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Pollution from cooking in rural and poor urban households of Africa: A methodological review

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The article examines the effect of cooking food in kitchens on the health of women, as women and children are at a greater risk to indoor air pollution (IAP). It is important to study the cooking practices and prevalent behaviours among African women to understand the magnitude of the danger they face. The study suggests that a decline in the combustion of solid fuels and the use of clean energy can improve health among women and children, as well as sustainability goals. Proverbs 17:22 says, 'A joyful heart is the health of the body, but a depressed spirit dries up the bones'. Bible verse Numbers 35:33–34 indicates, 'You shall not pollute the land in which you live'. The cooking fuel analysis framework among rural women in Africa will guide forward the governments' sustainability policies for communities to ensure healthy lives and promote well-being of women and children.

Contribution: The article conducts a comprehensive analysis of the literature on African cooking practices. A combined search string is made with keywords. Thematic content analysis is conducted with NVivo (produced by QSR International). The article covers two themes, namely improved well-being and suggesting policies to combat climate change and its impacts. Policies and schemes at grassroots levels and better economic conditions in African countries can help to overcome challenges and change health-damaging cooking behaviours. The new advanced sustainability analysis framework has the potential to influence modern kitchen fuels and increase the adoption of new technologies in African villages.

Keywords: cooking; rural women; biomass; indoor air pollution (IAP); health issues; sustainability goals; policies.

Overview

A woman in sub-Saharan Africa (SSA) is slowly killing herself by preparing meals for her family over a smoky stove. Using polluting fuels to cook is a silent killer. According to Whiting (2021), a third of the world's population lacks access to clean fuels. The air is severely polluted by cooking with kerosene, biomass such as wood, cow dung, crop waste and coal. Many individuals die from inhaling these hazardous gases, and women are most affected while cooking on open flames or rudimentary stoves.

The World Health Organization (WHO) approximates that four million people per year pass away from diseases like pneumonia and lung cancer connected to household air pollution (HAP) from using these fuels and stoves for cooking indoors, and yet in Africa, more than 80% of the population relies on unclean fuels. Makonese et al. (2018) found that in SSA, 25% of the sampled households had access to electricity, while 66% relied on biomass for cooking. As per the WHO (2021), soot inhaled from HAP caused almost 50% deaths from pneumonia among children under five years of age.

Lack of access to clean fuels and technologies could hinder the achievement of the 2030 Agenda for Sustainable Development from inadequate policy implementation (International Energy Agency 2017). The United Nations Sustainable Development Goal (SDG) 7 of universal access to cheap, dependable and sustainable energy has been affected by the coronavirus disease 2019 (COVID-19) pandemic. Since women bear a greater burden of household work and cooking, in Africa, it has a greater economic and health impact.

Sustainable Development Goal 7 on energy aims toward warranting worldwide access to clean fuel and technologies. This objective can save millions of lives and enhance the health and well-being of population that uses simple stoves and fuels for cooking, heating and lighting. A decline in the morbidity caused by air pollution, both indoors and outdoors, will indicate the growth

Note: Special Collection: Agenda 2063 – The Africa We Want – Perspective from GJHHD, sub-edited by Cheryl Potgieter (Durban University of Technology) and Nthuna Juliet Ramohai (Durban University of Technology).

towards achieving SDG 3 from Agenda 2063: the Africa we want.

The following questions arise from the overview:

1. To what extent does the combustion of solid fuels affect the health of women and children?
2. How can the prevalence of ill-health among women and children because of cooking pollution in Africa be prevented?
3. What are the challenges in adopting cleaner fuels for cooking?
4. What strategies can be employed to ensure healthy lives and promote well-being among rural communities?

Indoor air pollution (IAP) and sustainable goals demand that various perspectives are explored with qualitative research. This will assist in identifying clean energy gaps and also in establishing that ill-health and sustainability are interrelated. Improving the health status of women and children with cleaner fuels and with support from government policies will help achieve SDG 3 and SDG 7 for African countries.

Pope Francis has urged swift action to halt climate change and suggested including environmental protection among the traditional Christian works of mercy. Humans must not be indifferent to the loss of biodiversity, brought on by their recklessness and self-centred conduct, as thousands of species can no longer glorify God by their very survival.

Methodology

Critical content analysis was used to conduct an integrative literature evaluation with two goals in mind: recognising the health effects of pollution from cooking fuels and conceptualisation. It followed a two-step procedure that began with the study of current research and ended with a review of the findings to create a segment framework for a better Africa.

Three literature databases were used to discover newly published studies using a search method. Firstly, a combined search string was made in University Summons, Google Scholar and Scopus with the keywords: 'women in Africa', 'cooking fuels', 'biomass' and 'cooking fumes'. To find relevant articles about kitchen pollution in Africa, the Boolean search method was used. Important terms associated with the theme were identified and then used to create queries for each search keyword in the relevant field.

The search was confined to research conducted on women cooking food and published in peer-reviewed journals in English. Respiratory diseases and lung cancer caused by cooking in rural households with comparative analysis in different African countries were incorporated. Studies on external environmental pollution and other respiratory disorders related to cancer were not included. Table 1

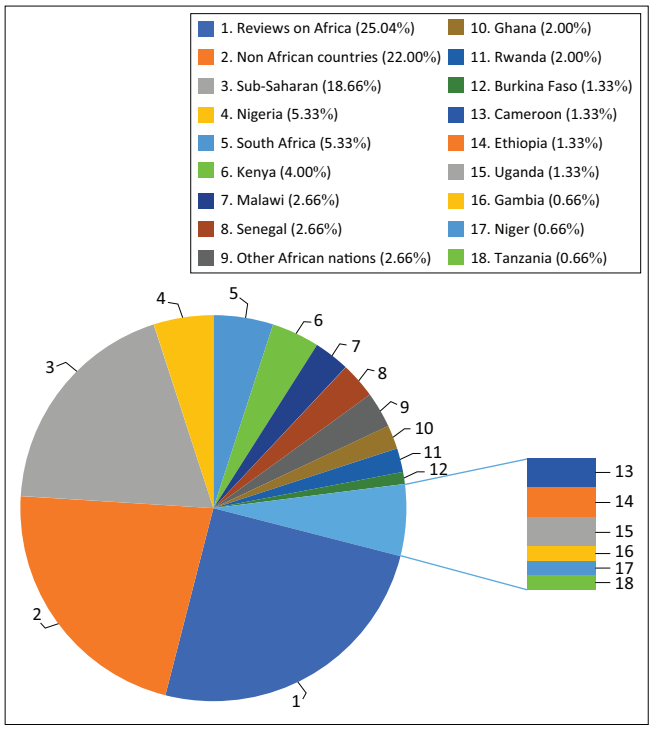


FIGURE 1: Distribution of relevant studies in the African continent (2012–2022).

summarises the important studies relevant to the review. The distribution of relevant studies in the African continent are given in Figure 1.

Scopus came up with 1623 articles, of which 663 were open access. The first 20 results indicated only 5 relevant articles; the database had 22 articles published in February 2022. Considering a combination of all the queries and updated articles resulted in 78 documents. The relevance and scope of these were then sifted. The number of publications was decreased to 40 by excluding review articles and those whose focus was outside of Africa by analysing the titles and abstracts. Rural studies and primary data-based articles were considered appropriate for the investigation, and only 20 articles were finalised for reviewing. These articles were then reviewed on NVivo (released March 2022, produced by QSR International, Burlington, Massachusetts, United States), March 2022. This technique eliminated 20 of the 40 publications; articles included used qualitative, quantitative and mixed methodologies. Six review studies on African and sub-Saharan African nations were selected among the 20 articles as they provided a comparative perspective. Themes that evolve from the review are discussed in the 'Cooking fuels' section of the article, with coded data.

A word cloud was created that highlights the relevant words related to the theme, as depicted in Figure 2. NVivo (produced by QSR International) has a wide range of visualisations, and particularly useful to thematic analysis is the word cloud. A word cloud quickly discovers the most frequently occurring words and phrases (Atenstaedt 2012).

A word cloud is a screening tool for large amounts of text data under which words that appear more frequently in a

TABLE 1: Summary of literature on indoor air pollution from cooking fuels in kitchens.

Author and country	Methodology	Source	Pollutants	Effect on health	Improvements and suggestions
Lambe et al. (2015), Kenya	Review	Charcoal, wood, ethanol-based cookstove	CO and $PM_{2.5}$	Ill health	• Raising awareness on the benefits of clean, safe cookstoves and fuels. Draw from home-grown inventions in the local cookstoves sector.
Okello et al. (2018), Uganda and Ethiopia	215 participants from 85 household	Firewood, dung, crop residue	CO and $PM_{2.5}$, black carbon	Women and girls had higher exposures than men	• Health education interventions for females, benefits to their health on reducing HAP concentrations. • A differentiated approach based on specific sociocultural contexts.
De la Sota et al. (2018), Senegal	A cross-sectional study of 22 households	Fuel wood, crop residue, dung	$PM_{2.5}$, UFP, BC and CO	Health risks for women and surrounding children, increased morbidity and mortality	• Adoption and continued use of stoves by families is central; employment of ICS projects is essential. Improvement of air quality in SSA, knowledge of good ventilation practices and appropriate instructions on cooking environment.
Buthelezi et al. (2019), South Africa	Two wards from the five located in Umlazi selected; 400 housing units were randomly selected	Coal, wood, gas, paraffin, electricity		URTI – hay fever, runny nose, earache LRTIs – wheezing, bronchitis and asthma	• Behaviour and socio-economics determine HAP, critical in defining relationship between respiratory health status, air pollution and fuel use type.
Agbo et al. (2021), Africa	Review	Biomass	$PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, O_3, VOCs, PAH	Cancer-causing capacity in humans	• Prohibition of poor-quality fuels will be helpful. By providing houses with tax-free clean energy incentives, power generators and solid fuels can be replaced with solar systems and biogas or LPG to enhance IAQ. Pursue the goal of improving access to modern infrastructure.
Amadu et al. (2021), Africa	DHS – 95 056 (29 countries) in SSA	-	-	IAP causes anaemia	-
Ayub et al. (2021), Kenya	Review	Biomass (firewood, charcoal, kerosene, cow dung, crop residues, wood processing residues) electricity and LPG	CO_2, CO, H_2O, N_2 and traces of NO_2 and SO_2	-	• A well-insulated pressure cooker. • Solar cookers include parabolic cookers, box cookers and Scheffler cookers. • Induction stove.
Nakora et al. (2020), Mbarara, Uganda	Descriptive and experimental study of 60 homes (10 from each village) where the main cooking fuel is charcoal	Charcoal	PM, CO and heavy metals	Chronic exposure is a risk to health	-
Pye et al. (2020), Cameroon	Purposive sampling data from 3343 peri-urban and rural households in Southwest Cameroon	LPG	Reductions in household air pollution	-	• Policy and interventions on adoption and exclusive use of LPG. • Effective ways to spread the word about LPG safety.
Abera et al. (2021), Africa	Review	Wood, charcoal and crop residues and traditional cooking stoves	PM, SO_2, NO_2, hydrocarbons and CO	Morbidity and mortality	• Develop policies that target low-income households and programs to enhance their cooking circumstances. • Awareness among homeowners on the health consequences of IAP. Encourage behavioural changes to reduce child exposure to IAP.
Dietler et al. (2021), Africa	131 DHS – 183 466 households	Charcoal, dung and wood	-	-	• Infrastructure of improved housing to counteract effect of greater exposure to outdoor sources of air pollution and tobacco use.
Kyayesimira and Muheirwe (2021), Uganda	A cross-sectional study design, 193 respondents and 10 key interviews. Four focus group discussions	Wood and other biomass	-	Respiratory disorders	• Promote use of ICS with sensitisation programs, promotional campaigns and development of supportive regulatory frameworks.
Mahmoud et al. (2021), Kenya	Transdisciplinary study conducted for 6 years, 150 households in 3 agro-ecological zones. A feasibility study of implementing a sustainable management approach for soil and human health, as well as energy efficiency	Biochar (formed by pyrolysing biomass in the absence of oxygen, yielding a carbon-rich, stable solid).	-	-	• Results indicate efficiency in fuel consumption, less exposure to indoor smoke and soil damage lessen demands on female labour. • Correct introduction of technology represents a workable plan to assist communities in addressing difficulties with indoor smoke exposure, fuel economy and soil fertility. It has favourable effects on home economies and surroundings, and it makes tasks done primarily by female laborers simpler.
Meng et al. (2021), Ghana	Survey data collected in three large cities of Ghana – 1010 households	Wood, kerosene, charcoal, LPG, electricity	-	Array of diseases	• Increasing incomes and improving education will lead to an increased use of cleaner cooking fuels, decreased fuel stacking and be advantageous to women's health and the environment.
Saleh et al. (2021), Malawi	Participant observation in a village over 7 months – 300 households (1800 individuals)	Three-stone stove, firewood cookstove, charcoal cookstove	Median $PM_{2.5}$ 35.2 µg/m³ (WHO 24-h average less than 25 µg/m³)	-	-
Shupler et al. (2021b), Cameroon, Ghana and Kenya (peri-urban areas)	Survey data on cooking habits including primary and secondary cooking fuels	LPG	-	-	• Supply-side determinants play a critical role in LPG consumption. • A lower cylinder price will increase consumption, increasing access to multiburner stoves and reducing the distance to LPG retail outlets to minimise fuel stacking and accelerate growth of clean cooking. • Household energy decisions are complex; additional participatory research methods are important to recognise the viewpoints of people using the cooking fuels.
Woolley et al. (2022), Rwanda (LMIC)	Review	Solid biomass firewood, dung, charcoal, crop residues	-	HAP exposure among those who are pregnant, as well as perinatal period, infants and young children up to the age of five	• National and local policymakers need to make effective policy changes. Requires affordable, effective and culturally acceptable interventions.

AQI, air quality index; BC, black carbon; CO, carbon monoxide; CO_2, carbon dioxide; DHS, demographic and health surveys; EI, exposure index; HAP, household air pollution; H_2O, dihydrogen monoxide (water); HR, hazard ratio; HQ, hazard quotient; IAQ, indoor air quality; IAP, indoor air pollution; ICS, improved cookstove; LMIC, lower- and middle-income country; LPG, liquified petroleum gas; LRTI, lower respiratory tract infections; N_2, nitrogen; NO_2, nitrogen dioxide; PAH, polycyclic aromatic hydrocarbons; PE, personal exposure; PM, particulate matter; SSA, sub-Saharan Africa; SO_2, sulphur dioxide; UFP, ultrafine particles; URTI, upper respiratory tract infections; VOC, volatile organic compounds.

Table 1 continues on the next page →

TABLE 1 (Continues...): Summary of literature on indoor air pollution from cooking fuels in kitchens.

Author and country	Methodology	Source	Pollutants	Effect on health	Improvements and suggestions
Giwa et al. (2022), Nigeria	Experimental study of 38 urban household kitchens with kerosene stoves	Kerosene	$PM_{2.5}$ and CO EI = 0.81, PE = 20.14 μg/m³, HQ = 1.38, and AQI for exposure CO was 262.59, $PM_{2.5}$ was 192.90	Health risk	• Government regulations and strong policies are required for improved and efficient stoves, well-ventilated kitchen designs, and home kitchen fuels.
Kumar et al. (2022), Global cities	Spot measurements in low-income inhabitants in densely populated areas of 12 global cities including Addis Ababa, Nairobi, Blantyre (Malawi), Akure (Nigeria) and Dar-es-Salaam	Electricity, LPG, ethanol, kerosene, charcoal	CO_2	Negative effect on human - 10% of the HR values for 25% kitchens exceeded the CO_2 reference value (1000 ppm)	• Better environmental conditions of low-income homes such as increase the volume of kitchens via the ceiling height and floor area for improved kitchen ventilation; passive occupancy by infants and children during cooking should be discouraged; use cleaner fuels and electric cookers; installing indoor CO_2 monitoring devices in kitchens.

Source: Gangiah, S., 2022, *Environmental ergonomics of commercial kitchens in a semi-tropical city*, AOSIS, Cape Town. https://doi.org/10.4102/aosis.2022.BK346

AQI, air quality index; BC, black carbon; CO, carbon monoxide; CO_2, carbon dioxide; DHS, demographic and health surveys; EI, exposure index; HAP, household air pollution; H_2O, dihydrogen monoxide (water); HR, hazard ratio; HQ, hazard quotient; IAQ, indoor air quality; IAP, indoor air pollution; ICS, improved cookstove; LMIC, lower- and middle-income country; LPG, liquified petroleum gas; LRTI, lower respiratory tract infections; N_2, nitrogen; NO_2, nitrogen dioxide; PAH, polycyclic aromatic hydrocarbons; PE, personal exposure; PM, particulate matter; SSA, sub-Saharan Africa; SO_2, sulphur dioxide; UFP, ultrafine particles; URTI, upper respiratory tract infections; VOC, volatile organic compounds.

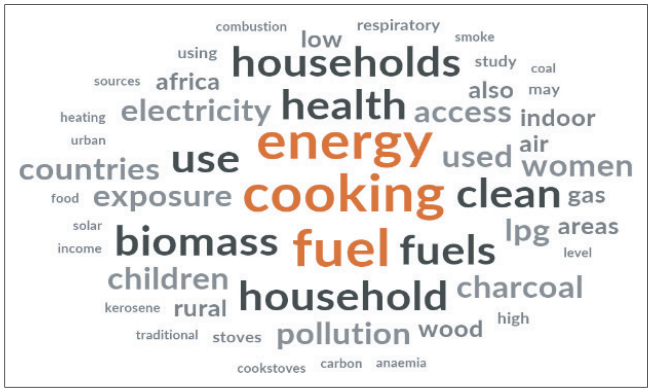


FIGURE 2: A word cloud from the review.

source text are highlighted more prominently in graphical representations of word frequency (Better Evaluation 2020). A maximum word limit of 50 words was set. As can be seen, 'energy' and 'cooking fuel' are two words with the most prominence. This result is consistent with the aim of the article to ponder these topics. The words 'households', 'health', 'use', 'clean fuels' and 'biomass' emerge as important terms in reference to the article's focus on the theme.

Similar words are grouped together, then they are coded, where raw data is converted into usable data through the identification of themes and concepts and identifying similarities and diff erences in the data (Castleberry & Nolen 2018). Once the concept is mapped, they are put into context with each other to create themes and put the data back together within themes. Thematic analysis, a system of analysing qualitative data, facilitates a researcher to establish a coherent structure for the research. The researcher closely investigates the data to detect common themes – topics, ideas and patterns of meaning that come up constantly (Caulfield 2019). Themes are developed to accord with the variables of interest.

Thematic hierarchies offer a visual aid for explaining how themes are subordinate or superordinate to each other. Peterson and Gaugler (2021) identified themes and subthemes in their thematic analysis. The two main themes that emerged in this study were IAP and SDG. The subthemes included: energy policies and government strategies, innovative holistic approaches, adoption and knowledge, attitude and practices (KAP). Other subthemes include: health problems and vulnerable groups. For further analysis, a mind map was drawn to propose associations between themes.

Cooking fuels

Regardless of nationality, cooking is an essential part of human existence and activities. Cooking is not only essential for human existence, but it also plays a huge cultural and social role all over the world (Ugochukwu 2020). Every day, people in some developing countries risk their lives while preparing their meals. Cooking in these countries typically involves the use of open flames or hazardous fuels, both of which are extremely dangerous to one's health.

According to Abera et al. (2021), Africa has fallen behind in the race for cleaner air and better health. The authors emphasise the importance of focusing on air quality for sustainable urban development in Africa. From rural parts of Western Uganda, Kyayesimira and Muheirwe (2021) confirmed that reliance on solid fuels can expose home cooks, particularly women, to both physical and psychological health difficulties. As women make meals with biomass fuel, the type of cookstove and cooking structure contribute to IAP. Abera et al. (2021) reported that IAP is the most significant environmental health risk factor in countries where solid fuels are used for cooking.

Shupler et al. (2021a) claimed that as household sizes grew during the lockdown, participants changed their cooking fuel, cooking methods and foods consumed. Furthermore, those with higher income losses are more inclined to abandon liquified petroleum gas (LPG). As a result, the coronavirus disease 2019 (COVID-19) lockdown may have increased discrepancies in clean cooking fuel access. There is a multifaceted association between household demographics, financial strain, diet and cooking patterns, suggesting a food-energy nexus approach to deal with several SDGs by 2030, including universal affordable, modern and clean energy access (SDG 7).

TABLE 2: Grading of cooking fuel.

Grading of fuels	Cooking fuel	Emissions
Unclean	Firewood, cow dung, coal, peat, kerosene, pellets	• Most undergo incomplete combustion. Produce fine carbon (soot), CO, CO_2 and chlorofluorocarbons that cause respiratory illnesses.
Cleaner	ICS, charcoal, biogas, smokeless biomass gasifier and LPG burners	• These fuels undergo complete combustion. Produce CO_2 and carbon aerosols that cause respiratory problems.
Cleanest	Solar, electrical and hydrogen cooking	• Hydrogen undergoes combustion to produce H_2O, no carbon compounds. No gases are emitted from other sources.

Source: Adapted from Ayub, H.R., Ambusso, W.J., Manene, F.M. & Nyaanga, D.M., 2021, 'A review of cooking systems and energy efficiencies', *American Journal of Energy Engineering* 9(1), 1–7. https://doi.org/10.11648/j.ajee.20210901.11

CO, carbon monoxide; CO_2, carbon dioxide; CS, improved cookstove; H_2O, dihydrogen monoxide (water); LPG, liquified petroleum gas.

Aemro et al. (2021) concluded that compared to traditional wood fuel cookstoves, electric cookstoves can lower energy utilisation by 95.7% and carbon dioxide (CO_2) emissions by 100%. This is supported by Ayub et al. (2021) and compiled in Table 2. The mean concentrations of indoor particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) exceed the relevant WHO air quality guidelines (AQG) in firewood-fuelled poorly ventilated kitchens in rural areas, causing higher exposure among women and children in Africa (Agbo et al. 2021). Amadu et al. (2021) established an association between the combined effect of type of household, cooking fuel, urbanicity and anaemia among children < 5 years in SSA. Therefore, it is crucial to encourage rural and poor urban households to adopt clean cooking fuels.

Demographics and pollution

Pye et al. (2020) from Cameroon reported that female-led households (52%) are leading with a median age of 36 years, and primary and secondary education at 97% and 62%, respectively. The main fuels used are LPG (56%) and wood (36%); other primary fuels include: kerosene (3.4%), charcoal (1.5%), sawdust (1.6%), piped gas (0.03%) and electricity (0.3%). Rural homes predominantly use wood as their principal cooking fuel (81%) and are less likely to use LPG (16%), given the convenience of freely collected wood in the rural community. Most households (70%) indicate fuel stacking. Meng et al.'s (2021) survey in Ghana indicated that charcoal and LPG are commonly used in meal preparation, while the use of firewood, kerosene and electricity is constrained. Incidence of use is dictated by income, sociodemographic characteristics and location of urban residents. Income and education seem to increase the regularity of using LPG or electricity to cook.

Okello, Devereux and Semple (2018) reported that girls and specifically women experience higher IAP exposures than men and boys in Ugandan and Ethiopian rural households. The WHO 24-h recommendation of 25 g/m^3 is six to seven times higher than the exposure of this group. Amegbor et al. (2022) indicated that anaemia is more prevalent among women with lower socio-economic status compared to men. Additionally, women (12.0 g/m^3) had a considerably greater mean lifetime $PM_{2.5}$ exposure than men (11.7 g/m^3). According to Shirinde et al. (2014), boys were found to be lessly to have wheezing from LPG than girls, although girls accounted for 52% of participants in the Highveld region of South Africa. Could this be because of the greater exposure of girls to kitchen fumes?

Cooking pollutants

Adesina et al. (2022) found seasonal variation in pollutants in Highveld region of South Africa, where the concentration of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 have maximum levels during the winter. Meanwhile, PM_{10} and $PM_{2.5}$ from cooking and coal plants exceeded the National Ambient Air Quality Standard, while NO_2 and SO_2 exhibited compliance. Munyeza et al. (2020) revealed that charcoal combustion stoves contribute to the highest polycyclic aromatic hydrocarbons (PAH) emissions, whereas no PAHs were detected from the gas stoves in Kenya. In Uganda, $PM_{2.5}$, heavy metals and CO levels characterise indoor air in charcoal-fuelled kitchens (Nakora et al. 2020). In addition to PM, CO, NO_2, formaldehyde and several toxic organic compounds (benzene and other PAHs) are present in biomass smoke (Balmes 2019).

The ordinary unleavened bread (from Hebrew maṣṣâ), which Jesus is said to have consumed, was baked by nomadic people on hot coals or a grill over an open fire. Mussa et al. (2020) found high $PM_{2.5}$ levels, 20 times the WHO's recommended limit for indoor air, while preparing a typical Nsima meal on a traditional three-stone stove with firewood. While cooking a popular Ethiopian traditional stew sauce (known as *wat*, *wot* or *tsebhi*), PM and total volatile organic compounds (TVOC) are released (Embiale et al. 2019). Abdullahi, Delgado-Saborit and Harrison (2018) compared the estimates of cooking aerosols of different cooking styles: Indian, Chinese, Western and African. Nigerian cuisine (chicken in tomato stew with rice and plantain, cooked by stewing and deep frying) emitted the least, in almost all compounds such as alkanes, PAH and acids correlating with cooking styles.

Carrión et al. (2019) reported that cookstove intervention decreases pneumonia species among infants in Ghana. To minimise the exposure to cooking-related emissions, efforts should be directed towards improving cooking devices and developing alternative energy sources, living environments and cooking behaviour.

Health effects

Biomass burning for cooking is estimated to cause more than half a million premature deaths in Africa each year. Pneumonia, acute respiratory infections, tuberculosis, chronic obstructive pulmonary disease, lung cancer and asthma can all be caused by biomass combustion. In South Africa and Malawi, increased respiratory problems have been observed in homes that utilise biomass fuel (Abera et al. 2021). Acute respiratory infections are more likely to affect women and small children from extended time spent in the kitchen

compared to men (Dida et al. 2022). The health effects of IAP include those mentioned above, cataracts and blindness, adverse effects on pregnancy, cancer and cardiovascular and cerebrovascular diseases (Mocumbi et al. 2019).

Respiratory disorders include asthma, cough, irritation, sneezing and runny nose. Symptoms of eye problems include irritation, tears and headaches. Upper respiratory tract infections entail symptoms such as hay fever and earache, and lower respiratory tract infections such as wheezing, bronchitis, emphysema and central nervous system can occur (Buthelezi et al. 2019). Besides burns, pregnant women could suffer from gestational hypertension, preterm birth or stillbirth. Indoor air pollution can affect neonatal health such as intrauterine growth restriction, impaired neurodevelopment, foetal thrombotic vasculopathy, premature mortality, low birth weight and perinatal mortality.

Indoor air pollution from cooking is linked with low birth weight in Ghana and poor neonatal health and foetal thrombotic vasculopathy in Tanzanian women's pregnancies, as well as untimely death among adults and children. Dherani et al. (2022) found that exposure to higher concentrations of $PM_{2.5}$ from cooking-derived smoke pollution is associated with an increased prevalence of pneumonia infection in young children.

Wright et al. (2022) reported on increased exposure to HAP and respiratory illness during COVID-19 lockdown levels 5 and 4 in South Africa as people switched to 'dirty fuels'. Nuhu, Bukari and Banye (2022) revealed that LPG, followed by charcoal-improved cookstoves (ICS), offers major health benefits. Liquified petroleum gas delivers the lowest HAP during cooking. Even after accounting for the environmental advantages of conserving trees, the LPG is ahead of biomass stoves. Woolley et al. (2022) reported that in Rwanda, levels of HAP source awareness and understanding of the health impacts of air pollution were low among women, reducing their capability to change their behaviour, along with barriers of cost, housing constraints and safety.

Abera et al. (2021) reported that lack of air pollution regulations were present in 45% of African nations, except for Cameroon, that implemented the WHO guidelines for NO_2, ozone (O_3), PM_{10} and $PM_{2.5}$. South Africa and Senegal have adopted the WHO's standards for NO_2, while Malawi has incorporated the PM_{10} and $PM_{2.5}$ guidelines. None of the African countries has adopted the guidelines for SO_2.

Suggestions

Kitchens must be redesigned to allow for sufficient ventilation, while cooking sections are away from living units to reduce negative health outcomes. Children are to be kept out of the kitchen during cooking to lower exposure to IAP (Dida et al. 2022). The problem of unhealthy housing in poor households is severe in urban areas where rent is a limiting factor, confining them to slums that impact health in countries such as Namibia, Malawi, Kenya, Burkina Faso, Cameroon, Senegal, Nigeria, Uganda and Tanzania, except in South Africa This may be attributed to child welfare grants and subsidised home building, which also provides some direction on quality housing (Iddi et al. 2022).

Muller and Yan (2018) argued that besides 'fuel stacking' (multiple fuels) in South Africa, the 'energy ladder' is practised wherein a household moves away from traditional fuels (biomass), firstly to adopt intermediate fuels (kerosene, coal) and then to use modern fuels (gas, electricity). As per Nuhu et al. (2022), free LPG cylinders and stove distribution to rustic homes in Ghana may result in stove abandonment or stacking as rural poor will not need to buy fuel; this scheme is suitable for both urban and peri-urban area. Higher urban household income means improved ability to purchase fuel and maintain such stoves. Pye et al. (2020) concluded that to accomplish SDG 7 (universal energy access), the goal is to scale up embracing of LPG for clean household energy. This will help to lessen the significant burden of disease from burning solid fuels and kerosene, as well as deforestation.

Amegah and Jaakkola (2016) recommended implementation of the WHO indoor air quality guidelines on household fuel combustion; effective advancement of ICS; expansion of LPG production and networks; harnessing of renewable energy, promotion of biogas manufacture at the community level; better ventilation of homes through education and administration of building standards; and adapting health-enhancing cooking behaviour. Understanding the dynamics of an African society influences adoption of ICS. Successful application of ICS requires active involvement by women, with cooperation from family and government with related sectors like health, energy, environment, housing and planning (Dida et al. 2022).

Haque, Lemanski and De Groot (2021) reported that consideration of the community's requirements and aspirations impact social acceptance of technology in Cape Town (South Africa). Knowledge of local social dynamics assists in engaging communities, conception and rollout of energy projects. Affordability can be a barrier to clean cooking fuels such as LPG; pay-as-you-go (PAYG) LPG smart meters can support poor households by permitting incremental fuel payments. In Nairobi, 95% of study households continued using PAYG LPG during the COVID-19 lockdown (Shupler et al. 2021b).

Kumar et al. (2022) evaluated health risks in household kitchens using different cooking fuels across 12 global cities and recommend natural ventilation. The authors found that natural ventilation was greater than dual ventilation (natural + mechanical) by ~4 L/s per person, and cooking in large sized kitchens with higher ceilings that will assist in lower hazard ratio for CO_2. Giwa et al. (2022) assessed environmental ergonomics (noise, humidity, temperature), in Nigerian kitchens with kerosene stoves. Metrics such as exposure index, personal exposure and hazard quotient for

$PM_{2.5}$ and air quality index for exposure to CO and $PM_{2.5}$ indicate a relatively unsafe environment.

Sustainability goals

Creation's gifts should be preserved for God's children over time (Gn 9:12). To improve sustainability and to reduce the degradation of the biosystem (Abera et al. 2021), several factors are elicited from the framework (Figure 3). Sala, Ciuffo and Nijkamp (2015) proved that when defining the sustainability framework, it is essential to consider values and sustainability principles as first options. The framework provides logic and a framework for integrating concepts, techniques, procedures and tools. It is imperative to understand the culture and tradition of a country before the implementation of any strategy. Active agents and the local population need to be enthusiastically involved, and plans should not be made in isolation by a European agency. The choice of cooking fuel for food preparation depends on its availability, affordability, ease of control and level of cleanliness.

The KAP play a role in adapting to clean fuel and technologies. Culturally acceptable interventions need to be adopted, as deviation from traditions can lead to an unwillingness to change among women. Certain practices can be associated with cultural traditions, such as cooking with charcoal for better taste; most practices are performed because no better options exist (Abera et al. 2021). Advancing formal education among women (Amadu et al. 2021) can lead to positive behaviour change such as willingness to adopt new technology. The use of multicookers and soaking beans that require longer cooking times can decrease time spent in the kitchen. This change requires capability, opportunity and motivation. Dim (2023) agreed that the choice of cooking fuel and energy consumption are found to be significantly influenced by income and education. Gender dimension and women's intra-household bargaining power need to be considered in energy transition plans.

Demand for unsustainable energy resources can be reduced by subsidising the cost of ICS, gas cylinders and solar energy that is ecofriendly, clean and cheaper with solar photovoltaic (PV) (eCook) stoves, as well as newer and improved forms of renewable energy such as biogas production (Amadu et al. 2021). Hydrogen cooking may be launched in small phases. Automated pressure cooking and induction cookers with 90% efficiency can decrease electricity use. Although the initial cost of technology can be high, eventually benefits can be reaped. Promoting double burners and use of branded LPG cylinders (recirculated) will enhance food production and safety. This can also free women from collecting biomass and the time saved to be used for economic activity. Thus, use of cleaner fuel will improve socio-economic status and health and decrease pollution levels in kitchens (Ayub et al. 2021).

Besides socio-economic capability, the government should enhance access to technology through improved road networks, electrification rates and grid connection. The government energy policies should have special schemes to increase biogasification, availability of PAYG schemes for electricity and gas to diminish the financial burden (Shupler et al. 2021b).

Likewise, reducing import taxes on new technology such as a mini moto (MM) stove; Lambe et al. (2020) suggested that cookstove designers and the rollout action planners need to appreciate purchasers' preferences and requirements and advance the stoves and provide after-sales services to achieve success. The introduction of cleaner fuel MM pellets in Nairobi, Kenya, revealed that reducing costs, convenience, health and safety motivated ICS.

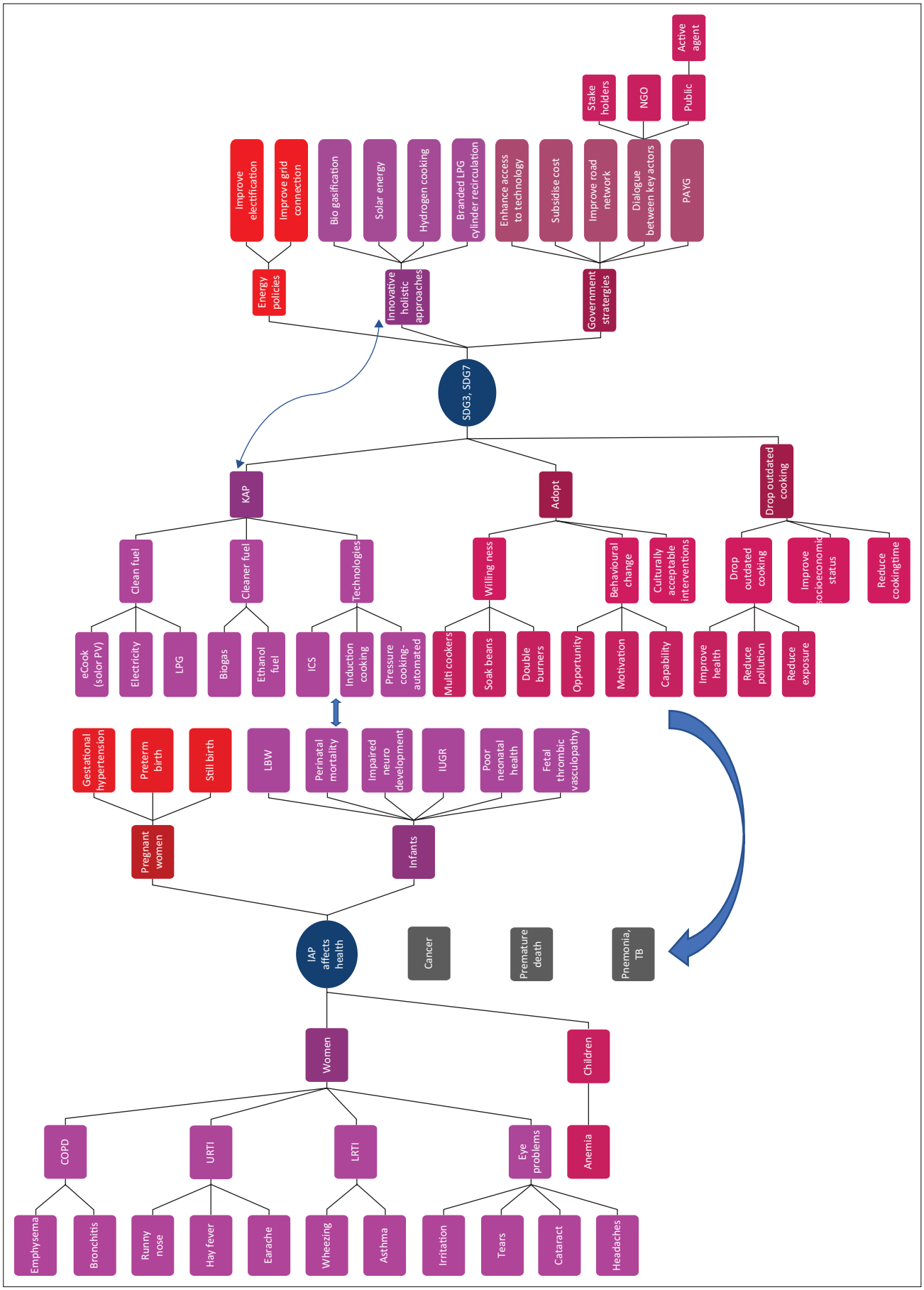
The government energy policy choices should be integrated with developmental policies to improve the sustainability of biodiversity that has minimal impact on human health and the environment.

Clean cooking fuels and technologies are the solutions to achieving SDG 7. The population needs a voice in local democracy and awareness about political commitment and accountability (Abera et al. 2021).

According to the OECD (2020), global environmental crises like climate change and biodiversity loss can result in community and economic impairment that is significantly greater when compared to a pandemic. Economic recovery plans should be created to 'build back better'. This strategy is fundamentally based on emphasis on inclusivity and well-being. In recovery programmes that generally address multiple issues simultaneously, like accelerating the shift to mobility-based accessibility and funding low-carbon, decentralised electrical infrastructure, alignment with long-term emission reduction objectives, accounting for resilience to climate effects and reducing biodiversity loss, are other critical factors (OECD 2020). Communities can be more resilient to environmental deterioration (climate change, air pollution, biodiversity loss and poor ocean health) from stimulus packages that spark investments and societal changes.

The need for a people-centred recovery that prioritises well-being, enhances inclusion and lowers inequality is a crucial component of 'build back better'. Recovery plans must be evaluated based on factors that enhance well-being, such as income, quality of jobs, housing and health. Emphasising on people's well-being is essential for securing the political and social approval of environmental policies (OECD 2020). Making taxes and subsidies progressive (supporting the most vulnerable) and preparing the workforce for the green transition are two ways to make sure that environmental measures are socially inclusive. However, deforestation and other types of land use change have also been related to the spread of illnesses. Biodiversity and ecosystem services are essential to economic activity and human health.

Kapfudzaruwa, Fay and Hart (2017) claimed that there are differences in the rates of ICS adoption between rural and



COPD, chronic obstructive pulmonary disease; IAP, indoor air pollution; ICS, improved cookstove; IUGR, Intrauterine growth restriction; LBW, low birth weight; LPG, liquified petroleum gas; LRTI, lower respiratory tract infections; NGO, non-government organizations; PAYG, pay-as-you-earn tax; PV, photovoltaic; SDG, sustainable development goals; URTI, upper respiratory tract infections.

FIGURE 3: Sustainability analysis framework.

urban households within countries, as rural households appear to be less aware of, and unable to afford, the stoves than urban consumers. These disparities are brought on by different income and literacy levels. Because of low literacy rates, rural residents, who are primarily the elderly, are less aware of the advantages that modern cookstoves can provide.

To increase the adoption of enhanced biomass stoves and contribute to the sustainable use of biomass energy resources, Olaoye, Bolaji and Oloyede (2022) reasoned that it is necessary to improve access to and the cost implications of the biomass fuel and stove. Bensch, Jeuland and Peters (2021) emphasised that well-designed cookstoves will lessen the burdens of energy poverty, which primarily affect women.

This can be supported by frugal grassroots ideas that develop in a resource-constrained environment. The communities at the bottom of the economic pyramid can be catered for that are ignored by research and development institutes, and inclusion is a key component of grassroots development (OECD 2020). Chakravorti and Chaturvedi (2019) endorsed that adoption of digital technology would help African nations advance economically, which is a part of a free-trade zone that could support collaborative projects to close knowledge gaps and realise the continent's long-promised prosperity while fostering inclusive growth.

Conclusion

The choice of cooking fuel is at the core of the problem and the solution. From the concept map, a sustainability analysis framework is created that can be instrumental in planning and operating systems to establish appropriate policy intervention in socio-economically disadvantaged African societies. These interventions will improve accessibility to cleaner fuels and clean technologies that will reduce exposure to IAP and the burden of respiratory disorders and enhance partial well-being in Africa. Lowered combustion of dirty fuels will reduce the effect of climate change with diminished pollutant emissions, and less consumption of biomass can improve biodiversity and ecological balance as pledged in Africa's National Determined Contributions to achieve SDG 7. However, some countries that declined to ratify the Paris Agreement can cause more emissions which can impact on the climate. Abudu, Wesseh and Lin (2023) proposed policies for integrated economic and environmental measures for achieving effective climate targets in Africa. Christians hold the view that humans are custodians of this Earth, which belongs to God (BBC 2022).

Interventions such as clean technology and digitisation require extensive outlay in many African countries, which can be hindered by political unrest. The author feels that investment in a country, however, can become attractive because of its younger inhabitants, who can be expected to be significant consumers over the next three decades, and becoming technologically smart with the use of mobile phones. Access to smart phones and other devices improves consumer information, networking, job-creating resources and even financial inclusion; an emerging digital ecosystem is especially important as a multiplier of progress. African governments can encourage high adoption of digital payments and provide a supportive regulatory framework (Chakravorti & Chaturvedi 2019).

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Author's contributions

S.G. is the sole author of this article.

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