

Domestic Biomass Burning in Africa

Introduction

About half of the world's population is using fuels from biomass as an energy source in the private household: for cooking, lighting and heating. The energy sources are fuelwood, agricultural residues (for example maize cobs or rice straw), charcoal or cow dung. This practice has consequences for the people and the environment:



1. Domestic fires concern people and the environment in several ways: health risks caused by smoke - deforestation caused by logging - emissions from the fires

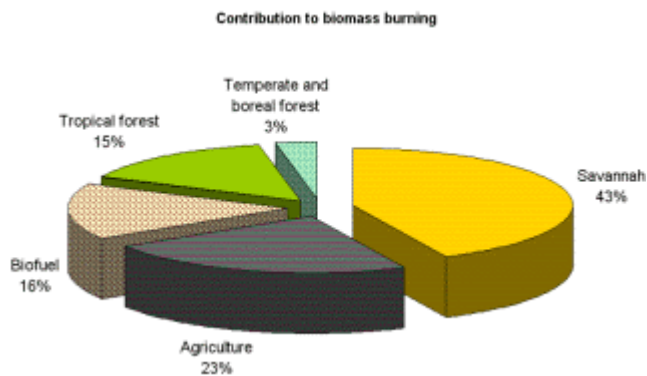
In many cases the stove is located in the hut and because of insufficient ventilation the released toxic gases like carbon monoxide (CO) and nitrogen oxide (NO) as well as dust particles become *health risks*.

In some cases the gathering of fire wood and the production of charcoal are related to *deforestation*, although nature already provides a major amount of dead wood which is just gathered from the ground. Conversion of woodlands to fields (so called landuse change) and logging for the timber industry are responsible for a much larger share of forest losses than firewood or charcoal production.

Finally, the domestic fires contribute significantly to the global *emissions* of several gases, in particular carbon monoxide, carbon dioxide and nitrogen oxides.



Domestic fire places in African households vary in their design and progressiveness. For most, firewood is the most common fuel. Photo: see acknowledgement



3. Contribution of biofuel and other fire categories to the total biomass burning. Estimations in % biomass globally burnt. (Andreae, 1991)

According to very rough estimations, annual emissions from domestic fires are in the range of 17% (1500 Tg CO₂-C), 13% (140 Tg CO-C) and 6% (2,5 Tg NO-N)* respectively for these three gases compared to the total global emissions. However, it has to be mentioned that most of the carbon dioxide is from renewable sources**. This is 100% the case if agricultural residues and dung are burnt. It is often the case if wood is burnt, but not if forests are cut and do not regrow.

* With the decription CO₂-C we express that only the carbon content in the carbon dioxide is mentioned. Each molecule CO₂ has 44 mass units of which 12 are carbon and 32 oxygen. Consequently a mass of 1500 Tg CO₂-C is equivalent to a mass of 5500 Tg carbon dioxide.

** With renewable resources we mean that a plant which dies and is burnt or decomposed in other ways releases carbon dioxide to the air. But if the same plant grows again during the following years at the same place, it takes up again the same amount of carbon dioxide from the air in order to grow. The long term net budget is nearly zero.

Studies in Africa

Researchers visited between 1995 and 1999 households in the African countries Kenya and Zimbabwe and tried to get an overview about the common practice. Looking over their shoulders we do not only get an idea how much (or how little) energy African households use up, we also get an impression of daily life.

In rural regions no electricity is available and fuelwood is the most important energy source. In the cities houses often have electricity and also the supply with other burning material like kerosene is more secure. But often electricity is only used for lighting and kerosene only when there are no alternatives, since both resources are regarded as expensive and the average citizens are poor.

Kerosene and liquid gas seem to be more modern and cleaner energy sources. What do the locals say and why they are hardly used?

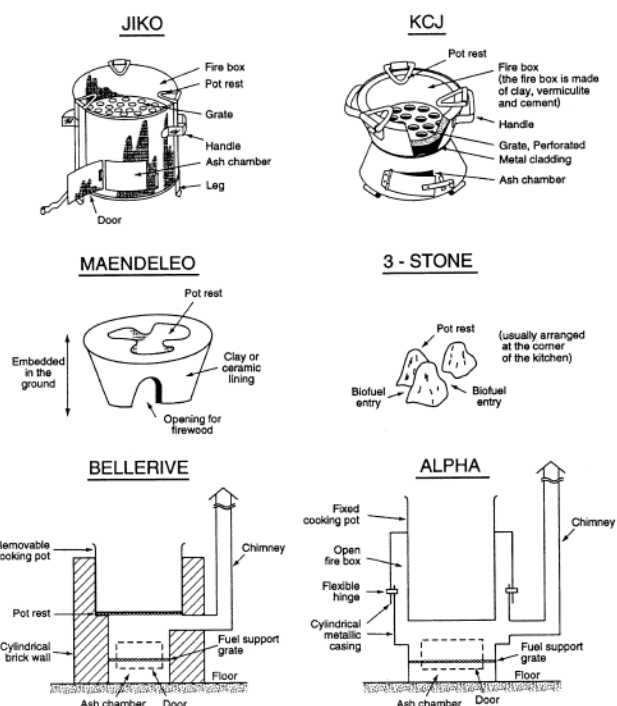


Fig. 1. The most popular biofuel stoves of Kenya.

4. The figure shows schemes of popular stoves in Kenya in their traditional constructions (JIKO, 3-stone, Alpha) and their advanced constructions (KJC, Maendeleo, Bellerive). The progress leads usually to a more efficient use of the energy content, but not always to better conditions for the users. If the house does not have a chimney, the three stone version is for example better than closed stoves, meaning that the CO emissions and the health risk are lower.

Source: Kituyi et al., Carbon monoxide and nitric oxide

from biofuel fires in Kenya, 2000



5. A stove made from three stones is the simplest cooking device, but not the worst option in a hut without chimney

Analysis of fuelwood consumption

What do we need to know in order to estimate the consumption of fuelwood in a country like Kenya and Zimbabwe? Here a few key questions:

- What sort of stoves are typically used and what are their emission characteristics?

See above in fig. 4 a scheme with some examples of different stove types.

- How much fuelwood does a typical family gather?

The fuelwood has been weighed in numerous households (image right)

Statements of the locals concerning kerosene and liquid gas:

- they are too expensive
- they are not always available in rural regions
- they require an initial capital input for buying a stove
- they cannot serve several purposes at once (heating, cooking, lighting)



6. Weighing of firewood; Source: see acknowledgement

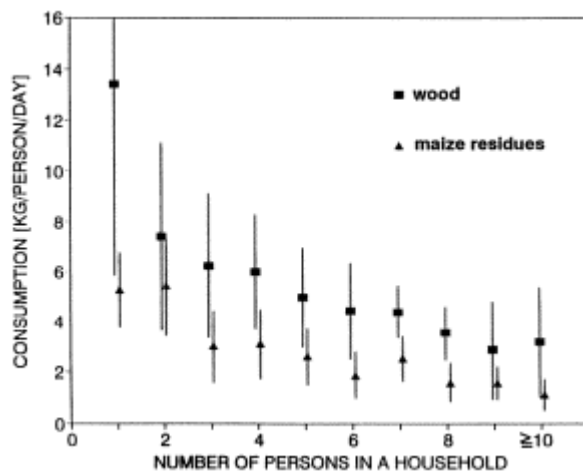
- How many alternative energy sources are used? For example agricultural residues like maize cobs or other energy sources like charcoal.



7. on the left: Charcoal production in Kenya. Charcoal is lighter than fuelwood and more suitable if longer transportation is necessary. This is in particular the case in densely populated regions and cities.

- What is the seasonal dependence of fuel resources? Agricultural residues in particular are only available in certain seasons. A questionnaire in another season can lead to a completely different result.

8. on the right: Besides maize cobs, coconut shells and palm leaves are also used in the stove.



- What is the relation of the population density to fuelwood availability. In regions where fuelwood is not scarce the fires tend to burn longer, also after cooking.

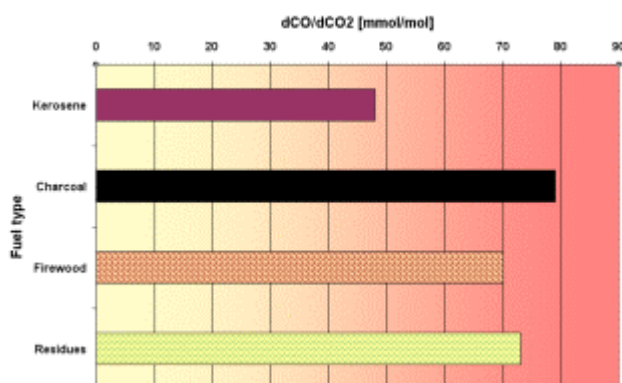
- What is the average size of the families? The larger a family is, the less fuelwood is needed per person.

on the left: 9. Household size versus fuel consumption. The graph demonstrates the decreasing consumption per capita with increasing household size. Source: Marufu et al., Domestic Biomass Burning in Rural and Urban Zimbabwe - Part A, 1996



Consumption in Kenya

Fuelwood consumption has been estimated from concrete measurements and a questionnaire in 2200 households in Kenya in 1997 from January to March. A rural household used up about 0.8 to 2.7 kg (average 2.14 kg) firewood per capita and day. The firewood is the main energy source. The average charcoal consumption was 0.26 kg per capita and day. Additionally the rural households used about 0.32 kg per capita and day material from maize cobs.

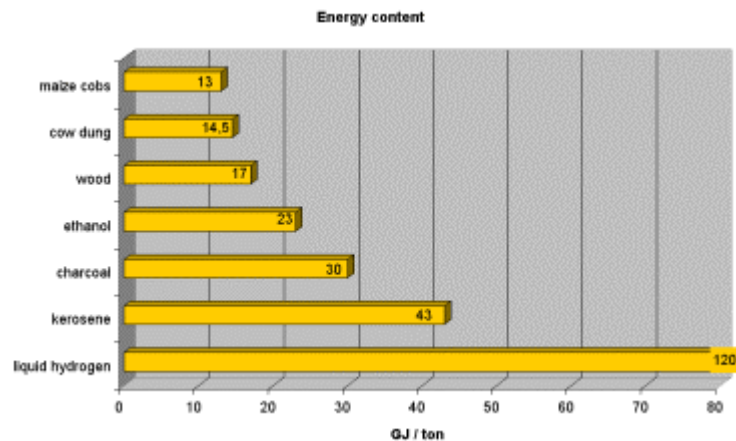


Urban households rely primarily on charcoal and use up about 0.2 to 0.7 kilograms per capita and day (average 0.37 kg), but only 0.1 – 0.5 kg (average 0.14 kg) firewood. They also make use of other more advanced energy resources, but not of plant residues. However, although 62% of the permanent households in the cities had electricity, most of them did not use it for cooking.

10. How much of the toxic carbon monoxide is released

per unit carbon dioxide for different fuel types? (in mmol per mol, or molecules per 1000 molecules). Kerosene is a "cleaner" fuel.

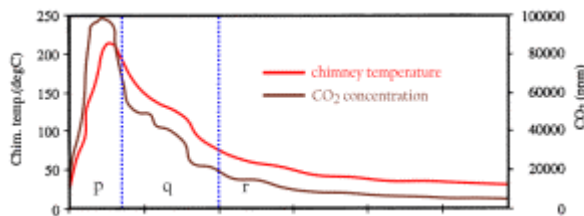
Generally towns are densely populated and the citizens cannot gather firewood next door but buy energy resources on the market. Charcoal has a much higher energy content per weight than wood has and it is more convenient to transport it to the towns. But charcoal is made from wood and with respect to the total production process it is more efficient to burn wood directly if the transport is not relevant. Towns are also often connected to the electricity network, while farms and little villages are not. Instead small villages have easy access to plant residues from the fields during certain seasons. These are the main reasons for different consumption behaviours in rural and urban regions.



11. Energy contents of different fuel types. The numbers given are typical values and can certainly vary depending on the specific properties of the fuel, the sort of the wood, the production of the charcoal, etc.

Emission studies:

In order to estimate the emissions from a wood fire in a stove we need to know the typical burning behaviour of a fire. The following graphs show the periods of a typical fire and the respective emissions.



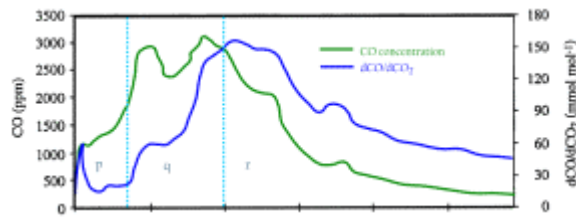
12. a) A typical wood fire has three phases: open flames (p), smouldering (q) and glowing (r). During the first phase the temperature and CO₂ emissions are highest.



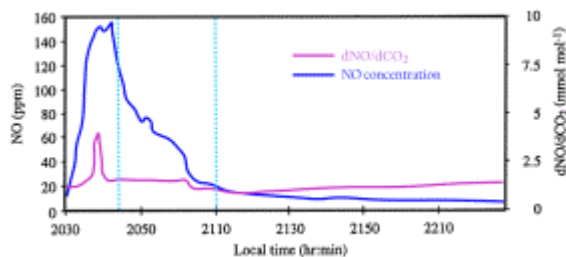
Difficulties for extrapolation

Comparable studies are not available for all countries in Africa and it is difficult to conclude from such studies on the energy and fuel consumption of the whole African continent or even other regions in the world with domestic biomass burning.

In many studies the investigated households are not well balanced with respect to different landscapes in the country or the time of the year or other circumstances are not sufficiently considered. For example in Zimbabwe a summer study was carried out and came to the following rural consumption rates: 3.2 kg fuelwood, 1.5 kg plant residues and 0.2 kg cow dung per capita and day.



12. b) The emissions of carbon monoxide are highest during the smouldering phase and still last during the glowing.



12. c) The emissions of nitrogen oxides depend strongly on the nitrogen content of the fuel and go parallel with the amount of burnt material and the CO₂ emissions. Only in the open flame period the temperature may be so high that nitrogen in the air is oxidised and NO emissions strongly increase (peak).

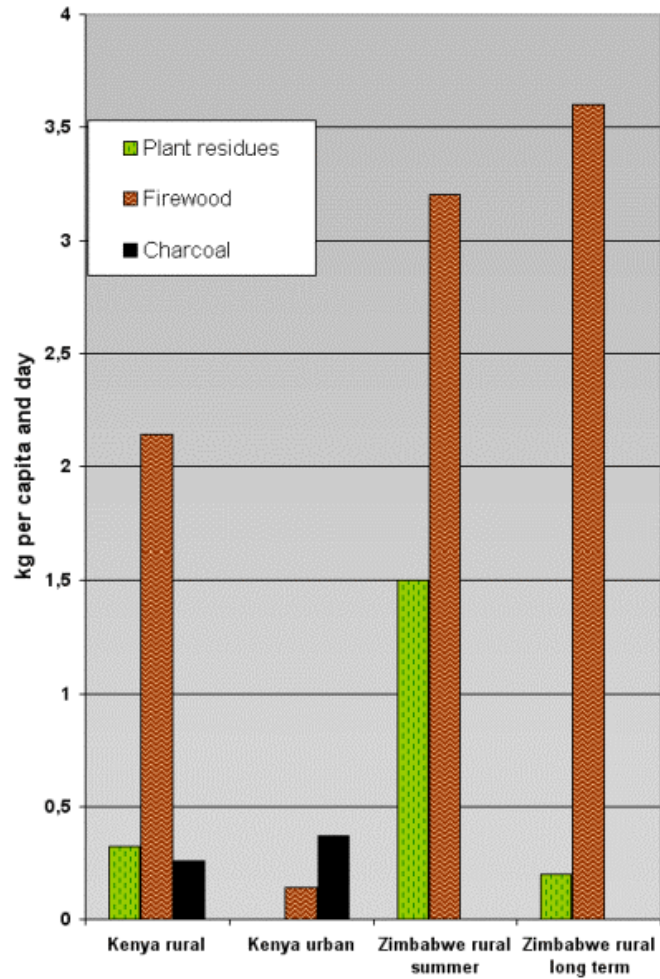
Source: Kituyi et al., Carbon monoxide and nitric oxide from biofuel fires in Kenya, 2000

Plant residues are, however, not available all year long and people are reluctant to admit to using cow dung, because it is regarded as a sign of extreme poverty. Moreover, in Zimbabwe charcoal is not used at all. Later on, the study was extended to more than one year from January 1996 to March 1997 and to different landscape types and towns in Zimbabwe.

The long term consumption was estimated to be 1.3 tonnes of fuelwood per capita and year (3.6 kg / day) and 0.07 tonnes of plant residues (0.2 kg / day) in rural areas. Consequently, it can be said that the much higher plant residue consumption was only observed during the respective season.



13. Emission measurements in Kenya



14. The consumption of biomass based fuels, results from studies in Kenya and Zimbabwe.

Data source: Kituyi et al., Biofuel consumption rates and patterns in Kenya (2000)



Estimations for Zimbabwe

Although Zimbabwe cannot represent all African countries we can learn from the available data about the basic energy usage in less developed Africa (the Mediterranean coast and the Republic of South Africa have much higher energy consumptions).

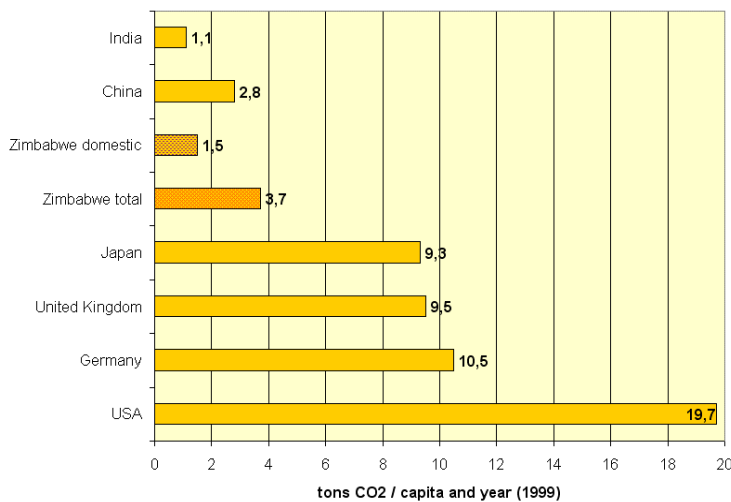
Zimbabwe had during the time of the study about 11.26 million inhabitants (7.64 million in rural areas, 3.62 million in urban areas).

The following emissions from domestic cooking fires are estimated for Zimbabwe. In brackets the contribution to the total emission of the country is given.

- 4.6 Tg CO₂-C (41%)
- 0.4 Tg CO-C (67%)
- 5.3 Gg NO-N (8%)



15. Locations for Kenya and Zimbabwe in the African continent.



16. The CO₂ emissions of Zimbabwe (and separately from domestic biomass burning) in an international comparison.

This means the people in Zimbabwe consume 4.6 Tg = 4.6 million tonnes CO₂-C (16.9 million tonnes CO₂) in domestic fires, which is 41% of the 41 million tonnes of CO₂ consumed in total. These are 3.65 tonnes of CO₂ per capita in total, and 1.5 tonnes per capita in domestic fires.

In European countries, the CO₂ emissions per capita are in the range of 10 tonnes, in the United States of 20 tonnes, of which only a very small fraction is from renewable sources but most from fossil fuels.

Such numbers such as 3.65 tons CO₂ per capita and year in Zimbabwe are not necessarily in agreement with official data from energy agencies, who publish for example about 1 tonne per capita and year for Zimbabwe. But in most cases data of private firewood usage are just not available and calculations have to rely on the consumption of oil products. On the other hand, since firewood is at least partially a renewable primary product, it can also not be directly compared to CO₂ emissions from fossil fuel consumption in industrialised countries. Therefore the uncertainty about the contribution of African countries to the greenhouse effect is high.

Author:

Elmar Uherek - Max Planck Institute for Chemistry, Mainz

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