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030

Early Warning, Emerging Issues and Futures

Charcoal as a global commodity: is it sustainable?

Background

The UN Environment Foresight Briefs are published by the UN Environment Programme to, among others, highlight a hotspot of environmental change, feature an emerging science topic, or discuss a contemporary environmental issue. The public is thus provided with the opportunity to find out what is happening to their changing environment and the consequences of everyday choices, and to think about future directions for policy. The 30th edition of UNEP's Foresight Brief considers the environmental impact of the increasing use of charcoal as a source of energy and in metallurgical applications.

Abstract

Charcoal is typically made from trees, is perceived to be a renewable resource, and is used in both low- and middle-income countries as well as high-income countries. There is a difference, however, between "renewable" charcoal that is primarily produced through the farming of trees, and "non-renewable" charcoal, produced through deforestation. Even so-called "renewable" charcoal has a detrimental effect on the environment through the use of monoculture, which compromises biodiversity. Alternative raw materials, such as agricultural and other organic waste (sawdust, nutshells, wheat straw etc.), should therefore be used more widely to produce charcoal.

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Introduction

Decades of innovation have altered the global energy landscape by increasing supply and consumption of modern energy alternatives, such as solar and wind power (Jaganmohan 2021; United States Agency for International Development [USAID] 2019). During the past ten years, renewable energy has been advanced to mitigate pollution and lower carbon dioxide (CO_2) emissions, aiming to counter the known effects of climate change (International Renewable Energy Agency [IRENA] 2021). However, charcoal consumption has persisted around the world and, in some nations, it dominates the energy mix, aggressively competing with electricity and gas, even where these energy options are readily available (Nabukalu and Gieré 2019). Consequently, global wood charcoal production has surged from 36 million tons (Mt) in 1995 to 54 Mt in 2019 (**Figure 1**).

Charcoal is typically made from trees and is obtained through a process called pyrolysis, during which logs are heated under low-oxygen conditions to remove moisture and volatile components. Whereas Africa, as a continent, accounts for nearly 60% of the world's average annual charcoal production (**Figure 1**), Brazil generates the highest absolute amounts (6.5 Mt/year) of any individual country (Food and Agriculture Organization of the United Nations [FAO] 2021). Widely used as an energy commodity for cooking and smoking (e.g., on hookahs, shishas, and similar water pipes), charcoal is an important domestic energy source for low- and middle-income countries. It is also applied extensively, and often endorsed, for heavy industry, such as metallurgical processing (Feliciano-Bruzual 2014; Nogueira, Coelho and Uhlig 2009; Scarpinella *et al.* 2011).

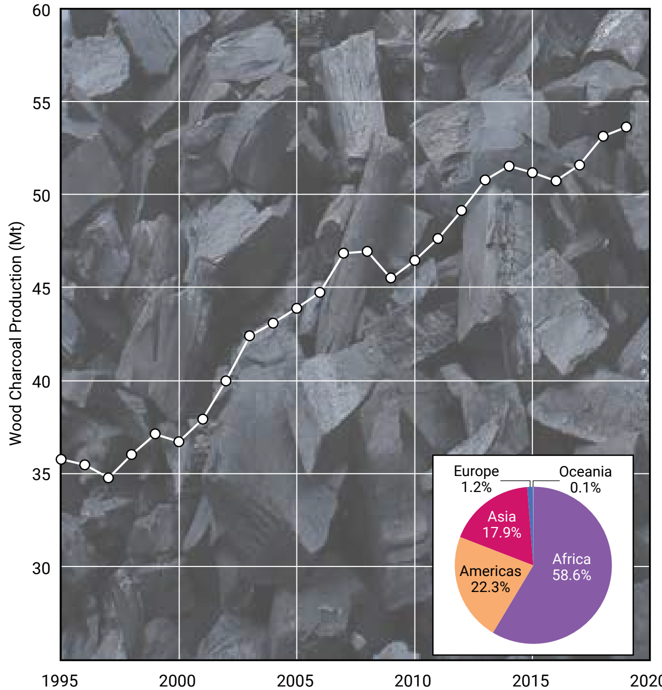
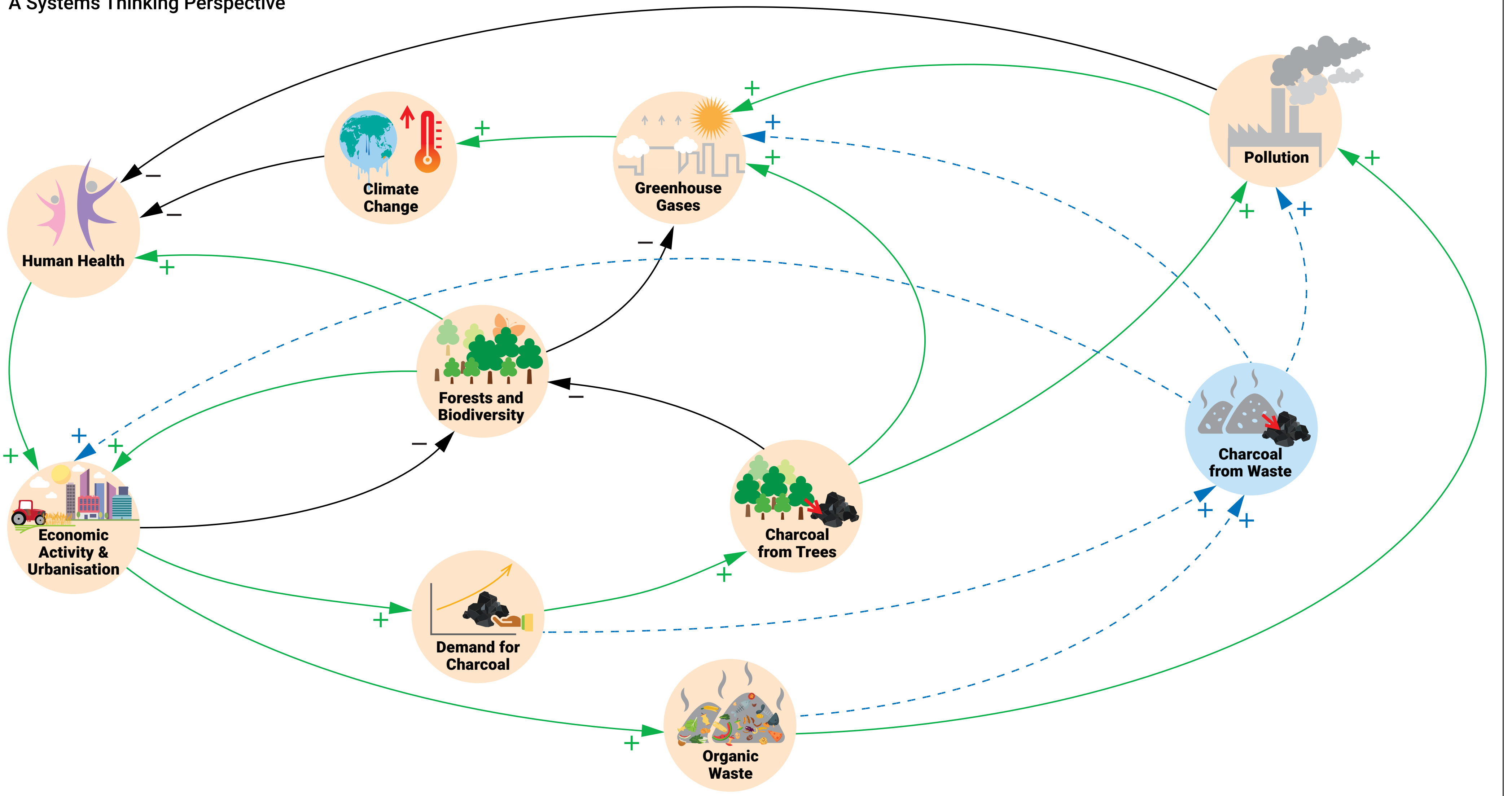


Figure 1: Global production of wood charcoal in million tons (Mt) between 1995 and 2019. Piechart shows the share by region of the global average annual production (in % for the period 1995–2019). *Data from FAO (2021).*
Photo credit: Catherine Nabukalu

To reduce the deleterious impacts of wood charcoal production on both forested and semi-arid regions, including the potential extinction of tree species, such as *Acacia bussei* in Somalia (UNEP 2018), alternative raw materials, for example the vast amounts of global organic waste (Kaza *et al.* 2018), must be increasingly used, including for charcoal manufacturing, which can be promoted through effective policies.

A Systems Thinking Perspective



Dominant causal loops in charcoal demand and alternatives to consider. Economic activity and urbanization drive the demand for charcoal, which in turn drives the production of charcoal from trees. Charcoal produced from trees reduces forests as well as biodiversity and increases pollution and emission of Green House Gases (GHGs), which amplify climate change and adversely impact human health. ***Policies encouraging the alternative production of charcoal from organic waste would mitigate the pollution and emission of GHGs from traditional methods, and are therefore more beneficial for both the environment and human health.*** This approach in turn leads to a more sustainable production of charcoal. (+) Influence is in the Same direction, (-) influence is in the Opposite direction. Dashed lines indicate the potential of waste-to-charcoal policies.

Why is this an important issue?

Even though a direct link between charcoal production and deforestation (Zorrilla-Miras *et al.* 2018) has been disputed in the literature (Chidumayo and Gumbo 2013; Tarter *et al.* 2018), there is a clear secondary association between the two, because the material is produced from trees felled in areas cleared for land-use changes (**Figure 2**), such as agriculture and urbanization.

Figure 2: Wood charcoal production on land cleared to plant *Eucalyptus* in Kyegaliro, Mityana District, Central Uganda (October 2021). *Photo credit: Catherine Nabukalu*

Major tropical wood charcoal producers, such as Brazil, the Democratic Republic of Congo and Nigeria (**Figure 3**) have lost significant biodiversity and forest cover (Okoth 2022; World Bank 2017a). For example, in Brazil and Australia, the demand for *Eucalyptus* to produce charcoal used in the blast furnaces of the pig-iron (crude-iron) industry enhances large-scale monocultures (Norgate et al. 2012; Scarpinella et al. 2011), thus compromising biodiversity (World Bank 2017b). Indeed, in Brazil alone, over 521 native plant species have been identified as threatened (World Bank 2017a). Moreover, other top-ten charcoal producers (**Figure 3**) and exporters (**Figure 4**), including Egypt, Somalia, Namibia, and Ethiopia, are considerably less forested than the top tropical charcoal-producing countries (**Figure 5**). Egypt, Somalia, Namibia,

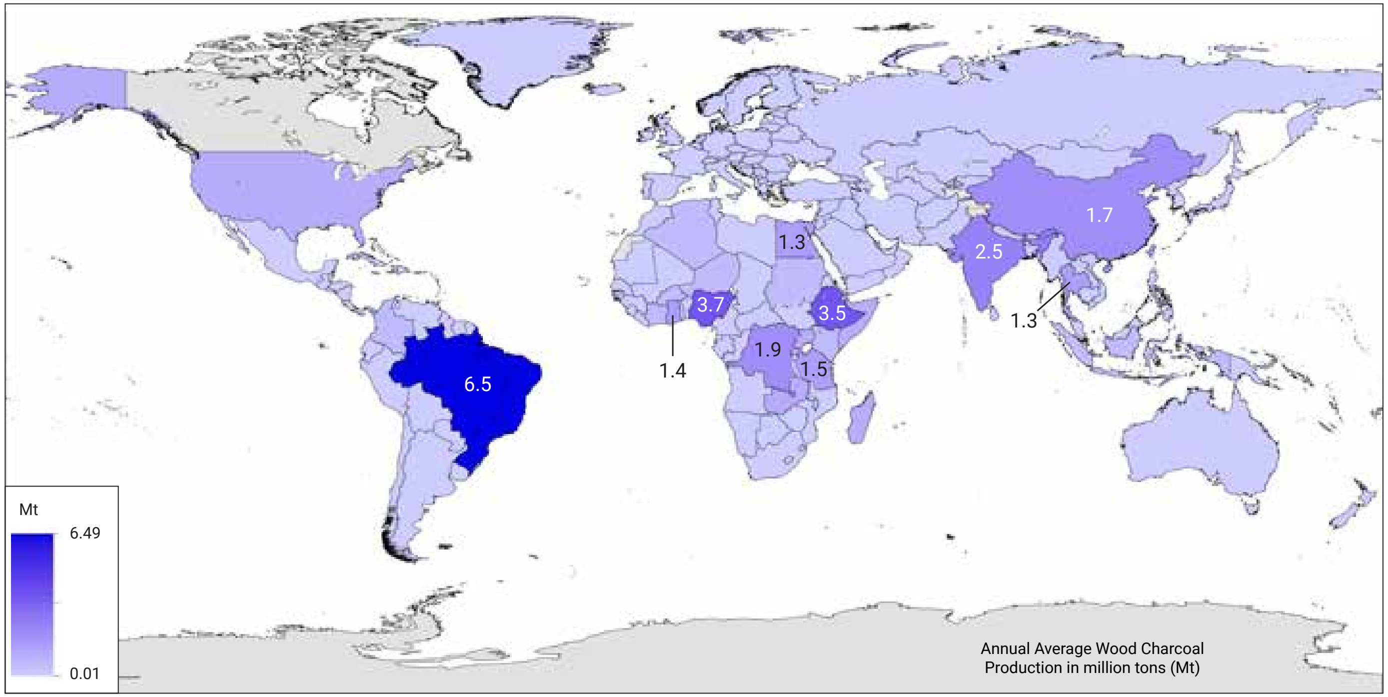


Figure 3: Annual average production of wood charcoal (1995–2019) in million tons (Mt). Top-ten producing countries highlighted with their annual average production values in Mt. Grey areas: no data available. *Data from FAO (2021).*

Figure 4: Top-ten exporters of wood charcoal in thousand tons (kt). Data represent annual averages for the period 1995—2019. *Data from FAO (2021). Photo credit: Catherine Nabukalu*

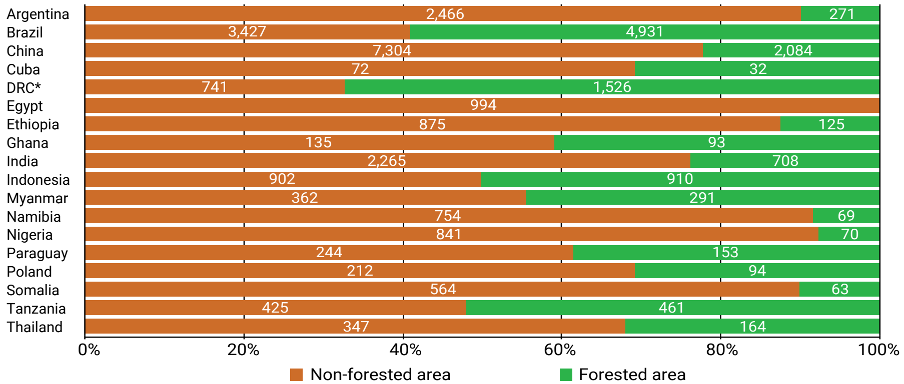


Figure 5: Proportion of forested vs. non-forested areas for top-ten wood charcoal producers and exporters. The total size of each country is the sum of its forested area plus its non-forested area. All country sizes were normalized to 100%, and all values shown in white within each bar represent areas in thousand square kilometers (km²). Forested area in Egypt (1000 km²) is too small to be displayed in this graph. *All data from World Bank (2017a).*

* Democratic Republic of the Congo

and Ethiopia are also located in semi-arid to arid regions, where the damage to the ecosystems is equally, if not more, severe than in the tropics due to the scarcity of vegetation, evidenced for example, by threatened tree species, such as *Acacia bussei* in Somalia (Nabukalu and Gieré 2019; UNEP 2018), the loss of fertile soil or arable land, and by desertification. To reduce the deleterious environmental impacts on these top-producing and -exporting regions, it is essential that the use of widely available alternative raw materials (e.g., agricultural waste, sawdust) is promoted to satisfy the continuous global demand for charcoal (Surono 2019).

Charcoal consumption is often associated with poverty (e.g., Adusah-Poku and Takeuchi 2019; Khundi *et al.* 2011; Schunder and Bagchi-Sen 2019) and lack of access to modern energy alternatives (World Bank 2018), and thus with the putative notion of "energy poverty" (González-Eguino 2015); in low- and middle-income countries, "energy poverty" considerably impacts the lives of women and girls who due to their gender roles spend the most time around these polluting fuels and this ultimately impacts their health as well as the health of younger children. Substantial amounts of charcoal, however, are still imported by "energy-secure" countries, including Germany, France, the United Kingdom, Japan and the United States (FAO 2021), which have diverse portfolios of newer, cleaner energy alternatives (Global Energy Institute 2020). Despite the accelerated investment in modern energy resources in Sub-Saharan Africa (USAID 2019), charcoal consumption is expected to remain prominent well into the 2030's (World Bank 2018; Schunder and Bagchi-Sen 2019). These trends, thus, sustain a complex international supply chain for the mostly informal charcoal trade (WWF 2018).

Indeed, the charcoal sector lifts some people out of abject poverty and provides socioeconomic benefits, including employment and government revenues (Mabele 2020; Sander, Gros and Peter 2013; Tarter *et al.* 2018; Marsoem, Sulistyo, and Irawati 2004). The international annual trade value of charcoal is exceedingly difficult to assess, with estimates ranging from US $1.2 million (FAO 2021) to US $1.42 billion (Observatory of Economic Complexity [OEC] 2020), which clearly shows the incongruence in data reported by the current gauging of the trade. The lower value is unquestionably too low, as even individual countries, such as Somalia, Indonesia and Haiti, maintain multimillion-dollar charcoal exports (Tarter *et al.* 2018; UNEP 2018; Marsoem, Sulistyo, and Irawati 2004). The upper value does not account for re-exports, i.e., where the exporting country is not the original charcoal producer (see also WWF 2018).

Charcoal perceived as a renewable energy source

Charcoal is typically classified as a renewable energy source, and thus, there are proposals to liberalize the international trade of renewables that include charcoal (Steenblik 2005), which is traded as a licit commodity on the global market. In metallurgical applications, charcoal has been shown to release less CO_2 and sulfur compounds than fossil fuels such as coke (Feliciano-Bruzual 2014; Monsen *et al.* 2001; Sommerfeld and Friedrich 2021).

Where carbon credits and taxes are considered, for example using Life Cycle Analyses (LCAs), charcoal is viewed as a more economical alternative in heavy industry (Feliciano-Bruzual 2014; Norgate and Jahanshahi 2011; Norgate and Langberg 2009; Scarpinella *et al.* 2011), and thus, there are significant prospects for the partial or full substitution of fossil fuels with charcoal (Feliciano-Bruzual 2014; Norgate and Jahanshahi 2011).

Smelting iron ore into crude iron, for example, has buttressed Brazil's position as the world's biggest charcoal producer (FAO 2021), with 80% of its output directed to industrial processes (Scarpinella *et al.* 2011). Charcoal consumption in metallurgy has surged although its production is still highly rudimentary, with arbitrary production standards (Norgate *et al.* 2012) and kiln efficiencies as low as 15-26% (Namaalwa, Hofstad and Sankhayan 2009; Marsoem, Sulistyo, and Irawati 2004). In comparison, a 32% efficiency can be attained by using retort kilns, with less air pollution, although their yields are still significantly low (Ankona *et al.* 2022).

What are the main findings?

Nomadism in charcoal production

Most tree species can be used to produce charcoal (Katende, Birnie and Tengnaes 2000), and tree-cutting for this purpose can be highly indiscriminate in some regions, including Uganda (Nabukalu and Gieré 2019). However, the scarcity of vegetation (Namaalwa, Hofstad and Sankhayan 2009; Servir Global 2018) causes producers to move to forests, burn charcoal, and migrate again in pursuit of new trees (Nabukalu and Gieré 2019; Marsoem, Sulistyo, and Irawati 2004). The high costs and the burden of moving logs to a single production point make nomadism viable to burners in some areas. In Uganda, for example, charcoal is produced in earth-mound kilns (**Figures 2,6**) at the locations where trees are felled, thus eliminating investments in raw-material transportation and stationary kilns. In Somalia and Uganda, charcoal production often takes place on communal and private land alongside other socioeconomic activities, such as grazing and agriculture. In Uganda, some landowners burn charcoal on their land, whereas others, when switching land-use types (**Figure 2**), provide waste logs and the permission to burn charcoal to nomadic producers (Nabukalu and Gieré

Figure 6: A producer makes charcoal through pyrolysis of the roots from freshly felled trees using a Kasisira (earth-mound kiln technique) in Kyegaliro, Mityana district, Central Uganda (October 2021).
Photo credit: Catherine Nabukalu

Figure 7: Charcoal producers near their makeshift tents in the vicinity of Naminato Bridge in Nwoya District, Northern Uganda (October 2017).
Photo credit: Catherine Nabukalu

Figure 8: Using charcoal to deep-fry fish in Mulungu, at the shore of Lake Victoria, Kampala, Uganda (October 2021)
Photo credit: Catherine Nabukalu

2019). Nomadic producers set up makeshift tents near kilns in open forests (**Figures 2,7**) to monitor pyrolysis cycles around the clock, for an average of 14 days per kiln, and to prevent full combustion of wood, a practice that exposes them to poor air quality among other unhealthy working conditions (Ankona *et al.* 2022).

Charcoal is still widely used alongside modern energy resources worldwide

Access to electricity has not dissuaded consumers worldwide from choosing charcoal. Charcoal is favorably linked to the taste of food (Drazu, Olweny and Kazoora 2015) and leisure (Bailis *et al.* 2013). Therefore, charcoal is used extensively for cooking (**Figure 8**), not only in key producing countries, but especially also in North America, Japan, and Europe, where imports (**Figure 9**) have persisted for decades to supplement the limited local production (FAO 2021; Nabukalu and Gieré 2019; WWF 2018). Erratic power supply in some nations, manifested as blackouts and brownouts, instigates consumers to continue using charcoal, because the fuel is ubiquitous and perceived as more reliable (Drazu, Olweny and Kazoora 2015). Moreover, unlike electric and gas ovens that require spare parts and have higher maintenance costs, charcoal stoves (**Figure 8**) are more affordable (Nabukalu and Gieré 2019).

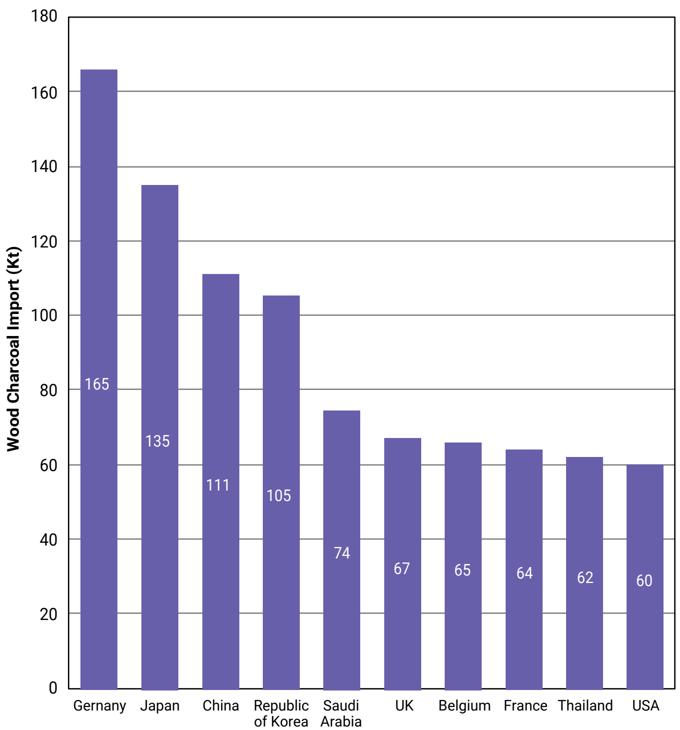


Figure 9: Top-ten importers of wood charcoal in thousand tons (kt). Data represent annual averages for the period 1995—2019.
Data from FAO (2021).

Resurgence of industrial charcoal consumption to reduce CO_2 emissions

International economic legislation, such as levying carbon taxes or awarding carbon credits to limit pollution along various supply chains (Feliciano-Bruzual 2014; Mathews 2008; World Bank 2022), has prompted several industries and countries (Hamuyuni *et al.* 2022) to seek new opportunities to reduce their CO_2 emissions or to decarbonize. The classification of charcoal as a renewable resource has revived interest in its emergent value for CO_2 mitigation in metallurgy (Scarpinella *et al.* 2011; Singh, Singh and Sinha 2022). Norgate and Langberg (2009) emphasized that carbon credits could be accrued by switching from fossil fuels to charcoal because trees are CO_2 sinks before being felled. The ironmaking industry, one of the world's most carbon-intensive sectors (International Energy Agency [IEA] 2022; Norgate *et al.* 2012), is currently exploring charcoal as a carbon source to replace coal (Echterhof 2021). In steel manufacturing, renewable alternatives, such as hydrogen, are already being used for ferroalloy processing (IEA 2022; Surup, Trubetskaya and Tangstad 2020). It has been argued that using charcoal in ironmaking creates a more sustainable "green pig-iron" or "green steel" industry (Scarpinella *et al.* 2011; Singh, Singh and Sinha 2022; Venkataraman *et al*. 2022) to fulfill the world's surging demand for steel associated with increasing urbanization (Aldred, 2012; Mousa *et al.* 2016). Since 2000, the global blast-furnace inventory has been expanded to enhance steel production (Holmes, Lu and Lu 2015), and currently, blast furnaces account for 59% of the world's 605 operational and proposed steel plants (Global Energy Monitor 2021a).

Indeed, Nogueira, Coelho and Uhlig (2009) attributed the intensifying charcoal production in Brazil's Amazon rainforest to industrial processes. Because *Eucalyptus* is a fast-growing tree species (5-10 years; Norgate *et al.* 2012; Norgate and Langberg 2009), it is highly valued to fulfill the iron industry's charcoal demand, thus sustaining mass monoculture plantations (de Gouvello 2010). Other sectors that use charcoal extensively include: automotive battery recycling (Kreusch *et al.* 2007), agriculture and carbon sequestration (Kalaba *et al.* 2013; Marsoem, Sulistyo, and Irawati 2004), and water purification (Nishida *et al.* 2017). Charcoal is also used for sintering, and as a reducing agent in aluminum and silicon production to directly replace coke or coal because it is more energy-efficient (Sommerfeld and Friedrich 2021). Indeed, manufacturing of solar cells and panels relies on the supply of silicon, whereby charcoal is used instead of fossil fuels to reduce quartz to silicon in efforts to combat pollution (Troszack 2021). The silicon industries in South Africa and the United States, for example, import charcoal from Namibia and Brazil, respectively (Troszack 2021; Zimmermann and Joubert 2002). Namibia is one of the world's top-10 exporters (**Figure 4**), yet a country with less than 10% forested land area (**Figure 5**).

What has been done?

Supply-side restrictions

Charcoal freely circulates in most markets as a licit commodity, for example as an export (Hofelein 2021), in stark contrast to its upstream sourcing and distribution practices (Sander, Gros and Peter 2013; WWF 2018). Many African countries, including some of the world's top producers and exporters of wood charcoal over the past twenty years (**Figures 3, 4**), have adopted policies to artificially restrict its supply. Production and export bans exist, for example, in Nigeria, Kenya, Tanzania, Somalia and Uganda (Haysom *et al.* 2021; Mabele 2020; WWF 2018). Further strategies include banning the use of machinery to slow the rate of tree-cutting (Nabukalu and Gieré 2019), applying a minimum harvestable tree diameter to control indiscriminate cutting (Namaalwa, Hofstad and Sankhayan 2009), and proposals to limit the downstream charcoal transportation to specific weekdays (Nabukalu and Gieré 2019; Sander, Gros and Peter 2013). In Brazil, where federal laws prohibit the harvest of near-extinct native plant species (Perdigão *et al.* 2020), pig-iron manufacturers are encouraged to refrain from using charcoal produced through deforestation of the Amazon rainforest, which means they would have to eliminate "non-renewable charcoal" in their supply chains (de Gouvello 2010) in favor of "renewable charcoal" from responsible reforestation. Large-scale *Eucalyptus* plantations are therefore financed by Brazil's government and the private sector to provide an alternative source of charcoal for steel production (Guinta and Munnion 2020). In Namibia, although charcoal production is legal to support de-bushing and to sustain the productivity of arable land, permits are required for areas larger than 15 hectares (Brüntrup and Herrmann 2012; United Nations Industrial Development Organization [UNIDO] 2019), as major producers sustain the charcoal supply for both South Africa's silicon manufacturing and the international market (Hofelein 2021; Zimmermann and Joubert 2002).

Investment in modern alternatives

Key objectives of the United Nations Sustainable Development Goals (SDGs) include poverty alleviation and the transition to clean energy, for example, through ensuring access to affordable "modern energy for all" (United Nations 2020) to mitigate the environmental and public health impacts of charcoal, e.g., air pollution,

Charcoal briquettes made from coconut shells drying in the sun
Photo credit: Shutterstock/phongwit phojurai

which especially affect women and children (Ankona *et al.* 2022; World Health Organization [WHO] 2021). African economies, where biomass is a dominant fuel for cooking, joined the Power Africa consortium to scale up electrification (African Development Bank [AfDB] 2021; USAID 2019) and indeed, the biggest investors (Tanzania, Nigeria, Ghana) are also some of the world's top charcoal producers (**Figure 3**). Consequently, the wood charcoal sector is receiving comparatively less investment than modern energy alternatives, although production technologies could be improved for better yields (Antal and Grønli 2003; Doggart and Meshack 2017). Organic agricultural waste (Kaza *et al.* 2018; Norgate and Jahanshahi 2011) could become a viable alternative raw material to logs from freshly felled trees (IRENA 2021; Nabukalu and Gieré 2021).

Some energy policies in Sub-Saharan Africa and the Caribbean have favored replacing charcoal with modern energy resources to protect forests and reduce energy-related mortality (Morrissey 2017; Schunder and Bagchi-Sen 2019). Despite the increased supply of electricity and gas in these parts of the world, however, charcoal use has persisted in these key charcoal-supplying markets (Nabukalu and Gieré 2021), with international trade figures (**Figures 3,4,9**) underlining its prevailing importance alongside modern energy alternatives.

Nonetheless, in Europe and North America, the inconspicuousness of the charcoal sector and the limited local production of this material (**Figures 1,3**) continue to conceal its unwaning significance as an energy resource (Nabukalu and Gieré 2019). Additionally, the limited reporting on demand, imports and consumption of charcoal (WWF 2018) as well as the predominance of modern energy alternatives in these "energy-secure" markets have led to the misleading notion that the modern resources directly substituted for charcoal in the energy-consumption mix. Energy security is thus predominantly seen as a function of the reliable availability and access to modern alternatives (Global Energy Institute 2020).

What are the policy implications?

Wood charcoal production has been sustained as a clandestine activity (Mabele 2020) in some countries, which perpetuates its informality and obscures the financial valuation of charcoal as an important commodity on the international market (**Figures 3,4,9**). National production bans create artificial scarcity, increase prices despite poor quality (Yuan and Gershenson 2021), and incentivize imports from neighboring countries (Haysom *et al.* 2021; Yuan and Gershenson 2021), because demand for charcoal persists. The sustenance of this demand, where consumers willingly choose charcoal despite access to modern energy alternatives, is an indicator of the relevance of this fuel and, at the same time, of the shortcomings of modern energy sources (e.g., blackouts, brownouts), for example in Sub-Saharan Africa, which stifle their ability to compete effectively with biomass (Drazu, Olweny and Kazoora 2015; Schunder and Bagchi-Sen 2019).

The global charcoal trade must aim for sustainability, for example, through investment in mixed-species afforestation (Thomas *et al*. 2021) and plantations management to restore biodiversity (de Gouvello 2010). Alternative production technologies (Antal and Grønli 2003) are also critical for improved charcoal yields (Monsen *et al.* 2001). **Furthermore, secondary raw materials can provide charcoal that is viable both in cooking and metallurgy (Biswas 2018).** The copious amounts of agricultural (more than 4700 Mt annually) and other organic waste (Kaza *et al.* 2018) accumulating worldwide (e.g., saw dust, nut shells, rice straw, wheat straw, coffee husks, pits of olives, apricots, peaches and other fruits) are promising targets for such initiatives (Biswas 2018; Bogale 2009; Xiong *et al.* 2014). Efforts to make briquettes from such wastes for household use in order to limit the dependency on charcoal from trees are observed in several countries, including Ethiopia (Bogale 2009), Cameroon (Kapen *et al.* 2022), Kenya (Yuan and Gershenson 2021), and Tanzania (Songole and Aston 2019). In addition, sex-disaggregated data should be collected to help ensuring that women, who are already key participants throughout the wood charcoal sector, are given more opportunities for innovation and employment in the waste-to-charcoal initiatives for better financial outcomes (Ihalainen *et al.* 2020). **Moreover, innovation and education to reduce the exposure to indoor air pollution when cooking should be targeted to women, who generally face higher risks (WHO 2021).** Education, however, should also be directed to male heads of the household, who may control the financial resources to decide energy choices despite limited participation and, thus, limited direct exposure to harmful emissions during cooking (Schunder and Bagchi-Sen 2019). The combination of such specific measures would enhance progress towards environmental sustainability of the charcoal sector. It would further represent a necessary and crucial step directed at maintaining ecosystem functions and biodiversity while contributing to the well-being of humans around the globe, consistent with the latest report by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES 2022).





Secondary raw materials that can provide alternatives for charcoal production
Photo credits: From L to R: Shutterstock/Ant Clausen; Shutterstock/Anastasia Martyshina; Shutterstock/Maxal Tamor; Shutterstock/iamlukyeee; Shutterstock/Lamuka

Production of wood charcoal poses a risk to human health
Photo credit: Shutterstock/Asian Images

Transformation of wood into charcoal during pyrolysis releases smoke (**Figures 2,6**) containing tarry vapors, including gases, such as, methane, carbon monoxide, and sulfur dioxide (Nabukalu and Gieré 2019). These emissions are unmanaged, deleterious for air quality, and harmful to human health (Morrissey 2017), especially to producers in close proximity to kilns (see also Ankona *et al.* 2022), thus requiring education initiatives. Education, however, is also essential on the consumer side, because the use of charcoal releases particulate matter and gases, including mercury (Pandey *et al.* 2009) and the lethal carbon monoxide, thus creating risks of premature death (Liu *et al.* 1993; Morrissey 2017), especially during indoor cooking, where women and children in many low- and middle-income countries are at a distinct risk (Cusick *et al.* 2018; Schunder and Bagchi-Sen 2019; WHO 2021). In addition, more consumer knowledge about organic wastes as an alternative raw material for charcoal production (Biswas 2018; Surono 2019) would improve waste collection and management, especially in cities where charcoal demand is more pronounced.

Some environmental and/or energy policies inadvertently enhance charcoal demand, specifically for industrial applications. For example, more steelmakers are transitioning from coal (Global Energy Monitor 2021b) in metallurgical processes (Surup, Trubetskaya and Tangstad 2020) to the "carbon-neutral" or "renewable" charcoal alongside other options, such as hydrogen. Overwhelmingly, the largely rudimentary charcoal production methods (**Figures 6,7**) perpetuate environmental risks, especially as illegal logging for industrial use continues in places, such as the Amazon (Nogueira, Coelho and Uhlig 2009).

As with wood charcoal from the logs of freshly felled trees, the characteristics and the quality of briquettes can be highly variable depending on the types of waste feedstocks used and the production process (Singh, Singh and Sinha 2022). In households, consumer preferences for wood charcoal or briquettes are based on a user's subjective judgement of variables, such as, weight, dryness and smokiness during use (Nabukalu and Gieré 2019). By contrast, the variability of physical and chemical characteristics (e.g., crushing or compressive strength, porosity, calorific value, carbon content) of charcoal is more restricted in metallurgy, as specific requirements must be met for charcoal to perform well during ore processing and to produce superior quality metals and metalloids, such as silicon (Mousa et al. 2016; Troszack 2021; Singh, Singh and Sinha 2022). To obtain charcoal with consistent properties, therefore, metallurgical operations tend to favor specific types of wood, e.g., *Eucalyptus,* thus promoting large-scale deforestation and monocultures.

Charcoal briquettes
Photo credit: Shutterstock/Brad Boon

Conclusion

Charcoal is a ubiquitous global commodity, and its demand can undoubtedly be decoupled from poverty. Despite strategies in several countries to transform or supplant the international wood charcoal trade, this resource has sustained a potent, albeit unacknowledged and under-documented path, enabling it to aggressively compete with modern energy alternatives. Global wood charcoal production has increased for decades, and remains an important domestic energy source for low- and middle-income countries, emphasizing both its longstanding and resuming relevance. **Therefore, innovation and policies aimed at producing charcoal from organic waste materials are urgently required to prevent further forest degradation and loss of biodiversity, and to increase the sustainability of this material.**

Forest protection is important
Photo credit: Shutterstock/Cavan-Images

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