Prospects of Biomass Energy

Policy Brief

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More out of less: future scenarios of clean cooking solutions in East Africa

In Kenya and Tanzania, the demand for biomass-based cooking energy is expected to increase. However, the supply of sustainably sourced biomass energy is limited, and the biomass-to-energy conversion rates of current cookstoves and charcoal is very low. Utilizing more efficient biomass fuels and stoves allows tripling the number of meals that can be cooked with the same amount of biomass, without increasing the carbon footprint. Such improvements are needed to satisfy future energy demand for cooking with biomass fuels in a sustainable way. Policymakers should therefore focus their action on promoting a shift from low efficiency charcoal solutions towards the sustainable use of firewood or wood chips. In combination with the most efficient and clean cookstoves, this solution is much more efficient than even the most improved charcoal solution. ▶

The need for knowledge-based policies

Biomass is, and will remain for several decades, the dominant source of cooking fuels for most rural and low-income urban households in East Africa. Population growth and urbanization will further increase demand. However, the biomass potential is limited by biophysical constraints and cannot be expanded indefinitely. Therefore, shortages or depletion of natural resources will worsen unless concerned authorities take immediate appropriate action.

Such actions only become effective if they are context specific and build on evidence-based and coherent policy frameworks. Evidence has to include broad knowledge and good understanding of current and future sustainable biomass potentials, and the resource efficiency and carbon footprint of biomass energy value chains[1] from production to consumption. Moreover, strategic foresight is required to take into account possible future outcomes of decisions taken today. The research project Prospect of Biomass Energy (ProBE)

KEY MESSAGES

Sustainable biomass potential is limited: With the present mix of biomass fuels and low-efficiency stoves, sustainably sourced biomass fuels do not satisfy the energy demand for cooking, which will increase, due to population growth, by about 40% until 2030.

More out of less: There is large potential to save fuel and reduce the carbon footprint. The use of briquettes from farm residues or wood chips in combination with most efficient stoves can triple the efficiency of biomass energy value chains in comparison to the present mix of charcoal-dominated solutions.

Diversify solutions: Policymakers should foster diverse and efficient biomass energy solutions that utilise sustainably managed natural resources. This calls for the formulation and effective enforcement of enabling biomass energy laws, policies, and regulations, as well as adequate capacity building for all actors involved to boost adoption.

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[1] Selected terms and expressions are explained in Box 1.

Box 1: Definitions

Carbon footprint: the amount of greenhouse gases produced by a human activity, expressed in carbon dioxide (CO_2). Greenhouse gases are responsible for climate change via the effect of global warming.

Pyrolysis: decomposition of organic material at elevated temperatures in the absence of oxygen. It is one of the processes involved in charring wood, starting at 200–300 °C.

Value chain: series of activities and processes from production to the utilization of a product or service. For example, it may include the procurement of resources, processing, transport, utilization, and disposal.

Biomass-to-energy conversion rate: the amount of primary resource required to cook one meal. We assume that one meal requires 5 mega joule (MJ) net energy at the pot. Cooking one meal with dead wood using a three-stones fireplace (thermal efficiency of 12%) demands 40 MJ primary energy and results in a biomass-to-energy conversion rate of roughly 8.

Scenario: a scenario is a plausible development of a system in future. A scenario does not forecast what will happen; but rather describes what might happen. In the context of the ProBE project, scenarios are used to explore policy options and highlight potentials for improvements.

assessed the current situation and possible developments up to 2030 of selected biomass energy value chains in two case study areas (see page 4). The results help to identify solutions that allow covering of future cooking fuel demand with sustainably sourced biomass fuels.

Determinants of current and future sustainable biomass potential

The availability of firewood and charcoal is constrained by several factors which include prevailing tenure regimes that regulate access to and use of land, land cover, biomass regeneration rate, and alternative uses of wood. The potential of farm residues, in our case maize cobs and rice husks, is determined by the area of rice and maize cultivation, and by competing alternative uses of residues (mulching, fodder, etc.). The availability of jatropha seeds depends on the use of jatropha hedges for cropland protection, or the demarcation of land parcel boundaries. Jatropha production on plots is not encouraged due to competition for land with food crops.

By 2030, the sustainable biomass potential can be increased by about 20% in Kitui and Moshi, if appropriate policy measures are taken and implemented that help to increase the tree cover. However, population will increase by 40% in the same period, pointing to a likely supply deficit unless resource efficiency is addressed with high priority. At that time, forests outside of protected areas will represent roughly 90% of the sustainable biomass potential in Kitui and Moshi, in the form of logged or dead wood. In contrast, non-woody biomass (jatropha seeds, maize cobs and rice husks) will potentially contribute only around 10% to the overall sustainable potential (Bär et al. 2017). Due to the different sizes of the study areas, the overall sustainable biomass potential for cooking is higher in Kitui than in Moshi.

Environmental performance of different value chains

From production to consumption, it is possible to combine different primary energy sources with different types of technologies (traditional or improved). In some cases, charcoal produced with traditional earth mound kilns is used with traditional stoves. In other cases, households use traditional firewood obtained through manual chopping with improved firewood cookstoves. The ProBE project defined nine possible value chains by varying five different production and four different cooking technologies, and investigated each one's resource efficiency and environmental performance.

Each value chain has a specific biomass-to-energy conversion rate corresponding to the amount of primary resource required (dead wood, logged wood, maize cobs, rice husks or jatropha seeds) – also known as Primary Energy Demand (PED) – to cook one meal. For example, the PED of charcoal is determined by the efficiency of the kilns and stoves that are used. In contrast, the PED of firewood and wood chips depends only on the efficiency of the stove, as there is no intermediate processing step causing losses.

The PED per meal differs significantly for the different value chains (Figure 1A). Charcoal is the most inefficient fuel. Even when using improved kilns, such as the improved basic earth mound kiln (BEK), and stoves, its resource efficiency is not much better than that of the three-stones fireplace. Considering that more than 90% of the charcoal in Sub-Saharan Africa is produced with basic BEKs (Wanjiru et al. 2016), the current resource efficiency of charcoal is worse than that of the traditional firewood value chain. In contrast, the best wood chips, briquette, and firewood value chains only use half of the primary energy per meal than the most improved charcoal value chains.

The carbon footprint of a value chain corresponds to the total amount of greenhouse gas emitted when cooking one meal (Figure 1B). The carbon footprint of wood-based value chains (charcoal, firewood and wood chips) is mainly determined by differences in forest management (Okoko et al. 2017). Clear-cutting of trees without regrowth causes very high greenhouse gas emissions.

However, even with sustainable forest regrowth and using the most efficient stove, the carbon footprint of charcoal is still about as high as that of the traditional firewood value chain. The inefficient pyrolysis of charcoal emits significant amounts

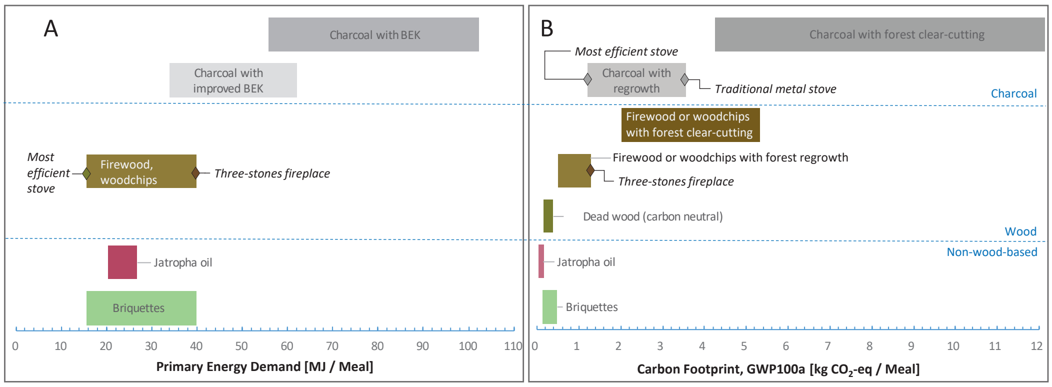

Figure 1: Primary Energy Demand (PED) (A) and carbon footprint (B) of the different value chains. PED and carbon footprint is calculated for cooking one meal. The different ranges of PED and carbon footprint are a result of the utilization of stoves with different efficiencies. (Abbreviations: BEK = Basic Earth Kiln)

of greenhouse gases even when using an improved kiln. The carbon footprint of non-woody biomass is low and mainly dependent on the efficiency of the stove. The jatropha value chain has the smallest carbon footprint because jatropha seeds are a by-product of cropland protection, i.e. of hedges cultivated for land demarcation. Therefore, their provision is considered free of any environmental burden.

2030: Biomass energy under different policy conditions

Biomass energy utilization can vary depending on the prevailing policy frameworks. Until 2030, policy conditions can change in different directions, resulting in a range of possible outcomes related to the use of biomass energy. Emanating from the status quo, we defined three scenarios to analyse what might happen in future:

The ***Status Quo*** represents the situation of biomass-based cooking in the study sites in 2015.

The ***Anti-Biomass Energy (Anti-BE)*** scenario assumes negative institutional and economic conditions for improved biomass energy production by 2030 including adverse policies, low prices of fossil fuels and electricity, as well as a lack of promotion of biomass energy.

The ***Pro-Biomass Energy (Pro-BE)*** scenario assumes enabling conditions for biomass energy production by 2030, including strong political incentives and the use of improved technology.

The ***Diverse-Biomass Energy (Diverse-BE)*** or diversification scenario is similar to the *Pro-BE* scenario, but assumes that by 2030 half of the woody biomass that is normally used for charcoal production will be used as wood chips in order to improve the biomass-to-energy conversion rate.

How many meals can be cooked?

Under the *Status Quo* conditions, the local supply of sustainably sourced biomass cooking fuels cannot cover the current demand (Figure 2). In other words, already today the natural resources are over-used. The situation will be worse in 2030, as population will increase by 40% in the case study sites, unless the resource efficiency of biomass energy value chains improves substantially. The *Diverse-BE* scenario leads to the best outcome, in which the number of meals can be more than tripled in comparison to *Status Quo*. However, this impressive increase will not be sufficient to satisfy the demand in Moshi in 2030, whereas the situation is slightly better in Kitui. In both study sites, the *Pro-BE* scenario will not be sufficient to bridge the gap between demand and supply. While, the *Anti-BE* scenario will lead to a supply gap of sustainably sourced biomass equivalent to 60% and 80% of the demand in Kitui and Moshi respectively. This will lead either to a massive overexploitation of the natural resources, or to the increased use of alternative cooking fuels, most probably fossil fuels.

What carbon footprint?

The carbon footprint for all scenarios, except for the *Diverse-BE* scenario, is mainly determined by the charcoal value chains (Figure 3). The relatively small differences across the scenarios reveal a surprising insight: when using half of the logged wood for wood chips instead for charcoal production, one can triple the number of meals without significantly increasing the carbon footprint.

Overall, the scenarios for 2030 show that policy can make a difference if effectively implemented, and can improve the environmental situation and help cover the increasing demand for biomass cooking fuel.

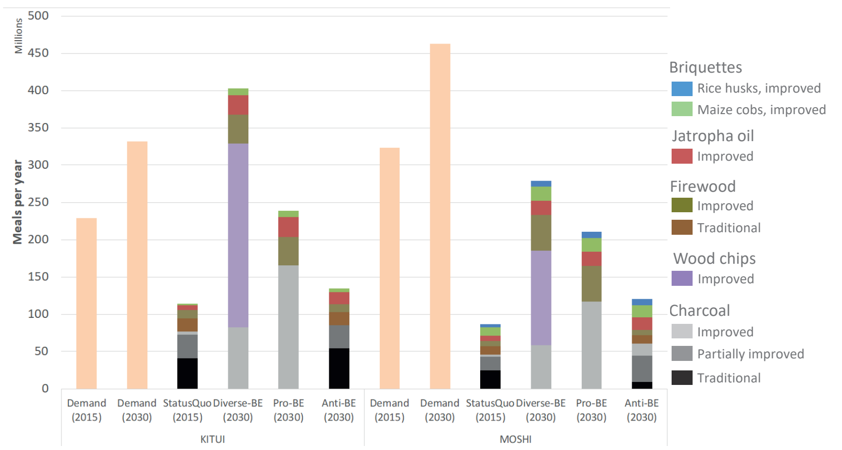

Figure 2: Number of meals (in millions) that can be cooked in 2015 and in 2030 according to three different scenarios, which assume the use of only sustainably sourced biomass, compared to the estimated demand.

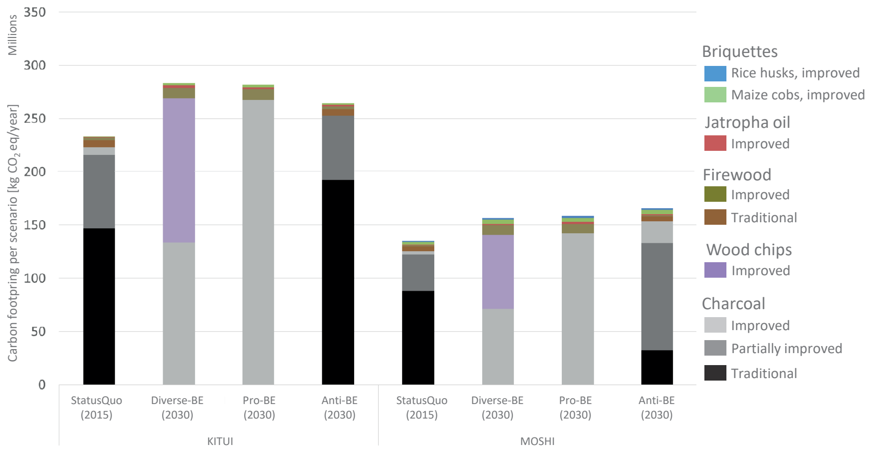

Figure 3. The cumulated carbon footprint for each scenario detailed according to the contributions of each value chain.

Policy implications of research

Policies and strategies matter

Based on the potential supply of biomass fuels, an improved biomass-to-stove efficiency is crucial in meeting the fast-growing demand for cooking energy, which is expected to be up to up to 40% higher in the case study sites in 2030 than the current levels. The pathways to realise such improvements will largely depend on the nature of policies and strategies that will be put in place, expectedly emphasising on more efficient energy carriers and efficient cookstoves.

Shift away from charcoal

Because charcoal-based cooking is carbon intensive and uses very high amounts of biomass for the energy delivered to the pot, the current policy focus should shift towards efficient and clean use of wood. Cooking with wood chips in efficient and clean stoves has a significantly higher biomass-to-stove efficiency and a lower carbon footprint. Well-performing and well-handled micro-gasifier stoves for example outstrip efficient charcoal stoves. To this end, more robust biomass energy strategies are needed to facilitate the use of wood in the form of wood-chips or firewood instead of charcoal.

Solutions for local conditions

The potential to save fuels and reduce carbon footprint in the biomass energy sector of East Africa can only be realized by implementing solutions that fit best to local situations because there is no one-fits-all solution. They must respond to diverse consumers' needs and preferences, and they must tap on locally available resources.

Further reading

Bär R, Heinimann A, Ehrensperger A (in print). Assessing the potential supply of biomass cooking fuels in Kilimanjaro Region using land use units and spatial Bayesian networks. *Energy for Sustainable Development.* DOI: 10.1016/j.esd.2017.05.007.

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The ProBE project

The research project *Prospects of Biomass Energy* (ProBE) in East Africa was part of the Swiss Programme for Research on Global Issues for Development (r4d programme; project no. IZ01Z0_146875). The project involved researchers and technical experts from the following organizations: Centre for Development and Environment (CDE), University of Bern, Switzerland; Centre for Training and Integrated Research in ASAL Development (CETRAD), Kenya; Quantis, Switzerland; Practical Action Eastern Africa, Kenya; and Tanzania Traditional Energy Development Organization (TaTEDO), Tanzania. Between 2013 and 2017, the ProBE team analysed the prospects of pro-poor biomass energy value chains in rural–urban contexts in East Africa, based on case studies in Kitui County, Kenya, and Kilimanjaro Region, Tanzania.

Swiss Programme for Research on Global Issues for Development

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