Carbonization 2.0: How to produce more charcoal with less wood and emissions

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This publication is part of a series of briefs describing findings from the EU-funded Governing Multifunctional Landscapes Sustainable Woodfuel project, which aims to contribute to knowledge, options and engagement for more sustainable woodfuel value chains across Sub-Saharan Africa.

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Key lessons

Enabling factors for improving charcoal making include:

- Context-specific kiln solutions, with suitable and available materials, acceptable to producers and considering transportation limits and wood sizes;
- Training to enhance the capacity and technical skills of charcoal producers, combined with awareness raising on the benefits of sustainable charcoal;
- Access to upfront finances (via partnership with private sector or micro-credits) for investments in improved kilns;
- Facilitation and capacity development of producer groups or cooperatives, and recognition of their legal status;
- Technical supervision and further research to optimize efficiency.

- Facilitation of the formalization of producer groups and simplification of taxes applied to legal charcoal;
- Linking of technical requirements to sustainable sourcing and management plans, including tenure rights;
- Raising awareness about improved charcoal processes among policymakers at different levels;
- Use of simple mechanisms to monitor use of improved kiln techniques (e.g. self- and peer-to-peer monitoring by cooperatives);
- Incentivizing more sustainably produced charcoal to compete with illegally produced charcoal.

Introduction

Carbonization efficiency and ‘solutions beyond the kiln’

In Sub-Saharan Africa, where charcoal is generally produced in traditional earth-mound kilns, it takes around 7 kg of air-dried wood to produce 1 kg of charcoal. At efficiency rates of only around 13%–15%, the kilns can convert the wood’s potential 112 MJ into only 28–33 MJ of charcoal (FAO 2017).

Improving the efficiency of the carbonization process has the potential to both spare trees and lower GHG emissions. By reducing the amount of wood needed to produce the same amount of charcoal, more trees and shrubs are left standing, along with their stored carbon – thereby mitigating climate change.

Options range from adapting the construction of existing earth mound kilns (e.g. by drying wood well and adding a chimney), to the use of metal or brick kilns, to industrial charcoal retorts that co-generate heat and electricity. But despite efforts aimed at introducing improved kiln technology in Sub-Saharan Africa (SSA), uptake remains low due to the relatively high investment costs needed for 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 carbonization practices (Schure et al. 2019).

Our proposed approach, ‘solutions beyond the kiln’, includes aspects of enhancing capacity, ensuring acceptability and creating an enabling institutional framework for improved carbonization and related socio-ecological outcomes. This brief presents lessons learned from experiences in co-developing locally relevant options with producers and other stakeholders in countries across SSA to enhance the efficiency of charcoal production in relation to sustainable woodfuel value chains.
Improving charcoal production and potential outcomes

Finding solutions for more efficient charcoal production has been central to Governing Multifunctional Landscape (GML) Sustainable Woodfuel activities. These included measuring wood-to-charcoal conversion efficiencies of existing and improved practices, proposing context-appropriate improved techniques or technology, and developing strategies for improved uptake.

Democratic Republic of the Congo (DRC) Yangambi landscape

In the Yangambi landscape, which spans 220,000 ha of tropical forest landscape in DRC’s Tshopo Province, charcoal producers generally achieve efficiency rates as low as 7.4% on a mass yield basis, or 12.8% on a dry wood basis (Schure et al. 2019). Producers in this landscape often work under uncertain institutional conditions and lack the skills for proper carbonization.

What is the best way to measure the efficiency of carbonization?

1. Measure all wood inputs in kilograms using a (hanging) scale. For logs over 200 kg, measure the volume and calculate weight based on the average density of the particular wood species.
   Weight of wood input (WI) to kiln ______kg

2. Measure the humidity of the wood using a humidity meter applied to the inside of the wood, just before carbonization. Take samples of different size (diameter) wood logs to calculate the average humidity of the wood.
   Humidity (H%) of wood in kiln ______%

3. Measure the weight of the charcoal produced (C) in kilograms immediately after unloading the kiln.
   Weight of charcoal produced (C) ______ kg

4. Measure the weight of unburned or incompletely burned wood.
   Uncarbonized wood (U) ______ kg

5. Calculate the charcoal yield efficiency:
   Efficiency (E%) in yield per mass basis = (C/(WI-U)) * 100 ______%
   Net efficiency (NE%) in yield per dry mass basis
   (WID = WI*(1-H%/100)) = (C/(WID-U)) * 100 ______%
In 2020–2021, selected members of newly established producer associations that had committed to sustainable harvesting and tree growing practices benefited from a participatory training programme that included different sessions over the course of the year, including both a theory component and an active component to construct and compare kilns. The training programme, led by charcoal producer and expert in improved carbonization Mr Rurenge Mpuruta-Ka-Tito from eastern DRC, built upon the principles of train-the-trainer and peer-to-peer skills enhancement. Training focused on improved practices for use of earth kilns, because the dispersed nature of charcoal production and lack of materials for external chimneys precluded other options. Another group of participants were 20 members of the women’s charcoal producer association AFEVADES (Association des femmes valorisatrices des déchets de scierie), who transform wood residues from the timber company CFT (Compagnie Forestière et de Transformation) into charcoal.

Since wood residues are smaller than whole logs, this wood supply is easier to collect and transport. For this reason, and because AFEVADES is near to the city where materials for a chimney can be obtained, these women were trained to use an external chimney with an improved earth kiln.

The efficiency of both improved earth kiln techniques (with and without chimneys) increased from around 11% to around 22% on a dry-wood basis, compared to prior kilns – effectively doubling production volumes and profits. The first investment needed is the producers’ time for training, for the careful construction of the kiln, and for monitoring carbonization. Yet producers save time with the improved kilns, which produce charcoal in about half the time (around 5 days compared to up to 17 days for traditional kilns). The second investment required of AFEVADES was to purchase an external metal chimney, at a relatively low initial cost of around USD 50, and the association is expected to save some of its profits for the eventual replacement of chimneys. When a fixed site is allocated to the association, investing in a stationary kiln can further improve efficiency and save labour costs.

Uptake is being promoted through the participatory ‘train-the-trainers’ format, in which producers can experience for themselves the benefits of the new methods and then share the message with fellow producers. Producer associations’ codes of conduct and peer review mechanisms include these techniques, thereby facilitating their use as part of the development of a green charcoal value chain and preventing any unintended negative consequences, such as producers venturing further into the forest because of increased profit margins.
Stakeholder story
Pooling efforts boosts profits from sustainable charcoal production in DRC

Fatouma Otoke is the President of the association Association des femmes valorisatrices des déchets de scierie (AFEV ADES), a Kisangani-based organization of women who produce charcoal out of sawmill waste wood.

“The way we used to do it, we had a lot of waste,” explained Otoke. “Now we have learned to separate the wood by species, to leave space for air to circulate in the kiln, and to properly cover the wood with leaves before covering it with soil.”

With the same amount of wood that the women had previously used to produce three bags, they are now producing six bags.

Each woman produces about 11 bags of charcoal per week, depending on the availability of wood residues. They employ some men to help out with heavy labour such as carrying heavy bundles of wood, and they rent a cart at a daily rate to transport larger amounts.

“The money we make here helps us send our children to school and sustain our household,” said Otoke.

The women are ready to expand their business, motivated by the wood delivery arrangement that their association negotiated with the sawmill. Their planned investment in purchasing a motorbike will facilitate the transport of charcoal directly to customers at higher profit margins.

The association buys wood residues from the Compagnie Forestière et de Transformation (CFT) transporting them to a nearby field where they produce ‘makala’, as charcoal is locally known.

CFT wood is of very high quality, and so is the charcoal produced from its residues. Word of mouth among people in the town takes care of any marketing needs, and the association can sell their makala at a premium.

Until recently, each woman operated her own small-scale business (Otoke has been producing charcoal since 2013). But in 2020 with the support of CIFOR-ICRAF they formed the association, allowing them to pool resources and boost their efficiency. None of the 20 members of AFEV ADES had ever been trained in charcoal production – as the only charcoal producers in Kisangani, they had no one to learn from. CIFOR-ICRAF provided training to improve their technique, bringing in an expert from the east of the country.
Cameroon
East and littoral region

Logging and wood processing are the main industrial activities in the eastern region of Cameroon. In 2019, there were 24 wood processing units or UTBs (unités de transformation du bois), generating an estimated 491,815 m$^3$ of sawmill waste – around 300,000 m$^3$ of which could be used for charcoal production. Although semi-industrial techniques (metal furnaces, Brazilian furnaces, retorts, etc.) have also been tested, the forest and environment project (ProFE) of the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) has opted to begin with traditional methods used locally by charcoal producers to offer simple, accessible and easily adapted improved carbonization techniques. Two techniques were proposed: the improved traditional kiln and the casamance kiln. Both allow the construction of larger kilns and the more efficient production of higher-quality charcoal through faster and better-controlled carbonization cycles. However, they do take more time to assemble and require close monitoring, even at night.

In 2019, 334 charcoal makers (30% women) received support to formalize their activities by regrouping into associations or commercial interest groups or GICs (groupements d’intérêt commercial), signing agreements with the UTBs for the supply of sawmill waste, compliance with tax and social regulations, and monitoring of the production and marketing of charcoal.

The carbonization yields were evaluated at 16% for traditional techniques (ProPFE/GIZ 2017). These increased to 22% for the improved traditional kiln and 30% for the casamance kiln (to a known maximum of 25% and 32%, respectively). These improved kilns reduce the time invested per tonne of produced charcoal by 52% and 35%, respectively. In addition, the chimney of the casamance kiln, made of superimposed metal barrels, allows beneficiaries to collect wood vinegar, which can be used to control insect pests and crop diseases.
The project also provided organizational and legal support to charcoal producers to ensure a smooth transition from individual to collective work, so that producers can join the market economy (ProPFE/GIZ 2020). This enables the drafting of agreements between the charcoal producer cooperatives and the managers of the UTBs to ensure consistent access to the raw materials at a reasonable price.

Development of the sawmill waste charcoal value chain has enabled the regulatory framework to evolve so that it recognizes the viability of a woodfuel production system based on the recovery and recycling of waste with improved carbonization; before, such products were neglected in related regulatory frameworks.

Because the urban system is more demanding in terms of environmental standards, a third technique was tested in the city of Douala. The Tambour kiln has two chimneys, which separately collect wood vinegar and tar. Yields sometimes exceed 25% and could increase further with experience. The charcoal produced is free of impurities and most of the vinegar and tar is recovered – all in just one day. The cooperatives set out to acquire more space to build more kilns. This technique offers better working conditions, as it is less dirty and there is no need for sleepless nights to control potentially damaging air leaks. The costs of producing charcoal by the drum kiln are reduced, but care must be taken to identify the end point of the charring process (visible when the smoke changes colour), to avoid lower yields.

In terms of emissions avoided, the gain is twofold. First, using wood residues that are usually wasted lowers the need to produce charcoal from other wood sources. Second, the higher yields, compared to rudimentary carbonization methods used in the informal sector, lead to further decreases in GHG emissions. For example, for the nearly 14,187 tonnes of charcoal produced from sawmill waste between 2018 and October 2020, the total avoided emissions amounted to 216,350 tonnes of CO₂ equivalent.

From a socioeconomic standpoint, carbonizing sawmill waste creates jobs and income in poor and isolated areas. Producing 14,187 tons of charcoal corresponds to 734.4 million FCFA (USD 1.3 million), and the marketing of charcoal from sawmill waste generated an average net monthly income of 114,000 FCFA (USD 209) for men and 83,300 FCFA (USD 153) for women.

In terms of health issues, the chimneys used in the two distributed kilns channel the fumes to one end of the kiln, thereby limiting pollution and improving efficiency. An analysis of the physical and chemical properties of charcoal produced from wood of different densities in the three types of kilns showed that improved kilns and denser woods produced higher quality charcoal (Zobo Mfomo et al. 2020).

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Improved carbonization techniques

Efficiency of earth kilns is often low, due to use of wet wood, irregular sized pieces of wood, improper ventilation, lack of monitoring of the carbonization process, and emptying the kiln too early.

General steps for improved carbonization using an earth kiln:

1. Dry the wood for at least two months.
2. Clear the area where the kiln will be built of vegetation and dig a hole.
3. Stack the wood tightly and fill spaces with smaller pieces of wood during stacking.
4. Stack the wood according to diameter, starting with the smallest pieces. Place medium wood in the first third of the kiln, followed by wood of large diameter in the second third, then top this with twigs.
5. Create space around the stack to allow for air circulation.
6. Add ventilation holes (the Casamance kiln includes a metal chimney consisting of three 200-litre oil drums).
7. Cover the kiln with a layer of leaves, followed by a layer of sawdust and earth. This improves the insulation of the kiln.
8. Watch the kiln carefully during all phases of carbonization; the further it advances, the more cracks appear, and these must be fixed immediately.
9. Cool for at least two days after charring.
10. Avoid using water to cool the charcoal. Earth can be used to cool the charcoal, while continuing to remove hot pieces with a fork or a rake.
Kenya
Baringo county

In Kenya, 46% of urban households and 42% of rural households use charcoal, and its production and use are on the rise. Almost all charcoal producers in Baringo county and across Kenya use traditional earth mound kilns due to their low input requirements, ease of management and proximity to sources of woodfuel, thereby eliminating the need to transport wood (Ndegwa et al. 2021). However, these types of kilns have poor efficiency, resulting in a greater demand for wood and higher emissions. While the logging moratorium of February 2018 has slowed the production and transportation of charcoal, discussions are underway to make an exception for producing charcoal from the invasive Prosopis juliflora shrub as a way to control its spread.

The GML project conducted ‘training of trainers’ sessions that focused on the use of Prosopis for charcoal, on improving local production practices for better management of natural woodlands, and on creating livelihoods and mitigating climate change. Thirty-two members of the community participated: 24 charcoal producers, 5 local artisans, 2 county government representatives and a primary school teacher (of these, 11 were men, 21 were women, and 15 were youth between 20 and 30 years old, 10 male and 5 female; Njenga et al. 2020). Participants received training on how to improve the traditional earth mound kiln, as well as on policy issues, marketing, and resource recovery and reuse of wood residues and charcoal dust for energy and of biochar for soil improvement.

Improvements to producing charcoal using earth mound kilns included thoroughly drying wood to a recommended moisture content of less than 20%, properly arranging the wood, creating 6 ‘breathers’ (air inlets and outlets) and 2 chimneys at a cost of KES5500 (USD 55) to enhance air circulation, and carefully monitoring the carbonization process. The diagram above lays out the steps for this improved process, which can also be found in a practical guide (Wanjira et al. 2021).

The efficiency of carbonization rose from 15% to 22% (on a mass yield basis), suggesting less wood was consumed, and the charcoal yield increased by 49% (Njenga 2020; Njenga et al. forthcoming). The improved traditional earth mound kiln reduced emissions of carbon monoxide (CO), carbon dioxide (CO₂) and methane (CH₄) by 40%, 49% and 44%, respectively (Njenga et al. forthcoming).

In Kenya, more efficient carbonization can lead to positive impacts on both livelihoods and the environment (Njenga et al. forthcoming). The improvements to earth mound kilns increase charcoal yields with little cash investment, contributing to higher incomes for dryland communities – an important benefit given that most charcoal is sourced from drylands in Kenya. Improving carbonization was one of the interventions prioritized in the community action plans developed in Baringo, with 24 charcoal producers who participated in the train the trainer workshop going on to train over 359 charcoal producers.

Lessons learned from this work on sustainable charcoal were integrated into Kenya’s Bioenergy Strategy 2020–2027 launched in November 2020, as well as its draft agroforestry strategy.
Eucalyptus plantation, tea fields and indigenous trees in the Mau Forest (Patrick Shepherd/CIFOR)
What is needed to scale up improved carbonization practices?

The experiences in improving carbonization yields from Cameroon, DRC and Kenya confirm the enormous potential of increasing the efficiency of carbonization, from as low as 12% on a dry-wood basis to 22%–30%. This means that only around half the quantity of wood is needed to produce the same amount of charcoal, with lower GHG emissions and higher profits for producers. The organization and training of producer groups that can source their wood sustainably – through rotational agroforestry woodlots, agreements with wood processing units for access to wood residues, peer-to-peer monitoring systems for harvesting, or management systems for controlling invasive wood species – is critical to ensuring a more sustainable charcoal supply.

Despite efforts to integrate industrial kilns, experiences with charcoal producers suggest that the low-investment option of improving the traditional earth mound kiln, with or without an external chimney, is the most appropriate approach in SSA, given the dispersed nature of charcoal production and the lack of access to investment in most rural areas. In places where wood supply is concentrated – such as near sawmills that have supply agreements with producer groups – investing in chimneys or stationary kilns becomes an economically viable option, as these can boost production and lessen the workload. But for charcoal producers to adopt new techniques, what is needed above all is participatory training and the associated awareness raised from direct experience of the benefits of improved kilns.

Increased awareness is needed not only among producers, but also among retailers, consumers and state agencies at various levels. There is a need to extend capacity development and effectively communicate options to scale up these simple and cheap innovations that improve local carbonization practices, while contributing to national agendas for mitigating environmental impacts. Improving carbonization is profitable, as investments for improved techniques are relatively modest and can double production quantities with same amount of wood input. Yet these improved practices need to be actively promoted and rewarded through government policies and incentive mechanisms – for example, better conditions for producer associations that commit to improved carbonization practices – so that they become attractive to producers and begin to gain market share over unsustainable charcoal.
References


Suggested citation


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Photo credits

Cover: Axel Fassio
P 10: Axel Fassio
This initiative is part of the project Governing multifunctional landscapes in Sub-Saharan Africa: Managing trade-offs between social and ecological impacts (GML), which is financed by the European Union.

This research was carried out by CIFOR-ICRAF as part of the CGIAR Research Program on Forests, Trees and Agroforestry (FTA). FTA is the world’s largest research for development program to enhance the role of forests, trees and agroforestry in sustainable development and food security and to address climate change. CIFOR leads FTA in partnership with Bioversity International, CATIE, CIRAD, INBAR, ICRAF and TBI. FTA’s work is supported by the CGIAR Trust Fund: cgiar.org/funders/