CHAPTER 6: WOODFUELS AND FORESTS IN TROPICAL AFRICA

- Introduction
- The state of woodfuels in tropical Africa
- Problems, challenges and future trends
- Interventions and responses

FPAN
KEY MESSAGES
ABOUT THE REPORT
CHAPTER 1
CHAPTER 2
CHAPTER 3
CHAPTER 4
CHAPTER 5
CHAPTER 6
CHAPTER 7
CHAPTER 8

CHAPTER 6: WOODFUELS AND FORESTS IN TROPICAL AFRICA

Chapter summary

Forests are a primary source of energy in most African countries: over 80 per cent of all the wood taken from forests is used for fuel. Hundreds of millions of people rely on woodfuels, which include fuelwood and charcoal, to generate energy for cooking and heating. Alternatives, such as electricity or liquid petroleum gas (LPG), are too expensive for the vast majority of households or simply unavailable in rural areas. Many businesses, industries and public institutions, such as schools, are also heavily reliant on woodfuels.

Woodfuels production has devastated many forests. Many near large towns and cities, or in areas with high industrial activity, are harvested far beyond sustainable levels. Slower growing types of forests, such as the miombo and acacia woodlands of East and Southern tropical Africa, are particularly vulnerable. The pressure of woodfuels on forests will grow in the 21st century as Africa becomes an urban continent: migrants from rural areas shift from fuelwood to charcoal as they enter the cash economy and adapt their cooking habits to the urban environment. Growing charcoal consumption matters for forests because traditional charcoal kilns are highly inefficient, consuming around 10 tonnes of wood to yield only 1 tonne of charcoal. Meeting the energy needs of an urban population therefore greatly increases the burden on forests.

The woodfuels sector provides many opportunities for philanthropy to help reduce woodfuels consumption and divert supply from natural forests. This chapter identifies three priorities.

- **Promoting efficient cooking stoves.** Improved stove designs that can reduce woodfuel consumption by up to half are available; supporting stove businesses to scale up their operations and microfinance schemes for households could boost market penetration and significantly reduce woodfuels consumption.
- **Establishing woodfuel plantations.** Woodfuel plantations, especially charcoal plantations near towns and cities, could help reduce deforestation and degradation by diverting woodfuel production away from forests.
- **Promoting alternatives to woodfuels.** Alternative sources of energy that can compete with woodfuels in terms of cost, convenience, safety and health have the potential to replace them in many cases.

1. Introduction

Most African countries are heavily reliant on wood to provide energy: wood contributes around three quarters of tropical Africa's energy supply.[1] Over 80 per cent of all wood harvested from forests in tropical African countries is used to meet the energy needs of households, businesses and public institutions.[2] Almost all households in rural areas use fuelwood as their primary source of energy. In urban areas, charcoal is the default energy source: the fuel of choice for the urban poor and a backup for the middle classes when Liquid Petroleum Gas (LPG) or electricity supply fails.

This overwhelming dependence on wood for energy has a serious impact on many forests and woodlands across tropical Africa. Charcoal made to meet demand from Kinshasa, the capital of the Democratic Republic of Congo, may cause up to 60,000 hectares of deforestation every year.[3] The consumption of woodfuels is high for a number of reasons. Most modern energy technologies, such as electricity, LPG and biogas, remain unaffordable for the majority of Africans; many are simply unavailable, especially in rural areas.

In an ideal world it would be possible to move directly from this state of play to a low carbon energy economy, powering homes and industry from large-scale solar, wind, wave and hydro sources. This vision of a truly sustainable energy future for Africa seems beyond reach, at least for the next few decades. All of these technologies (as in developed countries) are in varying states of technological readiness, and would require enormous investment in power generation, grids and other infrastructure to install. In the short and medium term, more efficient wood and biomass-based energy is one of the best available intermediate technologies. Better stoves that obtain wood from renewable sources ease pressure on forests and other land carbon, lower emissions and improve human health by reducing indoor air pollution.

For all these reasons, reducing woodfuel consumption should be a top priority within strategies that seek to protect and restore Africa's tropical forests. Some donors and funders are already active in this area, notably the Ashden Trust, which has championed sustainable energy solutions and implementation around the world over the last decade through the Ashden Awards for Sustainable Energy,[4] the Shell Foundation,[5] and E+Co.[6] But more finance and engagement is needed to achieve greater scale and impact. There are three approaches that provide donors and funders with huge opportunities.

Promoting efficient cooking stoves. Low-cost stoves that can halve fuel consumption are being promoted by NGOs, development agencies and small businesses in many countries. Taking improved stoves to scale could significantly reduce the total woodfuel harvest: our preliminary calculations suggest that distributing improved stoves to Kenya's 6 million rural households could potentially reduce fuelwood consumption by 50 per cent, saving up to 8.4 million tonnes of carbon a year. Commercialised supply chains have reached millions of households in some countries. Donors should be open to supporting businesses, not just NGOs, to expand their stove operations.

Establishing woodfuel plantations. Woodfuel plantations, especially charcoal plantations near towns and cities, could help reduce deforestation and degradation by diverting woodfuel production away from forests. Producing woodfuels from plantations could drastically reduce the amount of land required to meet demand for energy, and relieve the pressure of woodfuel harvesting on forests. Our preliminary calculations suggest that all of Kinshasa's annual charcoal demand could be met from acacia plantations covering about 410,000 hectares – about 25 per cent of the area of natural forest that would be required to grow this volume of wood every year. Donors with strong business expertise and the stamina to contemplate multi-year involvement could make a significant difference.

Promoting alternatives to woodfuels. While many millions of people across tropical Africa are likely to remain reliant on woodfuels for the foreseeable future, alternative energy sources are viable in many cases: biomass briquettes, biogas, solar cookers and liquid petroleum gas are all examples. Alternatives need to be price competitive, convenient, safe, and readily available if consumers are going to voluntarily switch en masse from woodfuels. Poor consumer awareness is a barrier for many alternatives. Donors could help by supporting NGOs and businesses manufacturing and distributing alternative energy technologies, and funding public education programmes.

FPAN
KEY MESSAGES
ABOUT THE REPORT
CHAPTER 1
CHAPTER 2
CHAPTER 3
CHAPTER 4
CHAPTER 5
CHAPTER 6
CHAPTER 7
CHAPTER 8

2. The state of woodfuels in tropical Africa

Woodfuels are very important to the economies of most tropical African countries. They contribute roughly three quarters of total energy supply, and are used by the vast majority of households in tropical African countries, often in conjunction with other fuels.[1] The production and trade of woodfuels, especially charcoal, is an important source of income and livelihood for millions of families living in rural areas. In some areas, household income from charcoal making rivals that from agriculture.[7-10]

The UN's Food and Agriculture Organization (FAO) estimates that in 2005, 80 per cent of all wood harvested from forests was consumed as woodfuels in sub-Saharan Africa.[2] Even in West and Central Africa, where industrial logging is concentrated, 88 per cent of all wood harvested from forests is still destined for cooking stoves and incinerators because of the overwhelming dependence of the population on woodfuels for energy.[11]

Woodfuels can be divided into three main types: fuelwood, charcoal, and waste-based woodfuels. The literature also identifies three distinct consumer groups: households, industry and agricultural processing, and businesses and institutions. Distinguishing between different types of fuels and consumers is important to understanding how the impact of woodfuels on forests varies across the continent.

2.1 Woodfuel types

There are three major types of woodfuels consumed in Africa: fuelwood is the most common type, making up about 75 per cent of total woodfuels consumption.[12] The remaining 25 per cent is wood transformed into charcoal, a practice concentrated in towns and cities.[10,12] The use of waste-based woodfuels, such as sawdust, briquettes, offcuts and agricultural residues, is very small and largely limited to industry, but their use is growing in response to the rising cost of woodfuels, and growing concern about their impact on forests.[1, 12]

Statistics for woodfuel production and consumption should be treated with caution, however (see Box 1). The International Energy Agency and the UN's Food and Agricultural Organization (FAO) are the two main sources of statistics, but because fuelwood is collected primarily for subsistence use and the charcoal trade is informal, and in some countries illegal, statistics are generally very poor. The FAO state that *'informally or illegally removed wood, especially fuelwood, is not usually recorded, so the actual amount of wood removals is undoubtedly higher.'*[2] Some FAO woodfuels data is also based on extrapolations of rural household consumption surveys from the 1960s.[13]

It is likely that FAO figures for non-fuelwood harvest (timber and other wood-based products) are also significantly underestimated because they only include 'industrial roundwood' – timber from large-scale concessions and other timber operations – and exclude timber harvested in the informal sector for domestic markets, much of which is illegal. Informal and illegal logging accounts for the vast bulk of timber harvested in tropical Africa (see the **Forestry** chapter). However, because levels of fuelwood and non-fuelwood harvest are probably both underestimated, the ratio between them may remain about the same.

2.1.1 Fuelwood

Collecting fuelwood for cooking and heating is a daily activity for most rural families in tropical African countries. Fuelwood includes branches, twigs, bark and leaves, and is harvested primarily for subsistence, although many people also trade fuelwood. Most fuelwood is used for cooking. Most rural households in tropical Africa still use a 'three stone fire' stove – the cooking pot is rested upon three large stones, and a fire lit beneath it – which are highly inefficient and fail to use about 90 per cent of the energy released from the burning wood.[14, 15]

Box 1: Woodfuel statistics

The principal source for woodfuel statistics for Africa is the UN's Food and Agriculture Organization (FAO), which is also the agency responsible for maintaining authoritative data on Africa's forest cover, forest and land carbon data and related storage, sequestration, emissions, deforestation and degradation information.

The most recent FAO report that provides an update on woodfuel statistics is the Global Forest Resources Assessment 2005 (FRA 2005).[2] This estimates the total harvest of 'industrial roundwood' (industrial timber) from forests in sub-Saharan Africa in 2005 at 42 million tonnes (70 million cubic metres). This was far outstripped by fuelwood removals for the region, which are reported as 251 million tonnes (418 million cubic metres), suggesting that over 80 per cent of the wood harvested from Africa's forests is for woodfuels. There are a number of difficulties with the data, however:

Understatement of timber removals from forests. Total removals of wood from forests for timber (as distinct from removals for woodfuel purposes) are probably higher than the industrial roundwood figure quoted above. This is because the roundwood data appears to be based on recorded figures for timber exports, and thus is unlikely to include timber harvested by the large informal and illegal logging sectors in tropical Africa.

Forests and plantations. The definition of forest used by the FAO – *'land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 per cent'* – includes plantations. The above figures may therefore overstate how much woodfuel (and industrial roundwood) is harvested from natural forests (excluding plantations).

Woodfuel removals from land areas outside of forests. It is known that large quantities of wood are removed for fuelwood and charcoal from non-forested lands, such as pasturelands. However, the volume of such removals is unknown. As a result, total woodfuel removals for the region (forests plus other lands) are likely to be higher than the FRA 2005 estimate.

NGOs and development agencies have been promoting modern stove designs that reduce fuelwood consumption and reduce indoor air pollution in Africa for many years. We analyse this as a potential intervention to reduce deforestation and degradation caused by woodfuels toward the end of this chapter.

Cooking with a three stone fire stove
Courtesy of Anna Ingwe/GTZ-Kenya

2.1.2 Charcoal

Charcoal consumption is concentrated in Africa's cities. The proportion of urban households using charcoal is commonly reported as 70–80 per cent.[7, 8, 10] Charcoal is usually cheaper than modern alternatives, such as liquid petroleum gas (LPG), electricity and kerosene, and supply is generally more reliable. In comparison to fuelwood, charcoal burns hotter, produces less smoke and toxic fumes, and is easier to transport and use.[10, 14, 16, 17]

Charcoal is made by charring wood at very high temperatures in the absence of oxygen. This process is called pyrolysis. During pyrolysis the wood does not turn into ash but is carbonised: methane, carbon monoxide and about half of the biomass (organic material) is burnt off, leaving behind a product that is 90 per cent carbon (wood is 50 per cent carbon), and about a quarter of the weight.[17]

The vast majority of charcoal makers in tropical Africa still use the traditional earth kiln. After wood is harvested it is usually left to dry out for several days before it is stacked, either in a pit, called a pit kiln, or on the ground, called an earth mound kiln, and covered in soil to create an oxygen-free environment. Part of the wood is set alight, which generates heat that drives the pyrolysis process. This is a very inefficient process; depending on the skill of the charcoal maker, traditional kilns need 8 to 12 tonnes of wood to produce a single tonne of charcoal.[7, 8, 15, 16, 18] We assume average production efficiency in traditional charcoal kilns of 10 tonnes of wood to 1 tonne of charcoal throughout this report.[i]

i This 'average' is supported in World Bank (2009), *Environmental Crisis or Sustainable Development Opportunity? Transforming the Charcoal Sector in Tanzania*.[7]

2.1.3 Waste-based woodfuels

Waste-based woodfuels include sawdust and timber offcuts from sawmills, 'black liquor' (a by-product of the paper and pulp industry), waste paper and packaging. These fuels make up less than 1 per cent of total consumption.[1] They are mostly used in industry and agricultural processing, but can also be used by households for cooking and heating as alternatives to woodfuels: for example, briquettes made out of sawdust and agricultural residues. NGOs and businesses have promoted these fuels as cheaper and environmentally friendly alternatives to fuelwood and charcoal for many years, however, as discussed below in the **Interventions** section, uptake has been slow.[19] Because waste-based woodfuels are a minor fuel in Africa, this chapter focuses on fuelwood and charcoal. Briquettes are discussed below as a possible intervention to reduce the negative impact of fuelwood and charcoal on forest carbon.

2.2 Consumer types

Although the vast majority of woodfuels are consumed in household cooking fires, many businesses (restaurants, food stalls, hotels), rural industries (brick making, tobacco curing, metalworking, tea drying), and institutions (schools and hospitals) are also heavily reliant on woodfuels for energy. Total aggregate consumption of woodfuels for these sectors is lower than the household sector, but a single business, institution or industrial consumer can consume far greater quantities of woodfuels than a single household.

2.2.1 Households

The domestic sector consumes the vast majority of woodfuels in Africa, approximately 85 per cent.[1] Woodfuels are used in the home primarily for cooking. In rural areas, families collect fuelwood on a daily basis, from forests and woodlands, but in many cases a large proportion of fuelwood also comes from trees on agricultural land (for example, agroforestry), and from roadsides. In urban areas, charcoal is the fuel of choice, and in most cases families buy this from vendors in markets.[10]

Estimates for average per capita consumption of woodfuels across tropical Africa range from 478 kilograms per person per year,[20] up to about 600 kilograms per year.[ii, 1] Variation between and within countries is substantial. In rural Rwanda, per capita woodfuels consumption is estimated to be as low as 300 kilograms a year; in urban areas this rises to 1,100 kilograms a year.[23] This could reflect greater use of charcoal in large towns and cities.

Bicycle overloaded with charcoal on its way to market in Dar es Salaam, Tanzania.

Courtesy of Thomas Sembrés

2.2.2 Industry and agricultural processing

Industry and agriculture are powered by woodfuels, especially in rural areas where access to electricity is very poor. These include: brick making, fish smoking, bakeries, salt production, lime production, pottery, processing beeswax, beer brewing and metalworking.[15] Most tobacco and tea farmers also use woodfuels to cure and dry their produce before selling.[24, 25] According to the FAO, industry and processing consume about 10 per cent of total woodfuels in Africa.[1] Industry and agricultural processing are also the principal consumers of waste-based fuels – ie, feeding energy generated from wastes back into industrial processing – and where combustible wastes are readily available, interventions to harness these fuels more efficiently could be an effective way of reducing woodfuels consumption.

2.2.3 Businesses and institutions

Many businesses and public institutions, such as restaurants, hotels, schools and prisons, also rely on woodfuels for cooking and heating. This sector is estimated to consume roughly 5 per cent of woodfuels.[1] Like the industry and agriculture sectors, single businesses or institutions can consume very large quantities of woodfuels, and reducing levels of consumption in these sectors could be a way of leveraging positive impacts for forests and woodlands.

ii Where volumes of woodfuels are expressed in cubic metres we convert them into kilograms or tonnes, where appropriate, assuming wood density of 600 kilograms per cubic metre.[21, 22]

3. Problems, challenges and future trends

The severity of the impact that woodfuels have on forests and woodlands in tropical Africa has been debated for many years. Woodfuels were, from colonial times, widely believed to be the single greatest cause of deforestation in the tropics.[26] This culminated in the 1970s with fears of an imminent 'fuelwood crisis', popularly referred to as 'the other fuel crisis' at the time. Foresters and development agencies projected that many developing countries would cut all of their forests down to generate energy by the year 2000, leaving millions of people in energy poverty.[27] Alarmed by these findings, the World Bank and donor governments made closing the 'fuelwood gap' a top development priority, and tens of millions of dollars were invested in programmes to distribute more efficient cooking stoves and establish fuelwood plantations and woodlots to relieve pressure on forests.[27]

By the 1980s, the poor track record of these programmes, coupled with new empirical research on the production and consumption of woodfuels, suggested that many of assumptions about how woodfuels affected forests were wrong.[iii, 27] As a result, woodfuels dropped off the development agenda in the 1990s (see Box 2).

Today, the sector appears to be marked by a serious lack of consensus on what role woodfuels play in deforestation and forest degradation, and forest carbon emissions. On the one hand, reports from the UN Food and Agricultural Organization (FAO) claim that woodfuels could present the single greatest challenge to conserving the world's tropical forests this century.[10, 29] On the other hand, some major estimates of greenhouse gas emissions from deforestation and degradation in Africa have excluded woodfuels, assuming that net emissions are zero.[30, 31]

There is clearly a need to move away from the generalisations of the past – either that dependence on woodfuels is an unmitigated disaster for all forests, or that it is a non-problem. As we explore below, there is strong evidence that some forests in tropical Africa have been severely affected by woodfuels production, and others have barely been touched. More research is needed to identify those forests that are under threat from woodfuels so that interventions can be targeted more effectively.

iii The Overseas Development Institute (ODI) has a useful online library containing research literature on the fuelwood crisis, and the many responses to it, from the 1980s–1990s.[28]

3.1 High population levels and woodfuel harvesting

Forests are more severely affected by fuelwood collection in areas with large populations, or near large urban areas. Countries with high rural population densities, such as Burundi, Rwanda and Uganda, may face severe shortages of fuelwood in the future.[23] Population densities can also be very high in refugee camps, where woodfuels are usually the only source of energy available. The concentration of such high numbers of people in small areas can have a significant impact on surrounding forests and woodlands.[34, 35] Furthermore, many refugee camps in Africa are found in dry and semi-dry regions, like Sudan, Kenya, Chad and Ethiopia, which cannot sustain high levels of fuelwood harvest.[10]

3.2 Rural industries and agricultural processing

Many rural industries are reliant on fuelwood for energy.[36] These include: brick making, fish smoking, bakeries, salt production, pottery, beer brewing and metalworking.[15] Most tobacco and tea farmers also use fuelwood to cure and dry their produce before selling.[24, 25]

Some sectors are particularly energy intensive. Consultations in the DRC reported that brick making, driven by the expansion of Kinshasa, is having a worse impact on some forests than charcoal making. In the agriculture sector, estimates for the amount of wood required to cure 1 tonne of tobacco (roughly equal to 1 hectare harvested) range from 12 to 30 tonnes.[15, 37] By comparison, the annual woodfuels consumption of the average family is estimated at roughly 3.9 tonnes.[iv]

iv Assumes an average family size of 7, and annual per capita consumption of 550 kilograms.[38]

Box 2: What happened to 'the other fuel crisis'?

Woodfuels encapsulate many of the wider issues that constrain consensus and action on climate change. The baseline data is to some extent in dispute; there are real difficulties in accurately defining the severity of impacts on forests, because the total volume of woodfuel removals is unknown; and the range of views are often underpinned by extrapolations from limited datasets, leading to accusations of unsound methodologies. The conclusion reached in this chapter is that both fuelwood and charcoal production pose major threats to many forests and other sources of land carbon, and that the tendency to treat unknown numbers as zeroes is leading to a dangerous understatement of the woodfuels problem in tropical Africa. Below, we provide summaries on the three controversies that underlie the contemporary debate around woodfuels and deforestation.

'Forests are not a major source of woodfuels'

Research found evidence that a significant proportion of woodfuels are actually collected from outside of forests – from trees on cultivated or abandoned farmland, or roadsides, for example. Earlier assumptions that the burden of woodfuels production was carried entirely by forests were wrong.[27, 32, 33]

'Woodfuels are largely collected as agricultural land expands, so separately counting emissions from woodfuel harvesting would be double counting'

Where woodfuels were harvested from forests, this was found to be largely a by-product of the expansion of the agricultural frontier. Farmers clearing forests to establish new croplands or pasture collect fuelwood or make charcoal by felling trees (either for domestic use or for trade). The primary cause of deforestation in the tropics therefore switched from woodfuels to agriculture. As a precaution and to avoid double counting, some estimates of deforestation rates and carbon emissions therefore assume that the impact of woodfuel removals on forests is accounted for by rates of conversion to agricultural land.[30, 31]

'Forests re-grow after woodfuels harvest, so they are carbon neutral'

Researchers found that people collecting fuelwood do not significantly alter the structure of forests – they collect dead and fallen wood, or lop branches off trees, rather than fell entire trees. As such, it was assumed that forests recover easily from woodfuels harvest, and as such woodfuels are irrelevant to the global carbon cycle: any carbon dioxide emitted during combustion will be re-sequestered by new growth.[27, 32, 33]

While these findings helped revise the earlier, misinformed projections of catastrophic deforestation, as we demonstrate below there is much evidence that these assumptions do not hold in all circumstances. Accepting these three statements as universal rules hampers efforts to address the impact of woodfuels on forests in cases where it is a serious threat.

One report estimates that fuelwood harvesting for tobacco curing alone is a cause of 5 per cent of deforestation across Africa, and an astonishing 20 per cent in Malawi.[24]

3.3 Rapid urbanisation trends and the shift to charcoal

In the last decade, multiple reports have observed a fundamental change to the energy mix of many sub-Saharan African countries: charcoal consumption is steadily growing, at the expense of fuelwood, driven largely by urbanisation.[1, 17, 18, 29, 39]

Charcoal is becoming increasingly important to Africa's energy mix. The FAO projects growth will continue into the future. Africa's cities are growing at almost 5 per cent a year, twice as fast as those in Latin America and Asia. The most growth will be among the urban poor: about 72 per cent of Africa's urban citizens live in slums – 190 million people; at current rates of growth the number will double every 15 years. Africa's largest city, Lagos, Nigeria, will have more than doubled from 10.3 million people in 2000 to 23.2 million in 2015. Kinshasa, the capital of the DRC, is expected to reach 16 million people by 2025, and enter the club of the 10 largest cities in the world soon after.[10]

Growing charcoal consumption matters for forests because, as we demonstrate below, there is substantial evidence that charcoal production has a much greater impact on forests than fuelwood collection. This can be summarised in three main points:

- **Making charcoal requires very large volumes of wood**, and charcoal makers often fell whole trees, so meeting energy needs with charcoal rather than fuelwood can degrade forests much faster.
- **Charcoal is usually sourced from natural forests**, not agricultural land or other trees outside land classed as 'forest'.
- **Charcoal is a booming rural industry** and for many people is a livelihood in itself, which means it is not so easily defined as a 'by-product of agricultural expansion'.

The different characteristics of fuelwood and charcoal are laid out in Table 1. Over page, we elaborate on these three points, and provide case studies demonstrating the impact of charcoal production on forests around three major African cities: Dar es Salaam, economic capital of Tanzania; Kinshasa, capital of the DRC and the second largest city in Africa (behind Lagos, Nigeria); and Maputo, capital of Mozambique.

3.3.1 Making charcoal requires very large volumes of wood

The impact of charcoal on forests is exacerbated by the inefficiency of traditional production methods, which greatly increase the amount of wood harvested. As noted above, the vast majority of charcoal makers use traditional earth kilns, which are highly inefficient and require on average 10 tonnes of wood to produce a single tonne of charcoal.[7] Unlike fuelwood harvesting, which draws mostly from single branches and sticks and wood lying on the ground, charcoal makers (in order to save time and labour) often utilise trunks, which means felling whole trees.

3.3.2 Charcoal is usually sourced from natural forests

Because of the large quantities of wood required, charcoal makers also source mostly from natural forests. Charcoal makers may be highly selective when choosing trees, going for species whose wood is thought to make better charcoal, such as hardwoods; or they may take every species and practice clear felling.[8, 10, 17, 36]

In some areas, charcoal production can be a catalyst of agricultural expansion. Removal of large trees opens up the forest to farmers. Some farmers make charcoal as they cut down trees and clear land for agriculture, or invite charcoal makers into their chosen forest to do the job.[7] In some cases, wood removals for charcoal will be occurring in forests that are already severely degraded. However, there is also substantial evidence pointing to charcoal as a driver of deforestation and degradation in areas that have not yet been converted to agriculture.[8, 18, 40]

Table 1: Comparison of fuelwood and charcoal

	Main features and implications of energy systems
Migration from rural situation dominated by use of fuelwood	**Fuelwood** ■ Often a by-product of agricultural expansion ■ Mainly non-commercial procurement; producer and user often the same ■ Relatively high production efficiency (use of residues and by-products) and low impact in respect of woody biomass resources ■ Generally low efficiency cooking stoves ■ Relatively high impact on living conditions (gathering time, indoor health conditions) of women and children in poorest households
To: urban situation with a wider energy mix dominated by charcoal	**Charcoal** ■ Product of exploitation of forests, woodlands or plantations through high intensity selective and/or clear felling ■ Fully commercial supply; producer and user always different ■ Relatively low production efficiency (due to energy loss in carbonization) and high impact on denser forests and woodland formations ■ Generally better efficiency (than three stone stove for fuelwood) ■ Relatively low impact on living conditions: better for health, labour time, but more expensive

Source: Adapted from Drigo, R. and F. Salbitano, *WISDOM for Cities: Analysis of Wood Energy and Urbanization using WISDOM Methodology*.[10]

3.3.3 Charcoal is a booming rural industry

The charcoal industry is now the second largest employer in many rural areas, behind agriculture. In Malawi, 93,000 people are estimated to work along the charcoal supply chain as producers, transporters and retailers in urban markets.[41] In Kenya, 200,000 people are estimated to work in charcoal production alone.[18, v] In Tanzania, the rocketing price of charcoal on the streets of Dar es Salaam is attracting thousands of new workers into the supply chain (see Box 3).

Because profits from farming are so poor, in many places charcoal is the most important source of income.[9] Studies in charcoal production areas in Mozambique, Tanzania and Zambia found charcoal provides 70–100 per cent of income for households surveyed.[8] Many subsistence farmers supplement their income by making charcoal, particularly in the dry season, but profits are so good that many people have abandoned agriculture altogether and taken up charcoal making or transporting as their primary livelihood.[7]

Box 3: Making a living from charcoal in Dar es Salaam

Dar es Salaam's growing appetite for charcoal is fuelling an economic boom in the surrounding countryside. The average price of a bag of charcoal on the streets of Dar es Salaam, or 'Dar', reportedly rose from around 5,000 Tanzanian shillings (about $3.50) to an astonishing 25,000 Tanzanian shillings (about $17) between 2003 and 2008.[7, 11] This is bad news for families and businesses in the city: the growing price might reflect, among other things, the growing scarcity of wood as forests and woodlands are cleared. It is good news, however, for families living in rural areas, which now have an opportunity to earn cash, and for businesses promoting improved charcoal stoves, as the higher price of charcoal means a stove could deliver greater financial savings and offset the cost of purchasing a stove more quickly.

The new opportunity for profits is attracting many people into the sector to work in the supply chain as charcoal makers, transporters and retailers. A 2007 survey of charcoal vendors and cyclists transporting charcoal to markets in Dar found that three quarters had started operating since 2004.[42] Entry into the charcoal industry is very easy: it requires few skills and very little capital. As one interviewee in Dar es Salaam said: '*Do you have an axe? Then that is your capital. For one pound, that is your capital!*'

It is estimated that the charcoal sector for the city generates total annual revenue of $350 million, as well as employment and cash income for several hundred thousand people. By comparison, coffee and tea, two major cash crops for Tanzania, are estimated to contribute only $60 million and $45 million to the national economy, respectively.[7] Another consultee in Dar noted: *'If you go into a village, you will see that everyone makes charcoal. The pharmacist, the local councillor, everyone. If a family has seven people, all seven of them will be making charcoal, including the children!'*

v Estimates suggest that employment in production may only account for about 50 per cent of all employment along charcoal supply chains – at least as many people may earn a living retailing charcoal in urban markets.[8]

FPAN
KEY MESSAGES
ABOUT THE REPORT
CHAPTER 1
CHAPTER 2
CHAPTER 3
CHAPTER 4
CHAPTER 5
CHAPTER 6
CHAPTER 7
CHAPTER 8

3.4 Case studies on charcoal and cities

3.4.1 Dar es Salaam, Tanzania

Half of Tanzania's annual total charcoal consumption is used in Dar es Salaam, its biggest city – 550,000 tonnes in total. There are many signs that this is growing rapidly. The proportion of households in Dar es Salaam citing charcoal as their primary energy source rose from 47 per cent to 71 per cent (about 2.1 million people) between 2001 and 2007.[7] One study found that 94 per cent of households in Dar es Salaam used charcoal to some degree.[42] The use of LPG has declined from 43 per cent to 12 per cent between 2001 and 2007, and electricity use for cooking remains below 1 per cent of households.[7] About 25,000 bags of charcoal, of about 50 kilograms each (meaning 1,250 tonnes), are estimated to be consumed in Dar es Salaam every day.[8, 42]

A 2002 study of deforestation in the areas supplying Dar es Salaam concluded that the impact of charcoal making far outweighed that of agriculture. The study found that charcoal production was responsible for forest degradation of 30,000 hectares and deforestation of 116,000 hectares between 1991 and 2000.[8] At the national level, according to the World Bank, approximately 100,000 to 125,000 hectares of forest and woodland are lost to charcoal production for Tanzania's towns and cities every year.[7]

3.4.2 Kinshasa, Democratic Republic of Congo

In the DRC, demand for woodfuels appears to be second only to agriculture as a cause of deforestation. Slow growing forests, like those found in the regions around the capital Kinshasa and in the province of Katanga (southern DRC), are rapidly disappearing as a consequence of woodfuel removals. The province of Bas Congo, on the coast, has seen most of its forests progressively degraded by Kinshasa's demand for energy: for charcoal in homes, businesses and institutions, and for making bricks. Kinshasa's impact is also being seen on forests in other surrounding provinces.

According to UNEP, 60,000 hectares are deforested each year by Kinshasa's demand for wood energy.[3]

Pugu Hills Forest Reserve outside Dar es Salaam. This forest is meant to be protected but it has been heavily degraded by charcoal production: most of the large trees have been cut down, and as such the canopy is almost non-existent. Shrubs and long grasses cover the ground.
Courtesy of Thomas Sembrés

3.4.3 Maputo, Mozambique

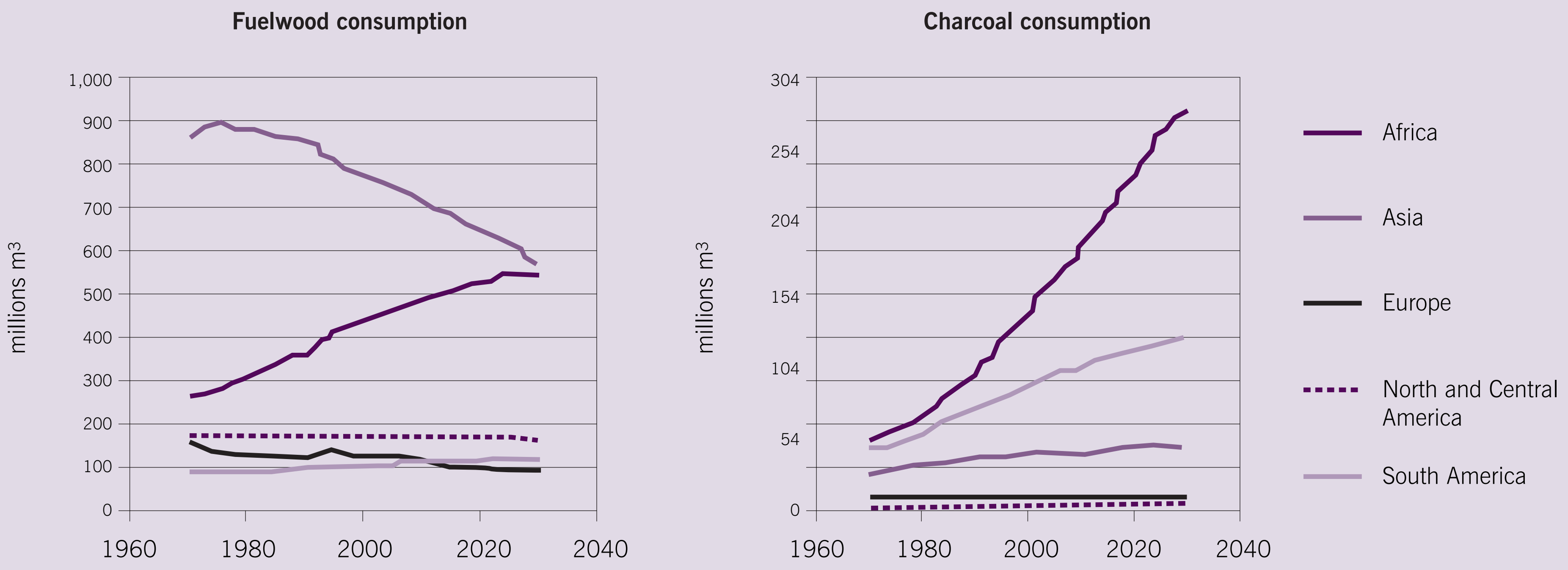
In Mozambique, the widespread adoption of modern energy sources like LPG, kerosene and electricity in the 1990s reduced fuelwood consumption, but the popularity of charcoal appeared to be unaffected.[43] Since then, the charcoal 'catchment area' for Maputo has reportedly increased from a radius of 50 kilometres up to 200, with some deliveries arriving by rail from up to 600 kilometres away.[8] Charcoal production for Maputo is described in one report as a clear felling system: charcoal makers do not discriminate between species, and clear all trees.[8] This is particularly damaging for the forests of southern Mozambique, which are open woodlands dominated by slow growing acacia trees. The report predicts that forest cover in Maputo Province will have declined by as much as 80 per cent by 2015, relative to 1998, driven by agricultural expansion as well as charcoal.

3.5 Future trends

Demographic trends for sub-Saharan Africa suggest that woodfuel consumption will continue to grow. One report from the FAO provides estimates for the growth of fuelwood and charcoal consumption up until 2030 (see Figure 1).[12] Between 2000 and 2030, Africa's total population will have grown from 820 million to 1.5 billion – an increase of 85 per cent.[38] During the same period, annual fuelwood consumption is expected to grow by 27 per cent, from 270 million tonnes to 330 million tonnes in 2030; meanwhile, annual wood consumption for charcoal production will roughly double, from about 87 million tonnes in 2000 to 170 million tonnes in 2030.[12] The total amount of wood consumed as woodfuels in 2030 is projected to reach approximately 500 million tonnes, with charcoal constituting a third, reflecting a larger and more urbanised population.

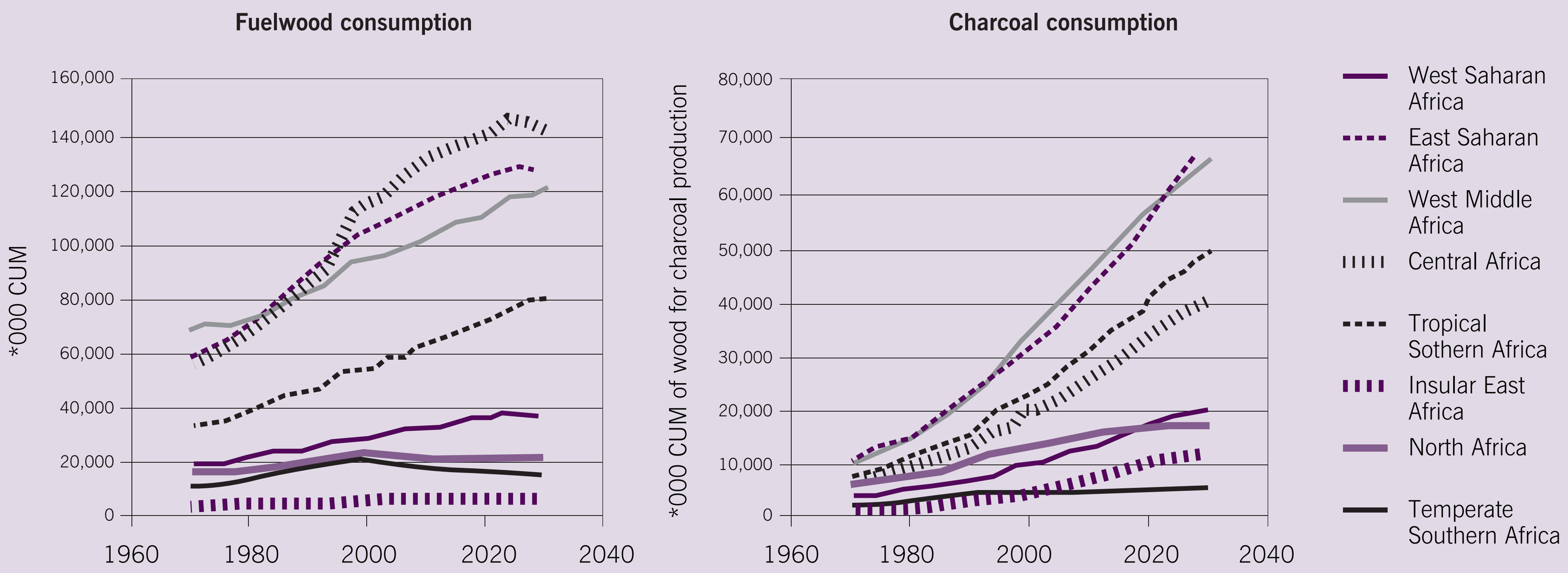
FPAN
KEY MESSAGES
ABOUT THE REPORT
CHAPTER 1
CHAPTER 2
CHAPTER 3
CHAPTER 4
CHAPTER 5
CHAPTER 6
CHAPTER 7
CHAPTER 8

Figure 1: Global fuelwood and charcoal consumption by region (1970–2030)



Source: Broadhead, Bahdon and Whiteman, 'Past trends and future prospects for the utilization of wood for energy', annexes 1 and 2 of the GFPOS, 2001.[12]

Figure 1 continued: **African fuelwood and charcoal consumption by subregion** (1970–2030)



Source: Broadhead, Bahdon and Whiteman, 'Past trends and future prospects for the utilization of wood for energy', annexes 1 and 2 of the GFPOS, 2001.[12]

This reflects trends in the urbanisation of poverty: by 2030, the UN estimates that one in two people in Africa will be living in urban areas.[38, 44] If the proportion of urban citizens living in slums does not decline from roughly three quarters, the slum population for Africa could reach over half a billion people. These trends will put enormous pressure on forests if charcoal remains the default fuel in urban areas.

Some commentators argue that the woodfuels challenge will be one of *'the most crucial environmental issues to be addressed in the future'*,[1] and that shifting the charcoal industry onto a more sustainable basis may be the single most important issue for Sustainable Forest Management in the 21st century.[10, 29]

4. Interventions and responses

Interventions related to reducing the impact of woodfuels production on forests are grouped around three priorities: improving the efficiency of woodfuels production and consumption; creating new sources of woodfuels; and promoting alternatives to woodfuels.

4.1 Improving woodfuel efficiency

There is much potential to increase the efficiency of fuelwood and charcoal in tropical Africa. Cooking stoves can be improved to increase the amount of heat they generate, which reduces the volume of fuel needed to cook a meal. For fuelwood stoves, this can mean a 30–50 per cent reduction in fuel requirements, and about 33 per cent for charcoal stoves (see examples below). There are also other gains to be made throughout the supply chain, such as design improvements to charcoal kilns.

4.1.1 Improved stoves

Improving efficiency produces multiple social and environmental benefits beyond reductions in wood consumption and cooking time. Efficient stoves save households money, by reducing the amount of fuel that needs to be purchased, and labour, if they collect their fuel for free from nearby forests and woodlands. Because the fuel burns hotter, the amount of smoke and fumes is reduced, with large benefits for health: indoor air pollution from cooking with woodfuels kills an estimated 1.6 million people every year, mostly women and children, and tens of millions of people are left ill.[19, 45, 46] Improved stoves are also promoted as tools to improve safety for women collecting fuelwood in conflict areas.[34]

Box 4: Fuelwood and charcoal – which is more efficient?

Charcoal is favoured over fuelwood by many consumers, especially in urban areas, because it is more efficient, lighter to transport, easier to extinguish and relight, and produces less smoke and toxic fumes. The calorific content (meaning the potential energy) of dry fuelwood is about 4,500 kcal/kg; for charcoal it is about 7,500 kcal/kg. This means that a kilogram of charcoal burns hotter than a kilogram of wood, reducing the amount of time spent cooking, and requiring less fuel to cook a meal. But comparing fuelwood and charcoal in terms of the fuel required to cook a meal can be misleading. The higher efficiency of charcoal at the point of consumption hides the very poor efficiency of charcoal at the point of production: traditional charcoal kilns in Africa require on average 10 kilograms of wood to produce only 1 kilogram of charcoal.[7] This means that much of the potential energy within a kilogram of wood can be lost in the charcoal production process. This is demonstrated in the tables below.

If charcoal is so much less energy efficient than fuelwood, why is it favoured by consumers, especially in urban areas? Consumers only receive charcoal after it has been converted from wood – after 90 per cent of the weight, and about 80 per cent of the potential energy, has been lost. Substantial energy savings can be made in the charcoal supply chain by increasing the efficiency of kilns. Doubling charcoal yields to 20 per cent can be achieved with metal and brick kilns (see below). This can double the energy provided to consumers (246 kcal and 462 kcal, respectively for the two charcoal stove types) but comparisons with raw fuelwood demonstrate that this still provides less energy overall than using raw wood in an improved ceramic stove. These calculations do not take into account energy used in other elements of the woodfuel supply chain, such as transport – charcoal is much lighter than fuelwood, so requires less energy to transport.

Fuelwood from forest to stove

Potential energy of 1kg wood (kcal/kg)	Efficiency of three stone fire	Energy provided to consumer (kcal)	Efficiency of mud Rocket stove	Energy provided to consumer (kcal)
4,500	*10%*	450	*30%*	1,350

Charcoal from forest to stove

Potential energy of 1kg wood (kcal/kg)	Efficiency of earth kiln	Potential energy of 100g charcoal (kcal/kg)	Efficiency of conventional metal stove	Energy provided to consumer (kcal)	Efficiency of improved ceramic stove	Energy provided to consumer (kcal)
4,500	*10%*	770	16%	123.2	*30%*	231

Sources: HEDON,[47] GTZ-PROBEC.[48]

For these reasons, NGOs, governments and development agencies have developed and disseminated improved stoves in developing countries for decades.[49] A plethora of different designs, made of different materials – mud, brick, metal, ceramics – are on the market in Africa, with varying levels of efficiency and suitability for different types of fuels (eg, fuelwood, charcoal, other biomass). Most stoves have been designed for domestic users, but much larger stoves and ovens have also been designed for institutions and businesses, including bakeries, schools, hospitals, restaurants, food stalls, and kitchens for farm labourers. An overview of the most common designs and some successful programmes is given on the page before.

4.1.1.1 Fuelwood stoves

As noted earlier, the baseline fuelwood stove for many households in rural Africa is still the 'three stone fire' stove. These stoves are highly inefficient, utilising only 8–15 per cent of the energy released from the burning wood.[50, 51] Improved stove designs can double energy efficiency and can reduce the amount of fuelwood needed by about 50 per cent.[48]

One of the most successful is the Rocket stove, designed by the US charity, Aprovecho Research Centre,[52] which is widely used in many developing countries. Rocket stoves consist of a ceramic combustion chamber, which can be housed in a structure made out of brick or mud. Portable Rocket stoves can be encased in metal. The energy efficiency of Rocket stoves is around 30 per cent, and they are estimated to reduce fuelwood requirements by up to 60 per cent, relative to a three stone fire.[48] Costs range from as little as $1.50, as reported in a consultation in Uganda (mud Rocket stove) to $32 for a metal stove.[48]

4.1.1.2 Charcoal stoves

Common traditional charcoal stoves are made out of metal. Their energy efficiency ranges from 10 to 24 per cent.[53] Improved charcoal designs often include ceramic liners in the combustion chamber, which lower the loss of heat, and doors or grates so the user can control heat levels. Improved charcoal stoves increase energy efficiency by 30–35 per cent, implying a charcoal saving of 30–50 per cent.[51, 54] Our consultations in tropical Africa highlighted two types of improved charcoal stoves: the Kenya Ceramic Jiko (KCJ), and a stove produced by Ugastoves, a small company in Kampala, Uganda.

The KCJ stove was developed in the 1980s, out of a collaborative effort between development agencies, the Kenyan government and Kenyan NGOs.[54] It is based on the design of the traditional charcoal stove used in Nairobi, and incorporates elements from international designs. Most important of these is a ceramic liner that increases heat insulation and improved energy efficiency. The design has now been exported to several other countries in East Africa where small businesses have sold hundreds of thousands of new stoves.[49]

Ugastoves produces stoves in a small factory in Kampala. They currently make 200 stoves a day (60,000 a year), through a manual process, but aim to mechanise production and increase output to 20,000 stoves a day in the next five years. The stoves can save charcoal consumption by up to 40 per cent. As the price of charcoal in Kampala has increased by up to ten times since 2005, the improved efficiency means that families can usually recoup the stove purchase price within a few months. Ugastoves reports that they received Gold Standard certification from Climate Care for selling carbon credits in 2008.[55]

A two-pot mud Rocket stove installed into a house in Kenya. GTZ offices in Uganda and Kenya reported these stoves can reduce fuelwood consumption by up to 60 per cent, compared to a three stone fire.

Courtesy of Anna Ingwe/GTZ-Kenya

A traditional metal 'jiko' (the local word for cooking stoves) and the Kenya Ceramic Jiko. The most important modification is the introduction of a ceramic liner to conserve heat.

Courtesy of BioEnergy Lists and Appropriate Infrastructure Development Group

4.1.1.3 Institutional and commercial stoves and ovens

Energy-efficient cooking technologies have also been promoted to larger consumers in the institutional and commercial sectors, including stoves and ovens. Given that single businesses or institutions can consume far more than single households, targeting these sectors could be a way of leveraging a greater impact on reducing levels of woodfuel consumption.

Comparative data on energy efficiency and distribution of institutional stoves and ovens is not as good as that for the household sector. GTZ Kenya reports that its institutional Rocket stoves and large-scale baking ovens reduce fuelwood requirements by up to 70 per cent, with more than 1,500 sold to institutions and businesses in a range of countries during 2007, including Lesotho, Malawi, Mozambique, Tanzania, Uganda and Zambia.[56]

4.1.1.4 The scope for increasing improved stove usage

There are many different types of improved stoves produced and distributed by a plethora of NGOs and small businesses across Africa, but the lack of systematic data on total sales by volume, geographies and product and customer types is a limiting factor in assessments of overall prospects. However, surveys have been carried out for some cities and regions, and these suggest that there is much scope for increasing the market penetration of improved stoves.

In Kenya, the penetration of the KCJ stove in urban areas is significant, reported to be used by 50 per cent of households.[49, 51] This leaves about 4 million potential users of improved cooking stoves in towns and cities.[57] However, some will be using other improved stoves, and not all residents will be using charcoal in their homes. In rural areas, GTZ Kenya reported in consultations that it helped distribute 700,000 improved fuelwood stoves to households over a four-year period (between January 2006 and December 2009). GTZ Kenya has been promoting two kinds of fuelwood stoves: the Jiko Kisasa and the mud Rocket stove. GTZ calculates that marketing this number of stoves equates to reaching around 3.5 million people (assuming five people per household). With a rural population of about 30 million people, there appears to be a big opportunity for scaling up improved fuelwood stove programmes.[57] This is confirmed by a 2002 government survey across 16 districts in Kenya which found that only 4 per cent of the population were using improved fuelwood stoves.[58]

A high efficiency bread oven at Tanzanian Traditional Energy and Development Organisation (TaTEDO).

Courtesy of Thomas Sembrés

In Uganda, GTZ has helped install mud Rocket stoves in 500,000 rural households between 2004 and 2008. With 3.2 million rural households in Uganda,[57] the potential for additional market penetration is large. Another factor is that mud Rocket stoves have a short lifespan: usually one to three years.

In Tanzania, estimates for the proportion of households in Dar es Salaam using improved charcoal stoves range from 20 to 45 per cent. Almost none of the institutional consumers surveyed in one report were found to be using improved stoves.[7, 59]

The technology is available to achieve these fuel savings; the real challenge is how to convince millions of households with minimal purchasing power to start using these stoves properly, and pay for their maintenance and eventual replacement. Disseminating stoves in rural areas, where potential consumers may be spread out over very large areas of land, with poor transport and communication links, is particularly difficult. Below, we offer some guidance, drawn from our research, on what a successful stove programme might look like.

4.1.1.5 Improved stove designs must be competitive

The affordability and convenience of improved stoves were cited in consultations as two key factors determining their widespread adoption. The uptake of improved stove designs in the past has been hampered by high costs. Prices fall when domestic production is used, and when cheap local materials (eg, mud) are used.

Box 5: Case study: How much wood harvest could be avoided if 100 per cent of households adopted efficient cooking stoves?

Below are some preliminary calculations for just how much wood harvest could be avoided every year by scaling up improved stove programmes to reach 100 per cent of households in two populations: rural Uganda (households using fuelwood stoves) and the city of Dar es Salaam in Tanzania (households using charcoal stoves).

Uganda

The rural population of Uganda is about 28 million, making up roughly 5.6 million households.[57] The consumption of fuelwood in rural Uganda is estimated at about 666 kilograms per person per year,23 which implies a total fuelwood consumption of 18.7 million tonnes. If every household shifted from three stone fires to mud Rocket stoves, this could save up to 9.4 million tonnes of wood and avoid 17.2MtCO_2 being emitted every year. This wood saving represents the amount of fuelwood that would be grown every year by 6 million hectares of semi-dry forest.

Dar es Salaam, Tanzania

Dar es Salaam is responsible for half of Tanzania's entire charcoal consumption. Every year, it consumes an estimated 550,000 tonnes of charcoal, 69 per cent (380,000 tonnes) of which is used by households. 7 If the 80 per cent of households in Dar es Salaam that are still using traditional metal stoves made the transition to improved stoves like the KCJ (33 per cent fuel saving), this could reduce charcoal consumption by up to 110,000 tonnes. Assuming that charcoal has been made in traditional kilns, this equals over 1 million tonnes of wood – equivalent to the yearly growth of over 700,000 hectares of Tanzania's miombo woodland, which is a primary source of Dar es Salaam's charcoal.[8] In terms of carbon emission, this could avoid approximately 2MtCO_2 being emitted every year.

In reality, the adoption of improved cooking stoves does not translate into woodfuel savings so easily. Several variables are involved: many households use multiple cooking stoves, so improved stoves do not automatically substitute for conventional stoves once purchased; people may not necessarily use less fuel; stove manufacturers may alter dimensions or produce poor quality stoves, which undermines potential fuel savings; and many other factors.

A major competitive advantage for the mud Rocket stove is that it is cheap, with production costs ranging from $1 to $3.

Successful stoves also need to compete with traditional stoves in terms of convenience and other benefits, such as reducing smoke. Diets and cooking methods vary widely across tropical Africa, and even within single countries: for example, the KCJ has been very popular in Kenya, but may be useless in Ethiopia where the staple food, a type of large flatbread called *injera*, requires a broad, flat cooking surface. Stove designs may need to be modified to meet the particular needs of locals – for example, to accommodate for the size, shape and weight of different pots.

People need to be aware of the benefits of improved cooking stoves over traditional designs, so marketing campaigns could play a very important role in getting improved stoves used on a large scale.

4.1.1.6 Commercialised distribution could have an advantage

Several of our consultations emphasised the advantages of disseminating improved stoves via a commercialised supply chain. GTZ seems to have achieved an impressive output with its approach of supporting enterprises and training people to manufacture and market improved stoves. Commercialised dissemination of improved stoves has multiple benefits over programmes reliant on government or donor support: commercialisation allows operators along the supply chain, from producers to retailers, to make a profit, which introduces incentives to disseminate more stoves, and provides new opportunities for employment and income generation. Commercialised supply chains can also potentially be self-sustaining financially.

4.1.1.7 Microfinance schemes could help encourage uptake of stoves

Households can recover the cost of investing in an improved stove in a reasonable amount of time – some people reported that, with the high price of charcoal, costs could be recovered within a matter of months. Many families cannot afford the initial financial outlay. This suggests that microfinance schemes, in which people are given small loans with low interest rates, may help millions more households access improved stoves.

Ugastoves factory in Kampala, Uganda, which at the time of FPAN's visit was producing 200 stoves a day. They want to completely mechanise production and increase output to 20,000 stoves a day in five years time.

Courtesy of Thomas Sembrés

4.1.1.8 Targeting large-scale consumers could amplify impact

A single school, tea estate, brick factory, bakery or restaurant can consume a huge amount of woodfuels every year, much more than a single household. Efficient bread ovens, brick kilns, and commercial-scale cooking stoves are available, but they can be very expensive. Microfinance could play a role here too, by allowing businesses or public institutions to make the initial capital investment. As with improved household stoves, such a project could substantially reduce woodfuels consumption while helping to reduce running costs and/or improve profits.

4.1.2 Improved kilns

One strategy for reducing the total volume of wood harvested to provide energy is to improve the efficiency of the charcoal production process. As noted above, traditional earth kilns remain in use by the vast majority of charcoal makers. The technology exists to reduce the amount of wood required to produce a tonne of charcoal by over 50 per cent. However, as discussed below, under current conditions the widespread uptake of improved kilns faces a number of challenges, and the effectiveness of increasing the efficiency of charcoal production for reducing levels of harvest is dubious.

4.1.2.1 Kiln types

A number of kiln designs with proven and substantial gains in efficiency have been developed (see Table 2). Simple modifications can be made to the traditional earth kiln, such as chimney and air holes to improve the flow of air, and stacking the wood carefully.

This can up to halve the amount of wood required per tonne of charcoal. Kilns made out of brick or metal can sustain pyrolysis more effectively and increase efficiency to 5 tonnes of wood per tonne of charcoal. 'Green charcoal' systems, which capture the gases released during pyrolysis and feed them back into the process to further increase heat, can achieve close to 2 tonnes of wood per tonne of charcoal.

4.1.2.2 What is the scope for increasing the use of improved kilns?

The market penetration of improved kilns appears to be very poor.[7, 8, 63] One study of the charcoal production area around Maputo (capital of Mozambique) found that professional charcoal makers had, on average, more efficient kilns than people for whom charcoal making is a complimentary source of income, such as subsistence farmers.[8]

But for most charcoal makers, it seems that improved kilns are too costly and impractical.[7, 8, 18] Improved kilns require greater investments of labour and capital, and the incentives to increase efficiency and make such investments are low when access to public forests is poorly monitored and poorly regulated, and therefore wood is 'free'. Another practical issue is mobility: charcoal makers build the kiln as close to felled trees as possible to reduce labour, and stationary brick or metal kilns become less useful as the forest frontier retreats from the kiln site.

An improved traditional kiln and brick kiln at Tanzanian Traditional Energy and Development Organisation (TaTEDO).

Courtesy of Thomas Sembrés

Table 2: Charcoal kilns

Kiln type	Production efficiency (ratio of wood to charcoal)	Additional notes
Traditional earth	8-12:1	Low yields, inconsistent quality.
Improved traditional	6-8:1	Earth kiln with chimney, usually metal; stacking wood tightly and filling gaps with grass, leaves, etc, improves pyrolysis. Sometimes called the Casamance kiln.
Brick or metal	5-6:1	Immobile kilns made out of brick or metal – 'half orange' kiln promoted by TaTEDO in Tanzania can achieve 20% efficiency (5:1).
Industrial retort	3-5:1	Industrial charcoal production, mostly in developed countries.
'Green charcoal' or biochar systems	2-4:1	Gases released during pyrolysis process are captured and fed back into the process (reducing greenhouse gas emissions further). Gases could be captured and used to provide cooking fuel or electricity for other purposes.

Sources: Stassen, H.E., *Developments in charcoal production technology*;[60] *World Bank, Environmental Crisis or Sustainable Development Opportunity? Transforming the Charcoal Sector in Tanzania*;[7] Mugo, F. and C. Ong, *Lessons From Eastern Africa's Unsustainable Charcoal Trade*, in ICRAF Working Paper no.20;[18] Pro-Natura;[61] Biochar Fund[62]

Another major issue impeding the widespread adoption of improved kilns and production techniques is the free availability of wood: most forests in tropical Africa are 'open access', with unclear ownership (including where local communities have customary rights), or are government owned with little or no management. With abundant wood resources available (even if deforestation is occurring), charcoal makers have little incentive to increase efficiency and improve yields.[7, 16, 18, 27]

4.1.2.3 Are improved kilns an effective way of protecting forest carbon?

The argument in favour of scaling up improved kilns as a strategy to reduce deforestation and degradation rests on the assumption that charcoal makers using more efficient kilns will take advantage of the higher efficiency to produce the same amount of charcoal from less wood, saving them time and labour. However, several consultees argued that, because charcoal production is, in most cases, a fully commercialised activity, and demand remains much higher than supply, improving the efficiency of charcoal kilns could have the opposite effect. Charcoal makers are more likely to take advantage of the higher efficiency to produce more charcoal and increase their profits.

1. Prices of charcoal are rising, indicating strong and increasing demand.
2. Charcoal production is a fully commercialised activity, so more efficient production techniques will help producers to increase supply to meet the rising demand.
3. Overproduction may reduce prices, but this will further increase demand.
4. Efficient kilns could therefore increase woodfuel harvest for charcoal production, and exacerbate deforestation and degradation.

The economics of the charcoal industry suggest that efforts to reduce the amount of wood harvested for charcoal should focus on the demand side of the equation, and reduce the amount of charcoal that households and businesses purchase to meet their fuel needs, rather than the supply side.

4.1.2.4 Charcoal supply chain reforms

Charcoal makers do not own the forests that they work in, and the implementation and enforcement of management plans and harvest restrictions in public forests is very weak in many tropical African countries. The incentives for charcoal makers to invest their labour and money in improving the efficiency of their kilns are therefore also very weak. Given the difficulties of improving kiln efficiency and reducing wood volumes, it may be sensible to limit support for improved kilns to charcoal plantations or community forests that have plans for the sustainable harvest of wood for charcoal.[7]

Outright bans on charcoal production and trade are also unlikely to be effective. Many African governments lack the capacity or resources to control the trade of informal products, and past charcoal bans in some countries have driven the trade underground, increasing costs for consumers and attracting more people into the trade.[7] Formalising the charcoal industry is likely to bring greater gains. This could include regulations requiring registration by producers, transporters and marketers. This strategy is preferred over banning by many NGOs because of the implications for livelihoods: the charcoal trade is a major source of income for rural families in many countries.[41, 64]

4.2 Creating new sources of woodfuels

Planting trees to provide woodfuels was a central component of the response to the fuelwood crisis in the 1970s–1980s.[27, 33]

Establishing large-scale fuelwood plantations and encouraging farmers and communities to establish small woodlots became priorities for development aid; multilateral agencies, such as the UN and the World Bank, and donor governments earmarked millions of dollars for plantations.[27] The World Bank estimated that the rate of tree planting would need to increase fifteen fold to meet demand in future years.[27]

According to much of the literature, these projects proved to be highly unsuccessful.[27, 65] Retrospectively, authors highlight two key reasons for this failure. First, fuelwood is produced and consumed on a subsistence basis, and paying for fuelwood is an unattractive option for most rural families. Fuelwood from plantations could not compete with fuelwood from open access forests, in terms of price. Second, fuelwood resources were not declining as rapidly as had been thought: the impact of fuelwood collection on forests appeared to be overstated, and the severe fuelwood deficits envisaged were failing to materialise.[27, 65] The financial incentives for business to invest in tree planting were therefore very poor; farmers and communities would not establish woodlots on their land at the expense of cropland or pasture. With the decline of 'fuelwood gap theory' and the poor success of some of the responses to it, it seems that the large-scale planting of trees for energy fell out of favour.

Growing demand for woodfuels, particularly charcoal, is prompting a revival of calls for woodfuel plantations.[18] In the DRC, large-scale agroforestry projects near Kinshasa grow cassava, a staple food crop, alongside trees for charcoal to feed the capital's growing demand, which consultations estimate is currently up to 2 million tonnes a year. In Tanzania, there are plans to source charcoal sustainably from forests under community-based management.[64] And one report highlights the management of charcoal production from plantations and natural forests in Sudan as a good example for other African countries to follow.[18]

Here we review three models for tree planting for charcoal and fuelwood: plantations, agroforestry and community forestry.

4.2.1 Plantations

Plantations can be enormously productive on a per hectare basis, especially if fast growing (or 'fastwood') species such as cloned varieties of eucalyptus are closely planted, and harvested on 3–7 year rotations. Trees in woodfuel plantations are usually coppiced – cut at the trunk just above ground level, to encourage multiple shoots – rather than replanted. The outputs can serve a range of purposes, including fuelwood, charcoal, pulpwood for paper and other materials, poles and other timber products. Wood waste can be converted to briquettes and pellets. In some cases, woodfuel plantations can be adapted to incorporate food crops between planted trees (agroforestry) so the land can be used to meet growing energy and food needs at the same time.

Establishing large-scale woodfuel plantations near major towns and cities could help reduce the impact on forests of rapidly growing urban demand for charcoal and, to some extent, for fuelwood. Producing charcoal on plantations makes it feasible to employ highly efficient, immobile kiln designs: production is not mobile and the financial incentive to extract as much charcoal out of each hectare of trees is greater.[18] Alternatively, charcoal could be a secondary output of timber plantations, using the 30–40 per cent wood waste that is typically generated.[66] One plantation timber company, Green Resources, is pursuing this route in its plantations in Uganda and Tanzania.[67]

FPAN
KEY MESSAGES
ABOUT THE REPORT
CHAPTER 1
CHAPTER 2
CHAPTER 3
CHAPTER 4
CHAPTER 5
CHAPTER 6
CHAPTER 7
CHAPTER 8

Box 6: Woodfuel plantations – the track record

To what extent have woodfuel plantations been successfully established and managed? There are encouraging examples in Madagascar, Republic of Congo and Sudan.

Madagascar

Outside Antananarivo, the capital of Madagascar, 100,000 hectares of eucalyptus plantations were established between 50–100 years ago, almost entirely on smallholdings. These reportedly produce enough charcoal for much of the 1.4 million inhabitants. The plantations produce charcoal that meets most of the domestic and industrial energy needs in the city, and also provide thousands of jobs in hundreds of small charcoal making and transport enterprises.[68]

Republic of Congo

Outside Pointe-Noire (the second largest city of the Republic of Congo, with a population of over 600,000), an area of 42,000 hectares has been planted with cloned varieties of eucalyptus, suitable for the sandy former savannah land that was considered too poor for agricultural purposes. Initially grown solely for pulpwood, the plantations now also produce electricity, telephone poles and fuelwood and charcoal, meeting almost 80 per cent of Pointe-Noire's domestic energy requirements. Local villagers are also involved in plantation protection through the tenant farming system, receiving payments from the company in return for surveillance of the plantations. In addition, the plantations produce 300,000–500,000 cubic metres of woodchips per year.[69]

Sudan

One report describes Sudan's charcoal plantations system as an example of good practice in Africa:[18] 'Every year, about 100,000 ha are planted with Acacia seyal and Acacia nilotica for charcoal. The wood is harvested after 15 years. Mature wood is sold to members of the Sudan Charcoal Association by tender. It then finds its way to users through a network of wholesalers and retailers. Charcoal traders pay taxes and other agreed fees to the government. After clearing the forests and making charcoal, producers use the thorny branches left to fence off the land. The forest department provides certified acacia seed, which the charcoal makers plant to replace the harvested trees. The forest department then takes over and manages the woodlots until the trees mature again, ready for harvesting.'

4.2.2 Agroforestry

Trees on farms are an important source of fuelwood for rural households. During consultations, some organisations highlighted agroforestry systems – in which tree species and food crops are integrated – as a potential source of fuelwood and charcoal. Intercropping woodfuel trees with food crops can have multiple advantages over just planting trees: both trees and crop productivity can benefit from this relationship – crop yields can be increased, while crops can act as a fire deterrent; the system may help solve growing competition for land between the need to provide food and the need to provide fuel for growing cities; it may provide more jobs; and by attracting farmers they could help reduce the conversion of natural forests for agriculture. Our consultations in the DRC encountered two agroforestry projects that produce charcoal for the capital of Kinshasa (see Box 7).

Box 7: Case study: Making fuel and food for Kinshasa

Kinshasa, the capital of the DRC, has a population of 8 million. It is growing at a rate of 4.8 per cent per year, and by 2025 is expected to reach a population of 17 million.[70] Kinshasa's annual charcoal consumption is currently estimated at about 1 million tonnes. The Batéké plateau, an area outside the city, is the site of multiple charcoal projects that aim to meet the city's charcoal demand.

The **Mampu** plantation was established in the late 1980s, by the Hans Seidel Foundation.[71] 8,000 hectares of acacia trees were planted on eight-year rotations. Farmers are allowed to grow cassava and maize among the young trees for the first two years, and wood is harvested and turned into charcoal in the eighth year. Mampu project reports that 1 hectare of their plantation produces 21 tonnes of charcoal, after 8 years of growth, and that the entire project caters for 1–5 per cent of Kinshasa's charcoal needs. The project also produces 700,000 tonnes of cassava annually. The Hans Seidel Foundation reported that establishment costs for the Mampu project are about €1,140 ($1,400) per hectare, including all indirect costs incurred by the Foundation. These costs reportedly cover the first three years before farmers are able to run their business independently.

The **IBI Batéké Carbon Sink project (I-BCS)** employs a similar agroforestry model, but unlike Mampu project, which is supported by donors, I-BCS is a private initiative partly relying on carbon finance. It is the first forestry-based project registered with the Clean Development Mechanism (CDM) in the DRC.[72] 4,200 hectares of the Batéké plateau have been planted with trees, sequestering an estimated 2.4MtCO_2 over the next 30 years. I-BCS plans to expand to 8,000 hectares by 2012, but there may be scope for far greater expansion.

4.2.3 Community forestry

Sourcing charcoal from natural forests that are being sustainably managed by communities is another strategy being proposed in some countries such as Tanzania, where the involvement of rural communities in the management of forests is a pillar of the country's forest policy. In Tanzania, one person we interviewed stated that timber production was currently out of reach of most community-managed forests. This could be because most community-managed forests are in miombo woodland areas, which lack valuable timber species.[73] As such, charcoal may provide a more accessible revenue stream for community forests than timber. However, we were unable to identify examples from our researches.

4.2.4 Environmental impacts

Plantations may relieve the pressure of fuelwood and charcoal production on forests, but planting fast growing or exotic tree species over such vast areas of land may have a detrimental impact on ecosystem services and biodiversity. Fast growing trees can use very large volumes of water, which could severely restrict the appropriate range of plantations in countries like Kenya. Monoculture plantations can involve large volumes of fertiliser and pesticides, which could harm animals and insects or pollute waterways. Furthermore, exotic tree plantations may become pests, if not controlled properly, and generally provide very poor habitat for indigenous animals. These risks need to be seriously considered for any large-scale plantation project.

4.2.5 Land competition between food and energy security

In many countries, establishing large plantations could involve substantial trade-offs with food security. Donors and funders need to be aware of any land competition issues associated with plantation projects. In some places, woodfuel plantations may not be the best use of land: even from a perspective narrowly focused on protecting forests, establishing woodfuel plantations on fertile land may be counterproductive by displacing farmers into forest areas. Agroforestry and community forestry could help provide a solution in these instances.

4.2.6 Land use planning reform and improved law enforcement may be needed to ensure new woodfuel sources are competitive

The availability of free woodfuels from 'open access' forests presents a major challenge to all projects that aim to shift woodfuels harvesting from natural forests to plantations, agroforestry or community forests. Managing plantations or forests costs time and money, and charcoal from managed sources in most cases has struggled to compete with charcoal from open access forests.[7, 27] This may change if the cost of charcoal continues to rise and the availability of trees nearer to towns and cities declines. But in the long run, projects to create new sources of woodfuels will greatly benefit from well-enforced policies that put open access forests under some sort of ownership – whether communal, individual or public.

4.3 Promoting alternatives to woodfuels

Per capita woodfuels consumption could be reduced by introducing alternative sources of energy. However, the relationship between the uptake of energy alternatives and subsequent reductions in woodfuels consumption is not linear. Many African households and businesses rely on a mix of energy sources, including kerosene or electricity to provide light, fuelwood, charcoal, and LPG for cooking.

As we demonstrate below, there are examples where energy alternatives have been shown to successfully reduce woodfuels consumption. To what extent energy alternatives substitute for woodfuels is unclear – evidence suggests that when new energy sources are introduced, they are often added to this energy mix, rather than wholly substituting.[7] Nevertheless, even if a particular energy technology substitutes for only part of businesses' or a household's woodfuels consumption, this still means that fewer woodfuels are being consumed.[43]

4.3.1 Waste-based fuels

Forestry and agricultural processing produce a lot of organic waste that could potentially substitute for woodfuels. These wastes include sawdust and timber offcuts, agricultural residues (the stems, leaves and husks left over from harvesting and processing crops), and a by-product of paper and pulp manufacturing called 'black liquor'. In Europe and North America, this sort of waste provides the majority of woodfuel consumed – the rest of their energy being derived from fossil fuels and a very small proportion of renewable electricity – but in Africa less than 1 per cent of woodfuels are waste-based fuels.[vi, 11] Waste-based fuels are principally used in the industrial sector: energy generated from burning waste is fed back into industrial processes.[1] It is also possible to utilise waste products for energy consumption in local households and businesses. Fuels made from organic wastes may be solid, liquid or gas – briquettes, waste-based biofuels, and biogas.

4.3.1.1 Briquettes

Briquettes are solid blocks of fuel made out of materials like sawdust, agricultural residues, waste paper and packaging (see Box 8). The material is shredded, compressed into blocks, and dried out or carbonised (similar to charcoal) before being sold. The advantage of briquettes is that they can be easily substituted for fuelwood or charcoal: they are very similar in function, and can be used in ordinary cooking stoves. Consumers do not have to learn to cook in a new way to use briquettes, but some are sceptical that they are better than charcoal, or that they will even work.

Some claim to have a higher calorific content than charcoal, meaning that they contain more potential energy, as well as producing less smoke, although one World Bank report states that many briquettes have lower calorific content than charcoal.[7] The rapidly rising price of charcoal means that briquettes are becoming much more competitive in some cities. In Dar es Salaam, Tanzania, briquettes from two separate companies (East Africa Briquettes Company and the Appropriate Rural Technology Institute) were reported in consultations to be less than the price of a bag of charcoal in comparative terms. Kampala Jellitone Suppliers, a briquette manufacturer in Uganda, claimed that its briquettes were almost a third of the current street price of charcoal for the potential energy.

vi Estimates for 'waste-based fuel' only seem to include 'black liquor', which dominates the wood/biomass fuels sector in developed countries.

Biomass briquettes look like a promising technology: they seem to have the potential to compete with charcoal on price, convenience, and safety, making them good candidates to substitute for charcoal. Substituting for fuelwood consumption in rural areas, where fuelwood is usually collected for free, may be more difficult, but agricultural waste for making briquettes is abundant in rural areas, and if they can be made more efficient than fuelwood then people might make the switch.

KJS Ltd in Kampala transforms mountains of agricultural waste into high-energy briquettes, which can substitute for charcoal.

4.3.1.2 Waste-based liquid fuels

The growing interest in biofuels centres on the large-scale cultivation of crops to produce fuels for the transport sector, and primarily the transport sector in developed countries. But biofuels can also be made from secondary sources (wastes) that are outputs from agricultural and industrial processing, and can potentially provide sustainable energy for households and businesses. One example is a project by the Gaia Association, an Ethiopian NGO, to make ethanol from molasses, a by-product of sugar processing, and to distribute stoves that can use the material.[74]

4.3.1.3 Biogas

Biogas plants use bacteria to transform organic waste – manure, sewage, food waste – into methane and carbon dioxide, which can then be used to generate heat, lighting or electricity. Waste is piped into an oxygen-free chamber, which allows bacteria to begin anaerobic digestion. Biogas plants come in many different forms: small, household-scale plants, usually made out of a plastic bag or drum, generate enough heat from food waste and manure to provide for cooking needs; very large multi-chamber plants, often made out of brick and buried beneath the ground, can process massive volumes of waste, such as sewage from hospitals, or manure and crop residues from large farms.

Biogas plants can help mitigate greenhouse gas emissions by reducing reliance on woodfuels for energy, and also capture gases (including methane) that are released by sewage and rotting organic waste and burn them to provide energy.

Box 8: Case study: Kampala Jellitone Suppliers Ltd

Businesses, institutions and industry consume only 10 per cent of all woodfuels in Africa, according to the FAO, but a single bakery or school will use far more fuelwood and charcoal every day than a single household. Targeting these sectors could be a good way to leverage a positive impact for forests. Kampala Jellitone Suppliers (KJS) have produced briquettes for large-scale consumers in Kampala since 2000. All sorts of organic wastes can be turned into briquettes: KJS mostly use husks from coffee, rice, wheat and groundnuts, and sawdust when available. Farmers usually burn off wastes following the harvest, so it is very low-cost, even following collection and processing.

KJS currently produce 5 tonnes of briquettes a day, which they claim could be avoiding the use of up to 6 tonnes of wood, or 1.5 tonnes of charcoal. They estimate that their output avoids 3,000 tonnes of CO_2 a year. This is a small percentage of Kampala's consumption of woodfuels, but KJS aims to grow, and the demand from clients and availability of waste seems to be there. They are looking for funding to expand, principally by upgrading from a homemade drying machine to an industrial drier at the cost of $50,000.

An example from Africa is the **Kigali Institute for Science, Technology and Management (KIST)** in Rwanda. KIST won an Ashden Award for Sustainable Energy in 2005.[75] KIST installs large-scale biogas plants in prisons around Rwanda. The large amount of sewage that is created by the prison every day is redirected into the biogas plants, solving a serious waste problem and sharply reducing the prison's use of woodfuels for cooking and heating.

Unfortunately, the distribution of biogas across Africa appears to be poor, compared to some other regions of the world (such as Asia), despite the fact that there are many organisations (NGOs, business, development agencies) working to promote biogas across the continent. **Biogas for Better** Life is a collaboration between about 20 development agencies, NGOs, businesses and research institutions to promote biogas across Africa.[76] It is currently working in 22 countries, although as of mid-2008 only one was at the implementation stage in one country (Rwanda).

Some consultations noted that high costs made biogas prohibitive for most households, but others argued that the money saved from not buying woodfuels, especially with the price of charcoal growing in some cities, meant that biogas plants could pay for themselves within a couple of years.

Other challenges to scaling up biogas may be poor consumer awareness, and the state of the agriculture sector (millions of small-scale farms spread over vast areas of land with high transport costs), which means that suitable waste is not concentrated in large amounts.

4.3.2 Cultivated biofuels

The expansion of agricultural land for the cultivation of biofuels can result in the loss of forests, woodlands, wetlands, and other land carbon sinks (see the **Agriculture** chapter). Biofuels are relevant here because they are also promoted as a way of preserving land carbon sinks: biofuels companies, African governments and NGOs argue that cultivated biofuels may reduce reliance on woodfuels in tropical African countries, thereby reducing deforestation and degradation.

This argument looks weak. *Jatropha*, for example, has been grown on small farms in several sub-Saharan African countries for a number of years for local consumption. Farmers plant *Jatropha* to form dense hedges around food crops to shelter them from wind and rain, and the inedible plants also keep grazing animals at bay. Most large-scale biofuel projects appear to be focused on biofuel exports, however.[77] Furthermore, the area of land required to produce enough biofuels to make a substantial contribution to total energy supply would be considerable, potentially leading to forest conversion or biofuels displacing farmers growing food into forest areas.[78]

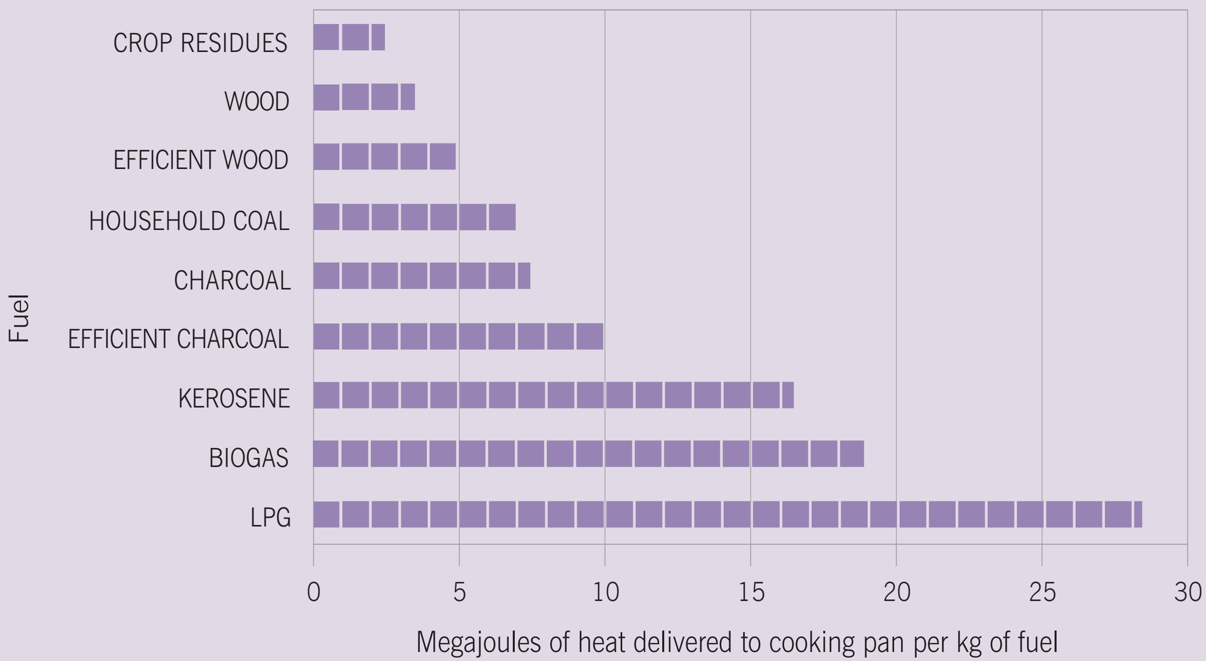
Domestic and institutional scale biogas digesters. The one on the left is at Tanzanian Traditional Energy and Development Organisation (TaTEDO) in Dar es Salaam; the second is from Kigali Institute for Science, Technology and Management (KIST).

4.3.3 LPG

Liquid petroleum gas (LPG) is used for cooking and lighting. LPG is a relatively expensive fuel, and using it requires an initial upfront investment to buy the gas bottle and cooking stove, so in many countries its use is largely limited to wealthier urban households, who often use it in conjunction with woodfuels.[79] LPG is believed to be the most energy-efficient cooking fuel (excluding electricity) available in developing countries (see Figure 2).

FPAN
KEY MESSAGES
ABOUT THE REPORT
CHAPTER 1
CHAPTER 2
CHAPTER 3
CHAPTER 4
CHAPTER 5
CHAPTER 6
CHAPTER 7
CHAPTER 8

Figure 2: Megajoules of heat delivered to cooking pan per kilogram of fuel



Source: Adapted from World Bank, *Rural Energy and Development: Improving Energy Supplies for 2 Billion People*.[80]

Some governments in tropical Africa have tried to promote the widespread adoption of LPG by lowering import taxes and subsidising gas bottles and stoves, with mixed success. In some cases, dropping the price of LPG below that of charcoal (thanks to government subsidies) has not been met by a take up of LPG: many people maintained a preference for charcoal because of non-economic reasons: eg, familiarity, the taste of food cooked with charcoal. In the short term at least, LPG is probably only a candidate for woodfuels substitution in urban areas, where families are more integrated into the cash economy and distribution challenges can be overcome. Charcoal prices are rapidly increasing in some cities. Where this trend is evident, LPG may become more competitive over time. LPG supply chains in rural areas are unreliable and very limited, and rural families are much less likely than urban to pay for energy when fuelwood can be collected for free.[79]

4.3.4 Kerosene

Kerosene (paraffin) is also a petroleum-based fuel. Like LPG, kerosene is transportable in bottles and can be used for cooking and lighting.[79] Kerosene is cheaper than LPG, and can be found in urban and rural areas, but the price still puts it beyond the reach of many families. Kerosene has some characteristics that have discouraged its use – it can have a bad smell, which also affects the taste of food; it can be polluting, and highly dangerous if used or stored improperly.[81] These problems can largely be solved by using pressurised bottles, but these cost more. Because of concerns about safety, the Household Energy Network (HEDON), a UK-based online portal for information on energy in developing countries, argues that kerosene should not be promoted as a household fuel except in special circumstances – for example, refugee camps where access to woodfuel resources is very poor.[79]

4.3.5 Solar cookers

Solar cookers harness the power of the sun to cook food, by concentrating large amounts of light onto a pot. Solar cookers come in a wide variety of shapes and sizes, and are made out of all sorts of materials. **Tanzanian Technology for Environment and Development Organisation (TaTEDO)** is promoting a 'parabolic' solar cooker that resembles a wide satellite dish, about 1.5 metres across, made from blades of reflective metal.

The metal blades reflect the sun's rays and concentrate them on a pot, which is held above the middle of the dish by a metal frame. Other solar cooker designs include boxes with reflective panels, and they can be made out of mirrors and cardboard.[82]

Despite the savings made on fuel, the distribution of solar cookers appears to be quite poor. One issue is awareness: humans have been cooking with wood for tens of thousands of years, and a degree of education is required to convince people that cooking can be done without it.[82] Another is practicality: solar cookers are limited by when and how they can be used: cooking must be done outside, during the day, with moderate sunlight. Cost also appears to be a barrier: Practical Action reports that durable, efficient designs can cost less than $50, but this is still prohibitive for many rural people.[82] As with other fuels, high costs are especially off-putting in areas where abundant woodfuels are freely available from local forests and woodlands.

Solar cookers may be more appropriate in dry and semi-dry areas where woodfuel resources are less available, particularly where high population densities, such as in refugee camps, have depleted woodfuel resources.[82]

4.3.6 Renewable electricity generation

Electricity currently meets less than 5 per cent of total energy demand in sub-Saharan Africa.[83] Hydroelectricity provides most of the electricity in sub-Saharan Africa (excluding South Africa), followed by coal. Some of the largest hydroelectricity dams are found on the Congo River in the DRC. Two large dams were constructed on the Congo at Inga, during the rule of Mobuto Sese Seko, although they operate well below capacity due to poor maintenance. Two more dams are planned; one, called the Grand Inga dam, would be roughly twice the size of the Three Gorges Dam in China in terms of electricity generation (40,000 megawatts).[84] Some countries, like Ethiopia, Kenya and Tanzania, have also announced plans for large wind farm projects.[85]

Decentralised and 'off-grid' electricity generation may have greater potential in reaching more people in tropical African countries, rather than expanding national electricity grids, which entail prohibitively expensive connection fees for most households and businesses. In consultations in Uganda we encountered interventions involving small hydroelectric projects. Consultations in Uganda found some strong support for mini-hydro (small) and pico-hydro (very small), which could produce enough electricity for 100 to 5–20 houses, respectively.

The Intermediate Technology Development Group (ITDG) has installed very small 'pico hydro' for communities living on Mount Kenya. The power plants generate electricity for lighting, radios and mobile phone charging. Pico hydro does not generate enough energy for cooking, however.

Courtesy of Ashden Awards

Biomass (wood and agricultural wastes) can also be used to generate electricity. One person consulted in Kampala claimed that harnessing the power of agricultural wastes across Uganda could generate up to 5,300MW (the current electricity capacity in Uganda is 400MW).

Decentralised electricity generation can be very expensive, however, and many schemes do not generate enough energy for cooking. Most small-scale hydroelectricity generation is used to power lighting, rather than cooking.

4.3.7 Energy alternatives must be competitive

Fuel alternatives must be able to compete with woodfuels if they are going to replace them. The widespread, voluntary adoption of fuel alternatives will be much more likely if consumers perceive them to be better than woodfuels, in terms of price, availability, convenience and safety.

Fuels that are much more expensive than fuelwood or charcoal are at an obvious disadvantage. High prices put many alternative fuels beyond the reach of most households in tropical Africa.

Multiple people reported to us that briquettes could be bought in Dar es Salaam at half the price of charcoal; other energy sources, like solar cookers and biogas, have very low running costs but high upfront costs. Many fuels are simply unavailable, especially in rural areas – examples are LPG and biogas – or are hampered by unreliable supply, such as electricity.

Fuels that save time and labour, are clean and easy to use, and fit well with established cooking habits have an advantage. Briquettes are a good example. Solar cookers, on the other hand, are at a disadvantage because of their limited practicality. Finally, the perceived safety and health of energy alternatives is a big draw card: fuels that produce less smoke than woodfuels have an advantage. Flammability is another safety concern: kerosene can be highly dangerous if poor equipment is used.[79]

5. Scenario: the impact of efficient stoves and woodfuel plantations at scale

The sections above refer to a range of reported estimates on the emissions reductions that can be obtained from improved fuelwood and charcoal stoves, and examples of the plantation areas that are needed to produce significant quantities of woodfuels as an alternative to unsustainable wood harvesting in Africa's tropical forests. The information is valuable but not unified, and it is difficult to assess how the factors would interrelate in a large-scale operation. Yet understanding the potential impacts is critical for donors and funders who want to support stoves and plantations, or support sustainable harvesting practices.

Below, we describe the results of a modelling exercise that explores what would be required to source the fuelwood and charcoal needs of a country (Kenya) and a city (Kinshasa) from sustainable plantations, using the most efficient available stoves. The model makes many assumptions, and the results need to be interpreted with caution.

5.1 Synopsis

Scaling up the dissemination of improved stoves and establishing fast growing tree plantations to a large scale could potentially avoid the need to harvest millions of tonnes of natural tropical forest wood for energy every year. This could represent a substantial benefit for forest protection. From a donor's perspective, a number of questions naturally arise about the implications of taking these interventions to scale:

- How many stoves would actually be needed to reach every household in a particular country or city?
- How many hectares of fuelwood or charcoal plantations would be needed to supply a city or country with 100 per cent of their woodfuel needs?
- What would be the impact of achieving this, in terms of annual woodfuels consumption, or the amount of forest saved?

Representing any reduction of the amount of fuelwood or charcoal consumed in terms of hectares of forest 'saved' is inherently difficult and even controversial. While much of the literature on woodfuels and forests does suggest that it would be incorrect to assume that *all* woodfuels are taken from forests,[27, 30-32, 86] it also appears widely accepted that the vast majority of wood that *is* taken from Africa's tropical forests is used as fuel – over 80 per cent of all wood according to the FAO.[2]

In order to represent woodfuels savings in terms of forest area, we pose the question: 'How many hectares of forest would be required to grow enough woodfuel every year to meet demand?' So for example, as semi-dry forest (as found in parts of Tanzania and Kenya) grows at an estimated rate of 2.5 tonnes of wood per hectare per year, 1 million hectares would be required to meet a fuelwood demand of 2.5 million tonnes.[vii]

We calculated the implications of scaling up improved stoves and woodfuel plantations for two case studies: Kenya's rural population, which is predominantly reliant on fuelwood; and the population of Kinshasa, capital of the DRC, where charcoal is the principal energy source. Each represents different scales of demand, different kinds of woodfuels and different types of forest. The examples are illustrative: the model could be applied to any other country or city across tropical Africa where woodfuel demand is significant.

Assumptions about the potential fuel savings for improved stove designs are based on two of the most common designs used in tropical Africa: for fuelwood, the **mud Rocket stove**, and for charcoal, the **Kenyan Ceramic Jiko** (popularly known as the KCJ). Both designs appear to have been successful in terms of uptake by households, as discussed earlier in the chapter.

vii For the purposes of this exercise, it is assumed that the amount of wood harvested from each hectare of forest is no greater than the amount of wood that grows each year ('sustainable harvest').

FPAN
KEY MESSAGES
ABOUT THE REPORT
CHAPTER 1
CHAPTER 2
CHAPTER 3
CHAPTER 4
CHAPTER 5
CHAPTER 6
CHAPTER 7
CHAPTER 8

5.1.1 Kenya

Kenya's rural population of about 30 million people[57] consumes an estimated 17 million tonnes of fuelwood every year. Per capita consumption is estimated at 550 kilograms per person – this is equivalent to almost fifteen acacia trees in a plantation (on a 10-year rotation). Growing this much fuelwood every year from Kenya's expansive semi-dry forest would require a huge area of land.

Growth rates for semi-dry forests and savannah across tropical Africa range from 0.06 to 2.6 tonnes per hectare per year.[8, 87, 88] If we assume an average of 1.7 tonnes per hectare per year, this means that meeting rural Kenya's current fuelwood demand would require sustainable harvest from **9.8 million hectares of forest**. This is over twice the size of Kenya's forest area according to the FAO. This could suggest that levels of woodfuel harvest are unsustainable, and also that in reality a large proportion of woodfuels in Kenya do not come from forests.

To market mud Rocket stoves to every single household in rural Kenya would require over 6 million stoves (one for each household) – or roughly 3 million a year, as the stoves need replacing every 2 years on average. Achieving this could potentially cut fuelwood consumption by up to half, to **8.4 million tonnes a year; this is equivalent to the yearly growth of 4.9 million hectares of semi-dry forest.** In terms of CO_2 emissions, this intervention could reduce gross emissions by 15MtCO_2 a year.[viii]

Kenya's current fuelwood demand could be met by plantations, by planting acacia trees on about **2.2 million hectares of land**. Acacia plantations can be much more productive than semi-dry forests, with a range of 0.6–15 tonnes of woody growth per hectare per year (we assume an average of 7.7 tonnes).[89] Marketing mud Rocket stoves to every household could reduce this to 1.1 million hectares. **This land area is approximately 10 per cent of the area of semi-dry forest required under current conditions.**

5.1.2 Kinshasa

Kinshasa has a population of about 8 million people. Data on the amount of charcoal used by Kinshasa's residents is very poor, but one estimate suggests it is around 120 kilograms per person per year. Using traditional earth kilns to make this much charcoal would require about 1.2 tonnes of wood – equivalent to up to 30 eucalyptus trees on a plantation (on a three year rotation). This would mean that meeting charcoal demand for the entire city consumes about 9.5 million tonnes of wood every year (assuming traditional earth kilns are used).

The forest-savannah landscape of south-east DRC is a major source of charcoal for Kinshasa. It has a mosaic of different types of vegetation, from savannah to semi-dry woodland, to patches of rainforest. For this scenario we assume a rate of forest growth in this region of 5.3 tonnes per hectare.[88] On the basis of this figure, growing 9.5 million tonnes of wood for charcoal every year for Kinshasa from this region could therefore require about **1.7 million hectares of forest**.

Reaching every household in Kinshasa with improved charcoal stoves would require 1.25 million stoves. KCJs can reduce fuel consumption by about 33 per cent. Equipping every household in Kinshasa with KCJs could therefore reduce the amount of wood used for charcoal every year by over 3 million tonnes. **This represents the annual growth of half a million hectares of forest, and gross emissions of 5.8MtCO_2**.

Kinshasa's current annual charcoal demand could be met by establishing acacia plantations over about **600,000 hectares**. If the dissemination of improved charcoal stoves throughout Kinshasa were 100 per cent, the plantation area required would shrink to **410,000 hectares**. **This is about a quarter of the area of tropical forest that would be required to produce the same quantity of charcoal**.

viii Calculations of emissions savings in this scenario are obviously crude, and do not take into account the many uncertainties noted earlier in this chapter (see Box 2), which make such calculations difficult – for example, that a proportion of woodfuels (especially fuelwood) is harvested from outside forests, and that a proportion may grow back. These figures are only meant to be indicative.

FPAN
KEY MESSAGES
ABOUT THE REPORT
CHAPTER 1
CHAPTER 2
CHAPTER 3
CHAPTER 4
CHAPTER 5
CHAPTER 6
CHAPTER 7
CHAPTER 8

Forest area potentially avoided from exploitation by scaling up improved stoves and woodfuel plantations

Table 3: Kenya

Proportion of rural households using improved fuelwood stoves	Proportion of woodfuel supply coming from plantations					
	1,000 ha	0%	10%	25%	50%	100%
0%	Plantation area required	0.0	217	543	1,087	2,173
	Equivalent forest area 'saved'	0.0	984	2,461	4,921	9,842
10%	Plantation area required	0.0	206	516	1,032	2,064
	Equivalent forest area 'saved'	492	1,427	2,830	5,167	9,842
25%	Plantation area required	0.0	190	475	951	1,901
	Equivalent forest area 'saved'	1,230	2,092	3,383	5,536	9,842
50%	Plantation area required	0.0	163	407	815	1,630
	Equivalent forest area 'saved'	2,461	3,199	4,306	6,152	9,842
100%	Plantation area required	0.0	109	272	543	1,087
	Equivalent forest area 'saved'	4,921	5,413	6,152	7,382	9,842

Table 4: Kinshasa

Proportion of urban households using improved charcoal stoves	Proportion of woodfuel supply coming from plantations					
	1,000 ha	0%	10%	25%	50%	100%
0%	Plantation area required	0.0	61	153	306	613
	Equivalent forest area 'saved'	0.0	178	445	891	1,781
10%	Plantation area required	0.0	59	148	296	593
	Equivalent forest area 'saved'	59	232	490	920	1,781
25%	Plantation area required	0.0	56	140	281	562
	Equivalent forest area 'saved'	148	312	557	965	1,781
50%	Plantation area required	0.0	51	128	255	511
	Equivalent forest area 'saved'	297	445	668	1,039	1,781
100%	Plantation area required	0.0	41	102	204	409
	Equivalent forest area 'saved'	594	712	891	1,187	1,781

Legend: Plantation area required (white rows)
Equivalent forest area 'saved' (shaded rows)

5.1.3 Costs and pricing

In this scenario we have not analysed the range of financial costs. Costs are highly variable and influenced by a number of factors, including the business model used, country of operation, and the specifications of the stove model. Donors could help disseminate improved cooking stoves by giving a manufacturing business a loan to mechanise production, or subsidise the distribution of free stoves to refugee camps, for example. Each business model implies a different set of costs for labour (programme staff, factory workers), capital investment in machinery, tools or other materials, and other programme costs.

One indicative figure for the cost of establishing and managing woodfuel plantations comes from a timber plantations project in Uganda, the Sawlog Production Grant Scheme. This project reports that the cost per hectare of establishing a timber plantation (first two years of rotation) is about $700.[90] Costs may be very different in other countries, depending on land prices, labour costs, and the availability of quality seeds, fertilisers and other materials. Start-up and management costs may also be different for woodfuel plantations: lower perhaps because maintenance requirements are not as high for woodfuels as for high quality timber.

5.2 Donor support is valuable at all scales

Equipping every single household with improved cooking stoves and sourcing all woodfuels from sustainable, managed sources such as plantations should be two priority goals for donors in the woodfuels sector. Scaling up these interventions may face a number of environmental, social and economic challenges, but donors should not be put off by the enormity of this task: incremental progress toward increasing the 'sustainability' of woodfuels supply chains could still have a substantial impact on reducing levels of consumption and the pressure on forests.

Table 3 and Table 4 show the potential impact that scaling up improved stoves and plantations could have on reducing woodfuels consumption, expressed in terms of the forest area required to produce the required amount of wood per year. The tables also show that the plantation area required to meet a proportion of demand shrinks as the use of improved cooking stoves increases.

5.3 Interventions must be combined to be properly effective

A variety of interventions are possible but their effectiveness will depend on how efficiently they are used in combination. Offsets could work very effectively with EIAs, for example, but, equally, if implemented wrongly, could undermine them and create even greater damage. Focusing on urbanisation might bring some benefits in the long run but also significant short-term damage. The obvious opportunities for donors and funders, therefore, are not numerous but they do exist and are credible options.

6. Conclusions

Eighty per cent of wood removed from tropical Africa's forests is used as woodfuel. Human population growth across sub-Saharan Africa and increasing use of charcoal in cities and towns are intensifying the impacts.

Woodfuel consumption is high for a number of reasons. Most modern energy technologies, such as electricity, LPG and biogas, remain unaffordable for the majority of Africans; many are simply unavailable, especially in rural areas. Traditional cooking stoves and charcoal production methods are highly inefficient, and improved designs that reduce the amount of wood required have not achieved significant market penetration in most countries in the region.

In an ideal world it would be possible to move directly from this state of play to a low carbon energy economy, powering homes and industry from large-scale solar, wind, wave and hydro sources right across the continent. But this vision of a truly sustainable energy future for Africa seems beyond reach, at least for the next few decades. In the short and medium term, sustainably sourced wood and biomass-based energy is one of the best available intermediate technologies.

For all of these reasons, reducing woodfuel consumption should be a top priority within strategies that seek to protect and restore Africa's tropical forests. Some donors and funders are already active in this area, but more finance and engagement is needed to achieve greater scale and impact. There are three approaches that provide donors and funders with huge opportunities.

6.1 Efficient cooking stoves

Low-cost stove designs that can halve the amount of fuel required to cook a meal are being promoted by NGOs, development agencies and small businesses in some countries. While most current stove production and distribution operations are small, some are serving hundreds of thousands of households, and there is no doubt that market penetration could be dramatically scaled up, both in rural areas and cities.

The core of the opportunity is that the products are affordable: many stoves sell for as little as $2, although keeping prices at this level may require some degree of subsidy. Identifying talented and committed entrepreneurs, building distribution channels and providing finance through a mix of philanthropic grants, microfinance and other instruments are likely to be the biggest challenges.

6.2 Establishing woodfuel plantations

Plantations can be enormously productive on a per hectare basis, especially if fast growing species are used. The outputs can serve a range of purposes, including fuelwood, charcoal, pulpwood for paper and other materials, poles and other timber products. Wood waste can be converted to briquettes and pellets. In some cases, woodfuel plantations can be adapted to incorporate food crops between planted trees (agroforestry). This would reduce the amount wood energy produced per hectare, but could help meet growing energy and food needs at the same time.

Donors and funders should focus on meeting urban demand for charcoal. The large-scale plantation model has been successfully demonstrated, but only in a few cases. Donors with strong business expertise and the stamina to contemplate multi-year involvement could make a very significant difference, perhaps by targeting the transformation of woodfuel consumption in a major city.

6.3 Going to scale

As our scenario shows above, stoves and plantations are complementary. Kinshasa's 8 million inhabitants could reduce wood harvest for charcoal by over 3 million tonnes a year by switching to more efficient charcoal stoves. Our preliminary calculations estimate that this wood could be sustainably sourced from over 410,000 hectares of acacia plantations sited around the city, a far better alternative than obtaining the same amount of wood from the annual growth produced by natural forests. For comparison, we calculate that around 1.7 million hectares of the forests around Kinshasa would need to be sustainably harvested each year to meet charcoal demand.

6.4 Promoting alternatives to woodfuels

While many millions of people across tropical Africa are likely to remain reliant on woodfuels for the foreseeable future, alternative energy sources are available in some places and contexts. They need to be price competitive, convenient, safe, and available for consumers to voluntarily switch from woodfuels. Donors and funders could help by supporting businesses and NGOs to scale up their production and distribution of alternatives, or by funding marketing or public education campaigns to raise consumer awareness about the products.

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