Renewable and Sustainable Energy Reviews 102 (2019) 285–306

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Adoption and impacts of clean bioenergy cookstoves in Kenya

Alice Karanja[a,*], Alexandros Gasparatos[b]

[a] Graduate Program in Sustainability Science – Global Leadership Initiative (GPSS-GLI), University of Tokyo, Japan
[b] Integrated Research System for Sustainability Science (IR3S), University of Tokyo, Tokyo, Japan

ARTICLE INFO

Keywords:
Fuelwood
Charcoal
Improved biomass stoves
Biogas
Ethanol
Sub-Saharan Africa

ABSTRACT

Kenya is one of the leading countries in the development and commercialization of clean bioenergy stoves in Sub-Sahara Africa. However, due to a series of interconnected factors, the adoption and sustained use of clean bioenergy stoves remains low in the country. This study synthesizes the current knowledge about clean and efficient bioenergy stoves in Kenya through a comprehensive review that brings together the disparate knowledge about the context, status, adoption and impacts of clean bioenergy stoves in Kenya. We start by outlining the main national policies technological, options and stakeholders involved in the clean bioenergy stove value chain such as government agencies, private companies, research organisations, and the civil society. Despite their different roles and interests, there is a shared expectation among all involved stakeholders that clean bioenergy stoves will curb the negative sustainability impacts of traditional cooking options on energy security/poverty, human health, rural livelihoods, gender equality, and the environment. However, a series of factors affect the adoption and sustained use of clean bioenergy stoves such as market structure, consumer awareness, stove design/performance, and the socioeconomic status and cultural practices of stove users. We develop a conceptual framework that illustrates the interlinkages between these factors of adoption and impacts, and outline their varying degree of importance in Kenya. We finish this review by suggesting six policy and practice domains that need to be targeted by policies and research if an effective transition towards universal clean cooking is to be achieved in Kenya. These include to (a) adopt integrated policy approaches and enhance stakeholder collaboration; (b) raise awareness of the benefits of clean bioenergy cooking options; (c) facilitate access to funding and establish appropriate economic incentives; (d) implement quality assurance mechanisms; (e) facilitate behavioural change among stove users; (f) enhance research, development, and technical capacity.

1. Introduction

Access to modern, clean and reliable energy affects practically every aspect of economic development and human wellbeing [1]. Energy demand, supply and use is tightly interlinked with multiple environmental and socioeconomic issues, and has emerged as one of the major sustainability challenges in Sub-Sahara Africa (SSA) [13,14]. Access to modern and sustainable energy has moved at the forefront of international policy discourse and has been enshrined in a dedicated Sustainable Development Goal (SDG7) that aims at *"ensuring universal access to affordable, reliable, sustainable and modern energy for all by the year 2030"*. Progress for SDG7 will partly be measured through the promotion, adoption and sustained use of clean fuels and energy technologies [15].

Currently, approximately 780 million people in SSA (out of 915 million) use traditional biomass such as fuelwood, charcoal and animal dung in open fire and inefficient stoves for their daily cooking and heating [1,2]. Such cooking practices have been linked to poverty, energy insecurity, gender inequality, and unhealthy living conditions [3–7]. For example, several studies have reported the dangers of using traditional inefficient cookstoves [5,8–10], and especially the health complications arising from exposure to indoor air pollutants [6], which cause an estimated 600,000 premature deaths annually [11]. At the same time, traditional and inefficient cooking practices can potentially have severe environmental impacts, especially linked to ecosystem degradation and greenhouse gas (GHG) emissions [12].

Clean cooking technologies that can substitute traditional and inefficient biomass stoves/fuels have become key elements in efforts aiming to curb the negative sustainability impacts of energy access and use in SSA [16,17]. Clean cooking encompasses "*cooking facilities which are used without harm to the health of those in the household and which are more environmentally sustainable and energy efficient than biomass*

* Correspondence to: Graduate Program in Sustainability Science – Global Leadership Initiative (GPSS-GLI), University of Tokyo, Japan, Building of Environmental Studies, 5-1-5 Kashiwanoha, Kashiwa City, Chiba 277-8563, Japan.
E-mail address: alice.karanja@s.k.u-tokyo.ac.jp (A. Karanja).

https://doi.org/10.1016/j.rser.2018.12.006
Received 21 June 2018; Received in revised form 18 November 2018; Accepted 6 December 2018
1364-0321/

cookstoves and the three-stone fires" [1]. This includes various technological options such as improved solid biomass stoves, biogas systems, liquefied petroleum gas (LPG) stoves, electric cookers, ethanol stoves, and solar stoves, all of which either do not use solid biomass or use it more efficiently compared to traditional stoves such as a "three-stone fire" [18–20].

Clean cooking has gained high visibility into policy and practice, and has been a cornerstone of numerous international initiatives. The Global Alliance of Clean Cookstoves (GACC) has been at the forefront of international efforts related to the adoption of clean and efficient cookstoves and fuels by 100 million households by 2020 [19,21]. Since GACC's launch in 2010, approximately 82 million stoves and fuels (including 53 million clean and efficient cookstoves) were disseminated globally through GACC partners between 2010 and 2015 [22]. Another relevant international initiative is the Sustainable Energy for All (SE4All), a global platform that aims to facilitate access to modern energy for all by 2030. SE4All has identified clean cooking as one of its high impact opportunities [23]. The World Bank launched in 2010 its Biomass Energy Initiative for Africa (BEIA) that seeks to modernise the biomass energy sector in SSA, and incorporate it into the organization's lending portfolio. The World Bank also launched in 2012 the Africa Clean Cooking Energy Solutions (ACCES), which aims to develop a market-transformation program that can enable scaling up the adoption of clean cookstoves in SSA through enterprise-driven approaches [22,24,25].

However, despite all these international initiatives, the adoption of clean cooking options has been notably slow throughout SSA [26]. Kenya is a good example of the current situation. Although it has been among the pioneers of clean cookstove development, marketing and distribution in SSA [2], only 6% of Kenyans have access to clean cooking fuels and technologies [1,27]. In fact more than 80% of Kenyan households (7.2 million households) still depend on woody biomass for their household energy needs [28]. Most of these households can be described as "rural" and "resource-poor", and face disproportionately the negative impacts of using traditional biomass fuels and inefficient stoves [29] (see above).

In order to curb these negative effects, the clean cooking sector has evolved rapidly in Kenya. Currently there are various stove and fuel options available to consumers, and a strong policy push to promote clean cooking throughout the country.[1] Numerous local and international companies, programmes and projects, produce, import and disseminate different types of clean cookstoves and fuels, either commercially or under carbon market schemes. These also include international development organisations such as the German Development Agency (GIZ) and Practical Action that have supported local artisans to design, assemble and disseminate clean stoves [31,32].

However, even though Kenya is widely regarded as a model African country for improved cookstoves, there is a fragmented knowledge about the impacts of different cooking practices, and the factors that influence the adoption of clean cooking interventions.

The main aim of this literature review is to synthesize the disparate current knowledge about clean and efficient bioenergy cooking in Kenya. We focus on clean bioenergy cooking options such as improved biomass stoves, biogas stoves, biomass gasifier stoves and ethanol stoves, as they have attracted extensive policy attention and form the backbone of clean cooking interventions in Kenya.

In particular, we synthesize the current knowledge about the policies (Sections 2.1–2.2), technologies (Section 2.3), stakeholders (Section 2.4), impacts (Section 3) and factors of adoption (Section 4) of clean bioenergy cooking options in the country. Our extensive literature review draws evidence from about 300 unique peer-reviewed papers, policy documents and technical reports, and develop a conceptual framework to illustrate the interlinkages between these factors and their varying degree of importance for the country (Section 5.1). We then identify six policy and practice domains that need to be targeted by policies and research if an effective transition towards universal clean cooking is to be achieved in Kenya (Section 5.2). In this respect this review is the most complete and comprehensive attempt to bring together the very disparate body of knowledge about the status, adoption and impacts of clean bioenergy stoves in Kenya.

2. Status of clean bioenergy stoves in Kenya

2.1. Biomass supply and demand

Biomass fuels dominate final energy use in Kenya. Biomass provides approximately 68% of the final energy use nationally [33], and 98% of domestic energy use in rural areas [34]. Various socioeconomic and environmental factors such as income, location, land use and cultural values, norms and practices affect the levels of biomass energy use in Kenya [32,36,37].

Fuelwood and charcoal account for approximately 70% of the biomass energy used for cooking and heating [35]. In 2010, more than 82% of Kenyan households (7.2 million households) relied on biomass for cooking, with fuelwood and charcoal being the main cooking fuel to 68.7% and 13.3% of households respectively [27,38,39]. Only 1.6 million households use predominately use other cooking fuels for cooking, including paraffin (11.5%), liquefied petroleum gas (LPG) (5%), and electricity (1%) [27].

Forests and woodlands cover about 7% of the country and provide about 45% of the biomass energy resources [32,40]. Farmland provides the remainder woody biomass, as well as other biomass resources such as agricultural residues and animal dung [41–44]. Conventional methods of fuelwood harvesting and charcoal production (e.g. inefficient earth kilns) contribute substantially to deforestation, land degradation, biodiversity loss, and greenhouse gas emissions [45].

However, the charcoal industry contributes approximately KES 32 billion (US$ 450million) annually to the Kenyan economy [32]. Charcoal production and trade has been legalized, with the Kenya Forest Service (KFS) handling the relevant regulations and permits. However, there is an overlap of mandates among the government agencies that relate to the charcoal value chain, which complicate the management and regulation of the woodfuel industry [32].

There is a large discrepancy in the national supply and demand, which cause a large annual wood supply deficit. In 2010 this wood supply deficit was estimated at 10.3 Mm^3 of wood [34]. Biomass energy supply and demand are expected to increase by 20.0% and 21.6% respectively by 2032, which will cause the fuelwood and charcoal deficit reach 18.3% and 19.1% respectively [46] (Fig. 1).

The low levels of biomass supply have been linked to several factors such as (a) inadequate management practices, (b) lack of alternative fuels, (c) forest conversion to agriculture and human settlements [39,47–49]. On the other hand, the high biomass demand has been linked to the (a) growing population, (b) high dependence on wood, (c) inefficient processing and utilization technologies across the entire value chain [39,47–49]. The combined effect of the above has contributed to the degradation of fuelwood stocks and has forced agrarian communities utilize animal dung and crop residues for cooking (rather than for fertilisers) [34,50,51]. Eventually all of the above have accelerated illegal charcoal production and forest loss [40,46,52].

It is in this context of a rapidly increasing biomass fuel demand and decreasing supply that efficient cooking options are promoted in Kenya. There is an expectation that the widespread adoption of such cooking options can help address the woodfuel supply deficit, and its associated negative environmental and socioeconomic impacts [32,40,47,53].

[1] For example, the Kenya Country Action Plan aims to facilitate the adoption of clean cooking practices by 5 million households and institutions by 2020 [30] (up from 3.2 million households in 2013).

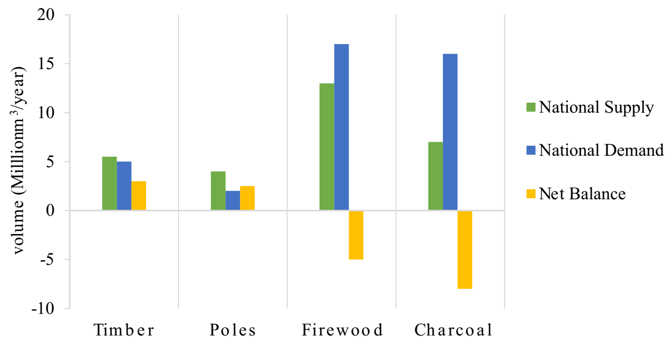


Fig. 1. Net-balances of potential national wood supply and current demand in Kenya (*Source:* [46]).

2.2. Energy policies and stakeholders

Kenya has a long history of policies, plans and programmes in the energy sector (including for biomass energy) [54–56]. Table 1 outlines the main recent energy policies and strategies in Kenya, and their link (or lack thereof) to clean bioenergy cooking options.

The Sessional Paper No 4 of 2004 articulates the overarching energy policy framework to realize economic growth in Kenya (Table 1). One of its key elements is the promotion of cost-effective, affordable and high quality energy services nationally in the period 2004–2023. This policy has framed several aspects of domestic cooking energy, including targets to catalyse the rate of adoption of efficient charcoal stoves in urban areas to 80% (by 2010) and to 100% (by 2020). Respective adoption targets for rural areas were 40% for 2010 and 60% for 2020. This energy policy also aimed to catalyse the adoption of efficient fuelwood stoves to 30% by 2020. Furthermore, there were prescription to (a) provide training to *Jua Kali* artisans[2] at the village level to improve the manufacturing, installation and maintenance of renewable energy technologies (including efficient cookstoves) and, (b) provide education on the appropriate use of biomass fuels to enhance public health [57].

The Energy Act No 12 of 2006 amended and consolidated several of the disparate energy policies but did not include any specific provisions for the promotion of clean bioenergy cookstoves (Table 1). However, in 2013, a miscellaneous provision related to improved biomass cookstoves was added through the intervention of the Clean Cookstoves Association of Kenya (CCAK). This provision was perceived to be crucial for the development of the Sustainable Energy for All Action Agenda. In particular this provision provided regulations for the (a) licencing of manufacturers, importers, distributors, technicians, and contractors of improved biomass cookstoves, and the institutional use of biomass fuels for cooking and heating; (b) provision of warranties to customers, and (c) disposal of stoves following other prevailing national environmental laws. This provision categorically defined improved biomass cookstoves as those that comply with the Kenya Standard KS 1814-1:2005.

The 2013 National Climate Change Action Plan (NCCAP) established provisions from the mitigate of (and adaptation to) climate change (Table 1). This policy estimated that the introduction of improved cookstoves and alternative cooking fuels could save up to 5.6 million tCO_2e annually. The NCCAP also formulated the Nationally Appropriate Mitigation Actions (NAMAs) that identify clean cooking as one of its Low Emission Development Strategies [58]. This NAMA expects that the promotion of clean cooking manufacturing and the development distribution centres can improve stove trade, licensing, and capacity building, having ripple effects for national poverty reduction.

Finally, the Energy Bill of 2015 consolidates a series of energy laws and regulations (Table 1). It establishes a regulatory framework in the energy sector that aligns the powers and functions of national government agencies, and outlines the responsibilities of it devolved structure. Table 2 outlines relevant government entities and their stipulated responsibilities. Unlike its preceding energy policies, the Energy Bill of 2015 does not include any provisions for the promotion of clean bioenergy stoves.

The overarching driver behind most of these energy policies has been the need to modernise the production, processing, distribution and consumption of energy (and particularly) biomass energy [54,59]. This was seen as particularly pressing in respect of the rapid urbanization that has increased the demand for charcoal, and raised concerns over resource degradation and energy insecurity [32,47,61–63]. Other underlying drivers include the need to accelerate economic growth, income equality and poverty alleviation [46,54,64–66]. To achieve these policy requirements the aforementioned policies include numerous measures and interventions that seek to facilitate energy transitions, expand sustainable biomass supply, capitalise on recent technological innovation, and promote overall enabling conditions [52,60].

However, the effective implementation of the existing energy policies and legal framework is hindered by the demand-supply imbalance of biomass energy (see Section 2.1) [67]. Policy implementation is also hindered by the insufficient investments in the biomass energy sector due to prevailing perceptions that biomass energy is inferior to other energy options such as electricity [68].

It is worth mentioning that until recently the national government was solely responsible for policy formulation and implementation. Other key stakeholders in the bioenergy and stove value chains (see also Section 2.4) have had limited participation in the development of energy policies, plans and programmes that sought to promote clean bioenergy cooking options [10,33,35,54,68–70]. However, recent experiences suggest that Kenyan policymakers are either unaware of (or ignorant about) the importance of traditional biomass fuels (and the absolute necessity to tackle issues related to their demand, supply and use) [54,71,72]. More importantly cooking energy seems to have been a marginalised (or even neglected) topic during the formulation of energy policies and related interventions in Kenya [55]. This is despite evidence that suggests that the adoption of an integrated set of measures that can formalise and modernise the biomass energy sector, could catalyse the successful implementation of current energy policies [73].

In fact, it has been suggested that improved, clean and energy-efficient bioenergy stoves (referred to as clean bioenergy stoves for the remainder of the review) can contribute in several aspects of these policies. For example, clean bioenergy stoves can increase fuel efficiency by 25–60% and reduce significantly indoor air pollution compared to the traditional three-stone fire [81,84,86]. Kenya is a pioneer country for the promotion of different types of clean bioenergy stoves such as improved biomass stoves (Section 2.3.1), biomass gasifier stoves (Section 2.3.2), biogas stoves (Section 2.3.3), and ethanol stoves (Section 2.3.4).

2.3. Commercialization of clean bioenergy stoves in Kenya

2.3.1. Improved biomass stoves

The first improved biomass stoves appeared in the 1900s and were followed by multiple other designs (Table 3). The early 1980s saw accelerated efforts to develop and promote new biomass stove designs due to extensive changes in population, urbanization, income and charcoal consumption [84,85]. In particular, charcoal scarcity (especially during the rainy season) interfered with reliable charcoal supply [84,87,88]. This marked the backdrop for the development of the Kenyan Ceramic *Jiko* (KCJ) through the collaboration of donors, local ceramists and metal-working artisans [89] (Table 3). The German Cooperation Agency (GIZ) spearheaded the promotion efforts in partnership with Practical Action, the Ministry of Agriculture, and the Ministry of

[2] These are clusters of informal metalworking artisans that operate near marketplaces. These artisans sell directly to end-users or work with last-mile distributors.

Table 1
Main energy policies in Kenya and provisions to promote clean cookstoves.

Policy/Legislation	Overall aim	Provisions		Actions to promote clean cookstoves
		Biomass energy	Cookstoves	
Sessional Paper No. 4 of 2004 on Energy, [74]	Lays the policy framework for sustainable, cost-effective, affordable and adequate quality energy services.	✓	✓	– Mainstreams gender issues in energy planning – Initiates programmes for promotion of (and education for) improved stoves – Increases the efficiency levels and rate of adoption of charcoal and fuelwood stoves – Requires the training of local stove artisans
Energy Act No. 12 of 2006, [75]	Amends and consolidates the law relating to energy. Provides clauses for the establishment, mandate and functions of the regulatory authority.	✓	X	– Puts provisions for the promotion of renewable energy technologies (incl. biomass) – Does not mention explicitly energy efficient cookstoves
The Kenya Vision 2030, [76]	Outlines the national long-term development blueprint for Kenya.	✓	X	– Requires the planting of at least seven billion trees to enhance food, water and energy security, and restore 10% of forest cover
Kenya National Climate Change Response Strategy (2010), [77]	Establishes measures for addressing the challenges posed by climate variability and change.	✓	✓	– Promotes energy efficient cookstoves as a means of catalysing lifestyle and livelihoods interventions – Includes provisions for subsidies and tax waivers for poor households to acquire energy efficient stoves
The National Climate Change Action Plan, (NCCAP) 2013, [78]	Identifies the key priorities to successfully achieve a low-carbon, and climate-resilient growth in Kenya to realize the ambitions of Vision 2030.	✓	✓	– Supports the use of improved biomass cookstoves and LPG cookstoves – Requires the increase of awareness of improved cooking practices and stove quality – Requires pilot initiatives to promote the use of LPG fuel and stoves – Includes provisions to increase access to soft loans, build the capacity of stove producers, and improve access to testing facilities.
The Energy (Improved Biomass Cookstoves) Regulations, 2013 *(Miscellaneous provision to Energy Act No. 12 of 2006)*, [79]	Provides regulations for the manufacturers, importers, distributors, technicians and contractors of improved biomass cookstoves.	✓	✓	– Establishes requirements for improved biomass stove alongside the entire stove value chain in terms of licensing, standardization, warranties and disposal
National Energy and Petroleum Policy, 2015, [80]	Ensures the affordable, competitive, sustainable and reliable supply of energy to meet development needs at the national and county scales, while protecting the environment.	✓	✓	– Acknowledges that kerosene stoves cause indoor air pollution – Incentivizes consumers to switch to clean household energy options
The Energy Bill of 2015, [81–85]	Consolidates energy laws to establish the functions and mandates of national and local government in relation to energy.	✓	X	– N/A

Table 2
Main government actors in the energy sector and their functions under the Energy Bill of 2015.

Entity	Key responsibilities
Ministry of Energy	– Develop an enabling environment for investors and protect consumers – Enforce energy regulations and standards – Create awareness for energy conservation and efficient energy use
County Government Ministries of Energy	– Develop energy plans and policies to meet national energy needs – Regulate and license renewable energy systems, and charcoal production and distribution – Establish energy centres for the promotion of renewable energy technologies
Energy Regulatory Commission (ERC)	– Regulate the production, conversion, distribution, marketing and use of renewable energy – Ensure the import of efficient and cost-effective energy appliances and equipment – Formulate, enforce and review environmental, health, safety and quality standards
Energy Tribunal	– Quasi-judicial body in the energy sector
Rural Electrification and Renewable Energy Corporation	– Develop, disseminate and promote renewable energy pathways and relevant technologies – Build local capacity for the manufacturing, installation, maintenance and operation of renewable energy technologies
Energy and Petroleum Institute	– Undertake research and development, and relevant dissemination activities related to the energy sector – Promote the local production of renewable energy technologies – Create awareness and disseminate information about the conservation and efficient use of energy
Centre for Energy Efficiency and Conservation (CEEC)	– Implement energy efficiency and conservation programmes nationally
Kenya Climate Innovation Centre (KCIC)	– Provide support for climate-related innovations through business incubation, seed financing, specialized policy interventions, network linkages and business training

Energy.

The KCJ was inspired by the Thai bucket stove and is among the most successfully commercialized improved biomass stove designs in Kenya [82,90]. In 1985, about 125,000 KCJ stoves were disseminated in Nairobi and other urban areas [81,83,84,88,90,91]. The successful implementation of this initial program was due to the (a) training of local artisans, (b) provision of working capital assistance, (c) awareness raising through demonstrations and marketing campaigns [92]. The KCJ stove is still very popular in Kenya, as it is used in over 50% of urban and 16% of rural households. Its use has spread to neighbouring African countries such as Uganda, Rwanda, Ethiopia, Malawi, Niger, Senegal, and Sudan [67].

The main reason for the long-term success of the KCJ stove has been the incorporation of design elements and features found in traditional stoves [91]. This allowed the evolution of the stove design through extensive field tests and continuous modification [91]. However, the mass production of KCJ stoves in the informal sector has put obstacles in the enforcement of manufacturing standards seeking to improve efficiency, as the local artisans tend to change the design and use inferior materials [91,93–97].

The efforts to develop and promote improved biomass stoves accelerated even more in the late 1990s and early 2000s (Table 3). These include both models manufactured domestically (e.g. *Jiko Kisasa*, fixed-brick rocket stove) and imported (e.g. Envirofit, *Jiko Poa*). The uptake of the imported mobile models has been very high, especially in the urban and peri-urban areas [103–106]. Most of these new designs have been tested in laboratories for thermal efficiency, and reportedly consume less fuelwood, emit less smoke and soot, and are more safe and convenient to use [102].

The extensive commercialization of improved biomass stoves since the late 1990s has been facilitated through the programmatic support of stove production and dissemination [26] through the provision of incentives to local artisans that use locally available materials, and focus on women empowerment and local employment generation [98]. In 2006, the GIZ launched the Energising Development programme that aimed to increase access to modern energy for households, social institutions and small- and medium-sized enterprises. Approximately 5 million people were commercially served with modern cooking energy by mid-2016, with targets to reach 6.2 million people by mid-2018 [103].

Carbon finance and private investments have become very prominent in the Kenyan stove sector, contributing to the massive boom of stove manufacturing and importation. The possibility to earn revenues through carbon markets [e.g. Clean Development Mechanism (CDM), Gold Standard carbon market programmes] also attracted large international investments, further increasing the financial capacity of the sector [56]. By 2017, eight cookstove Programmes of Activities (PoA) were registered [99] and aimed to reduce greenhouse gas emission by 2.4–3.0 tCO_2 per year per stove [56,167,263]. Despite uncertainties in the carbon market, this trend is likely to increase through the development of innovative financing mechanism, capacity building and scaling up carbon finance opportunities such as the Green Climate Fund [101].

2.3.2. Biomass gasifier stoves

The design and development of biomass gasifier stoves follows the Anderson and Reed model of biomass combustion gasifier units [107]. In principle, the biomass fuel in the form of wood, briquette, coffee husks or animal dung is converted into combustible gas through controlled pyrolysis, yielding clean heat and charcoal as a by-product [48,105,108,109]. Different variants include the natural draught design and the forced air design, with their main difference relating to how the airflow is fed to the combustion chamber.

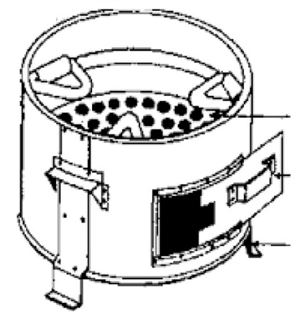
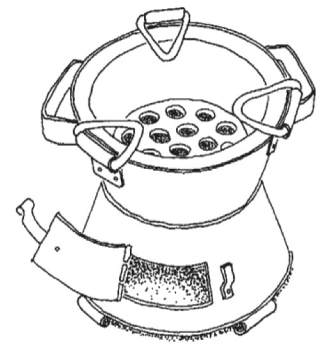
Gasifier stoves have been highly promoted in Kenya through the Kenya Industrial Research and Development Institute (KIRDI) that has developed prototypes for testing following the Anderson and Reed design. The char by-product can be used as a soil amendment to increase farm yields [103]. The gasifier system has reportedly reduced poverty among smallholders and improved indoor air quality in some rural areas of Kenya [107]. However, the high initial cost (approximately USD 35), difficulty during operation, low stove stability and the risk of burns from the hot galvanized wall are major challenges for its wide promotion [110].

2.3.3. Biogas stoves

Biogas is produced through the anaerobic fermentation of biomass, animal slurry and other organic waste [112] (Fig. 2). It contains approximately 50–70% CH_4 and 30–50% CO_2 depending on the substrate input [113]. Biogas is increasingly becoming popular among small-scale dairy farmers in rural communities as a means of producing both clean and reliable fuel, and organic fertilizer from the bio-slurry [114,115].

Historically, Kenya was among the first African countries to embrace biogas technologies in the early 1950s. By 1986 there were about 200 installed biogas plants, but fewer than 25% were actually operational [111]. The uptake remained low for several years until the Kenya National Domestic Biogas Programme (KENDBIP) was rolled out in 2009, under the Africa Biogas Partnership Programme (ABPP) [115,116]. Within its first phase (2009–2013), the programme constructed 11,529 biodigesters and provided investment subsidies to

Table 3
Main types of improved biomass stoves in Kenya.

Year of inception	Stove name	Technological description	Stove images (Cr: [83–85])
1900s	Traditional *jiko* stove[a]	– Introduced by Indian railroad laborers – Charcoal stove made of scrap metal and assembled by local tinsmiths (cottage industry scale) – Uninsulated. Radiates heat radially and to the pot – Retails at KES 35–45 per unit – Lasts about one year at full use. However the metal grate needs replacement after three months at a cost of KES 10	
1981	*Umeme* (power) Stove[a]	– Promoted by UNICEF – All-metal, double-walled, charcoal stove with an insulating layer between the two walls. Weighs about 6.5 kg – Features an outer body with a door frame and a sliding door to control the air intake in the inner cylindrical combustion chamber – High fuel efficiency due to the enclosed combustion chamber. Good convective heat transfer to the inserted pot, insulated chamber walls and regulated airflow. – Remains hot for a long time, cooks fast and is durable. The large firebox diameter provides stability. – Retails at KES 97–125 at a production cost of KES 60 per unit – The stove body last 3–4 years at full use. The metal grate needs replacement after 6–12 months at a cost of KES 15–20	
1982	Kenya Ceramic *Jiko* (KCJ)[a]	– Funded by USAID and implemented by the Ministry of Energy – Charcoal stove made predominately of ceramic and some metal elements – The ceramic lining reduces heat loss from lateral radiation and increase stove durability – The design features an inlet for draught control and perforated grate for ash collection, three hinged triangular-shaped flaps to hold one cooking pot, stove legs for support and a handle. – Retails at KES 125–250 at a production cost of KES 100 per unit	
2006	*Jiko Kisasa*[b]	– Promoted by GIZ (EnDev-Kenya) – Fixed stove with a combustion liner made from clay designed to use fuelwood, crop waste and other biomass fuel. – Fuel is fed through a single opening at the front of the stove. – No chimney, but can reportedly produce less smoke than an open fire – Uses 40% less fuelwood compared to the traditional three-stone stove – The price for the ceramic liner varies between KES. 250–12,000 depending on the size. An extra KES. 50–250 is required as installation fee if it has to be fixed in the kitchen	
2006	Fixed-brick rocket stove[b]	– Promoted by GIZ (EnDev-Kenya) – Wood stove made entirely from ceramics using rocket stove principles (i.e. burning small pieces of wood in a high temperature combustion chamber) – The design of the pot rest allow for the easy transfer of the generated heat to the cooking pot – Thermal efficiency of 24–32% and 30% smoke reduction compared to the three-stone stove – The price for the rocket stove varies between Ksh. 1200–10,000 depending on the type of material used and the size of the stove	

(*continued on next page*)

Table 3 (*continued*)

Year of inception	Stove name	Technological description	Stove images (Cr: [83–85])
2013 (Kenya)	*Jikokoa*[c]	– Commercialized by Burn Manufacturing Ltd – Mobile charcoal stove, designed in the USA and manufactured in Kenya. – Has a fuel efficiency of 48% and can reportedly achieve 60% smoke reduction – Incorporates a high-efficiency combustion chamber, light-weight ceramic insulation and insulated handles and has an ashtray designed to collect ashes and for draught control – Retails at KES. 4000–5000 depending on location	

[a] Germann and Westhoff [86]. Stove Images: A Documentation of Improved and Traditional Stoves in Africa, Asia and Latin America.
[b] Photo credit: GIZ EnDev – Kenya.
[c] Photo credit: Photo by author.

Fig. 2. Household biogas stove in operation (photo taken by author).

reduce upfront costs (each biogas plant received a flat subsidy of KES 25,000). Phase 2 (2014–2017) aimed to install a further 27,500 biodigesters, but without financial assistance through subsidies [117].

In parallel to the KENDIP, various private and carbon-finance investments have promoting different biogas designs such as the floating dome, fixed-dome type, tubular/balloon digesters [113,118,119]. The Nairobi River Basin Biogas Project is among the most successful CDM projects in Kenya. This programme aims to construct about 10,000 domestic biogas digesters (of 2–3 m^3 capacity) in rural households in Kiambu country that own a minimum of two zero-grazing cows [120].

Despite this boom in the development of biogas units, about 30% of the installed units may not be operational due to poor design/construction, low end-user awareness of best management practices, and poor water supply [121]. The Kenya Standard 2520:2013 established parameters to ensure that Kenyan biogas stoves and digesters are efficient, safe and durable [122].

2.3.4. Ethanol stoves

Ethanol stoves have been promoted less compared to the improved bioenergy stove options discussed above. The United Nations Development Programme (UNDP) launched in 2011 a pilot ethanol stove/fuel project with local micro-distilleries in Kisumu County. The particular stove design has an efficiency of 65%, reduces indoor air pollutant emissions and has flame characteristics similar to an LPG stove [123]. This pilot project intended to establish the necessary structures for the commercialization of ethanol fuel and stoves in Kisumu Country. It aimed to define the market, identify user preferences, and determine possible environmental and socioeconomic benefits [28,51,124].

Consumers Choice Ltd has recently developed a denatured ethanol gel used in specialized stoves. In particular, the ethanol stove uses non-pressurised denatured fuel canisters (1.2 L) that contain the ethanol fuel. The stove burner flame is controlled or extinguished through a regulating lever. The high viscosity of the ethanol gel minimizes the risk of accidental spillage. The ethanol fuel is produced in Kenyan sugar factories and is then shipped to Tanzania for processing into a viscous yellow liquid. The final fuel is then shipped back to Kenya for packaging and distribution through Moto Poa Ltd.[3]

2.4. Clean bioenergy stove value chain

The clean bioenergy stove value chain in Kenya consists of different stages, namely (a) raw material extraction, (b) stove production and assembly, (c) stove distribution and retail, (d) stove end-use [125] (Fig. 3). Due to the diversity of stove technologies and designs (Section 2.3), various stakeholders are involved in the Kenyan clean bioenergy stove value chain (Table 4).

Apart from those stakeholders that are directly involved in the production and delivery of clean bioenergy stoves, there are various other stakeholders that have vested interest in clean bioenergy cookstoves (Table 4) [122]. These include government agencies, NGOs, research organisations, donors and international organisations. Even though these peripheral stakeholders are rarely involved in the actual delivery of cookstoves, they play an extremely important for the successful integration of clean bioenergy stoves.

3. Impacts of clean bioenergy cookstoves

3.1. Energy security and energy poverty

In 2000,[4] fuelwood accounted for 89% of the household energy use in rural areas (741 kg/person/year) and 7% in urban areas (691 kg/person/year) [126–128]. However, biomass stocks in Kenya are declining (Section 2.1). There are substantial concerns about how the looming fuelwood scarcity will affect the (primarily poor) households that rely on fuelwood and charcoal for cooking [129–131].

Clean bioenergy stoves tend to have higher fuel efficiency, compared to traditional biomass stoves, requiring less fuel to achieve the same cooking outcomes. Thermal energy efficiency improvement has

[3] Personal communication with the CEO of Moto Poa Ltd., Kenya.

[4] The term 'energy poverty' encapsulates the multiple problems that arise from the lack of reliable access to energy. These include various economic, equity, education, health concerns as discussed in the following sections.

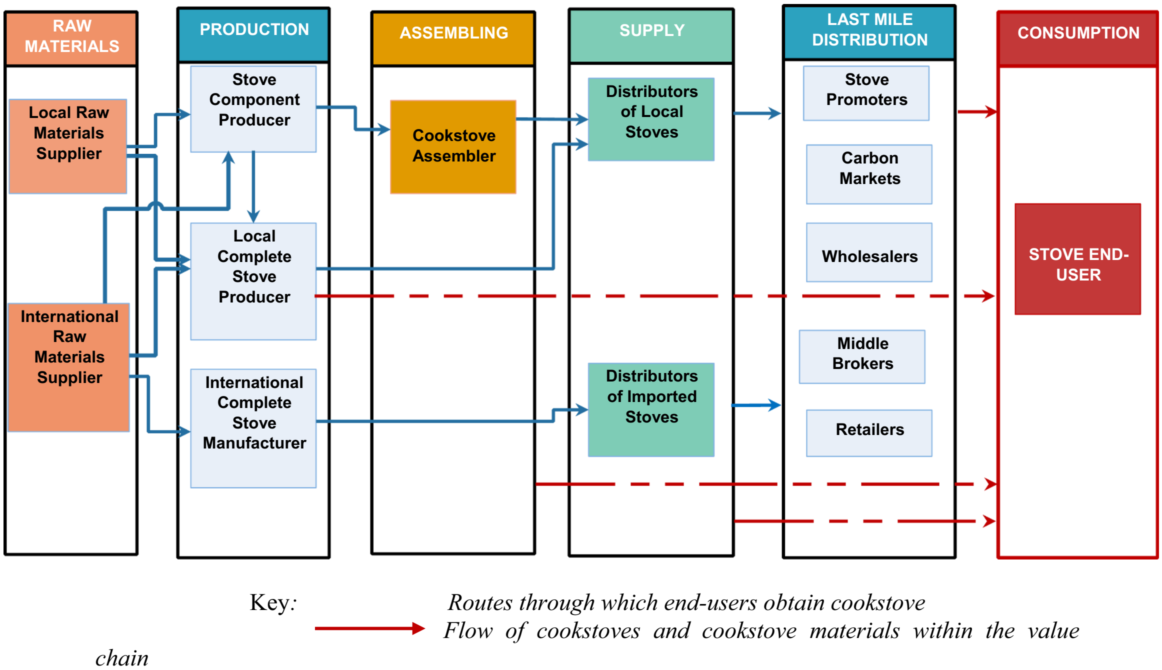


Fig. 3. Simplified value chain of clean bioenergy cookstoves (Adapted from [122]).

been identified as a key measure to reduce excessive fuelwood use for cooking, and at the same time deliver improved energy services [132–135]. Various water-boiling tests (in lab settings) and kitchen performance tests (in real settings) have quantified the efficiency improvement and fuel savings of improved bioenergy stoves in Kenya. Such tests have reported high fuelwood savings (25–60% depending on stove characteristics) compared to traditional three-stone stoves [129,136,137]. Similar studies have also shown that cleaner cooking options can have substantial time-savings by reducing the time invested in fuelwood collection and cooking (on average 4–6 h per day per family) [138–140].

Depending on the technology and design (Section 2.3), the adoption of clean bioenergy stoves can reduce (e.g. improved biomass stoves) or eliminate altogether (e.g. biogas stoves) fuelwood use (Table 5). This can improve the energy security of the (predominately poor) households that depend on traditional biomass stoves [124,141], and reduce household vulnerabilities to fuel scarcity, e.g. due to escalating fuel prices [142] or increasing time requirements for fuelwood collection (e.g. travelling longer distances) [124,129,143].

The monetary savings from the procurement of cooking fuel [141,144–146] can be diverted to meet other basic household needs. This can be especially beneficial for low-income households that reportedly spend about 15% of their income on cooking fuel [14]. However, the cost of procuring and maintaining an improved bioenergy stove needs to be taken into consideration, as such costs might be substantial for poor households [147,148]. The saved time can be invested to pursue other livelihood and educational activities (Sections 3.4–3.5), especially for women and girls (Section 3.7).

3.2. Ecosystems and climate

By reducing the amount of charcoal/fuelwood use or switching to a totally different fuel (Section 4.1), clean bioenergy stoves can reduce impacts on ecosystems and the climate (Table 5). For example, traditional biomass stoves require extensive amounts of fuelwood and charcoal that is often sourced or produced from natural forests and woodlands (Section 2.1). Unsustainable fuelwood harvesting often degrades such ecosystems [17], causing deforestation and land degradation in Africa [42,149] and Kenya in particular [150,151]. This in turn reduces species habitat, and contributes to the loss of biodiversity [152] and multiple ecosystem processes and services such as watershed functions [43,153,154], carbon storage [32,41,62,137,155,156] and soil fertility/health [17]. Several studies have pointed to the ecosystem benefits that a switch toward cleaner bioenergy cooking alternatives can have [157–161].

Biomass combustion in inefficient stoves can also emit large amounts of greenhouse gases (GHG). These emissions affect the global climate [149,150] and have been estimated at 1.0–1.2 Gt CO_2e yr^{-1} (or 1.9–2.3% of global GHG emissions) [58,162–165]. On the contrary, clean bioenergy cooking options generally emit less GHG due to their different fuel and/or higher efficiency [153,163,166–168] (Section 2.3). Switching to clean bioenergy cooking options can have substantial GHG emission savings estimated at 1–3 tCO_2e yr^{-1} per stove [152,154–157]. Finally, some clean bioenergy cooking options, such as biogas, can further reduce direct and indirect GHG emissions by capturing and using methane (CH_4), a potent GHG, and substituting chemical fertilizers [165,170,171].

3.3. Health and safety

The inefficient fuel combustion in traditional biomass stoves emits large amounts of indoor air pollutants such as fine particulate matter (e.g. $PM_{2.5}$), carbon monoxide (CO) and nitrogen oxides (NO_x) [5,172,173]. Women, girls and young children spend are particularly exposed to such pollutants as they spend substantial amounts of time kitchens (that are also often poorly ventilated) [107,174–176].

It was estimated that about 4.3 million premature deaths globally (600,000 in Africa, 14,300 in Kenya) are linked to indoor air pollution, largely from cooking with traditional biomass fuels [177,178]. Some of the most common health complications include respiratory diseases, chronic obstructive pulmonary disease, eye irritation, cataract, headaches and burns [179,180]. Additionally, cooking-related indoor air pollution has been linked to adverse pregnancy outcomes such as stillbirth, child survival, low birth weight [181], and increased risk of pneumonia to children below the age of five [6,182–185].

The adoption and sustained use of clean bioenergy cookstoves can reduce indoor air pollution and its adverse health outcomes [106,140,175,186,189] (Table 5). For example, improved stoves can

Table 4
Main stakeholders in the clean bioenergy cookstove value chain in Kenya.

Stakeholder group	Stakeholders	Role and activities
Private sector	Cookstove manufacturers, e.g. Burn Manufacturing Ltd., Afrisol Ltd., Sustainable Energy Strategies Ltd., Flexi biogas, Envirofit, Cookswell Jikos, Moto Poa Ltd.	– Design, manufacture and distribute clean and efficient cookstoves, including improved biomass stoves, biogas stoves, ethanol stoves, and biomass gasifiers, among others
	PayGo Energy Ltd.	– Sell LPG in small quantities through a product service platform that uses smart metering and a pay-as-you-go approach
	Equity Bank Ltd.	– Provide financing for the acquisition of clean cookstoves – Offers the *Ecomoto* loan, an initiative that employs flexible processing and repayment modalities
	Local Artisans (individuals and groups)	– Design, manufacture and sell clean and efficient cookstoves directly to end-users or work with last-mile distributors – Diverse stakeholder group that includes clusters of informal metalworking artisans that are active near marketplaces
	Women Producer Groups	– Develop networks to assist the production, sales and promotion of stoves as local ceramicists, marketers and installers. – Diverse stakeholder group that includes various women groups such as the Keyo Pottery Women's Group in Western Kenya that has manufactured and sold stoves since the 1980s.
Carbon market developers	Carbon market ventures e.g. Impact Carbon, My Climate, Carbon Africa Limited, Climate Care	– Generate a market for carbon offsets through the dissemination of clean cooking technologies – Register projects in the UNFCCC Clean Development Mechanisms, Gold Standard and other voluntary markets
Government agencies	Ministry of Energy	– Formulate energy policy and regulate the energy sector – Provide incentives for the adoption of relevant technologies, e.g. through the KENDBIP Biogas program
	Kenya Bureau of Standards	– Design and maintain quality standards for locally manufactured and imported stoves – Develop testing methods and protocols for biomass and biogas cookstoves
Non-Governmental Organisations (NGOs)	The Clean Cookstove Association in Kenya (CCAK)	– Facilitate business capacity development and advocacy for the formulation of clean cooking policies – Raise public awareness and induce behavioural change for clean cooking practices
	Global Alliance of Clean Cookstoves (Regional Secretariat is based in Nairobi, Kenya)	– Accelerate the production, deployment, and use of clean and efficient cookstoves and fuels – Offer funding, research, and logistical support – Undertake economic feasibility assessments for clean cooking interventions
	W-Power programme	– Formulate a cohesive and targeted advocacy agenda to strengthen women involvement in clean energy access and entrepreneurship
	NGOs e.g. Energy 4 Impact; Kenya Climate Innovation Center, Practical Action, Winrock International	– Support innovative projects, initiatives and business models related to clean cooking – Provide financial/technical assistance, resources and facilities to innovators to realize their ideas, develop management and business skills, and grow their businesses
Academia and research organisations	The University of Nairobi African Center for Technology Studies	– Provide market intelligence – Test the efficacy of the stoves introduced in the national market
	Kenya Industrial Research and Development Institute (KIRDI) Stove Testing Center	– Undertake Research and Development, and design of energy efficient cooking technologies – Champion the expansion of biofuels and other renewable energies pathways
	Kenya Forest Research Institute (KEFRI)	– Carry out research on woodfuel characterization (e.g. charcoal, fuelwood) and biomass gasification – Influence policies related forest resource management
	Stockholm Environment Institute (SEI) World Agroforestry Center (ICRAF)	– Conduct research and implement projects related to environmental and development challenges, including energy access, and sustainable biomass production and use

(*continued on next page*)

Table 4 (*continued*)

Stakeholder group	Stakeholders	Role and activities
Donors and international organisations	GIZ-EnDev Programme	– Develop energy markets to foster the diffusion of renewable energies and technologies to households, social institutions and businesses
	SNV Netherlands Development Organization	– Collaborate with local partners to facilitate the creation and development of markets for clean cooking technologies and fuels
	Hivos International	– Partner with government agencies, local stakeholders and entrepreneurs to promote clean cookstoves and domestic biogas systems through markets – Employ carbon finance to provide financial incentives – Offer a guarantee system to protect end-users against faulty construction and malfunctions
	The International Fund for Agricultural Development (IFAD)	– Support labor-saving technologies and innovations that reduce the workloads of rural women, including improved biomass stoves and biogas technologies
	The United States Agency for International Development (USAID)	– Develop the clean cookstove sector through projects that strengthen the business operations of cookstove enterprises – Encourage private sector participation in the energy market – Collaborate with financial institutions to increase private-sector finance available to enterprises involved in the cookstove supply chain and consumers that seek to purchase clean cookstoves
	United Nations Development Programmme (UNDP)	– Support business incubators to promote entrepreneurship in renewable energy technologies – Partnered with Project Gaia and Practical Action (in 2012) to pilot bioethanol use in Nyanza province, test its viability, and stimulate demand in rural areas and humanitarian settings [33]
Stove users	Individual stove users e.g. households, restaurants, food vendors institutional users (e.g. schools, hospitals)	– They are the end-users of various stove technologies – Different factors affect their decision over stove adoption and sustained use (see Section 4)

reduce CO and $PM_{2.5}$ emissions [171,175]. Based on various studies that have quantified pollutant concentrations in kitchens, traditional stoves and clean stoves result in ambient $PM_{2.5}$ concentration of 300 μg/m^3 and 70 μg/m^3 respectively [169,187,188]. However, to achieve the maximum health benefits, there is a need to prioritise the use of clean fuels at the community level to meet the WHO's air quality guidelines for CO and $PM_{2.5}$ emissions [187,190].

It should be noted that fuelwood collection often requires venturing over long distances and carrying heavy loads on the back or head. Such practices increase the likelihood of injuries and other adverse health effects [106,181,191], harassment and other forms of violence [192]. Due to their lower fuel requirement, clean bioenergy stoves reduce substantially the frequency of trips (and the time spent per trip) for fuelwood collection. Hence they can reduce the drudgery and associated health effects (e.g. back pains) related to fuelwood harvesting [144]. This in turns frees up time for rest, child caring, education or involvement in income-generating activities, especially for women and girls [107,111,112] (see Sections 3.4–3.6).

3.4. Income and employment

Multiple employment and income opportunities can be generated across the clean bioenergy stove value chain (Section 2.4), including in stove design, manufacturing, marketing, distribution and sales [101,111–113] (Table 5). This includes some high-skilled jobs that can provide sufficient income for decent living [140]. For example in 2016, GIZ reportedly created about 1000 jobs in stove production in different private enterprises in Kenya [54,96].

Some clean bioenergy cooking options such as biogas can even generate employment and income outside the stove value chain, e.g. for masons, plumbers, and civil engineers that build the biogas infrastructure [193,194]. Similarly the clean bioenergy stove sector can theoretically provide an alternative market for ethanol feedstock smallholders (e.g. cassava, sugarcane), diversifying their market options.[5] However, actual evidence of this pathway is still anecdotal considering the small penetration of ethanol stoves in Africa [20].

However, the promotion of clean bioenergy stoves can have important livelihood trade-offs. In particular the fuelwood and charcoal sector are major sources of rural employment and income in Africa [195,196], and Kenya in particular. Approximately 200–350 jobs/TJ are generated across the charcoal value chain [197], while commercial biomass energy value chains employ about 13 million people across SSA [198]. Fuelwood and charcoal production constitute a large proportion of the informal economy in Kenya. Approximately 635,000 people are involved [195], contributing an estimated US$1.6 billion per year to the national economy [101,104,111,199,200]. However, the increasing reliance on imported stoves can curb local employment and income opportunities both in the stove value chain (e.g. stove production, marketing, and instalment) [6,54,96,197,201] and the fuelwood/charcoal value chain. Such livelihood trade-offs need to be considered when promoting clean bioenergy cooking options.

3.5. Education

As discussed above, traditional stoves require higher quantities fuelwood. This in turn requires substantial time investment for fuelwood collection and cooking. These tasks are often assigned to young children, especially girls, whose time could have otherwise been invested attending school or doing homework [195]. Similarly, overburdened parents often prevent children from attending school in order to assist with fuelwood collection and cooking [202]. Clean bioenergy stoves can reduce the time needed for fuelwood collection and cooking, thus offering a real opportunity to improve educational attainment, especially in rural areas [203]. Similarly, clean bioenergy cooking options can free parents' time, thus enhancing the available time for child care work, e.g. for preparing breakfast for school children [203,204].

Furthermore, clean bioenergy cooking options can offer several

[5] Market diversification was one of the key elements of the unsuccessful CleanStar stove project in Mozambique. For a short period of time, cassava smallholders provided the feedstock to produce the ethanol used in the CleanStar cookstoves [271].

Table 5
Impacts and impact mechanisms of clean bioenergy cooking options.

Impacts	Impact mechanisms	Kenya references	Other references
Energy security and poverty (Section 3.1)	– Reduce household vulnerability to fuelwood scarcity through the reduction (e.g. improved biomass stoves) or elimination (e.g. biogas systems, ethanol stoves) of the need for fuelwood and charcoal – Provide economic savings from fuel procurement, which can be invested for other household needs	[132,134,135,138,140,143]	[126–131,136,137,141,142,144–148]
Ecosystems and climate (Section 3.2)	– Reduce deforestation and habitat loss (and the associated biodiversity loss and ecosystem services degradation) by reducing the demand for fuelwood and charcoal – Reduce the loss of carbon stock and GHG emissions by reducing the demand for fuelwood and charcoal – Biogas systems capture methane reducing overall GHG emissions from livestock rearing and waste management – Biogas systems produce bio-slurry that reduces the demand for chemical fertilizers, which reduces indirectly GHG emissions from agricultural systems	[112,113,119,137,163,169,170,180]	[163,174]
Health and safety (Section 3.3)	– Reduce the negative health effects related of indoor air pollution (e.g. respiratory diseases, post-pregnancy complication, stillbirths, pneumonia risk) by reducing the emissions of indoor air pollutant through the more efficient combustion of biomass (in improved biomass stoves) or the direct use of clean fuels (e.g. biogas, ethanol) – Reduce the risk of injuries (e.g. burns, scalds) and safety (e.g. house fires) associated with open-fire traditional stoves – Improve kitchen hygiene and home ventilation due to lower smoke emissions	[5,107,170,175–177,186,228]	[107,174,190]
	– Reduce the negative health effects (e.g. back pains, injuries) of fuelwood collection – Reduce the safety risks (e.g. violence, rape) of fuelwood collection	[10,174,191]	[96,101]
Income and employment (Section 3.4)	– Offer opportunities for income generating activities and local employment across the stove value chain – Cause loss of local employment in the charcoal and fuelwood value chains	[107,112,140,144,227]	[6,197]
Education and training (Section 3.5)	– Boost school attendance by reducing the workload placed on children (and especially girls) for fuelwood collection – Relieve school budgets from high fuel costs, with the monetary savings invested for improving educational activities	[174,204]	[5]
Food security and nutrition (Section 3.6)	– Prevent the decline of crop productivity due to the loss of ecosystem functions, by reducing pressure on ecosystems (see impacts on ecosystems and climate) – Enhance crop productivity by using the bio-slurry generated from household biogas systems as an organic fertilizer – Promote positive diet transitions and improved nutrition through improved cooking and food preparation practices	[116,207,208,210,211,229]	[80,95,213]
Women empowerment (Section 3.7)	– Reduce burden on women and girls from fuel collection and exposure to indoor air pollution, to allow them rest, pursue an education or engage in income-generating activities – Offer opportunities for engagement in entrepreneurial activities and employment along the clean stove value chain	[72,180,215,216]	[92,111,207,212,215,220,221,224–226]
Humanitarian impact (Section 3.8)	– Reduce the multiple vulnerabilities that displaced/refugee communities experience – Prevent/reduce conflicts with local host communities over limited biomass resources	[221]	[201–203,207,222,223,228,230]

benefits to educational institutions. For example, in Kenya, schools reportedly spend large amounts to procure fuelwood for cooking school meals. Depending on the number of children and location of the school such expense can range between USD 128 and 148 per month [72]. The availability of clean bioenergy cookstoves in schools can relieving financial pressure on school budget and at the same time ensure that children receive properly-cooked meals [205,206], This can both boost school attendance (e.g. school meals can incentivize poor families to send children at school) [207] and improve educational services by relieving school budgets [5,208,209].

3.6. Food security and nutrition

The unsustainable fuelwood collection and charcoal production can cause land degradation, desertification and the loss of watershed functions [43,154,210,211] (Section 3.2). These processes place an added pressure on agricultural systems in Africa [49,212] and curb agricultural productivity in some areas [205]. This can possibly reduce food availability and thus cause food insecurity [209].

Furthermore, prevailing fuelwood harvesting and charcoal production can cause the overexploitation of forests, leading to fuelwood scarcity (Section 3.1). Studies have identified the links between fuelwood scarcity and cooking habits, such as eating half-cooked food, cooking food with low nutritional value that require less cooking time, and not boiling water enough [213]. Other studies have shown that households that use consistently clean bioenergy stoves have higher diet diversity and consume food with higher nutritional quality [175,214,215]. This is because clean bioenergy stoves can allow for the easy regulation of the cooking temperature (Section 2.3). This is because clean bioenergy stoves can allow for the easy regulation of the cooking temperature (Section 2.3), allowing the preparation of meals that were previously avoided due to their time-consuming preparation, sensitivity to heat, or high risk of spoilage [181]. Similarly, households can, in theory, invest the saved money and time (see Section 4.1) to improve access to more nutritious food and adopt better food preparation practices [209]. However, currently there is anecdotal evidence of the above mechanisms rather than clear empirical evidence.

Finally, some clean bioenergy cooking options have indirect positive effects to food production. For example, households with biogas systems can use the generated bio-slurry as an organic fertilizer to boost food productivity and crop diversity [216] (Table 5). Furthermore, studies have found higher food crop productivity for households that produce sugarcane for ethanol, due to their better access to fertilisers from their involvement in out-grower schemes [217].

3.7. Women empowerment and gender equity

Most of the leading international organisations involved in the design, promotion, and implementation of clean cookstove interventions such as the GACC, World Bank and WHO have made a strong case that clean cooking can contribute manifold to women empowerment and gender equality [6,19,95,99].

The starting point of their rationale is that most of the negative health and educational outcomes of traditional cooking options are gender-differentiated, in that females face disproportionately the negative impacts (Sections 4.3 and 4.5). In particular, women and girls are usually disproportionately responsible for gathering fuelwood and cooking. For example in Kenya, women reportedly spend at least one hour per day gathering fuelwood for cooking [203], which reduces their available time to pursue activities related to education or paid employment (Table 5). Furthermore, women and girls are much more exposed to indoor air pollution due to cooking [95], and experience higher health and safety risks due to fuelwood collection (e.g. injuries, violence, rape) [218].

Several studies have found that females experience substantially higher negative health outcomes and loss of education/economic opportunities, due to their more substantial time investment in unpaid household work and exposure to indoor air pollution [4,92,94,218–221].

Apart from reducing exposure to indoor air pollutants (Section 3.3) and generating time savings (Section 3.1), clean cookstove value chains create opportunities for women to engage in entrepreneurial activities related to stove design and distribution [219,222] (Section 3.5). The strong engagement of females in such activities can not only enhance gender empowerment [223], but also the adoption and sustained use of clean cookstoves [224] (see Section 5).

3.8. Humanitarian impact

According to 2016 statistics, more than 65 million people have been displaced globally due to conflict, war and natural disasters [225]. Refugees are a particularly vulnerable group, which lives under very difficult conditions and often in conflict with surrounding communities. Most refugee camps in Sub-Sahara Africa have very limited access to reliable energy sources, and almost all do not have clean cookstoves and fuels [208,226]. Even though humanitarian organisations distribute the vast majority of food in refugee camps, they rarely provide, cooking fuel [224]. Thus refugees often depend on traditional wood-based fuel for cooking collected from nearby forests and woodlands.

This lack of reliable and clean cooking energy accentuates all the negative impacts described above (Sections 3.1–3.7). For example, the Moving Energy Initiative has estimated that more than 26,000 ha of forest are lost annually to meet the energy needs of displaced families living in refugee camps [28,51,124]. This enhances the probability of conflict with surrounding communities due to the competition over local (and often scarce) biomass resources [227]. Furthermore, some of the main coping mechanisms for fuel scarcity employed in refugee settings include skipping/undercooking meals, and bartering and selling food for cooking fuel [208]. Negative gender-differentiated outcomes are particularly prevalent in such humanitarian settings, as women and girls risk physical and sexual attack, dehydration, injuries and exertion from walking long distances to fetch for fuelwood [32,41,62,137,155,156,228–230].

The dissemination and sustained use of clean cookstoves can have very positive humanitarian and development outcomes [108,162,165,169]. For example, in Kenya, the GIZ has managed over 20 years the local production and distribution of *maendeleo* portable fuelwood stoves to 68% of refugee households within Dadaab refugee camps [230].

4. Factors of adoption of clean bioenergy stoves in Kenya

4.1. Conceptual framework

The effective switch to clean and energy-efficient cookstoves depends on a set of factors that collectively affect stove acceptance, initial uptake, sustained use, maintenance and future replacement. Systematic reviews have identified various relevant factors related to stove characteristics, household characteristics, and the prevailing institutional landscape [8,145,234,235]. In Sections 4.2–4.8 we populate the conceptual framework of Puzzolo et al. [231] with literature from Kenya as systematised in Table 6.

To allow for a smoother discussion of the interactions between factors of adoption we follow a relatively different structure than Table 6, across the following domains:

- Fuel and cookstove characteristics (Section 4.2);
- Household and intra-household characteristics (Section 4.3)
- Knowledge and perceptions (Section 4.4);
- Financial mechanisms and subsidies (Section 4.5);
- Market development (Section 4.6);
- Policy coherence (Section 4.7);
- Regulation and standardization (Section 4.8).

4.2. Fuel and cookstove characteristics

Costs influence substantially the adoption and sustained use of stoves in Sub-Sahara Africa [118,170,233,275] and Kenya in particular [155]. As already discussed clean bioenergy stoves offer significant financial and time saving, as they require lower amounts of fuelwood (or even nullify the need for fuelwood) (Section 3.1).

The expected or actual lower operational costs and monetary savings often influence the decision to adopt improved bioenergy stoves, especially for those households that depend on buying fuel from markets (rather than collecting or producing it) [235,269,276,277]. On the other hand, fuel/cost savings are not an important factor of stove adoption for households that procure their fuel for free or at low costs, due to their proximity to forests [175,235,278]. Additionally, the expected time-savings can influence the adoption of stoves that consume less fuelwood and cook faster, especially by households that invest substantial amounts of time in fuel collection and procurement [107,274] Conversely, the opportunity costs of time spent on cooking or fuel collection may not influence stove adoption in setting where fuelwood and labor are abundant [148]. However, the high capital and maintenance costs of some types of clean bioenergy stoves such as biogas can become a barrier for the adoption of stoves by poor households [119,147].

Stove characteristics can also affect stove adoption and sustained use. For example, high time savings can be achieved through stoves whose materials and design allows for improved heat transfer, energy

Table 6
Domains and individual factors of adoption of clean bioenergy stoves in Kenya [231].
Source: Domains adapted from [231].

Domain/factor of adoption	Refs.
1. Knowledge and perceptions	
Health impacts of indoor air pollution	[118,138,169,233–239]
Consumer research on stove design	[240]
Perceptions from previous projects/ programmes	NA
Participatory approaches	[230]
Cost of fuel collection (e.g. time/energy)	[5,33,143,201]
Views of women	[153]
Household characteristics	[118,169,232,233,240–242]
Desirability, affordability, convenience	[6,113,119,233,234,237,243–246]
Perspectives of international donor organisations	[242,247]
2. Fuel technology characteristics	
Choice of new and more efficient stoves	[119]
Choice of a wide range of technologies	
Pilot programmes to assess performance in practice	[162,235,248,249]
Quality and safety standards	[250]
3. Financial, tax and subsidy mechanisms	
New finance options linked to climate change	[251–253]
Impact of different financial models	[70]
Lessons from finance models used in small scale energy projects	NA
Role of financial institutions in administering funds	[100,254]
Private sector involvement	[138,255]
Option of spreading cost of stoves over time	[100,101,256]
Impact of short-term financing	[257]
Government grants	NA
Impact of financial model used	[87,119,140,183,256,258]
Technical assistance to support cookstove manufacturers	[259]
Indirect subsidies (e.g. stove design/ promotion, capacity development)	[64,118,200,249,260]
4. Regulation and legislation	
Cookstove standards	[261]
Quality control	[262–265]
Role of national institutions	[256]
5. Market development	
Use of consumer research and feedback	[235,250]
Issues of perceived performance and availability	[70,216]
Views of women	[153]
Role of private sector	[266]
Households characteristics	[118,169,201,232,233,241,267–269]
Desirability, affordability, convenience	[236,256]
Tension of cost vs sophistication	
6. Programmatic and policy mechanisms	
Evidence of multi-sectoral approaches (e.g., energy, gender, health, forestry, climate)	[109,259]
User training	[138,236]
Use of specific systems	[183,216]
Use of local artisans vs benefits of mass production	[30]
Capacity building	[270,271]
Role of national co-ordinating agencies	[245]

Note: NA denotes that it was not possible to identify relevant literature from Kenya.

efficiency and simultaneous cooking of different dishes [237,247]. In addition, stove designs that meet user needs and enable the preparation of local dishes with traditional cooking utensils are desirable in some local settings [113,116,119]. On the other hand, stove designs that fail to accommodate specific cooking styles, fuels, and available resources for maintenance and renovation might not be adopted in some local contexts [279].

Biogas systems are a prime example of how the above factors interact to influence stove adoption and sustained use. On the one hand, biogas systems can have substantial monetary savings from fuel purchase (about USD 0.40/m^3_{biogas}) compared to conventional fuelwood stoves [113]. Although the installation and capital costs are very high for poor households [119,279,280], the operating costs are often very minimal for household that have ready access to waste or animal dung for feedstock (e.g. livestock owners) [235,246]. However, as biogas systems are often marred with technical and operational difficulties [109,262,278], the proper training and reliable local support of users are essential for the adoption and sustained use of biogas systems [269,270].

4.3. Household and intra-household characteristics

Socioeconomic and demographic household characteristics such as size, income, education, and gender dynamics can influence decisions over the adoption of clean bioenergy stoves. For example, household income is a particularly important determinant of initial stove uptake [119,246], and becomes especially crucial when moving up the energy ladder, whereby the upfront stove cost increases (see above) [64,113,118,235,236,249]. Education often relates to knowledge and awareness about the perceived benefits of clean cooking [116,170,236,249] (see also Section 3).

On the other hand large household size can have a negative effect on stove adoption, as large households can share fuelwood collection and cooking among their members, thus assigning a lower value to the time and labor needed to perform such tasks [272,273,274]. Intra-household gender dynamics are also crucial for stove adoption, as households where women cannot make independent or consensual decisions over household budget allocation, might not prioritise stove purchase over other household needs [118].

Finally, home ownership (especially of permanent dwellings) may increase the willingness to invest in home appliances such as built-in stoves with chimneys [113,235,246]. Some technologies such as biogas systems require a spacious compound, strong land tenure, and ownership of at least 2–3 cows to provide a reliable source of fuel [148,237–239].

4.4. Knowledge and perceptions

Several studies in Kenya have highlighted a persistent lack of awareness on the available clean cooking alternatives and the consequences of cooking with traditional and inefficient stoves [100,138,239,281]. Enhancing public awareness and sensitizing the public about the health, safety, hygiene and environmental benefits of clean cooking is critical in catalysing the widespread adoption of clean bioenergy cookstoves [243,282]. However, some recent studies on consumer behaviour and stove choices have indicated a that strong focus on the health and climate mitigation benefits of clean bioenergy cookstoves does not influence substantially their adoption if they are not affordable [59,138,283–285]. In such contexts, stove promotion campaigns should prioritise messages that reflect the time and money savings, as such messages are more likely to boost the willingness to pay for clean bioenergy stoves [286].

Furthermore, combining techniques that forge social relations and facilitate behavioural change can influence the diffusion and adoption of clean cookstoves by creating social multiplier effects amongst peers [138,148,247,287–289]. However, the actual experience of the influencer can dictate the effect that social networks and peer influence can have either on stove adoption [46,234].

Cultural practices, traditions and beliefs can also enable (or act as a barrier to) stove adoption. For example, clean cookstove adoption can be hindered in cultural contexts where stove users use smoke as an insect-repellent, black soot for medicinal purposes or generally like the smoky taste of food [252]. In other cultural contexts the ability to accommodate the multiple utensils needed for cooking for large families or prepare local dishes with customized cooking utensils are pre-requisites for stove adoption [191].

4.5. Financial mechanisms and subsidies

Subsidies and financial incentives can influence significantly the initial acquisition of clean bioenergy stoves, especially if stoves are expensive or the potential users experience liquidity constraints [119,140,261]. However, large subsidies can have a negative affect on the perceived stove value, maintenance and future replacement [64]. Apart from financial incentives to low-income users, some studies have argued for offering subsidies in upstream activities in the stove value chain such as research, manufacturing, and distribution [252,259]. Similarly costs related to stove installation and maintenance (especially for stoves prone to malfunction and regular technical maintenance) may impede stove uptake and/or sustained use [100,272]. The availability of consumer finance through microcredit/loans, instalment payments options, price incentives and promotional offers can address to some extent such high upfront costs [101]. On the other hand, short repayment periods and high interest rates are significant barriers for obtaining microcredit/loans to purchase clean cookstove, especially for poorer households [243,259,287,290].

4.6. Market development

Stable markets, well-developed consumer strategies, and reliable supply chains can all have a positive effect for the adoption of clean stoves. Market development essentially increases marketing efficiency, distribution and sustained adoption of clean cookstoves [291]. However poor rural infrastructure can affect the distribution, accessibility, availability and pricing of stoves that are bulky, prone to malfunctions, and/or not locally produced [77]. To avoid such problems, organisations such as GIZ-Kenya, train local stove dealers and artisans to improve the accessibility, installation, maintenance and replacement of clean bioenergy stoves. These dealers also play an important role in raising local awareness and consumer education [233].

4.7. Policy coherence

Clean cookstove programmes ought to align their goals and complement the broader national energy policies (Section 2.2). Such coordinated efforts can mainstream clean cookstoves in existing and planned energy policies, thus creating a conducive policy environment to facilitate the widespread promotion and adoption of clean cookstoves [68,216].

The Government of Kenya has made several efforts to integrate cookstoves in existing energy policies, but not always in a coordinated manner (Section 2.2). One such recent effort (in 2016) has been the development of incentives to attract investments for scaling-up access to clean cooking, including the exemption of value added tax (VAT) on LPG. The Government of Kenya also announced the reduction of import duty on efficient cookstoves from 25% to 10% [80]. However, significant effort would be still needed to integrate more meaningfully cookstoves in the existing national energy policies (Section 5.2). For example, there must be coordinated action to link cookstoves with broader rural development programmes/policies and to foster greater community involvement [79].

4.8. Regulation and standardization

As already outlined in Section 2.3, very diverse clean bioenergy stove options are currently available in Kenya. It is very important to ensure the quality and performance of the available stove options to ensure both customer protection and trust [191] and ensure that proper incentives and market access is given to reputable stove manufacturers [30,100].

To ensure the quality of stoves introduced in the market, the Kenya Bureau of Standards (KEBS) developed household stove standards in 2005. However, these standards currently address only thermal efficiency, durability and the testing approach, but not the emissions of indoor air pollutants [292]. Moreover, enforcement mechanisms and penalties for non-compliance with the existing stove standards are yet to be formulated.

Currently, there are several stove-testing facilities at academic institutions (e.g. the University of Nairobi) and the *Kenya Industrial Research and Development Institute* (KIRDI). However, due to their high costs, many of the small local stove producers have limited access to these facilities [135].

5. Discussion

5.1. Knowledge synthesis

Section 4 outlined the very diverse social, economic, cultural, technical, organizational and personal factors that influence the initial adoption and sustained use of clean bioenergy cookstoves in Kenya. Some of these factors are more crucial for catalysing the initial household decision to adopt clean bioenergy stoves, while other factors

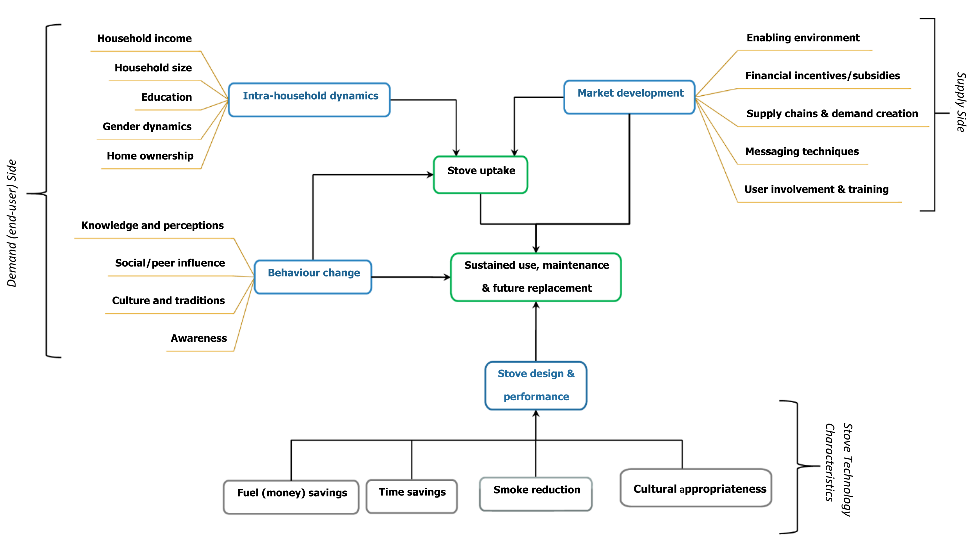


Fig. 4. Linkages and interactions between the different factors of stove adoption in Kenya.

influence more decisions related to stove maintenance, consistent use, and future replacement. Fig. 4 illustrates the main linkages between these factors in Kenya.

On the demand-side (i.e. user-side), our review indicates that affordability, awareness and willingness to uptake a "better" cooking stove are key determinants of the initial purchase. Affordability depends on the socioeconomic status of households (i.e. purchasing power) and the availability of subsidies and economic incentives. However, the factors that motivate stove purchase, may not necessarily motivate its ultimate adoption and sustained use. Adoption and sustained use seem to depend much more on stove technology and design, and as an extension on the benefits expected to accrue from them. As already discussed in Section 2.3, there are several clean bioenergy stove options in Kenya, which have radically different technological and design characteristics (e.g. fuel use, time/financial investment, pollutant emissions) and ability to meet the various cultural requirement related to food taste and cooking multiple meals (Section 3).

On the supply-side, our review suggests that the stakeholders involved in stove promotion and dissemination can influence significantly stove adoption. This is because they can strategically influence the market in terms of stove accessibility, availability and affordability, through effective supply chain management, user engagement, demand creation, and provision of appropriate financial incentives and subsidies. That said, stove dissemination programmes and sales campaigns ought to ensure the readily available support for the maintenance and future replacement of stoves. Economic incentives to such stakeholders (e.g. reduced taxes and import duties) can create an enabling environment for further investments in clean cookstove value chains, and ultimately facilitate the diffusion of clean cooking technologies at affordable prices (Sections 4.5–4.6). To ensure that stove design and attributes meet user needs, expectations and values, stove programmes must engage meaningfully the targeted stove users/communities (and particularly women) in stove design.

Stove adoption and sustained use can have multiple positive impacts for household energy security (Section 3.1), ecosystem conservation (Section 3.2), human health (Section 3.3), livelihoods (Section 3.4), education (Section 3.5), and food security (Section 3.6). Some of these impacts are gender-differentiated, so the adoption and sustained use of clean bioenergy cookstoves can provide an important impetus for female empowerment and gender equality (Section 3.7). Furthermore, clean bioenergy cookstoves can offer substantial benefits in humanitarian settings, reducing the multiple vulnerabilities that displaced groups face (Section 3.8). However, the widespread stove adoption can have some negative impacts, mainly through the loss of local livelihoods (Section 3.4). In order to minimise such negative impacts, such trade-offs must be taken into consideration by stove promotion policies and dissemination strategies.

It is worth mentioning that the type, mechanism and magnitude of these impacts can depend substantially on factors such as the: (a) stove technology and use patterns, (b) socioeconomic, environmental and cultural context within which stoves are promoted, (c) institutions that govern stove/fuel development, dissemination and use. Understanding the effect of these factors (and their interlinkages) would be crucial for informing the development and implementation of stove interventions that maximize the positive impacts of clean bioenergy stoves to humans and the environment.

5.2. Policy implications and future outlook for Kenya

Based on our literature review we identify six policy and practice domains that need to be targeted in order to achieve the effective promotion, adoption and sustained use of clean cooking interventions in Kenya. These include the need to: (a) adopt integrated policy approaches and enhance stakeholder collaboration, (b) raise awareness of the benefits of clean bioenergy cooking options, (c) facilitate access to funding and establish appropriate economic incentives, (d) implement quality assurance mechanisms, (e) facilitate behavioural change among stove users, (f) enhance research, development, and technical capacity.

Household cooking energy spans multiple policy domains (Sections 2.1–2.2) and several types of stakeholders (Section 2.3). Clean cooking policies and interventions should, to the extent possible, follow a multisectoral approach that integrates the perspective and interests of different government agencies with mandates ranging from energy, to agriculture, health, industry and the environment [191]. At the same time there is a need to enhance the role of local governments in the production and dissemination of stoves. It has been pointed that the lack of strong policy mandates at the level of the local government, may prevent the effective realisation of the clean cooking targets laid down in national energy policies [30] (see Section 2.2).

Overall, the lack of policy synergies, overlapping mandates and uncoordinated interactions with the private sector may lead to the suboptimal utilization of available resources and hamper stove production, financing, quality control, and scaling up [68]. Thus it is important to enable the development of a policy and regulatory environment that engages multiple stakeholders to actively regulate the clean stove sector, support innovation, attract investments, and enforce systems for non-compliance. Such a coordinated approach could maximize policy synergies and ensure that action plans are homogenous and not operating in a compartmentalized manner.

Raising effectively consumer awareness about the availability and benefits of clean cookstoves is a key example of why a multi-stakeholder approach is needed. In the recent past, Kenya has successfully achieved market transformation and behavioural change for public health issues such as malaria (e.g. promotion of bed nets) and sanitation (e.g. campaigns for hand-washing) [199,293]. However, when it comes to household energy use, many consumers are still not aware of the health risks associated with the use of traditional biomass and stoves [118,273,294]. Furthermore, consumer knowledge about the availability of different clean cooking alternatives is even more limited [138,239,281]. In order to enable behavioural change it is important to invest in educating (and raising the awareness of) consumers about the benefits of clean bioenergy stoves. This is a major undertaking that cannot be achieved by the private sector alone. Instead it will require the contribution of government agencies, international donors, research organisations and the civil society.

Access to finance is a key constraint across the clean stove value chain, especially as carbon finance markets weaken [252]. Evidence suggests that direct consumer subsidies may not be sustainable in the long-term, as income influences substantially the transition of households up the energy ladder [201,295,296]. However, direct subsidies linked to positive environmental and health impacts, or micro-financing, could enhance the affordability of stoves and fuels (and ultimately their long-term adoption) [100,211,297]. Flexible payment modalities for stoves and fuels, with longer payback periods, may also accelerate the adoption of clean bioenergy stoves [138,295]. At the same time, there is a need to rethink the taxes, import tariffs and trade barriers for stoves that are either imported or produced in Kenya by large international manufacturers. Lack of economic incentives to such players might preclude the extensive penetration of high-quality stove technologies or the manufacturing potential within Kenya.

Stove quality and high standards for energy services can also influence the adoption and sustained use of clean bioenergy stoves (Section 4.8). Whereas Kenya has made significant steps in formulating standards for biomass stoves [77], there is still a need to add provisions for emission reductions and enforcement mechanisms for non-compliance. When it comes to quality control, much more still needs to be done in Kenya, including long-term investment in testing centres that are not prohibitively expensive for local stove producers and artisans.

The transition towards universal clean cooking requires the radical transformation of the mindsets and cultural practices of stove users. Persuading users, mostly women, to stop using solid biomass requires tailoring policies and programmes to take account of the social and cultural context of the targeted users. The active engagement of local communities, particularly women, is fundamental for stove design to help develop and deliver appropriate solutions tailored to local conditions and needs [242,251].

Finally, domestic stove producers have low technical capacity and manufacturing capabilities [100,201]. Major financing gaps prohibit market entry and the development of innovative products [30,298]. It is critical to develop mechanisms that can build the capacity for domestic stove production, assembly, marketing and financing. For example market intelligence is critical for the development of clean cooking options and is often highlighted as one of the biggest current technical constraints [16,148,252,266]. The scientific community can provide knowledge and practical solutions for these priority policy and practice domains. Our review is a first step towards integrating cohesively the current literature, but also identifies several research gaps that need to be targeted in future empirical studies.

First, we find that the existing knowledge about the impacts and adoption of clean bioenergy stoves is highly fragmented (Sections 3–4). We develop a conceptual framework that links the main phenomena at the interface of clean cookstoves adoption and impacts (Section 5.1) that should be tested in future empirical studies.

Second, despite some pockets of excellence there is a lack of high-quality empirical research about the performance, impacts and adoption dynamics of clean bioenergy stoves. To start with, there is a need to assess stove performance in realistic settings beyond laboratories. Such research will be important to understand the effects related to new clean stove models. Furthermore most current studies focus on single (or a limited subset of) impacts, drivers of adoptions, geographical settings and/or technologies. There is a need for more comprehensive quantitative studies that adopt a multi-impact assessment approach or a comparative outlook between different geographical, technological and sociocultural settings. Such evidence about the impacts and adoption dynamics is conspicuously missing in the existing literature for marginalised groups (e.g. refugees camps, humanitarian settings).

Third there is a need to involve more critically the perceptions/needs of stakeholders and the voices of users and local communities. For example participatory and ethnographic research approaches can involve more meaningfully local communities to elicit some of the cultural factors that might affect stove adoption and sustained use. The adoption of research co-design and co-production approaches could enhance the relevance of empirical research to the different stakeholders involved in clean stove value chains.

6. Conclusion

This literature review provided a comprehensive outlook of the current state of the clean bioenergy cookstove sector in Kenya. Clean bioenergy stoves can provide a sustainable solution in Kenya in the face of the increasing demand-supply imbalance of biomass energy, and the negative environmental and socioeconomic impacts of traditional cooking practices. We identify that a wide range of factors affects the adoption and sustained use of clean bioenergy stoves, including market structure, consumer awareness, stove design/quality, and the socio-economic status and cultural practices of stove users. Nonetheless, all these factors are highly interlinked and have varying degrees of importance depending on the environmental, socioeconomic and institutional context.

Overall, the adoption and sustained use of clean bioenergy stoves offers a practical solution to address many of the interconnected sustainability challenges that Kenya faces, from energy security/poverty, to public health, rural livelihoods, food security, education, women empowerment, and environmental conservation.

Although Kenya has been striving to modernise its energy system, clean bioenergy cookstoves are still not well integrated in current energy policies. Different stakeholders have undertaken several disjointed efforts to promote clean bioenergy stoves, with mixed, however, results. We identify six policy and practice domains that need to be targeted to enhance the sustainable development potential of clean bioenergy stoves in Kenya. These include the need to: (a) adopt integrated policy approaches and enhance stakeholder collaboration; (b) raise awareness of the benefits of clean bioenergy cooking options; (c) facilitate access to funding and establish appropriate economic incentives; (d) implement quality assurance mechanisms; (e) facilitate behavioural change among stove users; (f) enhance research, development, and technical capacity.

A deeper understanding of the interaction between the factors of stove adoption and stove impacts can provide a solid evidence base for developing policies and practical solutions to achieve universal clean cooking in Kenya, and elsewhere in Sub-Saharan Africa.

Acknowledgements

We acknowledge the support of the Japan Society for the Promotion of Science (JSPS) for a Grant-In-Aid of Young Scientists (A) (17H05037). Alice Karanja is supported by a Monbukagakusho scholarship offered by the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT) through the Graduate Program in Sustainability Science-Global Leadership Initiative (GPSS-GLI), at the University of Tokyo.

We thank Ms. Anna Ingwe of GIZ EnDev – Kenya and Dr. Dorsi Doi Germann of Europa Universität Flensburg for permission reuse stove images in "Table 3".

References

[1] IEA. Energy access outlook. 2017: from poverty to prosperity Paris: International Energy Agency (IEA); 2017 [Available at: 〈https://webstore.iea.org/weo-2017-special-report-energy-access-outlook〉].
[2] World Bank. Global tracking framework 2017: progress towards sustainable energy. Washington D.C.: World Bank; 2017 [Available at: 〈https://www.seforall.org/sites/default/files/GTF%20Executive%20Summary%202017.pdf〉].
[3] Sovacool BK. The political economy of energy poverty: a review of key challenges. Energy Sustain Dev 2012;16:272–82. https://doi.org/10.1016/j.esd.2012.05.006.
[4] Dutta S. Energy as a key variable in eradicating extreme poverty and hunger: a gender and energy perspective on empirical evidence on MDG 1. In: Gender as a key variable in energy interventions. Draft background paper for ENERGIA/DfID/KaRResearch Project R8346; 2005. Available at: 〈http://www.energia.org/〉.
[5] Person B, Loo JD, Owuor M, Ogange L, Jefferds MED, Cohen AL. "It is good for my family's health and cooks food in a way that my heart loves": qualitative findings and implications for scaling up an improved cookstove project in rural Kenya. Int J Environ Res Public Health 2012;9:1566–80. https://doi.org/10.3390/ijerph9051566.
[6] WHO. Burning opportunity: clean household energy for health, sustainable development, and wellbeing of women and children. Geneva: World Health Organization (WHO); 2016 [Available at: 〈http://www.who.int/airpollution/publications/burning-opportunities/en/〉].
[7] Bailis R, Drigo R, Ghilardi A, Masera O. The carbon footprint of traditional woodfuels. Nat Clim Change 2015;5:266–72. https://doi.org/10.1038/nclimate2491.
[8] Puzzolo E, Pope D, Stanistreet D, Rehfuess EA, Bruce NG. Clean fuels for resource-poor settings: a systematic review of barriers and enablers to adoption and sustained use. Environ Res 2016;146:218–34. https://doi.org/10.1016/j.envres.2016.01.002.
[9] Ruiz-Mercado I, Masera O, Zamora H, Smith KR. Adoption and sustained use of improved cookstoves. Energy Policy 2011;39:7557–66. https://doi.org/10.1016/j.enpol.2011.03.028.
[10] Mark Blackden C, Wodon Q. Gender, Time Use, and Poverty in Sub-Saharan Africa; 2006. 〈http://siteresources.worldbank.org/INTAFRREGTOPGENDER/Resources/gender_time_use_pov.pdf〉.
[11] WHO. Indoor air quality guidelines: household fuel combustion. Geneva: World Health Organization (WHO); 2014 [Available at: 〈http://www.who.int/airpollution/guidelines/household-fuel-combustion/IAQ_HHFC_guidelines.pdf〉].
[12] Owen M, der Plas R, van, Sepp S. Can there be energy policy in Sub-Saharan Africa without biomass? Energy Sustain Dev 2013;17:146–52. https://doi.org/10.1016/j.esd.2012.10.005.
[13] Janssen R, Rutz D. Bioenergy for sustainable development in Africa. Expl Agric 2012;48(4):451. https://doi.org/10.1017/S0014479712000567.
[14] Brew-Hammond A, Kemausuor F. Energy for all in Africa — to be or not to be?!. Curr Opin Environ Sustain 2009;1:83–8. https://doi.org/10.1016/J.COSUST.2009.07.014.
[15] UN. Transforming our world: the 2030 agenda for sustainable development. United Nations General Assembly 70 Session; 2015. 〈https://doi.org/10.1007/s13398-014-0173-7.2〉.

[16] Simon GL, Bailis R, Baumgartner J, Hyman J, Laurent A. Current debates and future research needs in the clean cookstove sector. Energy Sustain Dev 2014;20:49–57. https://doi.org/10.1016/j.esd.2014.02.006.
[17] Pearson TR, Brown S, Murray L, Sidman G. Greenhouse gas emissions from tropical forest degradation: an underestimated source. Carbon Balance Manag 2017;12(1):3.
[18] GACC. 100 Million by 2020: the global alliance for clean cookstoves is expected to reach its phase I goal ahead of schedule. Washington, D.C.: Global Alliance of Clean Cookstoves (GACC); 2014〈http://cleancookstoves.org/about/news/09-30-2014-100-million-by-2020-the-global-alliance-for-clean-cookstoves-is-expected-to-reach-its-phase-i-goal-ahead-of-schedule.html〉 [Accessed 9 October 2017].
[19] Putti Venkata Ramana, Tsan Michael, Mehta Sumi, Kammila Srilata. The state of the global clean and improved cooking sector [ESMAP Technical Paper; No. 007/15]. Washington, D.C.: World Bank; 2015〈https://openknowledge.worldbank.org/handle/10986/21878〉.
[20] Stokes H, Luceno B. Clean Burning Ethanol Stoves; n.d. 〈https://www.projectgaia.com/files/AboutProjectGaia.pdf〉, [Accessed 13 September 2017].
[21] GACC. Clean cooking: key to achieving global development and climate goals Washington, D.C.: Global Alliance of Clean Cookstoves (GACC); 2016 [Available at: 〈http://cleancookstoves.org/resources/reports/2016progress.html〉].
[22] World Bank, IEA. Sustainable energy for all 2015: progress toward sustainable energy. Washington, D.C.: World Bank; International Energy Agency (IEA); 2015. https://doi.org/10.1596/978-1-4648-0690-2.
[23] World Bank. Scaling-up access to clean cooking technologies and fuels in Sub-Saharan Africa. Washington D.C: World Bank; 2012〈http://siteresources.worldbank.org/EXTAFRREGTOPENERGY/Resources/WorldBank_ACCES_AFREA_AFTEG_ESMAP_FINAL.pdf〉 [Accessed 12 June 2017].
[24] World Bank. Energizing Africa: achievements and lessons from the Africa renewable energy and access program phase I. Washington D.C.: World Bank; 2015 [Available at: 〈https://openknowledge.worldbank.org/handle/10986/25201〉].
[25] World Bank. Progress toward sustainable energy: global tracking framework. Washington D.C.: World Bank; 2015. https://doi.org/10.1596/978-1-4648-0690-2.
[26] Winrock International. Clean and Efficient Cooking Technologies and Fuels: Consumer Preferences and Stove Adoption; 2017. Available at: 〈https://www.usaid.gov/sites/default/files/documents/1865/cookstoves-toolkit-2017-mod6-consumer-preferences.pdf〉, [Accessed 13 February 2018].
[27] Wiesmann U, Kiteme B, Mwangi Z. Socio-economic atlas of Kenya: depicting the national population census by county and sub-location. Nairobi: Kenya National Bureau of Statistics; 2016 [Available at: 〈https://boris.unibe.ch/83693/〉].
[28] Githiomi JK, Oduor N. Strategies for sustainable wood fuel production in Kenya. Int J Appl Sci Technol 2012;10:21–5.
[29] GoK. Kenya action agenda – sustainable energy for all (SE4ALL). Nairobi: Government of Kenya (GoK), Ministry of Energy and Petroleum; 2016 [Available at: 〈https://www.seforall.org/sites/default/files/Kenya_AA_EN_Released.pdf〉].
[30] Atteridge A, Weitz N. A political economy perspective on technology innovation in the Kenyan clean cookstove sector. Energy Policy 2017;110:303–12. https://doi.org/10.1016/j.enpol.2017.08.029.
[31] Sepp S. Towards sustainable modern wood energy development Stocktaking paper on successful initiatives in developing countries in the field of wood energy development. Eschborn, Germany: GIZ; 2014〈http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/giz2015-en-report-wood-energy.pdf〉.
[32] MEWNR. Analysis of demand and supply of wood products in Kenya. Nairobi: Ministry of Environment, Water and Natural Resources (MEWNR); 2013 [Available at: 〈http://www.kenyaforestservice.org/documents/redd/Analysis%20of%20Demand%20and%20Supply%20of%20Wood%20Products%20in%20Kenya.pdf〉].
[33] Mugo F, Gathui T. Biomass energy use in Kenya. Nairobi: Practical Action-East Africa; 2010 [Available at: 〈http://pubs.iied.org/pdfs/G02985.pdf〉].
[34] Iiyama M, Neufeldt H, Dobie P, Njenga M, Ndegwa G, Jamnadass R, et al. The potential of agroforestry in the provision of sustainable woodfuel in sub-Saharan Africa. Curr Opin Environ Sustain 2014;6:138–47. https://doi.org/10.1016/j.cosust.2013.12.003.
[35] Karekezi S, Lata K, Coelho ST. Traditional biomass energy: improving its use and moving to modern energy use. Renew Energy- Glob Rev Technol Policies Mark 2006;1:231–61.
[36] Karekezi S, McDade S, Boardman B, Kimani J. Chapter 2 – energy, poverty and development. Global energy assessment – toward a sustainable future. Cambridge, UK and New York, NY, USA and Laxenburg, Austria: Cambridge University Press and the International Institute for Applied Systems Analysis; 2012. p. 151–90.
[37] Githiomi JK, Mugendi DN, Kung'u JB. Analysis of household energy sources and woodfuel utilisation technologies in Kiambu, Thika and Maragwa districts of Central Kenya. J Hortic For 2012;4:43–8. https://doi.org/10.5897/JHF11.071.
[38] GACC. Comparative analysis of fuels for cooking: an assessment of environmental, economic and social impacts Washington, D.C.: Global Alliance of Clean Cookstoves (GACC); 2015 [Available at: 〈https://cleancookstoves.org/assets-facit/Comparative-Analysis-for-Fuels-FullReport.pdf〉].
[39] Drigo R, Bailis R, Ghilardi A, Masera O. WISDOM Kenya: Analysis of woodfuel supply, demand and sustainability in Kenya; 2015. Available at 〈http://cleancookstoves.org/resources/426.html〉.
[40] Mahiri I, Howorth C. Twenty years of resolving the irresolvable: approaches to the fuelwood problem in Kenya. Land Degrad Dev 2001;12:205–15. https://doi.org/10.1002/ldr.433.
[41] Kiruki HM, van der Zanden EH, Gikuma-Njuru P, Verburg PH. The effect of charcoal production and other land uses on diversity, structure and regeneration of woodlands in a semi-arid area in Kenya. For Ecol Manag 2017;391:282–95. https://doi.org/10.1016/j.foreco.2017.02.030.
[42] Fontodji JK, Atsri H, Adjonou K, Radji AR, Kokutse AD, Nuto Y, et al. Impact of charcoal production on biodiversity in Togo (West Africa). The importance of biological interactions in the study of biodiversity InTechOpen; 2011. p. 216–30.
[43] 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. https://doi.org/10.1016/j.esd.2012.07.004.
[44] KEFRI. Available charcoal production technologies in Kenya: draft copy for sustainable charcoal production in the drylands of Kenya. Nairobi: Kenya Forest Research Institute (KEFRI); n.d. Available at 〈http://www.kenyaforestservice.org/documents/Charcoal_Production_kilns_study-1-.pdf〉.
[45] Iiyama M, Chenevoy A, Otieno E, Kinyanjui T, Ndegwa G, Vandenabeele J, et al. Achieving sustainable charcoal in Kenya: harnessing the opportunities for cross-sectoral integration. Nairobi: World Agroforestry Center (ICRAF) and Stockholm Environment Institute (SEI); 2014 [Available at: 〈https://www.sei.org/publications/achieving-sustainable-charcoal-in-kenya-harnessing-the-opportunities-for-cross-sectoral-integration/〉].
[46] Oduor GJK. Strategies for sustainable wood fuel production in Kenya. Int J Appl Sci Technol 2012;2:21–5.
[47] GoK. Kenya second national communication to the United Nations framework convention on climate change. Nairobi: Government of Kenya (GoK); 2015 [Available at: 〈https://unfccc.int/resource/docs/natc/kennc2.pdf〉].
[48] Jeffery S, Bezemer TM, Cornelissen G, Kuyper TW, Lehmann J, Mommer L, et al. The way forward in biochar research: targeting trade-offs between the potential wins. GCB Bioenergy 2015;7:1–13. https://doi.org/10.1111/gcbb.12132.
[49] FAO. Agricultural development and food security in Kenya: building a case for more support. Rome: Food and Agriculture Organisation (FAO); 2006 [Available at: 〈http://www.fao.org/3/a-a0782e.pdf〉].
[50] Mugo FW. Donor and partner programmes in sustainable forest management and fuelwood value chains in Eastern and Southern Africa. UK: Evidence on Demand; 2014. https://doi.org/10.12774/eod_hd.feb2014.mugo.
[51] Nyambane Johnson, Ochieng Oballa, Njenga Mugo M. Sustainable firewood access and utilization: achieving cross-sectoral integration in Kenya. Nairobi: World Agroforestry Center (ICRAF) and Stockholm Environment Institute (SEI); 2014 [Available at: 〈https://www.sei.org/publications/sustainable-firewood-access-and-utilization-achieving-cross-sectoral-integration-in-kenya/〉].
[52] Kituyi E. Towards sustainable production and use of charcoal in Kenya: exploring the potential in life cycle management approach. J Clean Prod 2004;12:1047–57. https://doi.org/10.1016/j.jclepro.2004.02.011.
[53] Birundu AO, Suzuki Y, Gotou J, Matsumoto M. Analysis of the role of forest, biomass policy legislation and other factors that may affect the future of Kenya's forests: use of Japanese forestry as a model. J Sustain For 2017;36:90–105. https://doi.org/10.1080/10549811.2016.1260037.
[54] Owen M, der Plas R van, Sepp S. Can there be energy policy in Sub-Saharan Africa without biomass? Energy Sustain Dev 2013;17(2):146–52. https://doi.org/10.1016/j.esd.2012.10.005.
[55] GoK. Sessional paper no. 4 on energy of 2004. Nairobi: Government of Kenya (GoK), Ministry of Energy; 2004 [Available at: 〈https://www.renewableenergy.go.ke/downloads/policy-docs/sessional_paper_4_on_energy_2004.pdf〉].
[56] UNDP. Nationally appropriate mitigation action on access to clean energy in rural Kenya Nama MRV system through innovative market based solutions. Nairobi: United Nations Development Programme (UNDP); 2017 [Available at: 〈http://www.undp.org/content/dam/LECB/docs/pubs-namas/undp-lecb-Kenya_Clean-Energy-NAMA-2016.pdf〉].
[57] Kituyi E, Marufu L, Huber B, O. Wandiga S, O. Jumba I, O. Andreae M, et al. Biofuel consumption rates and patterns in Kenya. Biomass Bioenergy 2001;20:83–99. https://doi.org/10.1016/S0961-9534(00)00072-6.
[58] Adkins E, Tyler E, Wang J, Siriri D, Modi V. Field testing and survey evaluation of household biomass cookstoves in rural sub-Saharan Africa. Energy Sustain Dev 2010;14:172–85. https://doi.org/10.1016/j.esd.2010.07.003.
[59] GVEP. The improved cookstove sector in East Africa: experience from the developing energy enterprise programme (DEEP). London, UK: Global Energy Village Partnership International (GVEP) International; 2012 [Available at: 〈http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.732.32&rep=rep1&type=pdf〉].
[60] O'Keefe P, Raskin P. Crisis and opportunity – fuelwood in Kenya. Ambio 1985;14:220–4. https://doi.org/10.2307/4313152.
[61] Ndegwa G, Anhuf D, Nehren U, Ghilardi A, Iiyama M. Charcoal contribution to wealth accumulation at different scales of production among the rural population of Mutomo District in Kenya. Energy Sustain Dev 2016;33:167–75. https://doi.org/10.1016/j.esd.2016.05.002.
[62] Kiplagat JK, Wang RZ, Li TX. Renewable energy in Kenya: resource potential and status of exploitation. Renew Sustain Energy Rev 2011;15:2960–73. https://doi.org/10.1016/j.rser.2011.03.023.
[63] Daley B. Resource scarcity and environment: review of evidence and research gap analysis. UK: Evidence on Demand; 2013. https://doi.org/10.12774/eod_hd062.jul2013.daley].
[64] Nguu J, Ndivo S, Aduda B, Nyongesa F, Musembi R. Livestock farmers 'perception on generation of cattle waste-based biogas methane: the case of Embu West District, Kenya. J Energy Technol Policy 2014;4(8):1–7.
[65] Birundu AO, Suzuki Y, Gotou JI, Matsumoto M. Analysis of the role of forest, biomass policy legislation and other factors that may affect the future of Kenya's forests: use of Japanese forestry as a model. J Sustain For 2017;36:90–105. https://doi.org/10.1080/10549811.2016.1260037.
[66] UNDP. The energy challenge for achieving the millennium development goals. United Nations Development Programme (UNDP); 2005〈http://www.undp.org/

content/undp/en/home/librarypage/environment-energy/sustainable_energy/the_energy_challengeforachievingthemillenniumdevelopmentgoals.html〉 [Accessed 9 October 2017].
[67] GIZ. Successful energy policy interventions in Africa. Eschborn: Deutsche Gesellschaft für Technische, Zusammenarbeit (GIZ) GmbH; 2007 [Available at: 〈http://www.globalbioenergy.org/uploads/media/0707_GTZ_-_Successful_energy_policy_interventions_in_Africa.pdf〉].
[68] UNEP. Kenya: integrated assessment of the energy policy with focus on the transport and household energy sectors Nairobi: United Nations Environment Programme (UNEP); 2016 [Available at: 〈https://unep.ch/etb/areas/pdf/Kenya%20ReportFINAL.pdf〉].
[69] Mugo F, Ong C. Lessons from eastern Africa's unsustainable charcoal trade. Nairobi: World Agroforestry Center (ICRAF); 2006 [Available at: 〈https://www.worldagroforestry.org/downloads/Publications/PDFS/wp06119.pdf〉].
[70] Kees M, Feldmann L. The role of donor organisations in promoting energy efficient cook stoves. Energy Policy 2011;39:7595–9. https://doi.org/10.1016/j.enpol.2011.03.030.
[71] Karekezi S. Renewables in Africa – meeting the energy needs of the poor. Energy Policy 2002;30:1059–69. https://doi.org/10.1016/S0301-4215(02)00058-7.
[72] Kappen JF, Putti VR, Rysankova D, Kammila S, Hyseni B. Clean and improved cooking in Sub-Saharan Africa: a landscape report Washington, D.C.: World Bank Group; 2014 [Available at: 〈http://documents.worldbank.org/curated/en/164241468178757464/Clean-and-improved-cooking-in-Sub-Saharan-Africa-a-landscape-report〉].
[73] GoK. The energy act, no. 12 of 2006. Nairobi: Government of Kenya (GoK), Ministry of Energy and Petroleum; 2006 [Available at: 〈https://www.erc.go.ke/download/the-energy-act-2006/〉].
[74] GoK. Kenya vision 2030. Nairobi: Government of Kenya (GoK); 2007 [Available at: 〈http://www.vision2030.go.ke/about-vision-2030/〉].
[75] GoK. National climate change response strategy. Nairobi: Government of Kenya (GoK), Ministry of Environment and Mineral Resources; 2010 [Available at: 〈https://cdkn.org/wp-content/uploads/2012/04/National-Climate-Change-Response-Strategy_April-2010.pdf〉].
[76] GoK. National climate change action plan 2013–2017. Nairobi: Government of Kenya (GoK), Ministry of Environment and Mineral Resources; 2017 [Available at: 〈http://kccap.info/index.php?option=com_content&view=article&id=31〉].
[77] GoK. Gazette notice no. 5744 Vol. CXV no. 65 of 26. energy act 2013;CXV:1–20. Nairobi: Government of Kenya (GoK), Ministry of Energy and Petroleum; 2014.
[78] GoK. National energy and petroleum policy, 2015. Nairobi: Government of Kenya (GoK), Ministry of Energy and Petroleum; 2015.
[79] GoK. The energy bill of 2015. Nairobi: Government of Kenya (GoK), Ministry of Energy and Petroleum; 2015 [Available at: 〈http://energy.go.ke/the-energy-bill-2015/〉].
[80] Ekouevi Koffi, Freeman Kate Kennedy, Soni Ruchi. Understanding the differences between cookstoves. Washington, D.C.: World Bank; 2014 [Available at: 〈https://openknowledge.worldbank.org/handle/10986/18411〉].
[81] Kinyanjui M, Childers L. Kenya renewable energy project: how to make the Kenyan ceramic Jiko. Energy Dev Int 1983:20–470.
[82] Hyman EL. The economics of improved charcoal stoves in Kenya. Energy Policy 1986;14:149–58. https://doi.org/10.1016/0301-4215(86)90125-4.
[83] Hyman EL. The experience with improved charcoal and wood stoves for households and institutions in Kenya. Washington, D.C.: Appropriate Technology International; 1985.
[84] Hyman EL. The strategy of production and distribution of improved charcoal stoves in Kenya. World Dev 1987;15:375–86. https://doi.org/10.1016/0305-750X(87)90019-2.
[85] Karekezi S, Turyareeba P. Woodstove dissemination in Eastern Africa – a review. Energy Sustain Dev 1995;1:12–9. https://doi.org/10.1016/S0973-0826(08)60094-0.
[86] Westhoff B, Germann D. Stove images: a documentation of improved and traditional stoves in Africa, Asia and Latin America. Frankfurt: GmbH; 1995 [Available at: 〈https://energypedia.info/images/6/69/Stove_Images.pdf〉].
[87] Opole M. The introduction of the Kenya jiko stove – a KENGO experience. In: Carr M (Hrsg.), editor. Sustainable industrial development. 1988. p. 1–32.
[88] Namuye, Sylvester A. Survey on dissemination and impact of Kenya Ceramic Jiko of Kenya. In: Stoves for people. Proceedings of the second international workshop on stoves dissemination. Intermediate Technology Publications, 1989.
[89] Karekezi S, Kithyoma W. Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor to sub-Saharan Africa? Energy Policy 2002;30:1071–86. https://doi.org/10.1016/S0301-4215(02)00059-9.
[90] Barnes DF, Openshaw K, Smith KR, Van, der Plas R. What makes people cook with improved biomass stoves? Washington D.C.: World Bank; 1994. https://doi.org/10.1016/0165-0572(87)90003-X.
[91] Kammen D. Research, development and commercialization of the Kenya Ceramic Jiko and other improved biomass stoves in Africa. Horizon International Solutions Site; 2006〈https://www.solutions-site.org/node/50〉.
[92] UNDP. The energy access situation in developing countries. A review focusing on the least developed countries and Sub-Saharan Africa. New York: United Nations Development Programme (UNDP); 2009 [Available at: 〈http://www.undp.org/content/dam/undp/library/Environment%20and%20Energy/Sustainable%20Energy/energy-access-situation-in-developing-countries.pdf〉].
[93] Karekezi S, Turyareeba P. Woodstove dissemination in Eastern Africa – a review. Energy Sustain Dev 1995;1:12–9. https://doi.org/10.1016/S0973-0826(08)60094-0.
[94] Batliwala S, Reddy AK. Energy for women and women for energy (engendering energy and empowering women). Energy Sustain Dev 2003;7(3):33–43.
[95] Shankar AV, Onyura MA. Understanding impacts of women's engagement in the improved cookstove value chain in Kenya. Washington D.C.: Global Alliance of Clean Cookstoves (GACC); 2015 [Available at: 〈https://cleancookstoves.org/binary-data/RESOURCE/file/000/000/356-1.pdf〉].
[96] Barnes DF, Openshaw K, Smith KR, Plas RV. The design and diffusion of improved cooking stoves. World Bank Res Obs 1993;8(2):119–41.
[97] Urmee T, Gyamfi S. A review of improved cookstove technologies and programs. Renew Sustain Energy Rev 2014;33:625–35. https://doi.org/10.1016/j.rser.2014.02.019.
[98] UNFCCC. Clean development mechanism: programme of activities. Bonn: The United Nations Framework Convention on Climate Change (UNFCCC); 2017〈https://cdm.unfccc.int/ProgrammeOfActivities/registered.html〉 [Accessed 26 November 2017].
[99] GACC. Scaling adoption of clean cooking solutions through women's empowerment: a resource guide. Washington D.C.: Global Alliance for Clean Cookstoves (GACC); 2013 [Available at: 〈http://cleancookstoves.org/resources/223.html〉].
[100] Silk BJ, Sadumah I, Patel MK, Were V, Person B, Harris J, et al. A strategy to increase adoption of locally-produced, ceramic cookstoves in rural Kenyan households. BMC Public Health 2012;12:359. https://doi.org/10.1186/1471-2458-12-359.
[101] GIZ. Energising development partnership-country project, Kenya factsheet. Nairobi: Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH GIZ; 2017 [Available at: 〈https://www.giz.de/en/worldwide/21975.html〉].
[102] GACC. Results report: sharing progress on the path to adoption of clean and efficient cooking solutions Washington, D.C.: Global Alliance of Clean Cookstoves (GACC); 2014 [Available at: 〈http://cleancookstoves.org/about/news/12-10-2015-results-report-2014-sharing-progress-on-the-path-to-adoption-of-clean-and-efficient-cooking-solutions.html〉].
[103] Anderson P, Reed T. Biomass gasification: clean residential stoves, commercial power generation, and global impacts. In: Proceedings of the LAMNET project international workshop on bioenergy for a sustainable development, 2004, p. 8–10.
[104] Anderson P, James S. Origins, history, and future of TLUD micro-gasification and cookstove advancement. TLUD Technology; 2016 [Available at: 〈http://www.drtlud.com/wp-content/uploads/2015/10/TLUDHistory20151011.pdf〉].
[105] Lotter D, Hunter N, Straub M, Msola D. Microgasification cookstoves and pellet fuels from waste biomass: a cost and performance comparison with charcoal and natural gas in Tanzania. Afr J Environ Sci Technol 2015;9(6):573–83.
[106] Njenga M, Iiyama M, Jamnadass R, Helander H, Larsson L, de Leeuw J, et al. Gasifier as a cleaner cooking system in rural Kenya. Clean Prod 2016:121. https://doi.org/10.1016/j.jclepro.2016.01.039.
[107] Njenga M, Mahmoud Y, Mendum R, Iiyama M, Jamnadass R, De Nowina KR, et al. Quality of charcoal produced using micro gasification and how the new cook stove works in rural Kenya. Environ Res Lett 2017;12(9):095001.
[108] Whitman T, Nicholson CF, Torres D, Lehmann J. Climate change impact of biochar cook stoves in western Kenyan farm households: system dynamics model analysis. Environ Sci Technol 2011;45:3687–94. https://doi.org/10.1021/es103301k.
[109] GIZ-Hera. Micro-gasification: cooking with gas from dry biomass. Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ); 2013 [Available at: 〈https://energypedia.info/images/0/05/Micro_Gasification_2.0_Cooking_with_gas_from_dry_biomass.pdf〉].
[110] IEA. Energy balances of non-OECD countries documentation for beyond 2020 files. Paris: International Energy Agency (IEA); 2010 [Available at: 〈https://www.iea.org/media/statistics/WORLDBAL_documentation.pdf〉].
[111] Ghimire P. Formulation of programme implementation document for domestic biogas programme in Kenya. Nairobi, Kenya: Netherlands Development Organisation (SNV); 2009 [Available at: 〈http://www.bibalex.org/Search4Dev/files/338060/171537.pdf〉].
[112] Mengistu MG, Simane B, Eshete G, Workneh TS. A review on biogas technology and its contributions to sustainable rural livelihood in Ethiopia. Renew Sustain Energy Rev 2015;48:306–16. https://doi.org/10.1016/j.rser.2015.04.026.
[113] Nzila C, Dewulf J, Spanjers H, Tuigong D, Kiriamiti H, van Langenhove H. Multi criteria sustainability assessment of biogas production in Kenya. Appl Energy 2012;93:496–506. https://doi.org/10.1016/j.apenergy.2011.12.020.
[114] Laichena JK. Rural energy in Kenya: is there a future for biogas? A survey. Energy Explor Exploit 7. 1989. p. 116–27. https://doi.org/10.1177/014459878900700205.
[115] Ngigi A. Kenya national domestic biogas programme: programme implementation document (PID). Nairobi, Kenya: Kenya National Federation of Agricultural Producers (KENFAP); 2009 [Available at: 〈http://www.build-a-biogas-plant.com/PDF/biogas_programme_implementation_kenya.pdf〉].
[116] Porras I, Vorley B, Amrein A. The Kenya national domestic biogas programme: can carbon financing promote sustainable agriculture? London: International Institute for Environment and Development (IEED) and Hivos; 2015 [Available at: 〈http://pubs.iied.org/pdfs/16588IIED.pdf〉].
[117] UNFCCC. The Nairobi river basin biogas project: project design document form (CDM-SSC-PDD). Bonn: The United Nations Framework Convention on Climate Change (UNFCCC); 2012.
[118] Mwirigi J, Balana BB, Mugisha J, Walekhwa P, Melamu R, Nakami S, et al. Socio-economic hurdles to widespread adoption of small-scale biogas digesters in Sub-Saharan. Afr: Rev Biomass Bioenergy 2014;70:17–25. https://doi.org/10.1016/j.biombioe.2014.02.018.
[119] Sovacool BK, Kryman M, Smith T. Scaling and commercializing mobile biogas systems in Kenya: a qualitative pilot study. Renew Energy 2015;76:115–25. https://doi.org/10.1016/j.renene.2014.10.070.

[120] GoK. Domestic biogas stoves — specification (KS 2520:2013). Nairobi: Government of Kenya (GoK), Kenya Bureau of Standards; 2013. [Avaialble at: 〈http://notifyke.kebs.org/sites/default/files/KEN%20401%28KS%202520%20%202013%29.pdf〉].
[121] Kangmin L, Mae-Wan H. Biogas China. Science in Society; 2006〈http://www.i-sis.org.uk/BiogasChina.php〉 [Accessed 26 November 2017].
[122] UNDP. Piloting bioethanol as an alternative cooking fuel in western Kenya. Nairobi: United Nations Development Programme (UNDP); 2012〈http://www.ke.undp.org/content/kenya/en/home/operations/projects/environment_and_energy/bioethanol.html〉 [Accessed 26 November 2017].
[123] Rogers C, Sovacool BK, Clarke S. Sweet nectar of the Gaia: lessons from Ethiopia's “Project Gaia.”. Energy Sustain Dev 2013;17:245–51. https://doi.org/10.1016/j.esd.2013.02.005.
[124] Sikei G, Lagat J, Mburu J. Rural households' response to fuelwood scarcity around Kakamega Forest, Western Kenya. Handbook for agroforestry management practices and environmental impact. 2009. p. 451–60.
[125] GVEP International. Kenya market assessment: sector mapping. Nairobi: Global Energy Village Partnership International (GVEP) International; 2012 [Available at: 〈http://cleancookstoves.org/resources_files/kenya-market-assessment-mapping.pdf〉].
[126] WHO. Clean household energy for health, sustainable development, and wellbeing of women and children. Geneva: World Health Organisation (WHO); 2016 [Available at: 〈http://apps.who.int/iris/bitstream/handle/10665/204717/9789241565233_eng.pdf?sequence=1〉].
[127] Halff A, Sovacool BK, Rozhon J, editors. Energy poverty: global challenges and local solutions. New York, United States of America: Oxford University Press; 2014.
[128] Kumar P, Chalise N, Yadama GN. Dynamics of sustained use and abandonment of clean cooking systems: study protocol for community-based system dynamics modeling. Int J Equity Health 2016;15:70. https://doi.org/10.1186/s12939-016-0356-2.
[129] Egeru A, Katereggga E, Majaliwa GJM. Coping with firewood scarcity in Soroti District of Eastern Uganda. Open J For 2014;4:70–4. https://doi.org/10.4236/ojf.2014.41011.
[130] Guta DD. Effect of fuelwood scarcity and socio-economic factors on household bio-based energy use and energy substitution in rural Ethiopia. Energy Policy 2014;75:217–27. https://doi.org/10.1016/j.enpol.2014.09.017.
[131] Waris VS, Antahal PC. Fuelwood scarcity, poverty and women: some perspectives. IOSR J Humanit Social Sci 2014;19(8):21–33.
[132] Mehetre SA, Panwar NL, Sharma D, Kumar H. Improved biomass cookstoves for sustainable development: a review. Renew Sustain Energy Rev 2017;73:672–87.
[133] Smith JU, Fischer A, Hallett PD, Homans HY, Smith P, Abdul-Salam Y, et al. Sustainable use of organic resources for bioenergy, food and water provision in rural Sub-Saharan Africa. Renew Sustain Energy Rev 2015;50:903–17. https://doi.org/10.1016/j.rser.2015.04.071.
[134] Bailis R, Smith KR, Edwards R. Kitchen performance test (KPT). London, UK: Household Energy and Health Programme, Shell Foundation; 2007.
[135] Bailis R, Berrueta V, Chengappa C, Dutta K, Edwards R, Masera O, et al. Performance testing for monitoring improved biomass stove interventions: experiences of the household energy and health project. Energy Sustain Dev 2007;11:57–70. https://doi.org/10.1016/S0973-0826(08)60400-7.
[136] Agea JG, Kirangwa D, Waiswa D, Okia CA. Household firewood consumption and its dynamics in Kalisizo sub-County, Central Uganda. Ethnobot Leafl 2010;14:841–55.
[137] Anenberg SC, Balakrishnan K, Jetter J, Masera O, Mehta S, Moss J, et al. Cleaner cooking solutions to achieve health, climate, and economic cobenefits. Environ Sci Technol 2013;47:3944–52. https://doi.org/10.1021/es304942e.
[138] Beltramo T, Blalock G, Levine DI, Simons AM. The effect of marketing messages and payment over time on willingness to pay for fuel-efficient cookstoves. J Econ Behav Organ 2015;118:333–45. https://doi.org/10.1016/j.jebo.2015.04.025.
[139] De DK, Shawhatsu NM, De NN, Ajaeroh MI. Energy-efficient cooking methods. Energy Effic 2013;6:163–75. https://doi.org/10.1007/s12053-012-9173-7.
[140] Abadi N, Gebrehiwot K, Techane A, Nerea H. Links between biogas technology adoption and health status of households in rural Tigray, Northern Ethiopia. Energy Policy 2017;101:284–92. https://doi.org/10.1016/j.enpol.2016.11.015.
[141] Adeoti O, Idowu DOO, Falegan T. Could fuelwood use contribute to household poverty in Nigeria? Biomass Bioenergy 2001;21:205–10. https://doi.org/10.1016/S0961-9534(01)00029-0.
[142] Daurella DC, Foster V. What can we learn from household surveys on inequalities in cooking fuels in sub-Saharan Africa. Washington, D.C.: World Bank; 2009 [Available at: 〈http://www.ecineq.org/ecineq_ba/papers/camos.pdf〉].
[143] Mahiri IO. Rural household responses to fuelwood scarcity in Nyando District, Kenya. Land Degrad Dev 2003;14:163–71. https://doi.org/10.1002/ldr.535.
[144] Kammen DM, Kirubi C. Poverty, energy, and resource use in developing countries: focus on Africa. Ann N Y Acad Sci 2008;1136:348–57. https://doi.org/10.1196/annals.1425.030.
[145] Debbi S, Elisa P, Nigel B, Dan P, Eva R. Factors influencing household uptake of improved solid fuel stoves in low-and middle-income countries: a qualitative systematic review. Int J Environ Res Public Health 2014;11:8228–50. https://doi.org/10.3390/ijerph110808228.
[146] Lee D, Neves B, Wiebe K, Lipper L, Zurek M. Rural poverty and natural resources: improving access and sustainable management. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO); 2009 [Available at: 〈http://www.fao.org/3/a-ak422e.pdf〉].
[147] Surendra KC, Takara D, Hashimoto AG, Khanal SK. Biogas as a sustainable energy source for developing countries: opportunities and challenges. Renew Sustain Energy Rev 2014;31:846–59. https://doi.org/10.1016/j.rser.2013.12.015.
[148] Rhodes EL, Dreibelbis R, Klasen E, Naithani N, Baliddawa J, Menya D, et al. Behavioral attitudes and preferences in cooking practices with traditional open-fire stoves in Peru, Nepal, and Kenya: implications for improved cookstove interventions. Int J Environ Res Public Health 2014;11:10310–26. https://doi.org/10.3390/ijerph111010310.
[149] Naughton-Treves L, Kammen DM, Chapman C. Burning biodiversity: woody biomass use by commercial and subsistence groups in western Uganda's forests. Biol Conserv 2007;134:232–41. https://doi.org/10.1016/J.BIOCON.2006.08.020.
[150] Ruuska E. Unsustainable charcoal production as a contributing factor to woodland fragmentation in southeast Kenya. Fenn - Int J Geogr 2013;191(1):58–75.
[151] Kiruki HM, van der Zanden EH, Malek Ž, Verburg PH. Land cover change and woodland degradation in a charcoal producing semi-arid area in Kenya. Land Degrad Dev 2017;28:472–81. https://doi.org/10.1002/ldr.2545.
[152] Lattimore B, Smith CT, Titus BD, Stupak I, Egnell G. Environmental factors in woodfuel production: opportunities, risks, and criteria and indicators for sustainable practices. Biomass Bioenergy 2009;33:1321–42. https://doi.org/10.1016/J.BIOMBIOE.2009.06.005.
[153] Lee CM, Chandler C, Lazarus M, Johnson FX. Assessing the climate impacts of cookstove projects: issues in emissions accounting. Chall Sustain 2013;1:53–71. https://doi.org/10.12924/cis2013.01020053.
[154] Woollen E, Ryan CM, Baumert S, Vollmer F, Grundy I, Fisher J, et al. Charcoal production in the Mopane woodlands of Mozambique: what are the trade-offs with other ecosystem services? Philos Trans R Soc B 2016;371(1703):20150315.
[155] Zschauer K. Households' energy supply and the use of fuelwood in the Taita Hills. Kenya: University of Helsinki; 2012 [Available at: 〈https://helda.helsinki.fi/bitstream/handle/10138/29517/househol.pdf?sequence=1〉].
[156] Bahru Tinsae. Indigenous knowledge on fuel wood (charcoal and/or firewood) plant species used by the local people in and around the semi-arid Awash National Park, Ethiopia. J Ecol Nat Environ 2012:4. https://doi.org/10.5897/JENE11.105.
[157] UNEP. Atlas of Africa energy resources. Nairobi, Kenya: United Nations Environment Programme (UNEP); 2017 [Available at: 〈http://wedocs.unep.org/handle/20.500.11822/20476〉].
[158] Gerst MD, Cox ME, Locke KA, Laser M, Kapuscinski AR. A taxonomic framework for assessing governance challenges and environmental effects of integrated food-energy systems. Environ Sci Technol 2015;49:734–41. https://doi.org/10.1021/es504090u.
[159] WLPGA. LP gas rural energy challenge: lessons learnt and recommendations. Paris: World LPG Association (WLPGA); 2006 [Available at: 〈https://www.wlpga.org/wp-content/uploads/2017/06/lp-gas-rural-energy-challenge-light.pdf〉].
[160] Kissinger G, Patterson C, Neufeldt H. Payments for ecosystem services schemes: project-level insights on benefits for ecosystems and the rural poor [Available at: 〈http://www.worldagroforestry.org/downloads/publications/PDFs/WP13001.PDF〉]. Nairobi, Kenya: World Agroforestry Centre (ICRAF); 2013.
[161] 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. https://doi.org/10.1371/journal.pone.0030338.
[162] Bailis R, Ezzati M, Kammen DM. Greenhouse gas implications of household energy technology in Kenya. Environ Sci Technol 2003;37:2051–9. https://doi.org/10.1021/es026058q.
[163] Dresen E, DeVries B, Herold M, Verchot L, Müller R. Fuelwood savings and carbon emission reductions by the use of improved cooking stoves in an Afromontane Forest. Ethiop Land 2014;3:1137–57. https://doi.org/10.3390/land3031137.
[164] Joubert F, Begovic M. Improved cookstove carbon offset project in Kenya: how a single technology can benefit both the environment and the local populations. In: Proceedings of the world congress in sustainable technologies (WCST-IEEE); 2012, p. 65–70.
[165] Ezzati M, Mbinda BM, Kammen DM. Comparison of emissions and residential exposure from traditional and improved cookstove in Kenya. Environ Sci Technol 2000;34:578–83. https://doi.org/10.1021/es9905795.
[166] Baillis R, Ezzati M, Kammen DM. An estimate of greenhouse gas emissions from common Kenyan cookstoves under conditions of actual use. Proc: Indoor Air 2002:225–30.
[167] Johnson M, Edwards R, Masera O. Improved stove programs need robust methods to estimate carbon offsets. Clim Change 2010;102:641–9. https://doi.org/10.1007/s10584-010-9802-0.
[168] Smith KR, Uma R, Kishore VVN, Zhang J, Joshi V, Khalil MAK. Greenhouse implications of household stoves: an analysis for India. Annu Rev Energy Environ 2000;25:741–63. https://doi.org/10.1146/annurev.energy.25.1.741.
[169] Pilishvili T, Loo JD, Schrag S, Stanistreet D, Christensen B, Yip F, et al. Effectiveness of six improved cookstoves in reducing household air pollution and their acceptability in rural western Kenya. PLoS One 2016;11:e0165529. https://doi.org/10.1371/journal.pone.0165529.
[170] Ochieng CA, Tonne C, Vardoulakis S. A comparison of fuel use between a low cost, improved wood stove and traditional three-stone stove in rural Kenya. Biomass Bioenergy 2013;58:258–66. https://doi.org/10.1016/j.biombioe.2013.07.017.
[171] Foote EM, Gieraltowski L, Ayers T, Sadumah I, Faith SH, Silk BJ, et al. Impact of locally-produced, ceramic cookstoves on respiratory disease in children in rural western Kenya. Am J Trop Med Hyg 2013;88:132–7. https://doi.org/10.4269/ajtmh.2012.12-0496.
[172] Kumari H, Joon V, Chandra A, Kaushik SC. Carbon monoxide and nitrogen oxide emissions from traditional and improved biomass cook stoves used in India. Singapore: IACSIT Press; 2011.
[173] Mutlu E, Warren SH, Ebersviller SM, Kooter IM, Schmid JE, Dye JA, et al. Mutagenicity and pollutant emission factors of solid-fuel cookstoves: comparison with other combustion sources. Environ Health Perspect 2016;124:974–82.

https://doi.org/10.1289/ehp.1509852.
[174] WHO. Indoor air quality guidelines: household fuel combustion. Geneva: World Health Organisation (WHO); 2014 [Available at: 〈http://www.who.int/airpollution/guidelines/household-fuel-combustion/en/〉].
[175] Dohoo C, VanLeeuwen J, Read Guernsey J, Critchley K, Gibson M. Impact of biogas digesters on wood utilisation and self-reported back pain for women living on rural Kenyan smallholder dairy farms. Glob Public Health 2013;8:221–35. https://doi.org/10.1080/17441692.2012.758299.
[176] Ezzati M, Kammen DM. Evaluating the health benefits of transitions in household energy technologies in Kenya. Energy Policy 2002;30:815–26. https://doi.org/10.1016/S0301-4215(01)00125-2.
[177] Pope DP, Mishra V, Thompson L, Siddiqui AR, Rehfuess EA, Weber M, et al. Risk of low birth weight and stillbirth associated with indoor air pollution from solid fuel use in developing countries. Epidemiol Rev 2010;32:70–81. https://doi.org/10.1093/epirev/mxq005.
[178] Olopade CO, Frank E, Bartlett E, Alexander D, Dutta A, Ibigbami T, et al. Effect of a clean stove intervention on inflammatory biomarkers in pregnant women in Ibadan, Nigeria: a randomized controlled study. Environ Int 2017;98:181–90. https://doi.org/10.1016/j.envint.2016.11.004.
[179] Dherani M, Pope D, Mascarenhas M, Smith KR, Weber M, Bruce N. Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: a systematic review and meta-analysis. [98C]. Bull World Health Organ 2008;86(5):390. https://doi.org/10.2471/BLT.07.044529.
[180] Foote EM, Gieraltowski L, Ayers T, Sadumah I, Faith SH, Silk BJ, et al. Impact of locally-produced, ceramic cookstoves on respiratory disease in children in rural western Kenya. Am J Trop Med Hyg 2013;88:132–7. https://doi.org/10.4269/ajtmh.2012.12-0496.
[181] Dohoo C, Guernsey JR, Gibson MD, Vanleeuwen J. Impact of biogas digesters on cookhouse volatile organic compound exposure for rural Kenyan farmwomen. J Expo Sci Environ Epidemiol Adv Online Publ 2013:31. https://doi.org/10.1038/jes.2013.42.
[182] Anenberg SC, Balakrishnan K, Jetter J, Masera O, Mehta S, Moss J, et al. Cleaner cooking solutions to achieve health, climate, and economic cobenefits. Environ Sci Technol 2013;47:3944–52. https://doi.org/10.1021/es304942e.
[183] Ezzati M, Kammen DM. Evaluating the health benefits of transitions in household energy technologies in Kenya. Energy Policy 2002;30:815–26. https://doi.org/10.1016/S0301-4215(01)00125-2.
[184] Foote EM, Gieraltowski L, Ayers T, Sadumah I, Hamidah Faith S, Silk BJ, et al. Impact of locally-produced, ceramic cookstoves on respiratory disease in children in rural western Kenya. Am J Trop Med Hyg 2013;88:132–7. https://doi.org/10.4269/ajtmh.2012.12-0496.
[185] Rosenthal J, Balakrishnan K, Bruce N, Chambers D, Graham J, Jack D, et al. Implementation science to accelerate clean cooking for public health. Environ Health Perspect 2017;125(1):A3–7. https://doi.org/10.1289/EHP1018.
[186] Balakrishnan K, Mehta S, Ghosh S, Johnson M, Brauer M, Zhang J, et al. WHO indoor air quality guidelines: household fuel combustion. Geneva: World Health Organisation (WHO); 2014 [Available at: 〈http://www.who.int/airpollution/guidelines/household-fuel-combustion/Review_5.pdf〉].
[187] Pope D, Bruce N, Dherani M, Jagoe K, Rehfuess E. Real-life effectiveness of "improved" stoves and clean fuels in reducing PM2.5 and CO: systematic review and meta-analysis. Environ Int 2017;101:7–18. https://doi.org/10.1016/j.envint.2017.01.012.
[188] Chafe ZA, Brauer M, Klimont Z, Van Dingenen R, Mehta S, Rao S, et al. Household cooking with solid fuels contributes to ambient PM2.5 air pollution and the burden of disease. Environ Health Perspect 2015;122(12):1314–20. https://doi.org/10.1289/ehp.1206340.
[189] Saatkamp BD, Masera OR, Kammen DM. Energy and health transitions in development: fuel use, stove technology, and morbidity in Jarácuaro, México. Energy Sustain Dev 2000;4:7–16. https://doi.org/10.1016/S0973-0826(08)60237-9.
[190] Edwards R, Karnani S, Fisher EM, Johnson M, Naeher L, Smith KR, et al. WHO indoor air quality guidelines: household fuel combustion – review 2: emissions of health-damaging pollutants from household stoves. Geneva: World Health Organisation (WHO); 2014 [Available at: 〈http://www.who.int/airpollution/guidelines/household-fuel-combustion/Review_2.pdf〉].
[191] Lambe F, Jürisoo M, Wanjiru H, Senyagwa J. Bringing clean, safe, affordable cooking energy to households across Africa: an agenda for action. Nairobi: Stockholm Environment Institute, Stockholm (SEI); 2015 [Available at: 〈http://newclimateeconomy.report/misc/workingpapers〉].
[192] AFDB. Empowering women in Africa through access to sustainable energy: a desk review of gender-focused approaches in the renewable energy sector. African Development Bank Group (AFDB); 2016〈https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/AfDB-Gender_and_Energy_Desk_Review-EN-2016.pdf〉.
[193] Van Dam J. The charcoal transition: greening the charcoal value chain to mitigate climate change and improve local livelihoods. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO); 2017 [Available at: 〈http://www.fao.org/3/a-i6935e.pdf〉].
[194] Smith HE, Hudson MD, Schreckenberg K. Livelihood diversification: the role of charcoal production in southern Malawi. Energy Sustain Dev 2017;36:22–36. https://doi.org/10.1016/j.esd.2016.10.001.
[195] GoK. Analysis of the charcoal value xhain in Kenya. Nairobi: Government of Kenya (GoK), Ministry of Energy and Natural Resource; 2013 [Available at: 〈http://www.kenyaforestservice.org/documents/redd/Charcoal%20Value%20Chain%20Analysis.pdf〉].
[196] GIZ. Multiple-household fuel use – a balanced choice between firewood, charcoal and LPG. Eschborn: Dtsch Gesellschaft Für Int Zusammenarbeit GmbH (GIZ); 2014 [Available at: 〈star-www.giz.de/fetch/4Q0qr4X0001N0g6aGn/giz2014-0192en-household-cooking.pdf〉].
[197] Openshaw K. Biomass energy: employment generation and its contribution to poverty alleviation. Biomass Bioenergy 2010;34:365–78. https://doi.org/10.1016/j.biombioe.2009.11.008.
[198] Ndiritu SW, Nyangena W. Environmental goods collection and children's schooling: evidence from Kenya. Reg Environ Change 2011;11(3):531–42.
[199] Goodwin NJ, O'Farrell SE, Jagoe K, Rouse J, Roma E, Biran A, et al. Use of behavior change techniques in clean cooking interventions: a review of the evidence and scorecard of effectiveness. J Health Commun 2015;20:43–54.
[200] Simon GL, Bumpus AG, Mann P. Win-win scenarios at the climate–development interface: challenges and opportunities for stove replacement programs through carbon finance. Glob Environ Change 2012;22(1):275–87. https://doi.org/10.1016/j.gloenvcha.2011.08.007.
[201] Simon GL, Bailis R, Baumgartner J, Hyman J, Laurent A. Current debates and future research needs in the clean cookstove sector. Energy Sustain Dev 2014;20:49–57. https://doi.org/10.1016/j.esd.2014.02.006.
[202] Gebru B, Bezu S. Environmental resource collection: implications for children's schooling in Tigray, northern Ethiopia. Environ Dev Econ 2014;19(2):182–200.
[203] Musungu AI, Lomosi A, Njenga MN, Wanjohi D, Hoffmann R, Johnson O, et al. From cleaner cookstoves to clean cooking: thinking beyond technology to a systems approach. Nairobi: World Agroforestry Center (ICRAF); 2014 [Available at: 〈http://www.worldagroforestry.org/downloads/Publications/PDFS/BR14110.pdf〉].
[204] Bizzarri M, Bellamy C, Bizzarri RM, Katajisto M, Patrick RE. Safe access to firewood and alternative energy in Kenya: an appraisal report New York: Women's Refugees Commission and World Food Programme (WFP); 2010 [Available at: 〈https://www.womensrefugeecommission.org/firewood/resources/734-safe-access-to-firewood-and-alternative-energy-in-kenya-an-appraisal-report〉].
[205] Kituyi E, Kirubi C. Influence of diet patterns on fuelwood consumption in Kenyan boarding schools and implications for data and energy policies. Energy Convers Manag 2003;44:1099–109. https://doi.org/10.1016/S0196-8904(02)00105-X.
[206] Moronge J, Maina N. Energy use and conservation in boarding schools in Thika sub-county, Kenya. Int J Educ Res 2015;3(9):81–92.
[207] Kafayat A, Abraham A. Improved cook stoves and green house gas reduction in Uganda. Int J Sci Res Publ 2014;4(1):2250–3153.
[208] Building FAO. resilience through safe access to fuel and energy (SAFE): moving towards a comprehensive SAFE framework. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO); 2018 [Available at: 〈http://www.fao.org/3/CA0021EN/ca0021en.pdf〉].
[209] Sola P, Ochieng C, Yila J, Iiyama M. Links between energy access and food security in sub Saharan Africa: an exploratory review. Food Secur 2016;8:635–42. https://doi.org/10.1007/s12571-016-0570-1.
[210] Thorlakson T, Neufeldt H. Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. Agric Food Secur 2012;1(1):15. https://doi.org/10.1186/2048-7010-1-15.
[211] Iiyama M, Neufeldt H, Njenga M, Derero A, Ndegwa GM, Mukuralinda A, et al. Conceptual analysis: the charcoal-agriculture nexus to understand the socio-ecological contexts underlying varied sustainability outcomes in African Landscapes. Front Environ Sci 2017;5. https://doi.org/10.3389/fenvs.2017.00031.
[212] Bogdanski A. Integrated food–energy systems for climate-smart agriculture. Agric Food Secur 2012;1(9). https://doi.org/10.1186/2048-7010-1-9.
[213] Anderman TL, DeFries RS, Wood SA, Remans R, Ahuja R, Ulla SE. Biogas cook stoves for healthy and sustainable diets? A case study in Southern India. Front Nutr 2015;2:28. https://doi.org/10.3389/fnut.2015.00028.
[214] Orskov ER, Yongabi Anchang K, Subedi M, Smith J. Overview of holistic application of biogas for small scale farmers in Sub-Saharan Africa. Biomass Bioenergy 2014;70:4–16. https://doi.org/10.1016/j.biombioe.2014.02.028.
[215] UNHCR. Figures at a glance. Geneva: United Nations High Commissioner for Refugees (UNHCR); 2017〈http://www.unhcr.org/figures-at-a-glance.html〉 [Accessed 27 November 2017].
[216] Mbuthi P, Odongo F, Machera M, Imitira J. Gender audit of energy policy and programmes in Kenya. Nairobi: Practical Action East Africa; 2007 [Available at: 〈http://catalog.ihsn.org/index.php/citations/25546〉].
[217] Herrmann R, Jumbe C, Bruentrup M, Osabuohien E. Competition between biofuel feedstock and food production: empirical evidence from sugarcane outgrower settings in Malawi. Biomass Bioenergy 2018;114:100–11. https://doi.org/10.1016/J.BIOMBIOE.2017.09.002.
[218] Miller G, Mobarak AM. Gender differences in preferences, intra-household externalities, and low demand for improved cookstoves. Cambridge: National Bureau of Economic Research; 2013. https://doi.org/10.3386/w18964.
[219] Shankar AV, Onyura M, Alderman J. Agency-based empowerment training enhances sales capacity of female energy entrepreneurs in Kenya. J Health Commun 2015;20:67–75. https://doi.org/10.1080/10810730.2014.1002959.
[220] Assmann D, Laumanns U, Uh D. Renewable energy: a global review of technologies, policies and markets. London, UK: Earthscan; 2006. p. 297–312.
[221] Cecelski E. The role of women in sustainable energy development. Boulevard,Germany: National Renewable EnergyLaboratory (NREL); 2000. https://doi.org/10.2172/758755 [Available at: https://www.nrel.gov/docs/fy00osti/26889.pdf].
[222] Choumert- J, Combes P, Le Roux M-L, Choumert J, Motel PC, Le Roux L Stacking up the Ladder: A Panel Data Analysis of Tanzanian Household Energy Choices. Études et Documents, 2017/24; 2018. Available at: 〈https://halshs.archives-ouvertes.fr/halshs-01677296/document〉.
[223] Gunning R. The current state of sustainable energy provision for displaced populations: an analysis. London, UK: Chatham House-Royal Institute of

International Affairs; 2014 [Available at: 〈https://www.chathamhouse.org/sites/default/files/field/field_document/20141201EnergyDisplacedPopulationsGunning.pdf〉].
[224] Lehne J, Blyth W, Lahn G, Bazilian M, Grafham O. Energy services for refugees and displaced people. Energy Strateg Rev 2016;13–14:134–46. https://doi.org/10.1016/j.esr.2016.08.008.
[225] Bellanca R. Sustainable energy provision smong displaced populations: policy and practice. London, UK: Chatham House-Royal Institute of International Affairs; 2014 [Available at: 〈https://www.chathamhouse.org/publication/sustainable-energy-provision-among-displaced-populations-policy-and-practice〉].
[226] Lahn G, Foreword OG, Annan K. Heat, light and power for refugees saving lives, reducing costs. London, UK: Chatham House-Royal Institute of International Affairs; 2015 [Available at: 〈https://www.chathamhouse.org/sites/default/files/publications/research/2015-11-17-heat-light-power-refugees-lahn-grafham-final.pdf〉].
[227] Owen M, Stone D, Davey C, Morten P. Cooking options in refugee situations: a handbook of experiences in energy conservation and alternative fuels. Geneva: UNHCR; 2002〈http://www.unhcr.org/406c368f2.pdf〉.
[228] Thulstrup A, Henry WJ. Women's access to wood energy during conflict and displacement: lessons from Yei County, South Sudan. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). Unasylva 2015;66(243/244):52–60.
[229] Barbieri J, Riva F, Colombo E. Cooking in refugee camps and informal settlements: a review of available technologies and impacts on the socio-economic and environmental perspective. Sustain Energy Technol Assess 2017;22:194–207. https://doi.org/10.1016/j.seta.2017.02.007.
[230] Gitau GC. TheGIZ Kenya Programme Dadaab household energy project; 2011. Available at: 〈https://energypedia.info/images/5/54/The_GIZ_Dadaad_Household_Energy_Project.pdf〉.
[231] Puzzolo E, Stanistreet D, Pope D, Bruce N. WHOIndoor air quality guidelines: household fuel combustion – review 7: factors influencing the adoption and sustained use of improved cookstoves and clean household energy. Geneva: World Health Organisation (WHO); 2014 [Available at: 〈http://www.who.int/airpollution/guidelines/household-fuel-combustion/Review_7.pdf〉].
[232] Recha J, Kapukha M, Wekesa A, Shames S, Heiner K. Sustainable agriculture land management practices for climate change mitigation: a training guide for smallholder farmers. 2016.
[233] Nerini FF, Ray C, Boulkaid Y. The cost of cooking a meal. The case of Nyeri County, Kenya. Environ Res Lett 2017;12(6):065007.
[234] Rehfuess EA, Puzzolo E, Stanistreet D, Pope D, Bruce NG. Enablers and barriers to large-scale uptake of improved solid fuel stoves: a systematic review. Environ Health Perspect 2014;122:120–30. https://doi.org/10.1289/ehp.1306639.
[235] Van der Kroon B, Brouwer R, Van Beukering PJH. The impact of the household decision environment on fuel choice behavior. Energy Econ 2014;44:236–47. https://doi.org/10.1016/j.eneco.2014.04.008.
[236] Fraser P, Pundo M, Fraser G. Multinomial logit analysis of household cooking fuel choice in rural Kenya: the case of Kisumu district. Agrekon 2006;45(1):24–37.
[237] Lambe F, Senyagwa J. Identifying behavioural drivers of cookstove use: a household study in Kibera, Nairobi. Nairobi, Kenya: Stockholm Environment Institute (SEI); 2015 [Available at: 〈https://www.sei.org/publications/identifying-behavioural-drivers-of-cookstove-use-a-household-study-in-kibera-nairobi/〉].
[238] Loo JD, Hyseni L, Ouda R, Koske S, Nyagol R, Sadumah I, et al. User perspectives of characteristics of improved cookstoves from a field evaluation in Western Kenya. Int J Environ Res Public Health 2016;13. https://doi.org/10.3390/ijerph13020167.
[239] Johnson O, Lambe F, Ochieng C. What's health got to do with it? Testing marketing messages for clean cookstoves in Cambodia and Kenya. Nairobi, Kenya: Stockholm Environment Institute (SEI); 2016 [Available at: 〈https://www.sei.org/publications/marketing-messages-cookstoves-cambodia-kenya/〉].
[240] Yonemitsu A, Njenga M, Iiyama M, Matsushita S. A choice experiment study on the fuel preference of Kibera slum households in Kenya. Energy Sustain 2014;186:821–30. https://doi.org/10.2495/ESUS140731.
[241] Ngusale GK, Luo Y, Kiplagat JK. Briquette making in Kenya: nairobi and peri-urban areas. Renew Sustain Energy Rev 2014;40:749–59. https://doi.org/10.1016/j.rser.2014.07.206.
[242] Johnson O, Nyambane A, Environment S, Cyoy E, Oito LG, Action P. County energy planning in Kenya: local participation and local solutions in Migori County. Nairobi, Kenya: Stockholm Environment Institute (SEI); 2016 [Available at: 〈https://www.sei.org/publications/county-energy-planning-paper/〉].
[243] Mutua J, Kimuyu P. Environment for development household energy conservation in Kenya: estimating the drivers and possible savings. Environ Dev 2015;15-04:30.
[244] Pachauri S, Rao ND. Gender impacts and determinants of energy poverty: are we asking the right questions? Curr Opin Environ Sustain 2013;5:205–15. https://doi.org/10.1016/j.cosust.2013.04.006.
[245] Karekezi S, Kimani J, Onguru O. Energy access among the urban poor in Kenya. Energy Sustain Dev 2008;12:38–48. https://doi.org/10.1016/S0973-0826(09)60006-5.
[246] Henriques JJ, Schnorr WG. Sustainability assessment and implementation of a biogas digester system in western Kenya. In: Proceedings of the IEEE green technologies conference; 2010, p. 1–5. 〈http://dx.doi.org/10.1109/GREEN.2010.5453784〉.
[247] Murphy JT. Making the energy transition in rural east Africa: is leapfrogging an alternative? Technol Forecast Soc Change 2001;68:173–93. https://doi.org/10.1016/S0040-1625(99)00091-8.
[248] HEDON. Barriers to cookstoves a practitioner's journal on household energy, stoves and poverty reduction. Chislehurst, UK: Household Energy Network (HEDON); 2014 [Available at: 〈https://www.dora.dmu.ac.uk/bitstream/handle/2086/11599/BP64-%20Barriers%20to%20Cookstoves%20.compressed.pdf?sequence=1&isAllowed=y〉].
[249] Osiolo HH. Willingness to pay for improved energy: evidence from Kenya. Renew Energy 2017;112:104–12. https://doi.org/10.1016/j.renene.2017.05.004.
[250] Bruce NG, Aunan K, Rehfuess EA. Liquefied petroleum gas as a clean cooking fuel for developing countries: implications for climate, forests, and affordability. Frankfurt, Germany: KfW Development Bank; 2017 [Available at: 〈https://static1.squarespace.com/static/53856e1ee4b00c6f1fc1f602/t/5b16ec08352f538a85f57d7c/1528228877332/2017_Liquid-Petroleum-Clean-Cooking_KfW.pdf〉].
[251] Foote EM, Gieraltowski L, Ayers T, Sadumah I, Faith SH, Silk BJ, et al. Impact of locally-produced, ceramic cookstoves on respiratory disease in children in rural western Kenya. Am J Trop Med Hyg 2013;88:132–7. https://doi.org/10.4269/ajtmh.2012.12-0496.
[252] Lambe F, Jürisoo M, Lee C, Johnson O. Can carbon finance transform household energy markets? A review of cookstove projects and programs in Kenya. Energy Res Soc Sci 2015;5:55–66. https://doi.org/10.1016/j.erss.2014.12.012.
[253] Wang Y, Corson C. The making of a "charismatic" carbon credit: clean cookstoves and "uncooperative" women in western Kenya. Environ Plan A 2015;47:2064–79. https://doi.org/10.1068/a130233p.
[254] IFC. Financial Institutions role in the uptake of solar lighting In Kenya – models, challenges, recommendations. International Finance Corporation (IFC) - Lighting Africa-Women Initiative; 2013 [Available at: 〈https://www.lightingafrica.org/wp-content/uploads/2016/07/The-Role-of-Financial-Institutions-in-Uptake-of-Solar-Lighting-by-Women-in-Kenya.pdf〉].
[255] Spalding-Fecher R, Sammut F, Ogunleye J. Promoting energy access through results-based finance within the framework of the CDM: assessing business models. Washington, D.C.: World Bank; 2015 [Available at: 〈https://www.ci-dev.org/sites/cidev/files/doucments/Ci-Dev%20-%20Business%20Model%20Study%20-%20Energy%20Access%20%26%20RBF%20-%202015-11-25%20-%20FINAL.pdf〉].
[256] Harvey CA, Chacón M, Donatti CI, Garen E, Hannah L, Andrade A, et al. Climate-smart landscapes: opportunities and challenges for integrating adaptation and mitigation in tropical agriculture. Conserv Lett 2014;7:77–90. https://doi.org/10.1111/conl.12066.
[257] Muok BO, Kingiri A. The role of civil society organizations in low-carbon innovation in Kenya. Innov Dev 2015;5(2):207–23. https://doi.org/10.1080/2157930X.2015.1064558.
[258] Freeman OE, Zerriffi H. Complexities and challenges in the emerging cookstove carbon market in India. Energy Sustain Dev 2015;24:33–43. https://doi.org/10.1016/j.esd.2014.11.004.
[259] Johnson O, Wanjiru H, Muhoza C, Lambe F, Jürisoo M, Amatayakul W, et al. From theory to practice of change: lessons from SNV's improved cookstoves and fuel projects in Cambodia, Kenya, Nepal and Rwanda. Nairobi, Kenya: Stockholm Environment Institute (SEI); 2015 [Available at: 〈https://www.sei.org/publications/from-theory-to-practice-of-change-lessons-from-snvs-improved-cookstoves-and-fuel-projects-in-cambodia-kenya-nepal-and-rwanda/〉].
[260] GIZ. Energising development partnership – country project Kenya factsheet. Eschborn, Germany: Internationale Zusammenarbeit (GIZ) GmbH; 2017 [Available at: 〈https://endev.info/images/f/f8/Factsheet_EnDev_Kenya_EN_SNV.pdf〉].
[261] Bazilian M, Nussbaumer P, Eibs-Singer C, Brew-Hammond A, Modi V, Sovacool B, et al. Improving access to modern energy services: insights from case studies. Electr J 2012;25:93–114. https://doi.org/10.1016/j.tej.2012.01.007.
[262] Salum A, Hodes GS. Leveraging CDM to scale-up sustainable biogas production from sisal waste. In: Proceedings of the 17th European biomass conference and exhibition: from research to industry and markets; 2009.
[263] Lambe F, Jürisoo M, Wanjiru H, Senyagwa J. Bringing clean, safe, affordable cooking energy to households across Africa: an agenda for action. Prepared by the Stockholm Environment Institute, Stockholm and Nairobi, for the new climate economy 2015 [Available at: 〈http://newclimateeconomy.report/misc/workingpapers〉].
[264] Pennise D, Charron D, Wofchuck T, Rouse J, Hunt A. Evaluation of manufactured wood-burning stoves in Dadaab refugee camps. Kenya: Berkeley Air Monitoring Group; 2010 [Available at: 〈http://www.pciaonline.org/files/Dadaab.pdf〉].
[265] Johnson O, Nyambane A, Cyoy LG. Can county-level energy planning give a stronger voice to end-users? Insights from Migori County in Kenya. Nairobi, Kenya: Stockholm Environment Institute (SEI); 2016.
[266] Atteridge A, Senyagwa J, Heneen M. Biomass energy use in Lusaka, Zambia: the dynamics of household choices and options for transforming energy use behaviour. Stockholm Environment Institute (SEI); 2012.
[267] Takama T, Johnson FX, Lambe F, Arvidson A, Debebe M, Atanassov B, et al. Will African Consumers Buy Cleaner Fuels and Stoves? A household energy economic analysis model for the market introduction of bio-ethanol cooking stoves in Ethiopia, Tanzania, and Mozambique. Nairobi, Kenya: Stockholm Environment Institute (SEI); 2011 [Available at: 〈https://www.sei.org/publications/cleaner-stoves-africa/〉].
[268] Rosenbaum J, Derby E, Dutta K. Understanding consumer preference and willingness to pay for improved cookstoves in Bangladesh. J Health Commun 2015;20:20–7. https://doi.org/10.1080/10810730.2014.989345.
[269] Malla MB, Bruce N, Bates E, Rehfuess E. Applying global cost-benefit analysis methods to indoor air pollution mitigation interventions in Nepal, Kenya and Sudan: insights and challenges. Energy Policy 2011;39(12):7518–29. https://doi.org/10.1016/j.enpol.2011.06.031.
[270] Van Der Kroon B, Brouwer R, Van Beukering P. The energy ladder: theoretical

myth or empirical truth? Results from a meta-analysis. Renew Sustain Energy Rev 2013;20:504–13.
[271] Sola P, Cerutti PO, Zhou W, Gautier D, Iiyama M, Shure J, et al. The environmental, socioeconomic, and health impacts of woodfuel value chains in Sub-Saharan Africa: a systematic map. Environ Evid 2017;6. https://doi.org/10.1186/s13750-017-0082-2.
[272] Jürisoo M, Lambe F. The journey to clean cooking: insights from Kenya and Zambia. Nairobi: Stockholm Environment Institute (SEI); 2016 [Available at: 〈https://www.sei.org/mediamanager/documents/Publications/SEI-WP-2016-13-User-journey-to-clean-cooking.pdf〉].
[273] Schlag N, Zuzarte F. Market barriers to clean cooking fuels in Sub-Saharan Africa: a review of literature. Nairobi, Kenya: Stockholm Environment Institute (SEI); 2008 [Available at: 〈https://www.jstor.org/stable/resrep00344〉].
[274] Ray C, Clifford M, Jewitt S. The introduction and uptake of improved cookstoves: making sense of engineers, social scientists, barriers, markets and participation. Boil Point 2014:2–5.
[275] GACC. Clean cooking loan fund financing carbon certification costs to spur clean cookstove and fuel market. Washington, D.C.: Global Alliance of Clean Cookstoves (GACC); 2014 [Available at: 〈http://www.wplus.org/sites/default/files/CCLF.%20Financing%20Carbon%20Certification%20Costs.pdf〉].
[276] Kammen DM, Bailis R, Herzog AV. Clean energy for development and economic growth: biomass and other renewable energy options to meet energy and development needs in poor nations. New York: United Nations Development Programme (UNDP); 2000 [Available at: 〈https://rael.berkeley.edu/wp-content/uploads/2015/04/RAEL_UNDP_Biomass_CDM.pdf〉].
[277] Ndegwa G, Breuer T, Hamhaber J. Woodfuels in Kenya and Rwanda: powering and driving the economy of the rural areas. Rural 2011;45(2):26–30.
[278] Sesan T. Navigating the limitations of energy poverty: lessons from the promotion of improved cooking technologies in Kenya. Energy Policy 2012;47:202–10. https://doi.org/10.1016/j.enpol.2012.04.058.
[279] Wilson L. Promoting biogas systems in Kenya: a feasibility study. Biogas for better life – an African initiative. 2007 [Available at: 〈http://kerea.org/wp-content/uploads/2012/12/Promoting-Biogas-Systems-in-Kenya_A-feasibility-study.pdf〉].
[280] Hamid RG, Blanchard RE. An assessment of biogas as a domestic energy source in rural Kenya: developing a sustainable business model. Renew Energy 2018;121:368–76. https://doi.org/10.1016/j.renene.2018.01.032.
[281] Barnes B, Rosenbaum J, Mehta S, Williams KN, Jagoe K, Graham J. Behavior change communication: a key ingredient for advancing clean cooking. Health Commun 2015;20(1):3–5. https://doi.org/10.1080/10810730.2014.996305.
[282] Karekezi S, Kithyoma W, Onguru O. Evaluating anaerobic digester energy generation: opportunities and barriers. New York: United Nations Development Programme (UNDP); 2009 [Available at: 〈https://www.compete-bioafrica.net/financing/D5-7/Bio-Carbon%20opportunities%20in%20Africa.pdf〉].
[283] Shankar A, Johnson M, Kay E, Pannu R, Beltramo T, Derby E, et al. Maximizing the benefits of improved cookstoves: moving from acquisition to correct and consistent use. Glob Heal Sci Pract 2014:2. https://doi.org/10.9745/GHSP-D-14-00060.
[284] Goodwin NJ, O'Farrell SE, Jagoe K, Rouse J, Roma E, Biran A, et al. Use of behavior change techniques in clean cooking interventions: a review of the evidence and scorecard of effectiveness. J Health Commun 2015;20(Suppl.1):S43–54.
[285] Evans W, Johnson M, Jagoe K, Charron D, Young B, Rahman A, et al. Evaluation of behavior change communication campaigns to promote modern cookstove purchase and use in lower middle income countries. Int J Environ Res Public Health 2017;15:11. https://doi.org/10.3390/ijerph15010011.
[286] Vulturius G, Wanjiru H. The role of social relations in the adoption of improved cookstoves. Stockholm environment institute working paper. Nairobi, Kenya: Stockholm Environment Institute (SEI); 2017 [Available at: 〈https://www.sei.org/publications/social-relations-cookstove-adoption/〉].
[287] Treiber MU, Grimsby LK, Aune JB. Reducing energy poverty through increasing choice of fuels and stoves in Kenya: complementing the multiple fuel model. Energy Sustain Dev 2015;27:54–62. https://doi.org/10.1016/j.esd.2015.04.004.
[288] Shankar A, Johnson M, Kay E, Pannu R, Beltramo T, Derby E, et al. Maximizing the benefits of improved cookstoves: moving from acquisition to correct and consistent use. Glob Heal Sci Pract 2014;2:268–74. https://doi.org/10.9745/GHSP-D-14-00060.
[289] Sesan T. What's cooking? Evaluating context-responsive approaches to stove technology development in Nigeria and Kenya. Technol Soc 2014;39:142–50. https://doi.org/10.1016/j.techsoc.2014.09.005.
[290] Rupf GV, Bahri PA, de Boer K, McHenry MP. Development of an optimal biogas system design model for Sub-Saharan Africa with case studies from Kenya and Cameroon. Renew Energy 2017;109:586–601. https://doi.org/10.1016/j.renene.2017.03.048.
[291] GoK. Budget statement statement for fiscal year 2016/17. Nairobi, Kenya: Government of Kenya (GoK), The National Treasury; 2016 [Available at: 〈http://www.treasury.go.ke/component/jdownloads/send/7-budget-statement/2-2016-budget-statement.html?option = com_jdownloads〉].
[292] Mudombi S, Nyambane A, von Maltitz GP, Gasparatos A, Johnson FX, Chenene ML, et al. User perceptions about the adoption and use of ethanol fuel and cookstoves in Maputo, Mozambique. Energy Sustain Dev 2018;44:97–108. https://doi.org/10.1016/j.esd.2018.03.004.
[293] Jürisoo M, Lambe F, Osborne M. Beyond buying: the application of service design methodology to understand adoption of clean cookstoves in Kenya and Zambia. Energy Res Soc Sci 2018;39:164–76. https://doi.org/10.1016/j.erss.2017.11.023.
[294] Malla S, Timilsina GR. Household cooking fuel choice and adoption of improved cookstoves in developing countries: a review. Washington D.C.: World Bank; 2014 [Available at: 〈https://openknowledge.worldbank.org/handle/10986/18775〉].
[295] Bedi AS, Sparrow R, Tasciotti L. The impact of a household biogas programme on energy use and expenditure in East Java. Energy Econ 2017;68:66–76. https://doi.org/10.1016/j.eneco.2017.09.006.
[296] Ruiz-Mercado I, Masera O. Patterns of stove use in the context of fuel–device stacking: rationale and implications. Ecohealth 2015;12:42–56. https://doi.org/10.1007/s10393-015-1009-4.
[297] Jeuland MA, Bhojvaid V, Kar A, Lewis JJ, Patange O, Pattanayak SK, et al. Preferences for improved cook stoves: evidence from rural villages in north India. Energy Econ 2015;52:287–98. https://doi.org/10.1016/j.eneco.2015.11.010.
[298] Ndegwa G, Anhuf D, Nehren U, Ghilardi A, Iiyama M. Charcoal contribution to wealth accumulation at different scales of production among the rural population of Mutomo District in Kenya. Energy Sustain Dev 2016;33. https://doi.org/10.1016/j.esd.2016.05.002.