Energy for Sustainable Development 17 (2013) 75–85

Contents lists available at SciVerse ScienceDirect

Energy for Sustainable Development

Review

Dispelling common misconceptions to improve attitudes and policy outlook on charcoal in developing countries ☆

Tuyeni H. Mwampamba [a,*], Adrián Ghilardi [b,c], Klas Sander [d], Kim Jean Chaix [e]

[a] Centro de Investigaciones en Ecosistemas (CIEco), Universidad Nacional Autónoma de México, antigua carretera a Pátzcuaro 8701, Morelia, Michoacán 58190, Mexico
[b] Centro de Investigaciones en Geografía Ambiental (CIGA), Universidad Nacional Autónoma de México, antigua carretera a Pátzcuaro 8701, Morelia, Michoacán 58190, Mexico
[c] School of Forestry & Environmental Studies, Yale University, 195 Prospect Street, New Haven, CT 06511, USA
[d] World Bank 1818 H Street, N.W.10 Washington, DC 20433, USA
[e] The Charcoal Project, 378 Clinton Street, Ste. #1, Brooklyn, NY 11231, USA

ARTICLE INFO

Article history:
Received 22 December 2012
Revised 6 January 2013
Accepted 7 January 2013
Available online 14 February 2013

Keywords:
Biomass energy
Charcoal
Energy policy
Fuelwood
Misconceptions
Woodfuel

ABSTRACT

The production, use and trade of charcoal for domestic cooking and heating are characterized by contradictions, stereotyping, and misconceptions. Partial information, over-generalizations, and the tendency to consolidate charcoal with other biomass fuels have contributed to gross misrepresentation of charcoal in terms of its actual impact on forests, its role in improving energy access, and in appropriate interventions. An underlying and often amplifying challenge that results from this situation is the lack of reliable, consistent, and comparable data on the charcoal sector which would form a necessary baseline for robust decision making. Further, clarifying misconceptions and debunking of myths is paramount for demonstrating the contribution that charcoal could have in addressing energy access and economic challenges in developing countries. We present five commonly held myths about charcoal that are perpetuated by different stakeholders and actors in the sector. Namely, that: 1) Charcoal is an energy source for the poor; 2) charcoal use is decreasing; 3) charcoal causes deforestation; 4) the charcoal sector is economically irrelevant, and; 5) improved charcoal cook stoves reduce deforestation and GHG emissions. Using a review of the literature and our own experience with charcoal research and practice, we propose reasons for the existence of these myths, why they are highly disputable, and the consequences that the myths have had on policy and intervention responses to charcoal. Widespread beliefs of these myths have and continue to misguide policy response and intervention approaches relating to charcoal. We propose some policy and research recommendations to curb further perpetuation of misconceptions that have been particularly harmful for charcoal.

Contents

☆ Disclamer: The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the views of The Charcoal Project and the International Bank for Reconstruction and Development/World Bank or their affiliated organizations, Administrators, Directors, Executive Directors or the countries and governments they represent.

* Corresponding author. Tel.: +52 443 322 2772; fax: +52 443 322 2719.
E-mail addresses: tuyeni@cieco.unam.org (T.H. Mwampamba), aghilardi@ciga.unam.mx, adrian.ghilardi@yale.edu (A. Ghilardi), ksander@worldbank.org (K. Sander), jeankimchaix@charcoalproject.org (K.J. Chaix).

0973-0826/$ – see front matter © 2013 International Energy Initiative. Published by Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.esd.2013.01.001

Introduction

Charcoal is the main cooking fuel for millions of households in urban and peri-urban sub-Saharan Africa (IEA, 2009). To a significant but lesser extent, traditional lumpwood charcoal is also used for food preparation in South Asia (e.g. Jayakumar et al., 2009; Larpkern et al., 2011; Metz, 1994; Semple et al., 2010; Sood and Mitchell, 2011), Latin America (e.g. Estevez et al., 2010; Huszar and Bucher, 2001; Masera et al., 2010; Ramos, 1999; Torres, 1997; Xander, 1987) and the Caribbean (e.g. Checo, 2010; Knudson et al., 1988; Lea, 1996; Roth, 2001; Sagawe, 1991; Schneichel and Asmussen, 1998). In this paper, we focus most of our arguments on charcoal use in sub-Saharan Africa, being explicit when addressing other regions.

The production, use and trade of charcoal for domestic cooking are characterized by contradictions, stereotyping, and myths.[i] Partial information, over-generalizations, and the tendency to consolidate charcoal with other biomass fuels have contributed to gross misrepresentation of charcoal in terms of its actual impact on forests, its role in improving energy access, and in appropriate interventions (Fig. 1). At individual country levels policies are often unclear, conflicting, and unsure about the role that charcoal should play to meet current and future energy needs and to reduce energy poverty. In many charcoal-dependent developing countries policies are non-existent. Where they exist, they communicate the use of charcoal as 'traditional' or 'primitive' and as contradictory to development objectives (e.g. Owen et al., 2013-this issue). Improved cook stove programs and fuel switching to 'modern' and 'cleaner' fuels have been the dominant approach for addressing the charcoal 'problem'. Banning of production, trade, and use of charcoal has been enforced in several countries, but due to protests and the lack of viable alternatives, they tend to be lifted soon after they are implemented (Girard, 2002; Mwampamba, 2007; World Bank, 2010; Zulu, 2010).

Policies for addressing charcoal have – for the most part – been insufficient at meeting their objectives (Maes and Verbist, 2012). Rising costs of fossil fuels, accelerating impacts of climate change, and significant shortfalls in meeting energy access goals in the developing world calls for a re-examination of the potential that charcoal holds as a modern, renewable fuel contributing to low carbon development. A definitive fuel switch from firewood to charcoal is occurring today in many developing countries driven, primarily, by rapid urbanization (Girard, 2002; Maes and Verbist, 2012). This is in par with the 'energy ladder hypothesis' which – in its simplest interpretation – predicts that households will switch to increasingly cleaner and more efficient fuels with increase in affluence (Leach, 1992). Indeed, for users of dung, firewood and crop residues, cooking with charcoal can represent a significant upgrade in terms of exposure to smoke, safety, and convenience (Van der Plas, 1995).

Contrary to this hypothesis, however, charcoal users are not upgrading to kerosene, gas or electricity (fuels that are higher up the energy ladder) at the rate or scales expected (Hiemstra-van der Horst and Hovorka, 2008; Hosier and Dowd, 1987). A broader interpretation of the energy ladder hypothesis, however, predicts that with increasing affluence, household diversify the types of fuels consumed and include increasingly more efficient fuels into the mix, a phenomenon referred to as 'energy stacking' (Masera et al., 2000). Thus, for the case of charcoal, the absolute number of charcoal users is increasing even though per capita use may be decreasing due to stacking (Arnold et al., 2006; IEA, 2009). New approaches and ideas are emerging on how to address charcoal (Carneiro de Miranda et al., 2013; Mwampamba et al., 2013; Owen et al., 2013-this issue) but their success depends on flipping around the policy outlook on charcoal while remaining conscious of the limitations and constraints.

A necessary starting point for understanding the charcoal sector today is to clarify misinformation, debunk harmful misconceptions, and identify more appropriate policy responses for the sector. Consequently, two objectives motivate this review. The first is to extract the charcoal story from the more general wood energy one. We argue that the tendency for the energy literature to address charcoal with other biomass fuels and to consolidate charcoal information into ambiguous terms such as 'woodfuels', 'fuelwoods', 'wood energy' or 'biomass energy' has and continues to distort what we know about charcoal, and subsequently what we do about it (i.e. interventions).

Our second objective is to debunk five common misconceptions (or myths) about charcoal that have materialized over time, largely due to the blended approach of handling charcoal data and analyses (Fig. 1), but also for other reasons. We address six myths that we believe are the most influential in either perpetuating negative attitudes towards charcoal or in misguiding interventions. Namely, these are that: 1) Charcoal is an energy source for the poor; 2) charcoal use is decreasing; 3) charcoal production causes deforestation; 4) the charcoal sector is economically irrelevant, and; 5) improved charcoal cook stoves reduce deforestation and GHG emissions. These myths are maintained and perpetuated by stakeholders of the charcoal sector which include – but are not limited to – the energy and forestry sectors, conservation and development organizations, research institutions, and consumers. Debunking these myths is paramount for demonstrating the contribution that charcoal could have in addressing energy access and economic challenges in developing countries.[ii]

Depending on stakeholders' values and objectives and on the information available to them, stakeholders believe or perpetuate these misconceptions differently. Consequently, contradicting myths can exist. We argue that the lack of cohesion over what is believed and not believed about charcoal perpetuates confusion in the sector and contributes substantially to the absence of appropriate policy responses in many charcoal-dependent nations.

We hope that this paper improves current understanding of charcoal as a domestic cooking fuel for developing countries and that it will stimulate adoption of more positive and balanced attitudes towards the sector and subsequently to better informed policies. Further, we hope it inspires more targeted and better designed research on charcoal that addresses and clarifies these and other misconceptions. To this end, we end the review with a list of recommendations for improving policy responses and research on charcoal.

[i] We acknowledge that charcoal is also used for heating, but often in combination with cooking. For the remainder of the paper we refer mainly to the application of charcoal for cooking.

[ii] Although the five myths about charcoal were independently derived, it became clear that most coincided with RWEDP's (1997) list of 14 "Misconceptions about Wood Energy" which addresses 'traditional' biomass in general.

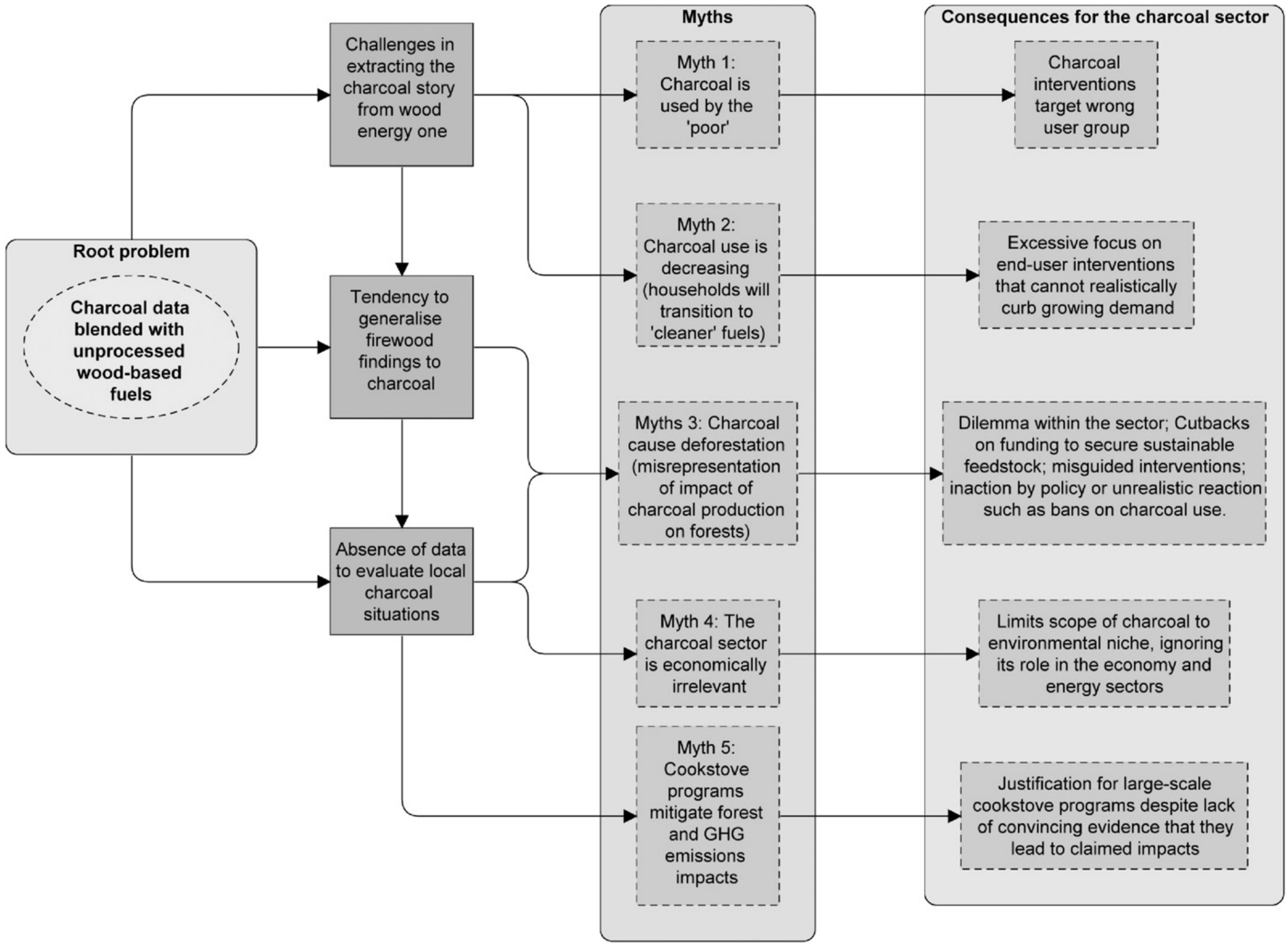

Fig. 1. Flow diagram for understanding how myths in the charcoal sector have emerged from taking blended approaches to addressing the wood energy sector.

Insights into the charcoal sector and recommendations for the sector are based on an extensive literature review that was followed by synthesis of the information obtained. We reviewed scientific papers published in academic journals, project and organizational reports of the United Nation's Food and Agriculture Organization (FAO) and the World Bank, FAO and International Energy Agency (IEA) databases.

Challenges in generating 'facts' about charcoal

Charcoal is not firewood: extracting the charcoal story from the wood energy one

In the 1970s, FAO and World Bank reports consolidated all wood-based fuels into umbrella terms such as 'fuelwoods' and 'woodfuels', probably because at the time urban centers were much smaller and the development focus was predominantly in rural areas. Since then, the term "woodfuel" in the literature has referred to both firewood and charcoal, but sometimes also extended to include use of wood as feedstock for gas, liquid fuel, or electricity production. The term "fuelwood" should only apply to unprocessed woodfuel which includes 'firewood' (FAO, 2004) but 'fuelwood' is often used as a direct substitute for 'firewood' (e.g., FAO, 1983; Dewees, 1989; May-Tobin 2009) which, according to glossary of the Unified Bioenergy Terminology (FAO 2004), is a term reserved to describe "cut and split oven-ready fuelwood used in household wood burning appliances…" (pp. 34).

Occasionally, however, the terms 'woodfuel' and 'fuelwood' are interchangeably used in the literature (e.g., Maes and Verbist, 2012). The confusion of terminology lends itself to overgeneralizations usually by extending interpretation of findings from one wood-based fuel study to other biomass fuels, even if only a single fuel type was studied. A recent effort by FAO (2004) to harmonize terminologies in the bioenergy sector (i.e., Unified Bioenergy Terminology or UBET) proposes a new classification scheme which does not necessarily resolve the issue of separating charcoal from other 'solid woodfuels'.

The decision to consolidate wood energy data has been particularly devastating for charcoal which got lumped together with fuels such as firewood, dung, and crop residues which are interchangeable with one another but not necessarily substitutes for charcoal. Stark differences exist in the physical, chemical, economic, and social characteristics of charcoal relative to other 'woodfuels', particularly when its final use is for residential cooking and heating. Notably, charcoal is a processed wood which requires two important considerations: a) it implies investment costs for the producer (i.e. charcoal is not collected or gathered from a source, and thus b) there is an outlook to commercialize (i.e., it is always sold as a commodity). Further, charcoal is almost exclusively consumed in urban and peri-urban areas. This implies that the charcoal sector constitutes a different set of stakeholders from those of other fuel types. Hence, interventions in the charcoal sector affect a different set of actors from those of the firewood or dung sectors.

Despite notable differences between charcoal and firewood, it is still extremely difficult to detangle the woodfuel story to obtain facts about charcoal. Recent reviews of the woodfuel sector (e.g. Arnold et al., 2006; Maes and Verbist, 2012) continue to tell the firewood and charcoal stories together. As we will demonstrate with the myths, blending of

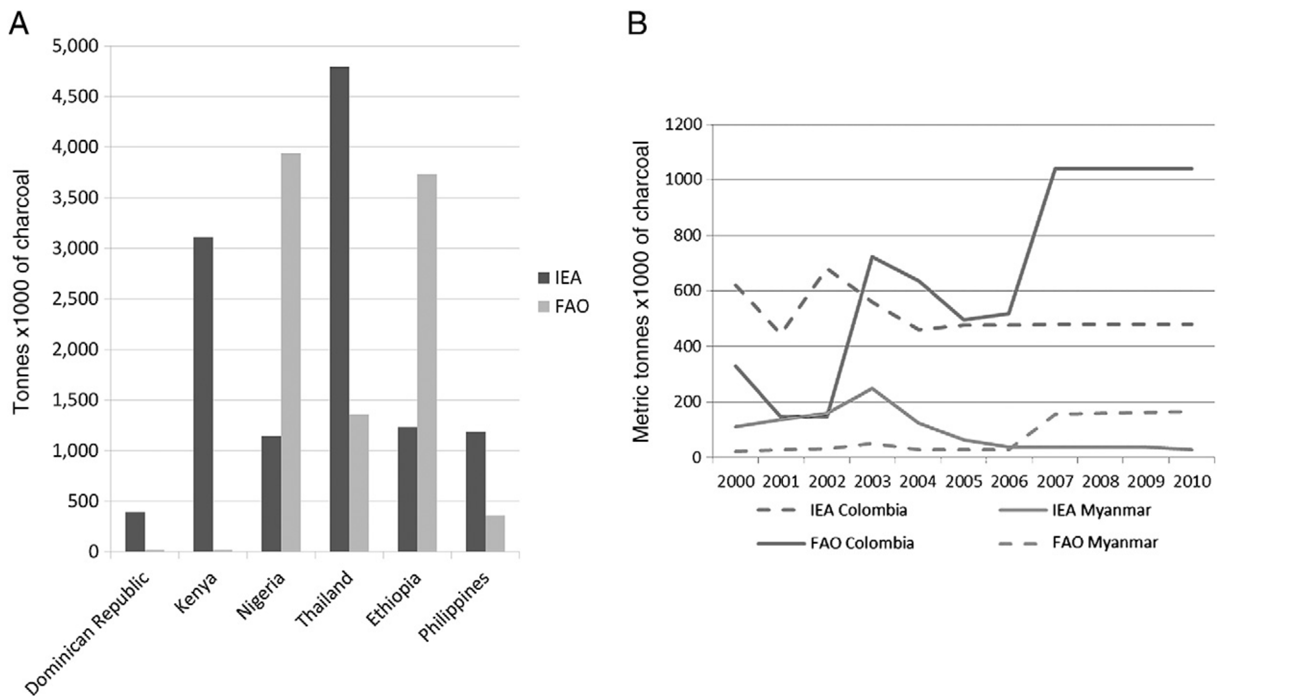

Fig. 2. A: Inconsistencies between IEA and FAO estimates of national charcoal production for year 2010 for selected countries. In some countries IEA estimates are higher, and in others, the opposite is true. The reliability of this data for many developing countries is weak, implying that basing national policies on even an average between the two databases is a potentially dangerous approach. Local assessments will provide much more meaningful data for informing in-country interventions. Note: Please refer to the online Supplementary material for comparisons for all available countries and regions. B: Differences in national charcoal production trends during the last decade between IEA and FAO for Colombia and Myanmar.

charcoal with firewood data has contributed to gross misrepresentation of charcoal in policy, literature and interventions. It also makes it difficult to analyze the impact of charcoal production and use on forest resources and to address issues of sustainability of the sector.

Source of charcoal data

Unlike fossil fuels and electricity, it is rare for the charcoal sector to generate data that capture production and consumption volumes. To a large extent, data scarcity is due to the clandestine nature of production, poor regulation and informality of the sector. Additionally, production is usually conducted by thousands of (mostly) scattered rural producers working independently of a national or regional agenda.

Data on charcoal are usually generated from surveys, which are expensive to conduct (hence, scarcity of data), not always well executed (and thus of questionable reliability), and focus either on consumption or production, rarely both. In the absence of records on production or trade of charcoal, estimates of consumption are often generated by assuming that consumption is equivalent to production without necessarily demonstrating this.

Given the high spatial heterogeneity of charcoal production and use patterns, sub-country extrapolations do not necessarily culminate into sound national estimates. Instead, they can easily produce wrong or misleading estimates. Where attempts have been made to estimate production using transported volumes as a proxy, the difference between recorded and reported figures is enormous. For example, as much as 90% of charcoal transported into Dar es Salaam City, Tanzania went unreported in official records (Norconsult, 2002). Similarly, it is estimated that only 1% of charcoal production in Mexico was reported to authorities prior to 2011 (Masera et al., 2010).

Charcoal databases

Despite data acquisition challenges, databases on country-level charcoal production exist which are constructed from integrating information from various sources and from experts' guesstimates. Two main datasets reporting global, regional and country-based charcoal production, exports and imports (in tons) are available and commonly cited: FAO (FAOStat, 2012) and IEA (IEA, 2012). Definitions of charcoal do not vary substantially between the two organizations. According to IEA, charcoal is listed under solid biofuels and "covers [all] the solid residue of destructive distillation and pyrolysis of wood and other vegetal material", including charcoal briquettes made from non-forest based feedstock. In the case of FAO charcoal is "wood carbonized by partial combustion or the application of heat from external sources". It includes the production of charcoal for other applications such as a reduction agent in metallurgy or as an absorption or filtration medium.

For many countries, however, the FAO and IEA databases do not coincide (Fig. 2). This makes it difficult to discern the reliability of these databases or to deduce whether a charcoal deficiency problem exists, the extent of the problem, and what would be appropriate interventions. Figs. 2A and B illustrate this challenge for selected countries. In any given year (in this case 2010), production volumes can be highly disparate between the two databases (Fig. 2A). Moreover, it is unpredictable which database generates higher values; for Kenya and Thailand, for example, IEA values are several-fold higher than FAO's. In the case of Nigeria and Ethiopia, the opposite is true. Production trends over time are also inconsistent and subsequently, unreliable (Fig. 2B).

Debunking myths and clarifying misconceptions

Myths are popular beliefs that are based on incomplete information or fiction which over time are taken as the truthful representation of a person or institution or sector. Policy responses and interventions that are informed by myths are destined for failure because they most likely over- or under-estimate the real 'problem' — if indeed there is one.

As pointed out earlier, in the case of charcoal, different myths are held by different actors within the sector and it is possible for contradicting myths to exist simultaneously because they are upheld by different stakeholder groups. Depending on their power to influence policies the myths that stakeholders uphold can be harmful for the charcoal sector. For example, Ribot (1995, 1999) has argued on several occasions that the tendency for charcoal forestry departments in West Africa to hold strongly to myths about the deforestation role of charcoal have facilitated the formation of "merchant oligopolies…who collude to create high urban woodfuel prices".

For each of the myths that we address in this paper, we describe its basic elements, our deduction for what perpetuates the myth, the stakeholders upholding the myth, and the implications to policy and interventions. These myths are most pertinent to sub-Saharan Africa where most domestic charcoal consumption occurs and where most studies and analyses on charcoal have been conducted. It is generally accepted that policy interventions in the SSA charcoal sector have been either completely lacking, or slow or inadequate (Maes and Verbist, 2012). Nevertheless, some of these myths are applicable to other regions where domestic use of charcoal exists, albeit at lower volumes.

Myth no. 1: charcoal is an energy source for the poor

Charcoal is often referred as "an energy for the poor" (e.g. Arnold et al., 2006; Wood and Baldwin, 1985) and charcoal interventions often claim that they address the energy needs of 'the poor'. Studies on energy consumption trends, however, consistently demonstrate that the poor — in particular the 'poor of the poor' cannot afford charcoal (e.g., Karakezi et al., 2008; Nansaior et al., 2011; Ouedraogo, 2006). Regardless of how one defines "poverty" (Fukuda-Parr, 2009) charcoal is consumed along a wide range of income categories without a lot of variation in per capita consumption (Karakezi et al., 2008; Mwampamba, 2007). Moreover, the simple fact that charcoal is often reported to be the principal energy source for the majority of urban populations (i.e. above 50%, but often even 70%–80%), automatically implies that consumption encompasses a wide range of socio-economic groups (World Bank, 2011).

We believe that this misconception about charcoal persists partially because charcoal data are combined with that of unprocessed fuels, which indeed are consumed by poor households. Lacking the cash to purchase charcoal, the poorest of the urban poor rely primarily on firewood (Karakezi et al., 2008; Nansaior et al., 2011; Ouedraogo, 2006), obtaining it from building sites, rubble, and peri-urban forests or purchasing it at lower cost than charcoal.

The consequences for perceiving charcoal as an energy for the poor is not thoroughly understood because it has not been sufficiently researched. We offer three hypotheses, however. We suggest that firstly, if charcoal is perceived (by policy makers) as an undesirable fuel that contradicts development objectives because it is associated with poor, 'traditional' or even 'primitive' practices (Owen et al., 2013-this issue) it very likely contributes to the general reluctance by policy to recognize charcoal as a viable fuel to include in policies about achieving long-term energy security. It would also partly explain why the dominant response to charcoal interventions has been to catalyze switches to 'modern' alternatives even if the long term sustainability of such alternatives is questionable or increases dependency on imported fuels (Arnold et al., 2006; Maes and Verbist, 2012). Secondly, in terms of interventions, it may have diverted large resources of funding aimed at 'poverty alleviation' to charcoal users, who are not necessarily poor. Thirdly – and related to interventions that have focused on poor end-users rather than on middle and upper income households – end-use charcoal interventions would have set themselves up for failure by promoting new technologies to those who can least afford them in the long run (e.g.., once subsidies are lowered).

A focus on poor households may have also contributed to overshadowing charcoal use by commercial sectors and institutions (e.g. hospitals, schools, prisons) — which are little accounted for in the literature but are known to consume large and increasing volumes of charcoal (Norconsult, 2002). Small efficiency improvements can represent substantial energy savings to large consumers, enough to encourage a switch with little effort on the part of projects.

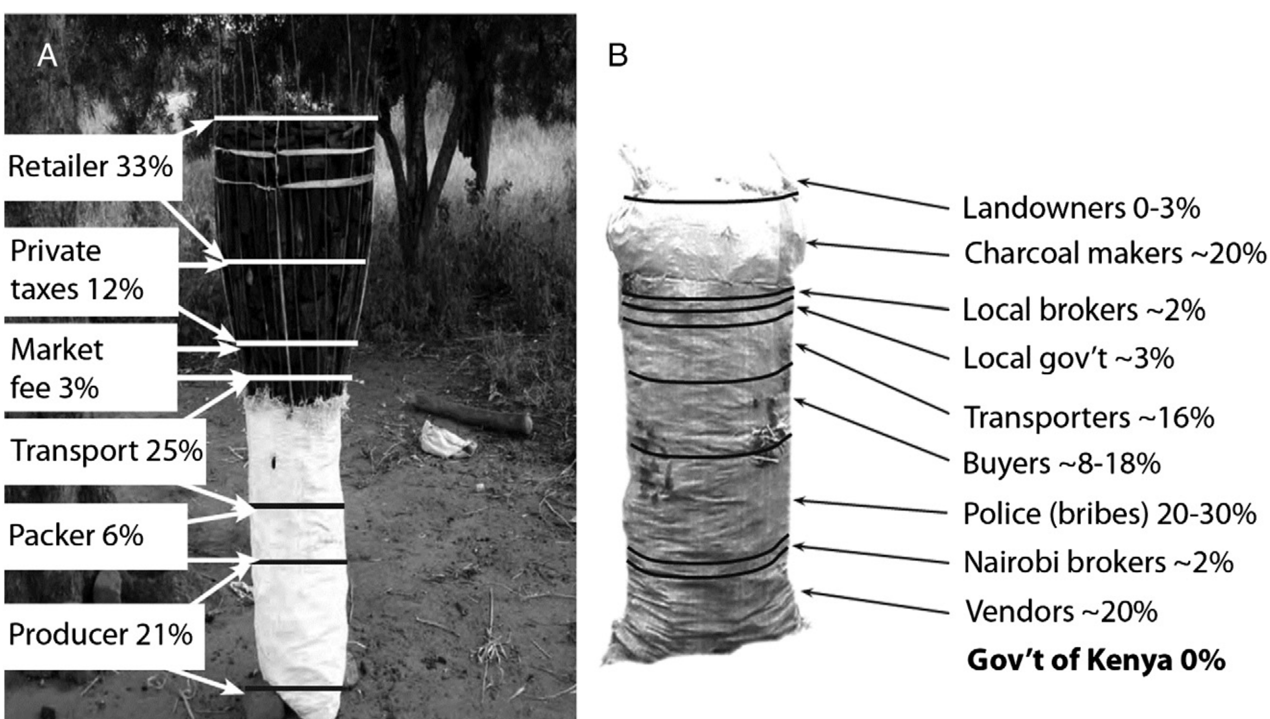

Fig. 3. The proportion of revenue captured by different stakeholders along the charcoal commodity chain in Malawi (A) and Kenya (B). Note how in both cases, the government captures none of the charcoal revenue, yet 12% to 30% is captured by 'private taxes' otherwise known as bribes. Legalizing and regulating the charcoal sector could divert revenue from bribes to government coffers without affecting charcoal prices for consumers [*Rights to reprint from original sources pending*].

Instead, programs have spent enormous amounts of resources relative to success on convincing individual households to switch.

Myth no. 2: charcoal use for cooking will decrease

Contrary to the energy ladder hypothesis (Leach, 1992), which is used in many energy policy agendas of SSA to justify promotion and infrastructure for expanding modern energy access, decrease in per capita use of biomass for cooking with increased urbanization and income has not been demonstrated for many developing countries (Arnold et al., 2006; Masera et al., 2000). Rather, higher income and urbanization are associated with reduction in firewood demand coupled with greater access to alternative fuels, including charcoal (FAO, 2009; Nansaior et al., 2011). Changes in relative price of alternative fuels and the intrinsic growth of cities are also associated with persistent and growing reliance on charcoal. Migration to cities almost always implies a switch from firewood to charcoal consumption (Hosier and Kipondya, 1993; Van der Plas, 1995).

On the one hand, the firewood to charcoal switch reduces exposure to indoor air pollution particularly for women and children (Koyuncu and Pinar, 2007; Smith et al., 2000). However, given inefficient production techniques prevalent in many developing countries, the switch signifies a four- to six-fold increase in per capita wood consumption (Kammen and Lew, 2005; Van der Plas, 1995). Hosier and Kipondya (1993), for example, estimate that a 1% increase in Tanzania's urban population is equivalent to a 14% increase in national per capita wood consumption. Changes in household structures towards smaller households and growth in institutional consumers (e.g., hospitals, schools, prisons) and restaurants all contribute to increased demand.

Increase in demand is also apparent in many developing nations outside sub-Saharan Africa (IEA, 2009). A 1997 household survey conducted in Myanmar among rural and urban households demonstrated that 42% and 4% of urban and rural households, respectively, used charcoal for cooking (Government of Myanmar, 2009). Moreover, although 93% of urban households had access to electricity, only 1.5% used it for cooking; charcoal use remained constant (Government of Myanmar, 2009). In Laos PDR, households continue to rely heavily on woodfuels with charcoal often dominating urban markets. Between 1995 and 2005, the share of households using woodfuels for cooking in Laos declined slightly (from 97% to 94%), but nationally the use of charcoal increased threefold in urban areas (from 10% to 35%). Similarly, Remedio and Terrence (2003) report a decline (from approx. 6% to 3%) between 1992 and 2002 in the use of charcoal as a primary residential cooking fuel in Cebu Province, Philippines. In the same period, however, its use as a secondary fuel increased from 53% to 67%. In Thailand, fuelwood use is expected to be completely replaced by charcoal by 2030 (Thailand, undated).

Myths no. 3: charcoal production causes deforestation

Charcoal is usually produced using inefficient kilns (e.g. Bailis et al., 2005; Pennise et al., 2001) and the production process is routinely associated with deforestation and forest degradation (e.g. Ahrends et al., 2010; Alem et al., 2010; Chidumayo and Gumbo, 2013; Kutsch et al., 2011; Singh et al., 2010; Zulu and Richardson, 2013) and with high emissions of greenhouse gases (GHGs) (e.g. Bailis, 2009). The deforestation myth is deep-rooted in most developing countries that depend on wood energy, and it has driven intervention and policy response to the sector for the last 50 years. It is a perception that is held by policy makers, conservation organizations, practitioners, and researchers despite the fact that links to deforestation have been rebuked by several studies and reviews since the early 90s (e.g. Benjaminsen, 1997; Chidumayo and Gumbo, 2013; Cline-Cole, 1998; Cline-Cole et al., 1990; Ribot, 1999). Country level bans on production and trade of charcoal are a good example of policy response to reports linking charcoal to deforestation (Ribot, 1999; Zulu, 2010). In practitioners' circles, "ecological" charcoal or "green charcoal" are promoted as charcoal that does not contribute to deforestation.

There are two interpretations of the deforestation myth. First, that charcoal is a primary and direct driver of deforestation and second, that deforestation actually occurs. Most studies of the 1980s and early 90s demonstrated evidence against the first interpretation of this myth: they showed that deforestation was the direct result of other forces, namely agricultural expansion and logging, and that charcoal was merely a by-product of these processes (Hiemstra van der Horst and Hovorka, 2009). We are by no means discrediting studies that demonstrate a direct deforestation–charcoal link. The myth is to assume that the observed deforestation as a) a country- or region-wide phenomenon, and b) the inevitable outcome in charcoal producing areas, a claim that cannot be made without sound spatiotemporal assessments that acknowledge coexisting and interacting drivers, most notably the conversion of forests for agricultural production, pastoralism, and logging (May-Tobin, 2009).

The driver-of-deforestation misconception persists because it is extremely complicated to quantitatively demonstrate the sustainability or non-sustainability of traditional charcoal production systems. The complex analyses, tools, and methods that would be needed to make one claim or the other are seldom applied. On the same note, it would be equally harmful to claim that charcoal production cannot be a driver of deforestation. Rapid urbanization and the lucrative nature of the charcoal business are strong economic forces that could – by themselves – translate into sufficient motives for large scale forest clearing for charcoal.

The persistence of the other interpretation of the myth – that deforestation in charcoal production areas actually occurs – might be a question of semantics. It is only recently that forest sectors worldwide have begun to make distinctions between the processes and drivers of deforestation versus those of degradation. Deforestation is the long-term loss of forest cover while forest degradation is the temporary removal of all or part of forest biomass (Sasaki et al., 2011); curbing either process requires very different approaches (Skutsch et al., 2011). Charcoal production tends to consist of complete and indiscriminate clearing of all standing biomass (Chidumayo 1993; Castillo-Santiago et al., 2013; Chidumayo and Gumbo, 2013) such that the immediate visual impact is easily likened to deforestation. In many cases, however, these areas regenerate and can sometimes produce subsequent cycles of charcoal (Chidumayo, 1993; Ribot, 1999; Bailis, 2009). Hence, forest degradation rather than deforestation is the more probable outcome of charcoal production. Indeed, there are few who contend with the claim that charcoal production degrades forests.

Myth no. 4: the charcoal sector is economically irrelevant

The contribution of the charcoal sector to the formal economy is small because the sector is largely informal. With the exception of a few countries, the business of producing and transporting charcoal is usually clandestine in nature. The use of charcoal, however, is rarely regulated even when production and transportation are (Minten et al., 2013). Clandestine trade implies high transaction costs in the form of bribes and perceived risk culminating in high charcoal prices at consumer-end and extremely low prices at points of production. The extent to which bribes affect final prices is mostly anecdotal, however, since access to the necessary information can be challenging. Some studies that have quantified 'private taxes' or bribes along the charcoal supply chain indicate that they can represent 12%–30% of the final price paid by consumers (Bailis, 2005) (Fig. 3).

Economic impact of charcoal

Compared to similar – but unregulated – commodities such as agricultural products, transportation and sale of charcoal are lucrative business worth millions of dollars; (Minten et al., 2013; World Bank, 2009). In Rwanda, the charcoal sector is estimated to generate US$77 million annually (Plas van der, 2008) while in Kenya, it is estimated at US

$450 million, equal to the country's tea industry (ESD, 2007). In Tanzania, the total annual revenue generated by the charcoal sector supplying Dar es Salaam is estimated at US$350 million, exceeding sectors such as coffee and tea which are considered drivers of economic development yet contribute merely US$60 million and US$45 million to the national economy, respectively (World Bank, 2009). In Malawi, the market value of traded fuelwood was around US$81 million in 2008 equivalent to about 3.5% of GDP (Openshaw, 2010). The illicit nature of the sector, however, implies that national finance departments capture only a small fraction of the generated revenue in the form taxes on legal components of the trade (e.g. transportation, retail) (World Bank, 2009; Zulu, 2010).

Despite its complex and informal attributes, the charcoal supply chain tends to be highly efficient at meeting demand (Hansfort and Mertz, 2011; Maes and Verbist, 2012). Year-round demand for charcoal generates reliable markets. Consequently, charcoal shortages in urban areas are extremely rare. When they occur, they are almost always singly attributable to government interventions mostly in the form of production and transportation bans or crack downs.

Livelihood impact

The charcoal industry is an important livelihood source and provides income for tens of millions of people in rural and urban areas around the world. Actual estimates of the number of people dependent or participating along the charcoal value chain are best available for SSA. The wood-based biomass sector (which includes but is not limited to charcoal) in SSA employs a significant workforce, generally providing regular income to millions of people. For example, along its full commodity chain, the charcoal sector for Dar-es-Salaam (Tanzania) is estimated to provide labor and cash income in rural and urban areas to several hundred thousand people (World Bank, 2009). In Kenya, it is estimated that about 700,000 people work in the charcoal sector (Sepp, 2008). Studies from Malawi indicate similar trends: Kambewa et al. (2007) estimate that about 100,000 people regularly support their livelihoods through charcoal production, transport, and retailing. Openshaw (2010) estimates that about 133,000 people were employed full-time in 2008 in the biomass supply chain compared to approximately 4600 people employed in the supply chain of other fuels. In Uganda, around 200,000 people depend on charcoal as a permanent source of income (ESD, 2007). Furthermore, involvement of rural households in charcoal production in Uganda is associated with reduced risk (by 14%) that households fall below the poverty line (Khundi et al., 2011).

Extrapolating to the whole of Sub-Saharan Africa rough estimates indicate that the charcoal industry in Sub-Saharan Africa currently provides income and livelihood to seven million people. The International Energy Agency (IEA) forecasts that by 2030 the number of people relying on traditional use of biomass may increase to 918 million (IEA, 2009). Using this as a basis for prediction, the charcoal sector could be the livelihood source of up to 12 million people by 2030.

Myth no. 5: improved charcoal cook stove (ICS) mitigate deforestation and GHG emissions

Although direct interventions in the charcoal sector have occurred along the full supply chain, (i.e., from production areas to domestic cook stoves or furnaces), they have focused (and continue to focus) primarily on demand-end rather than supply-end solutions. There have been many more improved cook stove programs, for example, than there have been kiln efficiency improvement projects or sustainable forest management interventions specifically addressing charcoal production (Mwampamba et al., unpublished data).

Unlike interventions in improved charcoal cook stove (ICS) for firewood – first motivated to save fuel and people's time, and is increasingly more concerned with reducing indoor air pollution and GHG emissions – ICS for charcoal interventions focus primarily on fuel saving. Fuel saving as an intervention objective – it is claimed – leads to two main desired outcomes: 1) reduction in the amount of charcoal used (and thus reduction on impact on forests and GHG emissions), and 2) reduction in the proportion of household income spent on charcoal (i.e. a poverty alleviation or welfare improvement impact). Many existing ICS interventions specifically advertise their interventions as having these objectives. For example, the multiple objectives of the Global Alliance for Clean Cookstoves (GACC) – which addresses many other types of cook stoves in addition to charcoal ones – is to “save lives, improve livelihoods, empower women, and protect the environment” (GACC, 2012). Similarly, one of four justifications for International Lifeline Fund's efficient cook stove program in Uganda is “because it [a traditional cook stove] ravages the environment” (Lifeline Fund, 2012).

The four main contentions with myth 5 is that a) the link to deforestation is doubtful (see Myth no. 3), b) ICS stoves sometimes increase rather than decrease fuel consumption; c) the GHG impact of charcoal stoves is insufficiently understood, and d) the impact on poverty is misguided (see Myth no. 1).

As demonstrated in the previous section (Myth no. 3), it is not guaranteed that the long-term impact of charcoal production on forests is deforestation or even exacerbated forest degradation. In some cases, charcoal production is sustainable, albeit from degraded forests that are managed specifically to produce charcoal (Ribot, 1999; Bailis, 2009). Moreover, negative impact on forests varies over time and space and it is usually not monitored or sufficiently evaluated or well understood whether the charcoal consumed by ICS end-users is from sustainable or non-sustainable sources. The tendency, however, is to assume that sources are unsustainable. ICS programs have been allowed to make claims to having positive effects on forests without necessarily being asked to demonstrate this with local studies. We are by no means suggesting that ICS programs should not be developed. Rather, that they should not make claims to achievements other than those that they actually realize.

It is generally accepted that the adoption of ICS stoves has been below expectations. Findings from recent studies are improving our understanding of why cook stove interventions have done poorly. Hanna et al. (2012) found that household consumption of fuel did not decrease with the adoption of ICS four years after stoves were bought in this particular case partially due to poor cook stove design, but also due to improper use; households ended up consuming the same amount of charcoal. Improper lighting of charcoal and design flaws in combustion chamber can also result in higher charcoal consumption and it can introduce higher levels of indoor air pollution from the smoke generated (Maes and Verbist, 2012). Consequently the claim that households will always reap positive and high benefits from adopting ICS needs reassessment (Jeuland and Pattanayak, 2012). The inability of women to make decisions about household purchases also affects adoption (Mobarak et al., 2012) as does income, education level, and other socio-economic factors.

Due to poor monitoring of charcoal programs, huge gaps exist in our comprehension of households' motivations to own ICS and, once adopted, their response to the stoves. For example, decreased charcoal consumption might encourage households to purchase a second stove to increase overall household efficiency (i.e., increasing capacity to cook), something referred to as the “rebound effect”. Households might decide to boil water when they previously did not; or they might decide to cook more, which are desirable outcomes from a household perspective, but do not necessarily lead to overall fuel savings. Better monitoring of post-adoption behavior is needed to identify whether the rebound effect exists in charcoal stove (and kiln) interventions and to gauge the size of the effect. To date, we are unaware of charcoal interventions that have considered the rebound effect in their calculations of expected impact.

Programs that claim that they achieve reduction in CO2 emissions can usually only do so for end-use emissions since they oftentimes cannot control for the origin of charcoal. There are at least four projects under the voluntary (3) and regulated (1) carbon markets that are

Table 1
Likelihood of an intervention in the charcoal sector to yield a desired impact. Unrealistic and sometimes undemonstrated claims to desired impacts are sometimes made by charcoal projects. They are often based on weak and unconvincing logic, however.

Desired or claimed impact	Intervention: change promoted by intervention							
	Open wood fire to charcoal cookstove	Traditional charcoal stove to energy efficient charcoal stove	Wood charcoal to charcoal briquettes	Charcoal stove to non-fossil fuel based 'cleaner' energy (e.g. solar, ethanol, biogas)	Charcoal stove to fossil fuel based 'cleaner energy (e.g. LPG, kerosene)	Traditional kiln to more efficient kiln	Traditional kiln to retort	Non-sustainable to sustainable feedstock supply (plantations, SFM)
Health benefits (decrease indoor air pollution)	Large potential benefits, especially if charcoal cookstove is used outside or in airy space	Small and unlikely benefits; studies needed to demonstrate the effects of this type of switch	Benefits are highly unlikely: The two fuels are very similar in terms of emission levels (ref.)	Potential for medium to large benefits; especially if charcoal stove was used indoors	Potential for medium to large benefits; especially if charcoal stove was used indoors	Not applicable	Not applicable	Not applicable
Increase household income (due to less income spent on cooking & heating energy)	Very unlikely: charcoal more expensive than firewood; firewood sometimes free	Potentially up to 50% reduction if cooking frequency or amount cooked doesn't change (rebound effect)	Not necessarily; briquettes are often the same price as charcoal. Prices might be kept lower as an incentive to switch fuel types	Highly variable: Unlikely if cost of appliances & maintenance are high; but could reduce long-term costs if alternative fuel is cheaper than charcoal (e.g. solar)	Highly variable: Unlikely if cost of appliances & maintenance are high; but could reduce long-term costs if alterna-tive fuel is cheaper than charcoal	Not applicable	Not applicable	Not applicable
Reduced forest loss or degradation	Highly unlikely: A lot more forest needed to produce charcoal than to produce firewood	Very minor reduction if any: Rebound effect and complex human behaviors indicate weak link	Potentially large if briquettes are widely adopted and completely replace traditional charcoal	Highly variable; life-cycle analysis needed to determine contribution of al-ternative fuel to for-est loss and degradation	Highly likely if charcoal consumption drastically decreases (complete switch away from charcoal unlikely)	Not necessarily; rebound effect could mean that the same amount or more forest is affected; increased income from charcoal could improve efficiency of harvest. Requires coupling with SFM	Highly likely but also variable; co-production of gas or electricity intro-duces additional non-charcoal based income; needs to be coupled with SFM; Unfeasible for small-subsistence producers	Highly likely but will require fast growing trees to ensure continuous supply of feedstock; likely to require plantations rather than rely on natural regeneration of native forests.
Reduction of GHG emis-sions (and thus claims to carbon emission reduction credits)	Reduction of direct emissions at user-end highly likely; however, since char-coal requires more wood, emissions from forest loss and degradation increase; CO emis-sion increase	Theoretically, high user-end reductions pos-sible but unlikely because it re-quires user to maintain same frequency of use as traditional stove, which rarely happens	High reduction is possible especially if waste biomass is otherwise left to rot (high methane emissions); reduction from the decreased use of traditional charcoal is weak and difficult to demonstrate	Highly likely for some fuel switches (e.g. to solar) — but requires LCA to de-termine GHG impact of alternatives. Also, requires monitoring continued charcoal use to determine whether it actually decreases	Likely, depends on the efficiency of kilns: global warming commitment (GWC) of charcoal produced from inefficient kilns is higher than that of fossil fuels	Potentially high if GHG reducing tech-nologies are inte-grated into kiln design	High potential to reduce emissions drastically, to recycle heat and convert gases into safe and usable alternatives; However, retort requires external source of power (usually fossil fuel)	High potential to produce zero-emission charcoal if rotations are strictly adhered to

currently generating emission credits by switching from traditional charcoal stoves to ICS (Mwampamba and Skutsch, unpublished data). Many more ICS projects perceive the carbon market as an opportunity to generate emission credits that can be used to offset cost of program and adoption. For the same reason that it is difficult for projects to claim fuel use reduction, claiming GHG emission reduction is not straightforward for ICS. Assuming no design flaws, an ICS stove should emit less GHG than a traditional stove, but to ensure that lower emissions are maintained over time, users have to continue using the new stove and abandon using the old stove. This is not always the case. For example, of the 30 million improved stoves that were dispersed through India's National Program on Improved Cookstoves less than a third were in use 17 years later monitoring (Arnold and Persson, 2003). Programs also need to assume that the new stoves do not trigger new use habits – or if new ones evolve – that they do not lead to an increase in overall emissions. Without sufficient studies monitoring the overall long-term stove emissions of households adopting ICS, it is too early to say whether the assumptions that cook stove programs make hold.

Along these same lines, the evidence that ICS use reduces household expenditure on charcoal is inconclusive and debatable (Jeuland and Pattanayak, 2012). In the past, design flaws that resulted in increased rather than decreased use of fuel were common (RWEDP, 1993) and partially explain low long-term adoption and reverting back to traditional stoves. Design flaws are increasingly less common, but do still occur (Benston et al., this issue). The poverty alleviation claims are equally debatable. Given that charcoal users are not as poor as is commonly depicted (Myth no. 1) and that ICS usually cost more than traditional stoves, the most likely adopters are the non-poor. While indeed a claim to having a positive impact on their welfare can be made, one on poverty alleviation is perhaps more doubtful.

Recommendations

Charcoal is often referred to as a 'transition' fuel, indicating that it is *the* energy that will sustain cooking needs of developing nations while other fuels are explored and their dissemination and adoption are more widely spread. An undisputed fact about charcoal is that it will continue to be the dominant cooking energy in sub-Sahara Africa for the next decades to come. In order to ensure that energy interventions addressing charcoal match local realities, we propose a set of recommendations that is informed by the findings from this review. Table 1 provides a guide for practitioners and policy makers to consider when developing charcoal-related interventions. Charcoal interventions cannot rely on logic that is informed by unconvincing evidence or derived from 'conceptual leaps of faith'.

Recommendation 1: address charcoal separately from unprocessed fuels

Lumping charcoal with unprocessed wood fuels based on their common starting material has been a gross mistake of the energy sector. As we have pointed out, charcoal as a cooking energy is in a league of its own. Being processed, it represents a highly dynamic commodity chain that extends to urban markets. Unlike unprocessed fuels, charcoal competes directly with other liquid and gaseous fuels such as kerosene and LPG. Separating out the charcoal story should provide a very different appreciation of the sector and its impact on forests, on global warming and the economy. It also will set the stage for developing interventions that are in par with the local context.

Petroleum-based fuels have been proposed on multiple occasions in multiple countries as alternatives to charcoal, but they have repeatedly failed to compete against the price and convenience of charcoal. Ethanol-based fuels are becoming increasingly more available in developing countries, but it is too early to gauge how well and widely they will be adopted. We recommend that in countries (or regions within countries) where continued supply of charcoal is deemed unsustainable, the energy and forest sectors should develop a joint-department or section aimed at improving charcoal data and developing appropriate interventions.

Recommendation 2: conduct landscape-level studies to determine impact on forests

Whether or not charcoal production leads to forest loss or degradation is highly variable. For the most part, charcoal problems tend to be localized and relevant specific regions within a country. Consequently, charcoal needs to be addressed at local or regional level, to ensure that policies match the realities on the ground. After the 1970's fuelwood crisis alarm, reappraisals of the wood energy situation suggested that – in most areas where local studies were conducted – a wood energy gap was neither evident nor imminent (Bhagavan, 1984; Dewees, 1989; Leach and Mearns, 1988; Patel, 1985; Pearson and Stevens, 1989). Despite new information, the association between negative forest impacts and charcoal has persisted, even as forest programs to secure wood-based energy were being cutback.

Local-level studies that use temporal data and a landscape approach for evaluating impact will help identify whether forests, as they are presently managed for charcoal, can or cannot continue to provide feedstock at current or increasing demand rates. Local studies will also facilitate identification of appropriate interventions, which may range from slight tweaks for improving kiln efficiencies to a complete overhaul of the sector. By targeting interventions to the local context, resource use (i.e., funding for programs) can be more efficient than implementing broad-sweeping interventions that may not be applicable to all areas.

Recommendation 3: prioritize interventions at production-end rather than user-end

The charcoal 'problem' – when there is one – is usually interpreted as being caused by high demand which leads to shortages of feedstock. ICSs for charcoal and fuel-switch programs are aimed at decreasing demand. Given the sheer volume of consumers and the fact that consumption is predicted to grow, it is inconceivable that end-user interventions will have a notable effect on curbing demand. Rather production-end interventions are better suited to address the impacts of high demand that require securing feedstock supply through means such as improved forest management, assisted regeneration and plantations.

Increasingly, the energy literature is becoming explicit about what are inappropriate interventions in the wood energy sector. Two recent reviews of the effectiveness of policy responses in the woodfuel sector have explicitly pointed out that stove programs are unlikely to have any significant impact on improving the overall woodfuel situation (Arnold et al., 2006; Jeuland and Pattanayak, 2012; Maes and Verbist, 2012). In comparing the effect of six parameters that could affect estimates of forest availability for future charcoal production in Tanzania, Mwampamba (2007) found that production-related parameters such as variations in kiln efficiency and percent of forest regenerating had the largest effect on forest availability. In other words, small changes to production-end practices could have large positive impacts on feedstock availability for the long-term. According to the same analysis, altering the number of charcoal users and per capita consumption rates had the least impact on forest availability.

Existing user-end interventions require reappraisals to determine whether they are targeting the appropriate consumers. In particular, whether they are targeting consumers of charcoal who can afford to adopt new technologies in the long run. Undoubtedly, pro-poor interventions have laudable objectives, but their efficiency and likelihood of success if targeting the urban poor is likely to be low in terms of uptake and long-term adoption.

Recommendation 4: conduct assessments and monitor social and economic impact of interventions

A substantial amount of what we know about the impact of interventions in the charcoal sector is based on deduction rather than real data because monitoring of projects is rarely conducted. Moreover, charcoal interventions have focused on single-components of the charcoal value chain even though the sector constitutes of a wide array of stakeholders and extends over large geographic areas. Changing one aspect of the sector can have positive and negative repercussions for stakeholders along the chain. Given the importance of the charcoal sector to livelihoods, policy responses should consider the economic impact of proposed interventions. Social and economic impacts need to be understood, gauged, and mitigated for, preferably before wide-scale implementation.

Conclusions

Charcoal is the predominant cooking fuel in sub-Saharan Africa's cities and towns, and its use is expected to grow. Nevertheless, energy policies in charcoal-dependent countries significantly undervalue charcoal and tend to view it as a problem rather than as a solution to the energy access challenges they are facing today. Early associations in the 1970s of charcoal with forest loss and degradation have persisted in the minds of policy makers despite subsequent rebuttals and clarifications. Associations of charcoal with damage to forests have limited the scope of discussions about charcoal to an environmental niche, undermining the substantial role that it already plays in contributing to energy security.

In this review, we bring to the attention of readers misconceptions about charcoal that we believe have been particularly harmful for the sector. We hope that doing so helps clarify the root of commonly held myths and illustrates the influence they have had on the sector. Our recommendations for improving interventions and research on charcoal are intended to generate better understanding of the rare cases when myths apply and the many cases when they do not.

Acknowledgments

We are grateful for a generous grant from the Swiss Development Corporation (SDC) to organize a charcoal workshop in Arusha in June 2011. Many of the ideas put forth in this review emerged from the discussion held at the Arusha workshop. We are also grateful to Dr. Gautam Dutt for helping us improve earlier versions of the manuscript.

References

Ahrends A, Burgess ND, Milledge SAH, Bulling MT, Fisher B, Smart JCR, et al. Predictable waves of sequential forest degradation and biodiversity loss spreading from an African city. Proc Natl Acad Sci U S A 2010;107:14556–61.
Alem S, Duraisamy J, Legesse E, Seboka Y, Mitiku E. Wood charcoal supply to Addis Ababa City and its effect on the environment. Energy Environ — UK 2010;21: 601–9.
Arnold JEM, Kohlin G, Persson R. Woodfuels, livelihoods, and policy interventions: changing perspectives. World Dev 2006;34:596–611.
Arnold M, Persson R. Reassessing the fuelwood situation in developing countries. Int Forest Rev 2003;5:379–83.
Bailis R. Fuel from the savanna: the social and environmental implications of the charcoal trade in Sub-Saharan Africa. Berkeley, California, US: University of California, Berkeley; 2005.
Bailis R. Modeling climate change mitigation from alternative methods of charcoal production in Kenya. Biomass Bioenergy 2009;33:1491–502.
Bailis R, Ezzati M, Kammen DM. Mortality and greenhouse gas impacts of biomass and petroleum energy futures in Africa. Science 2005;308:98-103.
Benjaminsen TA. Natural resource management, paradigm shifts, and the decentralization reform in Mali. Hum Ecol 1997;25:121–43.
Bhagavan MR. The woodfuel crisis in the Sadcc countries. Ambio 1984;13:25–7.
Carneiro de Miranda R, Bailis R, Vilela AdO. Cogenerating electricity from charcoaling: A promising new advanced technology. Energy Sustain Dev 2013;17:171–6.
Castillo-Santiago MÁ, Ghilardi A, Oyama K, Hernández-Stefanoni JL, Torres I, Flamenco-Sandoval A, Fernández A, Mas J-F. Estimating the spatial distribution of woody biomass suitable for charcoal making from remote sensing and geostatistics in central Mexico. Energy Sustain Dev 2013;17:177–88.
Checo H. Desarrollo de las comunidades carboneras de la frontero domínico–haitiana. Santo Domingo: FAO; 2010.
Chidumayo EN. Zambian Charcoal Production - Miombo Woodland Recovery. Energy Policy 1993;21:586–97.
Chidumayo EN, Gumbo DJ. The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis. Energy Sustain Dev 2013;17:86–94.
Cline-Cole R. Knowledge claims and landscape: alternative views of the fuelwood-degradation nexus in northern Nigeria. Environ Plan D 1998;16:311–46.
Cline-cole RA, Main HAC, Nichol JE. On fuelwood consumption, population-dynamics and deforestation in Africa. World Dev 1990;18:513–27.
Dewees PA. The woodfuel crisis reconsidered — observations on the dynamics of abundance and scarcity. World Dev 1989;17:1159–72.
ESD. Energy for sustainable development (ESD). Situation analysis of charcoal dynamics, energy policies and possibilities of switching to alternatives. WWF-Tanzania; 2007.
Estevez RA, Squeo FA, Arancio G, Erazo MB. Production of charcoal from native shrubs in the Atacama Region, Chile. Gayana Bot 2010;67:213–22.
FAO. Wood Fuel Surveys. Rome: Food and Agriculture Organization of the United Nations; 1983.
FAO. Unified Bioenergy Terminology (UBET). Rome: Food and Agriculture Organization of the United Nations; 2004. p. 50.
FAO. Biomass energy in the Asia-Pacific region: current status, trands and future setting; 2009.
FAOStat. ForestStat — forestry statistics. http://faostat.fao.org/ Rome: FAO; 2012.
Fukuda-Parr S. Defining poverty in the developing world. J Hum Dev Capab 2009;10: 155–7.
GACC. http://www.cleancookstoves.org/. Visited in December 2012.
Girard P. Charcoal production and use in Africa: what future? Unasylva 2002;53: 30–4.
Government of Myanmar. Greater Mekong Subregion Economic Cooperation Program. Myanmar: Country Assessment on Biofuels and Renewable Energy; 2009.
Hanna R, Duflo E, Greenstone M. Up in smoke: the influence of household behavior on the long-run impact of improved cooking stoves. Cambridge, MA: MIT; 2012. p. 02142.
Hansfort SL, Mertz O. Challenging the woodfuel crisis in West African woodlands. Hum Ecol 2011;39:583–95.
Hiemstra-van der Horst G, Hovorka AJ. Reassessing the “energy ladder”: household energy use in Maun, Botswana. Energy Policy 2008;36:3333–44.
Hiemstra-van der Horst G, Hovorka AJ. Fuelwood. The "other" renewable energy source for Africa? Biomass Bioenerg 2009;33:1605–16.
Hosier RH, Dowd J. Household fuel choice in Zimbabwe: an empirical test of the energy ladder hypothesis. Resour Energy 1987;9:347–61.
Hosier RH, Kipondya W. Urban household energy use in Tanzania — prices, substitutes and poverty. Energy Policy 1993;21:454–73.
Huszar PC, Bucher EH. Land degradation and renewal in the Gran Chaco of South America. Response to Land Degradation; 2001. p. 293–303.
IEA. World energy outlook 2009. Paris Cedex, France: International Energy Agency (IEA); 2009.
IEA. World energy statistics and balances (database). International Energy Agency; 2012. http://dx.doi.org/10.1787/data-00510-en (Accessed on 09 October 2012).
Jayakumar S, Ramachandran A, Bhaskaran G, Heo J. Forest dynamics in the Eastern Ghats of Tamil Nadu, India. Environ Manage 2009;43:326–45.
Jeuland MA, Pattanayak SK. Benefits and costs of improved cookstoves: assessing the implications of variability in health, forest and climate impacts. PLoS One 2012:7.
Kambewa P, Mataya B, Sichinga K, Jonhson T. Charcoal: the reality. A study of charcoal consumption, trade and production in Malawi. UK: International Institute for Environment and Development; 2007.
Kammen DM, Lew DJ. Review of technologies for the production and use of charcoal. Renewable and Appropriate Energy Laboratory Report; 2005.
Karakezi S, Kithyoma W, Muzee K, Annah O. Scaling up bioenergy in Africa. Presented during the International Conference on Renewable Energy in Africa, Dakar 16–18 April 2008; 2008.
Khundi F, Jagger P, Shively G, Sserunkuuma D. Income, poverty and charcoal production in Uganda. Forest Policy Econ 2011;13:199–205.
Knudson DM, Chaney WR, Reynoso FA. Fuelwood and charcoal research in the Dominican Republic. Purdue University, Dept. of Forestry and Natural Resources, Government of the Dominican Republic with support from the U.S. Agency for International Development; 1988.
Koyuncu T, Pinar Y. The emissions from a space-heating biomass stove. Biomass Bioenergy 2007;31:73–9.
Kutsch WL, Merbold L, Ziegler W, Mukelabai MM, Muchinda M, Kolle O, et al. The charcoal trap: Miombo forests and the energy needs of people. Carbon Balance Manage 2011;6:1-11.
Larpkern P, Totland O, Moe SR. Do disturbance and productivity influence evenness of seedling, sapling and adult tree species across a semi-deciduous tropical forest landscape? Oikos 2011;120:623–9.
Lea JD. A review of literature on charcoal in Haiti. Prosopis: Semiarid Fuelwood and Forage Tree Building Consensus for the Disenfranchised; 1996. p. B33–43.
Leach G. The energy transition. Energy Policy 1992;20:116–23.
Leach G, Mearns R. Beyond the woodfuel crisis: people, land, and trees in Africa. London: Earthscan Publications; 1988.
Lifeline Fund. Why stoves? International Lifeline Fund webpage accessed in December 2012 http://www.lifelinefund.org/why-stoves.php.
Maes WH, Verbist B. Increasing the sustainability of household cooking in developing countries: policy implications. Renew Sustain Energy Rev 2012;16:4204–21.
Masera OR, Saatkamp BD, Kammen DM. From linear fuel switching to multiple cooking strategies: a critique and alternative to the energy ladder model. World Dev 2000;28:2083–103.
Masera O, Arias T, Ghilardi A, Guerrero G, Patiño P. Estudio sobre la evolución nacional del consumo de leña y carbón vegetal en México 1990–2024. México DF: Universidad Nacional Autónoma de México (UNAM); 2010.
May-Tobin C. Chapter 8: Wood for fuel, the root of the problem: what's driving tropical deforestation today? Union of Concerned Scientists. 2009.
Metz JJ. Forest product use at an upper elevation village in Nepal. Environ Manage 1994;18:371–90.
Minten B, Sander K, Stifel D. Forest management and economic rents: Evidence from the charcoal trade in Madagascar. Energy Sustain Dev 2013;17:106–15.
Mobarak AM, Dwivedi P, Bailis R, Hildemann L, Miller G. Low demand for nontraditional cookstove technologies. Proc Natl Acad Sci U S A 2012;109:10815–20.
Mwampamba TH. Has the woodfuel crisis returned? Urban charcoal consumption in Tanzania and its implications to present and future forest availability. Energy Policy 2007;35:4221–34.
Mwampamba TH, Owen M, Pigaht M. Opportunities, challenges and way forward for the charcoal briquette industry in Sub-Saharan Africa. Energy Sustain Dev 2013;17:158–70.
Nansaior A, Patanothai A, Rambo AT, Simaraks S. Climbing the energy ladder or diversifying energy sources? The continuing importance of household use of biomass energy in urbanizing communities in Northeast Thailand. Biomass Bioenergy 2011;35:4180–8.
Norconsult. The true cost of charcoal: a rapid appraisal of the potential economic and environmental benefits of substituting LPG for charcoal as an urban fuel in Tanzania. May 2002 Consultancy report to the LPG Committee of the Tanzania Association of Oil Marketing Companies; 2002.
Openshaw K. Biomass energy: employment generation and its contribution to poverty alleviation. Biomass Bioenergy 2010;34:365–78.

Ouedraogo B. Household energy preferences for cooking in urban Ouagadougou, Burkina Faso. Energy Policy 2006;34:3787–95.
Owen M, van der Plas R, Sepp S. Can there be energy policy in Sub-Saharan Africa without biomass? Energy Sustain Dev 2013;17:146–52 (this issue).
Patel VJ. Rational approach towards fuelwood crisis in rural India. Econ Polit Wkly 1985;20:1366–8.
Pearson PJG, Stevens P. The fuelwood crisis and the environment — problems, policies and instruments. Energy Policy 1989;17:132–7.
Pennise DM, Smith KR, Kithinji JP, Rezende ME, Raad TJ, Zhang JF, et al. Emissions of greenhouse gases and other airborne pollutants from charcoal making in Kenya and Brazil. J Geophys Res-Atmos 2001;106:24143–55.
Plas van der R. Charcoal and taxation in Africa. Discussion Draft; 2008.
Ramos MM. Producción y comercialización de carbón vegetal en la microregión Teopisca-San Cristóbal. Región Altos de Chiapas. San Cristóbal de las Casas, México: UACh; 1999.
Remedio EM, Terrence G. Socioeconomic and environmental impacts of woodfuel consumption and production: a case study of Cebu Province, Philippines. Rome: EC-FAO Partnership Programme; 2003.
Ribot Jesse C. From exclusion to participation: turning Senegal's forestry policy around. World Dev 1995;23(9):1587–99.
Ribot JC. A history of fear: imagining deforestation in the West African dryland forests. Glob Ecol Biogeogr 1999;8:291–300.
Roth LC. Enemies of the trees? Subsistence farmers and perverse protection of tropical dry forest. J Forest 2001;99:20–7.
RWEDP. Patterns of commercial woodfuel supply, distribution and use in the city and province of Cebu, Philippines. RWEDP, FAO. 1993.
RWEDP. The “Fuelwood Gap Theory” rejected. In: FAO, editor. Regional study on wood energy today and tomorrow in Asia. Regional Wood Energy Development Programme (RWEDP) in Asia — Field Document 50, Bangkok, Thailand; 1997.
Sagawe T. Deforestation and the behavior of households in the Dominican-Republic. Geography 1991;76:304–14.
Sasaki N, Asner GP, Knorr W, Durst PB, Priyadi HR, Putz FE. Approaches to classifying and restoring degraded tropical forests for the anticipated REDD+ climate change mitigation mechanism. ISTF NEWS Bethesda, Maryland 20814, USA Special Report, April 2011.
Schneichel M, Asmussen P. Dry forest management — putting campesinos in charge. Adv Geoecol 1998;31:1023–7.
Semple S, Devakumar D, Fullerton DG, Thorne PS, Metwali N, Costello A, et al. Airborne endotoxin concentrations in homes burning biomass fuel. Environ Health Perspect 2010;118:988–91.
Sepp S. Promotion of Sustainable Charcoal Production Through Community Level Approaches: Experiences and Lessons Learned from Selected Sub-Saharan African Countries. discussion paper; ECO-Consulting Group, Oberaula, Germany, 2008.
Singh G, Rawat GS, Verma D. Comparative study of fuelwood consumption by villagers and seasonal “Dhaba owners” in the tourist affected regions of Garhwal Himalaya, India. Energy Policy 2010;38:1895–9.
Skutsch MM, Balderas Torres A, Mwampamba TH, Ghilardi A, Herold M. Dealing with locally-driven degradation: a quick start option under REDD+. Carbon Balance Manage 2011;6:16.
Smith KR, Uma R, Kishore VVN, Zhang JF, Joshi V, Khalil MAK. Greenhouse implications of household stoves: An analysis for India. Annu Rev Energy Environ 2000;25:741–63.
Sood KK, Mitchell CP. Household level domestic fuel consumption and forest resource in relation to agroforestry adoption: evidence against need-based approach. Biomass Bioenergy 2011;35:337–45.
Thailand, G.o. Thailand 20-Year Energy Efficiency Development Plan (2011–2030). undated.
Torres JE. Biomass energy use and statistics in Latin America: methodological and institutional challenges. Biomass Energy: Key Issues and Priority Needs, Conference Proceedings; 1997. p. 175–86.
Van der Plas R. Burning charcoal issues. Energy Issues, the World Bank Group, FDP Energy Note No 1; 1995.
Wood TS, Baldwin S. Fuelwood and charcoal use in developing-countries. Annu Rev Energy 1985;10:407–29.
World Bank. Environmental crisis or sustainable development opportunity? Transforming the charcoal sector in Tanzania. Washington DC: World Bank; 2009.
World Bank. Enabling Reforms: a stakeholder-based analysis of the political economy of Tanzania's charcoal sector and the poverty and social impacts of proposed reforms. Washington DC: The World Bank; 2010.
World Bank. Wood-based Biomass Energy Development in Sub-Saharan Africa – Issues and approaches. Africa Renewable Energy Access Program / Energy Sector Management and Assistance Program (ESMAP), The World Bank, Washington, DC; 2011.
Xander P. Geographical aspects of charcoal production. Isla del Carmen, Mexico: Louisiana State University, Baton Rouge; 1987.
Zulu LC. The forbidden fuel: charcoal, urban woodfuel demand and supply dynamics, community forest management and woodfuel policy in Malawi. Energy Policy 2010;38:3717–30.
Zulu LC, Richardson RB. Charcoal, livelihoods, and poverty reduction: Evidence from sub-Saharan Africa. Energy Sustain Dev 2013;17:127–37.