institution, Accra, Ghana. http://www.value-chains.org/dyn/bds/docs/859/GhanaCassavaMarketStudy-FinalFebruary2013_anonym.pdf

Kula, O., & Dormon, E. (2009). *Global Food Security Response Ghana Rice Study* (microREPORT #156). ACDI/VOCA for USAID. https://pdf.usaid.gov/pdf_docs/pnaea870.pdf

Kwarteng, E. (n.d.). *Energy Audit Report: Morrison Fish Smoking Stove* (p. 28). SNV-Netherlands Development Organization.

Kwarteng, E., Nsiah, A. A. H., & Aziebor, E. (2016). *Energy Expenditure and Comparative Economics of Fish Processing Techniques Report.* (GH 2014_ACT076_SNV; The USAID/Ghana Sustainable Fisheries Management Project (SFMP)., p. 38). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island.

Kwofie, E. M., Ngadi, M., & Mainoo, A. (2016). Local rice parboiling and its energy dynamics in Ghana. *Energy for Sustainable Development, 34,* 10–19. https://doi.org/10.1016/j.esd.2016.06.007

Leistner, E. (1984). Fuelwood: Energy crisis of the poor. *Africa Insight, 14*(2), 5.

Lemke, M. (2020). *Challenges and profitability of woodlot establishment in Ghana* [A baseline study for farmers and investors]. Eberswalde University for Sustainable Development. https://doi.org/10.13140/RG.2.2.25380.91521

Lemke, M. (2021). *Charcoal Production in the Bono East Region: An in-depth analysis* [Summary of BSc thesis research at Eberswalde University for Sustainable Development].

Maes, W., & Verbist, B. (2012). Increasing the sustainability of household cooking in developing countries: Policy implications. *Renewable and Sustainable Energy Reviews, 16,* 4671–4712. https://doi.org/10.1016/j.rser.2012.03.031

Mainoo, A. A., & Ulzen-Appiah, F. (1996). Growth, wood yield and energy characteristics of Leucaena leucocephala, Gliricidia sepium and Senna siamea at age four years. *Ghana Journal of Forestry, 3,* 11.

Ministry of Energy. (2010). *National Energy Policy.*

Ministry of Energy. (2017). *National Policy on Promotion of LPG.*

Ministry of Energy. (2019a). *Charcoal Value Chain Baseline Study.* Ghana Energy Development and Access Project, Ministry of Energy.

Ministry of Energy. (2019b). *National Bioenergy Action Plan (NBEAP) of Ghana (2020-2030).* ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE).

Ministry of Energy. (2021). *National LPG Promotion Program: Concept Paper.*

Ministry of Food and Agriculture. (2019). *Agriculture in Ghana. Facts and Figures 2018.* Statistics, Research and Information Directorate. http://mofa.gov.gh/site/images/pdf/AGRIC%20IN%20GHANA%20F&F_2018.pdf

Ministry of Food and Agriculture. (2021). *Facts & Figures: Agriculture In Ghana 2020.* Statistics Research and Information Directorate, Ministry of Food and Agriculture.

Mohammed, S. (2021). *Contribution of firewood harvesting and trading to the livelihood of rural households in the northeast Gonja District in the Savannah Region of Ghana* [MPhil thesis]. Department of Silviculture and Forest Management, Kwame Nkrumah University of Science and Technology.

Mohammed, S., & Heijndermans, E. (2013). *Behind the butter: An energy analysis of Shea butter processing* (p. 30). SNV-Netherlands Development Organization.

National Petroleum Authority. (2022). *National Consumption from 1999-2021.* Acts, LIs, Template, Manuals & Statistics. http://www.npa.gov.gh/download-media/industry-data/downloads

Nketiah, K. S., & Asante, J. (2018). *Estimating national charcoal production in Ghana* (p. 68). Tropenbos Ghana. https://ifro.ku.dk/english/research/projects/ax/publications/Estimating-national-charcoal-production-in-Ghana_report-2018.pdf

Nketiah, K. S., Asante, J., & Hansen, C. P. (2021). Annual Charcoal Production in Ghana: Implications for Sustainable Production and Trade. *Access and Exclusion along the Charcoal Commodity Chain in Ghana (AX) Research Project, 2.*

Obiri, B. D., Kwarteng, E., Nunoo, I., Owusu-Afriyie, K., & Nutakor, E. (2013). *Analysis of the Fuelwood Value Chain for the Ghanaian Fish Smoking Industry* (p. 150). SNV-Netherlands Development Organization.

Obiri, B. D., Nunoo, I., Obeng, E., Owusu, F. W., & Marfo, E. (2014). *The Charcoal Industry in Ghana: An Alternative Livelihood Option for Displaced Illegal Chainsaw Lumber Producers.* Tropenbos International.

Ofosu-Budu, K., & Sarpong, D. B. (2013). Oil palm industry growth in Africa: A value chain and smallholders' study for Ghana. *In Rebuilding West Africa's Food Potential* (A. Elbehri (ed.), p. 44). FAO/IFAD.

Ohimain. (2012). Traditional Fermentation and Distillation of Raffia Palm Sap for the Production of Bioethanol in Bayelsa State, Nigeria. *Journal of Technology Innovations in Renewable Energy.* https://doi.org/10.6000/1929-6002.2012.01.02.8

Osei-Amponsah, C., Visser, L., Adjei-Nsiah, S., Struik, P. C., Sakyi-Dawson, O., & Stomph, T. J. (2012). Processing practices of small-scale palm oil producers in the Kwaebibirem District, Ghana: A diagnostic study. *NJAS - Wageningen Journal of Life Sciences, 60–63,* 49–56. https://doi.org/10.1016/j.njas.2012.06.006

Owusu-Takyi, S., Addai, K., & Heijndermans, E. (2013). *Pito Brewing Process Characterization.* SNV-Netherlands Development Organization.

Preferred by Nature. (2017). *Ghana Palm Oil Risk Profile.* www.preferredbynature.org/sourcinghub/palm-oil/palm-oil-ghana

Quaye, W., & Stosch, L. (2008). A study of fuel consumption of three types of household charcoal stoves in Ghana. *Ghana Journal of Agricultural Science, 41*(1), Article 1. https://doi.org/10.4314/gjas.v41i1.46150

Roser, M., Ritchie, H., & Spooner, F. (2021, September 25). *Burden of disease.* Our World in Data. https://ourworldindata.org/burden-of-disease

Samey, B. (2015). *Literature Review On Sardinella Value Chain* (p. 36). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island and SNV Netherlands Development Organization.

Schure, J., Hubert, D., Ducenne, H., Kirimi, M., Awono, A., Mpuruta-Ka-Tito, R., Mumbere, G., & Njenga, M. (2021). *Carbonization 2.0: How to produce more charcoal with less wood and emissions* (Governing Multifunctional Landscapes Project Brief #1; Sustainable Woodfuel Brief Series). CIFOR-ICRAF.

Schure, J., Pinta, F., Cerutti, P. O., & Kasereka-Muvatsi, L. (2019). Efficiency of charcoal production in Sub-Saharan Africa: Solutions beyond the kiln. *BOIS & FORETS DES TROPIQUES, 340.* https://doi.org/10.19182/bft2019.340.a31691

Schwöppe, C., & Wojewska, A. (2018). *To plant, or not to plant? A case study of woodlot and plantation establishment under ELCIR+ in Kintampo Forest District* [Master's thesis]. Department of Food and Resource Economics Faculty of Science, University of Copenhagen.

Simon, G. L., Bailis, R., Baumgartner, J., Hyman, J., & Laurent, A. (2014). Current debates and future research needs in the clean cookstove sector. *Energy for Sustainable Development, 20,* 49–57. https://doi.org/10.1016/j.esd.2014.02.006

Smith, K. R. (2015). Changing Paradigms in Clean Cooking. *EcoHealth, 12*(1), 196–199. https://doi.org/10.1007/s10393-015-1020-9

SNV Ghana. (2017). *An Analysis of the Ghanaian Cookstove Market.* SNV-Netherlands Development Organization.

Technoserve. (2018). *Natural Resource Product Analysis – Shea Roadmap.* USAID Ghana Agriculture and Natural Resource Management Project. https://ghanalinks.org/documents/206403/229906/Natural+Resource+Product+Analysis+%26%23x2013%3B+Shea+Roadmap/3a2b7023-b5a2-4c0a-858e-ce87ded282c0?download=true

Tomlins, K. I., Manful, J. T., Larwer, P., & Hammond, L. (2005). Urban consumer preferences and sensory evaluation of locally produced and imported rice in West Africa. *Food Quality and Preference, 16*(1), 79–89. https://doi.org/10.1016/j.foodqual.2004.02.002

UNDP. (2012). *Technology Transfer and Training on the Local Manufacture of Environment Friendly Energy-Saving Cook stoves (Ahibenso).* UNDP GEF Small Grants Program. https://www.sgp.undp.org/spacial-itemid-projects-landing-page/spacial-itemid-project-search-results/spacial-itemid-project-detailpage?view=projectdetail&id=5540

UNDP. (2015). *NAMA study for a sustainable charcoal value chain in Ghana.* https://www.undp.org/content/dam/undp/library/Environment%20and%20Energy/MDG%20Carbon%20Facility/NAMA%20Study%20Ghana%20final.pdf

UNFCCC. (2015). *ASB0016: Standardized baseline. Institutional Cook Stoves in Uganda. Version 01.0.* United Nations Framework Convention on Climate Change. https://cdm.unfccc.int/filestorage/e/x/t/extfile-20151020172118401-C--Users-Stickdorn-Desktop-ASB0016.pdf/ASB0016.pdf?t=Tjh8cjdpNXZ3fDC0ZiNQP_ySIt3CGEMRCuT0

United Nations. (2019). *2019 Revision of World Population Prospects.* United Nations - Deparment of Economics and Social Affairs. https://population.un.org/wpp/

United Nations. (2022). *Goal 7 | Department of Economic and Social Affairs.* https://sdgs.un.org/goals/goal7

Van der Kroon, B., Brouwer, R., & van Beukering, P. J. H. (2013). The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. *Renewable and Sustainable Energy Reviews, 20,* 504–513. https://doi.org/10.1016/j.rser.2012.11.045

WHO. (2018). *Global status report on alcohol and health 2018.* World Health Organization. https://apps.who.int/iris/handle/10665/274603

World Bank. (2011). *The Role of Liquefied Petroleum Gas in Reducing Energy Poverty* [Extractive Industries for Development Series].

Zormelo, P. E. (2018, October 9). *Sustainable Feedstock Supply for Charcoal Production.* 4th Ghana Renewable Energy Fair.

ANNEX C DETAILED METHODOLOGY

Modelling woodfuel demand for cooking

Household woodfuel consumption was derived from Kitchen Performance Test (KPT) results from both rural and urban areas, for HHs using either firewood or charcoal as their primary cooking fuel, with both efficient and traditional stoves. The share of HHs using firewood or charcoal as their primary fuel was extracted from the latest (2021) census (Ghana Statistical Service, 2022) and the share of efficient versus traditional stoves was derived from the 2017 Ghana Living Standard Survey (Ghana Statistical Service, 2017). Data on secondary fuel use was obtained from a recent cooking practice survey of over 7,000 HHs (Kintampo Health Research Centre & Columbia World Projects, 2021). As well as providing data on the proportion of HHs using different primary and secondary cookstove (and therefore fuel) combinations, this survey estimates the time spent using each fuel. Taking the time estimates as a proxy for consumption, it is possible to adjust the KPT energy consumption figures for all cookstove combinations.[46] These consumption figures were extrapolated on a per capita basis for firewood and charcoal to the whole population using demographic data from the 2021 census, for both urban and rural areas, disaggregated to regional level (Ghana Statistical Service, 2021a). Demand for each region was then mapped down to a resolution of 1 km^2 using the WorldPop dataset,[47] which was calibrated to match the urban and rural populations from the 2021 census at regional level.

As the extrapolation of demand was based on the total population, it implicitly includes meals taken outside the home, such as in commercial food outlets and institutional settings, which are thus considered to have the same energy requirements as meals taken inside the home, for demand modelling purposes. The woodfuel requirements for institutional and commercial cooking are therefore included in the overall demand totals, but separate figures for these subsets of demand were still calculated to provide an indication of their relative significance and the potential for targeted efficiency interventions.

The assessment of woodfuel consumption by institutions focussed mainly on educational institutions, from primary up to tertiary level, as this sector accounts for the bulk of demand for institutional catering. Consumption estimates were derived from district-level enrolment figures by institutional type from the GoG's Education Management Information System,[48] combined with estimates of the proportion of day and boarding students and standardised consumption figures for each category (UNFCCC, 2015), adjusted according to whether children (up to secondary level) or adults (tertiary level) are being fed. A more complete assessment would need to extend to health institutions, prisons, military installations and other sites of mass catering.

The woodfuel requirement for commercial catering in hotels, restaurants and street food outlets was estimated using economic data on the percentage of HH food budgets spent on catering outside the home, from the 2017 Ghana Living Standards Survey ((Ghana Statistical Service, 2017), adjusted downwards to account for the cost of the food ingredients only, and translating this expenditure percentage to an equivalent percentage of HH energy consumption.

Modelling woodfuel demand for non-cooking purposes

Research was carried out into commercial sectors known to be consuming significant quantities of woodfuel. These included fish smoking, the production of traditional beers (*pito*) and spirits (*akpeteshie*), shea nut processing, gari production, rice parboiling and artisanal palm oil production (see respective sections in main report for methodology). Other sectors worthy of future investigation might include brickmaking and the ceramics industry.

46 As an example, 9.4% of the HHs use LPG as a primary fuel and charcoal as a secondary fuel. On average, these HHs use LPG 89% of the time and charcoal 11% of the time. For estimating energy consumption, they are assumed to consume 89% as much LPG as an LPG-only HH and 11% as much charcoal as a charcoal-only HH.

47 www.worldpop.org/project/categories?id=3

48 moe.gov.gh/emis

Quantifying woodfuel exports

Data on charcoal exports was obtained from published GoG statistics (Energy Commission, 2021) and from the UN Comtrade database.[49] Visits were made to the northern border crossings at Paga and Tumu to investigate potential overland exports to Burkina Faso.

Modelling total woodfuel demand and projections

Charcoal exports were added to the domestic consumption total to derive total national demand. This was converted to an equivalent in wood feedstock at an assumed carbonisation efficiency of 16.7% by weight (IPCC, 2019). This amount was added to the consumption figure for firewood to give the total wood requirement to meet national woodfuel demand.

Total demand was projected to 2030 based on two scenarios, both using a population growth rate corresponding to the median probabilistic projections from the UN World Population Prospects 2019[50] and scaled on the 2021 census. A 'business as usual' demand scenario assumed a moderate evolution of current patterns and was compared with an alternative 'intervention' scenario which assumed an accelerated switch to LPG by HHs currently using charcoal as their primary fuel to reach 50% of HHs by 2030, in line with the National LPG Promotion Policy, together with higher fuel efficiency in cooking by HHs and institutions as a result of accelerated adoption of improved cookstoves, and a 10% improvement in the efficiency of charcoal production (bringing it to 15% by weight).

Modelling woodfuel supply

Land cover was derived from the European Space Agency (ESA) Climate Change Initiative Land Cover time-series for the years 2016 to 2020. The quantity of biomass was obtained using the ESA Biomass Climate Change Initiative for the years 2017 and 2018.[51] The Mean Annual Increment (MAI) in each land cover class, in both forest and non-forest areas, was determined using equations from Bailis et al. (2015). It was assumed that National Parks and Game Reserves were not accessible for woodfuel supply and that Forest Reserve accessibility was 20% of similar forests not classified as Forest Reserves. It was further assumed that at least 75% of the charcoal for any demand point would come from savannah land, as classified by the ESA imagery.[52] To account for the supply of wood from trees outside forests (e.g., the collection of dead branches or low tree density pruning), a minimum available MAI of 0.5 t/ha for cropland and grassland and 0.2 t/ha for urban areas was assumed. The net output was a national map of the potential supply of wood available for woodfuel production across all land uses, at a 500 m resolution.

Wood supply made available by land cover change was also determined, by quantifying changes in land cover between 2018 and 2019, and applying biomass quantities in forested ecosystems in 2018. This allowed the contribution to overall woodfuel supply of changes in land cover, such as the expansion of cropland, to be determined.

To provide additional socio-economic information on charcoal production, an original survey was commissioned through the University for Development Studies (UDS) in Tamale. 20 enumerators from UDS spent five days in 13 districts identified as areas of significant charcoal supply by Nketiah & Asante (2018). They located 552 earth mound charcoal kilns and interviewed producers at the kiln sites about their production techniques, scale, seasonality and commercial model. The survey was designed for Android smartphones using Kobo Collect, enabling location coordinates, photos and questionnaire responses to be uploaded in real-time. UDS carried out simultaneous research into woodfuel costs and units of sale at different rural and urban locations, to develop a picture of the supply chain price build-up. The UDS survey results are quoted throughout the report, with maps and supporting data in Annex D.

49 comtrade.un.org/data

50 population.un.org/wpp/Download/Probabilistic/Population/

51 climate.esa.int/en/projects/land-cover/

52 www.esa-landcover-cci.org/

Supply/Demand modelling

By comparing the spatial distribution of wood supply with the spatial distribution of woodfuel demand, the sustainability of harvesting for woodfuels could be assessed.

This assessment of the wood supply/demand balance was carried out in two stages. First, local demand for firewood was compared to locally available supply, and this demand was deducted from the available MAI. In areas where the MAI was lower than the firewood demand, the remaining demand was considered to be supplied commercially from elsewhere. This was common in areas of high population density. The modelling of commercial woodfuel (purchased firewood and all charcoal) differed significantly from collected firewood, as the supply area for commercial fuels tends to extend much further from the demand centre. To model the most likely supply areas for commercial woodfuels and assess potential impacts on tree cover, a cost-distance model was developed. A similar approach has been used to assess woodfuel impacts on forest resources across various areas in the tropics (Bailis et al., 2015) and to develop woodfuel management scenarios at country scale (Ghilardi et al., 2018).

The objective of cost-distance modelling is to identify the 'woodshed' supplying a given demand centre. Analogous to a watershed as a water catchment zone, a woodshed represents the supply area that is accessible to commercial woodfuel suppliers to meet a given demand. Woodsheds around a particular demand point are defined using a 'friction layer' model that simulates how quickly transporters can access biomass resources from that point. As the modelling approach was computationally intensive, instead of running the model for all village and towns in Ghana, demand was centralised to largest towns within each district. From those points, all the areas meeting specific criteria (minimum biomass stock, type of land-use) and accessible within a defined period of time were mapped, and the pressure from the demand centre was applied to these areas. In order to calculate how long it would take to access a particular location, assumptions were made about the time needed to cross different types of land cover. A cost-distance model was run outwards from the demand centres using a friction raster with the parameters listed in Table 33.

Table 33. Parameters used for the development of the cost-distance friction model

Land cover/land use		Assumed crossing time (min/km)
River		12
Road	Main	1
	Secondary	2
	Tertiary	4
Land-use	Cropland	9
	Grassland	9
	Shrubland	9
	Mosaic	9
	Evergreen forest	60
	Deciduous forest	48
	Savanna	18
	Rocky land	60
	Gallery forest	60
	Mangrove	90
	Urban	2
	Bare	1
	Water bodies	30

A discount factor was applied to each crossing time based on slope, using the following equation:

$$Crossing\ time_{new} = \frac{Crossing\ time_{old}}{e^{(-3*slope\ percentage)}}$$

Once the locations reachable within the defined maximum travel time from each district centre were identified, only the areas above a minimum MAI (which is a function of the AGB) were considered to have commercially viable biomass stocking levels. Using a global map of AGB from the European Space Agency (ESA, 2019), a minimum MAI of 0.5 t/ha was assumed as the commercially viable threshold for charcoal, while a minimum MAI of 0.2 t/ha was applied to traded firewood.

The demand from each district centre was then applied to these areas and another iteration was run for the next district, before summing the pressures from all districts and producing a national pressure map.

The friction layer model identified those areas accessible within a maximum defined travel distance from the demand point. For charcoal, the model required at least 75% of the demand is to be coming from savannah ecosystems (as classified in the ESA satellite image) with a maximum travel time of 16 hours from the district demand centre. For the remaining charcoal, which corresponds to more localised production either using wood from savannah or other land-uses, the maximum travel time was set at 8 hours. Commercial firewood was assigned the lowest travel time due to more expensive transportation costs relative to its value, so a maximum limit of 6 hours was set. Commercially viable woodfuel sources within these time radii were identified, based on the above-mentioned minimum MAI thresholds of 0.5 t/ha for charcoal production and 0.2 t/ha for commercial firewood supply. The process was carried out 261 times, once for each district.

The results allowed woodfuel demand to be mapped against supply and, after deducting the MAI of each area, to identify areas where harvesting exceeds the sustainable level. This modelling revealed 'hotspots' of demand with respect to available biomass resources. Identifying these areas of highest pressure on wood stocks can help direct both supply and demand-side interventions to the locations or value chains where they are most needed.

Finally, the woodfuel demand projections for 2030 were overlain on the current land cover layer to give a visual impression of the possible spatial evolution of the pressure hotspots under the 'business as usual' and 'intervention' demand scenarios. This should not be seen as an accurate forecast of the future supply/demand situation, as it is based on the present-day land cover map. Land cover in 2030 will of course be somewhat different. But it facilitates comparative modelling of the potential effectiveness of different interventions to reduce pressure from woodfuel on tree cover.

ANNEX D ADDITIONAL DATA FROM UDS SURVEYS

Table 34. Locations of kilns surveyed by UDS, by region and district

Region/District	Count
Ashanti	**138**
Ejura	7
Mampong	38
Sekyere Afram Plains	79
Sekyere Central	14
Bono East	**190**
Atebubu Amanti	16
Jema	81
Kintampo North	41
Kintampo South	36
Sene West	16
Eastern	**69**
Kwahu Afram Plains South	69
Savannah	**72**
Bole	42
West Gonja	30
Upper West	**83**
Sissala West	83
Grand Total	**552**

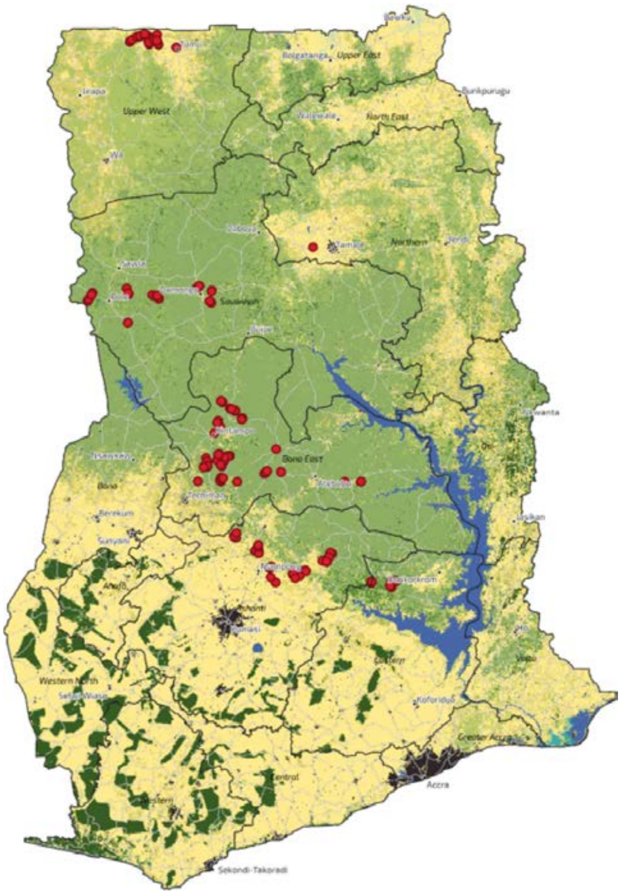


Table 35. Wood species named for charcoal-making in UDS survey, in addition to dominant four

Vernacular name	Ashanti	Bono East	Eastern	Savannah	Upper W	Total	Botanical name
Kane	31	18	0	9	0	**58**	Anogeissus leiocarpus
Senya	4	39	13	1	0	**57**	Danielia oliveri
Kande	26	17	0	0	0	**43**	Talbotiella gentii
Papia	40	0	0	0	0	**40**	Papao/ Afzelia africana
Ongo	15	5	0	0	0	**20**	Terminalia avicenioides/T. laxiflora/T. glaucescens
Papar	0	18	2	0	0	**20**	Broussonetia papyrifera
Takorowa	20	0	0	0	0	**20**	Hymenostegia afzelii
Sapele	0	19	0	0	0	**19**	Entandrophragma cylindricum
Teak	10	5	0	0	1	**16**	Tectona grandis

Vernacular name	Ashanti	Bono East	Eastern	Savannah	Upper W	Total	Botanical name
Potrodom	12	0	0	0	0	**12**	Erythrophleum africanum; E. guineense; E. ivorense
Kwadonee	11	0	0	0	0	**11**	
Lisalasi	0	11	0	0	0	**11**	
Cashew	0	10	0	0	0	**10**	Anacardium occidentale
Kookoowa	0	9	0	0	0	**9**	
Asekanea	0	0	8	0	0	**8**	Talbotiella gentii
Botom	0	8	0	0	0	**8**	
Bonaaso	0	7	0	0	0	**7**	
Sabakyee	7	0	0	0	0	**7**	
Badee	6	0	0	0	0	**6**	Badi / Nauclea diderrichii = Sarcocephalus diderrichii
Mango	3	3	0	0	0	**6**	Mangifera indica
Sese	5	1	0	0	0	**6**	Holarrhena floribunda
Anuma duya	0	5	0	0	0	**5**	
Kikale	0	0	0	5	0	**5**	
Ngo ne Nkyene	5	0	0	0	0	**5**	Cleistopholis klaineana Pierre
Ankara	0	4	0	0	0	**4**	
Apujori	0	4	0	0	0	**4**	
Atweretwerewa	4	0	0	0	0	**4**	
Pear	4	0	0	0	0	**4**	
Akese	0	0	3	0	0	**3**	Akasa/ Chrysophyllum spp.; C. albidum; C. giganteum; C. subnudum
Apekyesie	3	0	0	0	0	**3**	
Ebony	0	0	0	0	3	**3**	Diospyros ebenum
Kanye	3	0	0	0	0	**3**	
Koogyadu mpaboa	0	0	3	0	0	**3**	
Kotere amfo	3	0	0	0	0	**3**	
Kwagyadu mpaboa	0	0	3	0	0	**3**	
Kyenkyen	2	1	0	0	0	**3**	Antiaris toxicaria
Onyina	0	3	0	0	0	**3**	Ceiba pentandra
Pepewa	0	3	0	0	0	**3**	
Potorowa	3	0	0	0	0	**3**	
Prekese	3	0	0	0	0	**3**	Tetrapleura tetraptera
Rayie	0	3	0	0	0	**3**	
Samena	3	0	0	0	0	**3**	
Abayifuo dua	2	0	0	0	0	**2**	
Akorowa	2	0	0	0	0	**2**	
Angu	0	2	0	0	0	**2**	
Apia	2	0	0	0	0	**2**	
Atwi aa	0	2	0	0	0	**2**	Lovoa klaineana = L. trichilioides (African walnut)
Awiemfuo	2	0	0	0	0	**2**	
Dua pa	2	0	0	0	0	**2**	

Vernacular name	Ashanti	Bono East	Eastern	Savannah	Upper W	Total	Botanical name
Kigbim	0	0	0	2	0	**2**	
Kinkan	0	2	0	0	0	**2**	
Kotere nforo	2	0	0	0	0	**2**	
Krebenten	0	1	1	0	0	**2**	
Melina	1	1	0	0	0	**2**	
Mofoduawe	0	0	0	2	0	**2**	
Neem	0	1	1	0	0	**2**	Azadirachta indica
Ngo	0	2	0	0	0	**2**	
Odum	1	1	0	0	0	**2**	Milicia excelsa = Chloroplora excelsa; M. regia = C.regia
Petri	0	2	0	0	0	**2**	
Premi	0	2	0	0	0	**2**	
Primu	0	2	0	0	0	**2**	
Red berry tree	0	0	0	0	2	**2**	
Shia	0	2	0	0	0	**2**	
Soronu	0	2	0	0	0	**2**	
Wabire	0	2	0	0	0	**2**	
Apar	0	1	0	0	0	**1**	
Awiafo	1	0	0	0	0	**1**	
Bunaso	0	1	0	0	0	**1**	
Cecilia	0	0	0	1	0	**1**	
Chira	0	1	0	0	0	**1**	
Chufuu	1	0	0	0	0	**1**	
Duga	0	1	0	0	0	**1**	
Emeri	1	0	0	0	0	**1**	Terminalia ivorensis
Enya	0	1	0	0	0	**1**	
Fig tree	0	0	0	0	1	**1**	
Kapuli	0	0	0	1	0	**1**	
Kokomo	1	0	0	0	0	**1**	
Konkroma	0	1	0	0	0	**1**	
Koojedu mpabwa	0	0	1	0	0	**1**	
Kookonisuo	0	1	0	0	0	**1**	
Kpamkpam	0	0	0	1	0	**1**	
Kug	0	0	0	1	0	**1**	
Kuwi	0	0	0	1	0	**1**	
Kyeforo	1	0	0	0	0	**1**	
Leadwood	0	1	0	0	0	**1**	Combretum imberbe
Ligaa	0	1	0	0	0	**1**	
Mase gye wo ba	1	0	0	0	0	**1**	
Nkuto dua	1	0	0	0	0	**1**	
Nsuomu ndua	0	0	1	0	0	**1**	

Vernacular name	Ashanti	Bono East	Eastern	Savannah	Upper W	Total	Botanical name
Nwadua	0	0	1	0	0	**1**	
Nyina	0	1	0	0	0	**1**	
Onkroma	0	1	0	0	0	**1**	
Pakadom	0	1	0	0	0	**1**	
Pampana	1	0	0	0	0	**1**	
Santa	0	1	0	0	0	**1**	
Tagbonukuu	0	0	0	1	0	**1**	
Tufiri	1	0	0	0	0	**1**	
Twifori	1	0	0	0	0	**1**	
Ua pa	1	0	0	0	0	**1**	
Wawa	1	0	0	0	0	**1**	Triplochiton scleroxylon
Acacia	0	0	0	0	0	**0**	Acacia spp.
Bimbol	0	0	0	0	0	**0**	
Total species	**43**	**48**	**11**	**11**	**4**	**100**	

Figure 14. Locations surveyed by UDS for charcoal price and weight survey

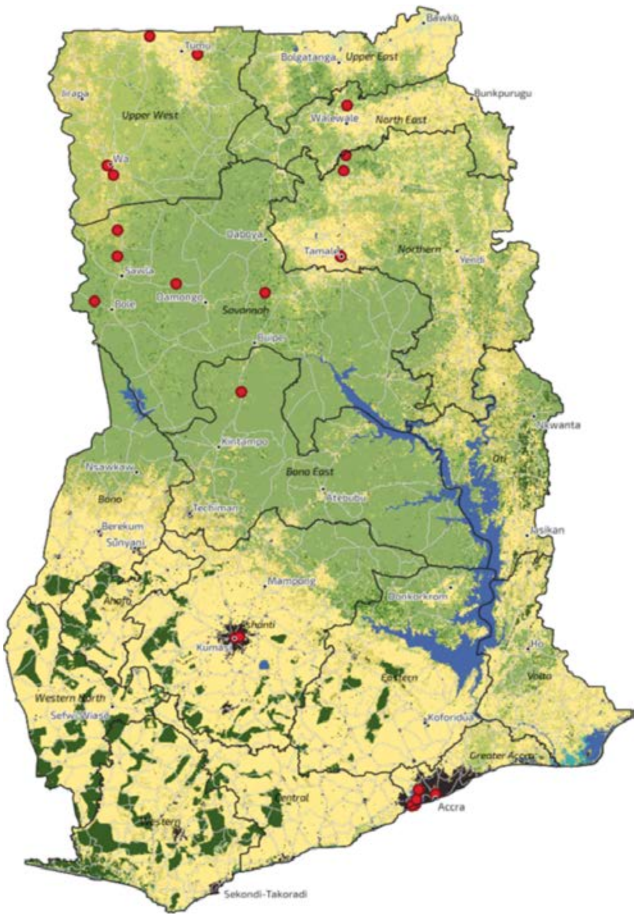


Table 36. Summary data from UDS price and weight survey

Location	Unit of sale	Average price (GH¢)	Average weight (kg)	Average price (GH¢/kg)	Average price for location (GH¢/kg)
Kiln	Size 5	30.0	63.0	0.5	0.5
Roadside – remote NSZ	Size 4	35.0	55.0	0.6	0.7
	Size 5	55.0	73.8	0.7	
Roadside – main routes to market	Size 4	42.5	35.7	1.2	1.1
	Size 5	58.8	66.5	0.9	
	Small bag	15.0	12.0	1.3	
Retail – Wa, Tamale	Size 5	60.0	55.0	1.1	1.1
	Basin	20.0	20.0	1.0	
	Bucket	4.0	3.5	1.1	
	Poly bag	5.0	4.0	1.3	
Retail – Kumasi	Size 4	70.0	43.7*	1.6	1.6
	Size 5	100.0	64.6*	1.5	
Retail - Accra	Size 4	76.7	40.5	1.9	2.4
	Poly bag	2.8	1.0	2.8	

* Bag weights for Kumasi not recorded, so averaged from other locations

Table 37. Raw data from UDS price and weight survey (March 2022)

Location	Lat	Long	Type of source	Unit of sale	Price (GH¢)	Sample weights (kg)		
						1	2	3
Dimajang	10.8473146	-1.8698579	Roadside - remote	Size 4	50	64	62	66
Kpenaayiri	9.0925051	-2.6126618			20	47	46	45
Dimajang	10.8472694	-1.8697833		Size 5	60	89	85	80
Gwollu	10.9779679	-2.2135314			50	65	61	63
Wulugu	10.4793259	-0.7962228	Roadside	Small bag	15	12		
Wulugu	10.479715	-0.796245		Size 5	65	56	55	60
Disiga	10.013855	-0.8239417			60	45	57	46
Tuna	9.4123814	-2.4482426			60	85	80	83
Kabampe	9.2168404	-2.0285081			50	73	77	81
Wulugu	10.4792976	-0.7961446		Size 4	50	35	40	34
Wulugu	10.4792817	-0.796145			40	27		
Kukobila	10.1249905	-0.8071595			50	37	45	42
Pongiri	9.5967946	-2.4471277			30	41	32	41
Kawampe	8.44668	-1.56479			40	29	32	33
Kawampe	8.4465491	-1.5644284			45	40	39	41
Tamale timber market	9.4051432	-0.848685	Retail NSZ	Size 5	60	56	55	54
Wa	10.0592257	-2.5191282		Bucket	2	2	2	2
Wa	10.0591702	-2.5191258			6	5	5	5
Wa UDS	9.9915963	-2.476033		Basin	20	20	18	22
Tamale timber market	9.4052057	-0.8487555		Poly bag	5	4	4	4
Nima Kumasi	6.703884	-1.584302	Retail Kumasi	Size 4	65			
Aboabo station Kumasi	6.697333	-1.614833			70			
Akwatia Line Kumasi	6.697333	-1.614833			75			
Aboabo - Kumasi	6.697333	-1.614833		Size 5	100			
Agape Station (Ablekuma, Accra)	5.612843	-0.315124	Retail Accra	Size 4	80	41		
Kanda Highway	5.579747	-0.19567			90	41	42	
New Aplaku	5.541899	-0.330377			60	39		
New Aplaku	5.542105	-0.330439		Small poly bag	5	1.4		
New Aplaku	5.541762	-0.330513			2	0.6		
Bortianor	5.507317	-0.338961			2	0.8		
Bortianor	5.506736	-0.339122			5	2		
Kokrobitey	5.506715	-0.339405			2	0.8		
Kokrobitey	5.498684	-0.363835			1	0.4		
Kojokuru	9.1513139	-1.3919766	Kiln	Size 5	30	64	62	63

ANNEX E CALCULATION OF FIREWOOD DEMAND IN EDUCATIONAL INSTITUTIONS

	Primary - private	Primary - public	JHS - private	JHS - public	SHS - private	SHS - public	TVET - GES	TVET - other	College of Agriculture	College of Education (Public)	College of Education (Private)	Nursing, Midwifery & Health Training College (public)	Nursing, Midwifery & Health Training College (private)	Specialised/Professional Teaching Institution (public)	Technical University or Polytechnic	University (public)	University/University College (private)
Percentage by type							moe.gov.gh/emis										
Day	90%	90%	90%	90%	15%	20%	15%	15%	10%	10%	10%	10%	10%	80%	30%	30%	30%
Boarding	0%	0%	0%	0%	35%	30%	6%	6%	80%	40%	40%	80%	80%	10%	10%	10%	10%
Mixed	10%	10%	10%	10%	50%	50%	79%	79%	10%	50%	50%	10%	10%	10%	60%	60%	60%
Percentage of each category catering																	
Day	50%	90%	30%	0%	30%	0%	0%	30%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Boarding	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	10%	10%	10%	10%
Mixed	70%	90%	60%	45%	60%	45%	45%	60%	45%	45%	45%	45%	45%	5%	5%	5%	5%
% of those catering using firewood	50%	80%	50%	80%	50%	80%	90%	80%	80%	90%	60%	80%	60%	80%	80%	80%	60%
Firewood demand (t/pers/yr)*																	
Day	0.05	0.14	0.03	0.00	0.03	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boarding	0.17	0.27	0.17	0.27	0.17	0.27	0.31	0.27	0.42	0.48	0.32	0.42	0.32	0.05	0.05	0.05	0.04
Mixed	0.10	0.21	0.09	0.10	0.09	0.10	0.12	0.14	0.16	0.18	0.12	0.16	0.12	0.02	0.02	0.02	0.01
Average firewood demand (t/pers/yr)	**0.05**	**0.14**	**0.03**	**0.01**	**0.11**	**0.13**	**0.11**	**0.13**	**0.36**	**0.28**	**0.19**	**0.36**	**0.27**	**0.01**	**0.02**	**0.02**	**0.01**

* - Total firewood demand for the subset that are catering and using firewood is based on a requirement of 0.19 t per student per year for day schools, 0.38 t for boarding schools and 0.59 t for 'adult' boarding institutions (UNFCCC, 2015), taken to be Colleges of Agriculture and above, with a similar proportional uplift for adult day institutions to give 0.29 t/pers/yr. Consumption in mixed day/boarding institutions is assumed to be an average of the day and boarding figures.

ANNEX F FINANCIAL ANALYSIS OF CHARCOAL WOODLOTS

A financial model was created for a *Senna siamea* woodlot for charcoal production, assuming five 4-year coppicing cycles over 20 years.

Labour inputs and costs were taken from Lemke (2020) (see Table 38), converted from US$ to GH¢ at his (2020) rate of 5.325. He modelled three options for tree spacing, each with different labour costs for establishment and maintenance. To derive a labour cost 'per seedling' that could be applied to any possible spacing, his labour cost for each task was plotted against the number of trees per hectare as a scatter graph, and the formula for the best-fit line was used to derive the labour cost for any planting density. The cost inputs are summarised in Table 38.

These costs of establishment and maintenance are significantly lower than official GoG estimates. For example, at 3 x 3 m spacing (1,111 trees/ha), the FC-recommended planting density for *S. siamea*, and applying the costs from Table 38 and a March 2022 exchange rate of GH¢ 7.5 per US$, this model delivers a cost of US$ 487/ha for establishment and US$ 57/ha (annualised) for maintenance and harvesting over three years. The Ghana Forest Plantation Strategy (2016-2040) assumes much higher costs of US$ 1,500/ha for establishment and US$ 600/ha/yr for maintenance. This model is therefore optimistic and illustrates a relatively cheap 'best case' outcome.

The other assumptions in the woodlot financial model are summarised in Table 39.

Table 38. Establishment, maintenance and harvesting costs used for woodlot model (GH¢/ha)

Task	Cost per seedling	Cost per ha	Source
Establishment			
Seedlings	1.2		RAINcorp commercial tree nursery, Tamale; Jan 2022 discounted price to FC, incl. transport (NGOs pay GH¢ 3).
Clearing		751	(Lemke, 2020) converted from US$ to GH¢ at his (2020) exchange rate of 5.325
Digging	0.21		
Planting	0.27		
Beating up	0.053		
Firebelt clearing		208	
Tools		272	
Weeding 1		226	(Lemke, 2020) using formula for best-fit trendline for all modelled tree spacings
Weeding 2		166	
	Total per ha	**7,399**	
Maintenance			
Yr 2		658	(Lemke, 2020) using formula for best-fit trendline for all modelled tree spacings
Yr 3		272	
Yr 4		272	
Harvesting			
Yr 4	0.37	1,233	ditto

Table 39. Additional assumptions in woodlot financial model

Cost item	Cost (GH¢/kg)	Cost (GH¢/kg)
Tree spacing	3 x 1 m for main economic analysis, though model permits other spacings to be run	Spacing optimised for woodfuel (Acquah et al., 2015)
Wood yield per ha after 4 years	Cocoa Belt: 86.15 t dm or 114.9 t air-dry (25% MC)	(Mainoo & Ulzen-Appiah, 1996)
	Northern Savannah Zone: 56.0 t dm or 74.7 t air-dry (25% MC)	Downwards yield adjustment of 35% from Cocoa Belt (moist tropical) to NSZ (dry tropical), in line with IFCC default values for eucalyptus in Africa (IPCC, 2019)
Mortality rate per coppicing cycle	20%, 10% or 5%	Base Case, Improved Case or Optimised Case
Carbonisation efficiency	16%, 20% or 24%	Base Case is traditional earth kiln with average management. Improved Case is improved basic earth kiln. Optimised Case is maximum efficiency from earth kiln, with dry wood and skilled management.
Charcoal sale price	GH¢ 0.48, 0.52 or 0.57 per kg	Base Case is typical ex-kiln price to producer (UDS survey, 2022). Improved Case assumes 9% profit gain, in line with roadside traders surveyed at Wulugu, NE Region. Optimised Case assumes further 9% profit gain, in line with data from urban traders in Tamale.
US$/GH¢ exchange rate	7.52	www.xe.com March 2022
Discount rate	10%	

Table 40 below provides a sample cashflow analysis for one of the woodlot scenarios in the NSZ.

Table 40. Cashflow analysis, woodlot financial model

US$

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Establishment costs/ha	984																			
Maintenance costs/ha		88	36	36	88	36	36	36	88	36	36	36	88	36	36	36	88	36	36	36
Harvesting costs/ha				164				164				164				164				164
Total costs	**984**	**88**	**36**	**200**	**88**	**36**	**36**	**200**	**88**	**36**	**36**	**200**	**88**	**36**	**36**	**200**	**88**	**36**	**36**	**200**
Biomass yield (t/ha), air-dry				74.7				59.7				47.8				38.2				30.6
Charcoal output (t/ha)				11.9				9.6				7.6				6.1				4.9
Charcoal revenue				**760**				**613**				**485**				**389**				**313**
Annual profit/loss	**(984)**	**(88)**	**(36)**	**559**	**(88)**	**(36)**	**(36)**	**413**	**(88)**	**(36)**	**(36)**	**285**	**(88)**	**(36)**	**(36)**	**189**	**(88)**	**(36)**	**(36)**	**113**

The example shown is the Base Case scenario for the Northern Savannah Zone. Separate analyses were run for the Improved Case and the Optimised Case for both the NSZ and the Cocoa Belt.