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Policy Pathways for Mapping Clean Energy Access for Cooking in the Global South—A Case for Rural Communities

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Abstract: Currently, over 1.5 billion people, especially in the Global South, live without access to modern energy for household uses, especially for cooking. Therefore, this study examines the cooking space of the Global South with a specific focus on the rural communities to map alternative energy sources, technologies and supporting policies to drive clean cooking services for improved socioeconomic development. It begins with a literature review on clean cooking technologies and clean energy access for the Global South, which leads to the suggestion of clean cooking policies by mapping technology, affordability, accessibility, climate action, business model and local capacity. In order to ensure that the validation is appropriate, three online questionnaires were designed to capture three categories of key stakeholders with distinctive and complementary interests in clean energy access for cooking: (i) End-users, (ii) Energy Suppliers and (iii) Interest Groups in rural communities in Fiji, Ghana and Nigeria. The responses are analysed to conduct a comparative study across the three countries examined. Based on the above, an attempt is made to present broad base policy pathways for adopting clean cooking services in the rural community for sustainable development. The policy pathways harmonize the major stakeholders in the cooking space: Governments, Non-Governmental Organizations (NGOs), clean energy developers, business services and the end-users. In addition, a business model in the context of a rural community cooking space is proposed, stating that the initial life of the clean cooking business should be government-driven and, thereafter, followed by incentive-driven at the mid-life of the business (say, 25% technology penetration) and private-sector-driven at the late-life (say, 45% technology penetration). It is expected that the effort made in this work could be advanced by investigating the detailed techno-economic parameters of clean cooking technologies that could be influenced by the policy pathways established in connection with the sociocultural factors associated with energy services.

Keywords: clean technology mapping; cooking technologies; clean cooking; policy development; business model; energy poverty

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1. Introduction

There is abundant evidence of a gap in the socioeconomic development in the world's richest and poorest countries (i.e., the "Global North vs. Global South Divide"). Regrettably, faster economic growth in the Global North meant that it became responsible for 90%+ of excess global carbon emissions [1] leading to the climate breakdown the world is experiencing today. However, the Global South is most vulnerable to the repercussions of our changing environment (e.g., desertification, flooding, rise in temperatures, intensive tropical cyclones). Therefore, the scientific opinion suggests that we must change our living patterns to protect vulnerable communities and preserve the planet for future generations. This includes a targeted approach to changing how we generate and use energy to meet the varying needs of different communities while contributing to achieving the United Nations Sustainable Development Goals (SDGs).

Burdened by the need to close the socioeconomic gap with the Global North, and despite abundant availability of renewable energy resources (solar, wind, biomass, hydro and geothermal, etc.), countries in the Global South have insufficient financial and technical capabilities to produce and utilize green energy in critical sectors (including housing, agriculture, transport) [2]. This slows the global effort to mitigate climate change and exposes the least resilient rural communities to adverse conditions. Within this context, the research community has been very active in its effort to contribute in reducing the effects of climate change, with works that focus on minimizing energy consumption [3–5] as well as CO_2 equivalent emissions [6,7] aiming to contribute towards sustainable development through the use of renewable energy [8,9]. The adverse conditions of the current *status quo* could come in the form of health hazards [10], environmental pollution [11] and unsustainable living [12], which contravene SDG 3 "Good health and wellbeing", SDG6 "Clean water and sanitation", and SDG11 "Sustainable cities and communities". Furthermore, unsustainable living in rural communities imposes heavy financial burdens on governments to recover from the repercussions of climate change, which lead to poverty that contravenes SDG1 "No poverty" [13].

The interdisciplinary and multifaceted aspect of the subject is also met in the literature, with several researchers analyzing and investigating the correlations between energy sustainability and poverty, focusing on the Global South. In their research, Franco et al. [14] highlighted how energy can be a crucial parameter for delivering and improving healthcare services and life-saving interventions in the Global South. They concluded that access to reliable, affordable, and sustainable energy is essential for improving living standards and economic growth. In the same context, Terrapon-Pfaff et al. [15] analyzed the findings of an impact evaluation of 30 small-scale energy development projects, in order to understand whether and how the provision of sustainable energy services could have positive effects on local livelihoods. Based on the above, Vanegas Cantarero [16] illustrates through a roadmap the possible synergies that might be formed across sectors to facilitate the energy transition in developing nations, when the challenges of this enterprise are underlined by several researchers [17].

As discussed above, a number of projects have been implemented in order to provide sustainable energy to these communities, although in many cases they have been designed within a top-down, technologically driven paradigm, which hinders their capacity to address energy poverty and enhance livelihoods [18]. Initiated by that, a number of researchers investigating solutions, with Cloke et al. [18] suggesting a Social Energy Systems (SES) strategy that is developed by examining the interactions between three different but complementary forms of energy literacy: political literacy, project community literacy, and energy systems literacy. On the other hand, Akizu et al. [19] examine some of the sociocultural, technical, economic, and political aspects influencing global transitions at various scales toward low-energy societies, from both the Global South and the Global North. This is done through the analyzation of their national energy settings, taking into consideration the hidden energy flows, given the limits of the local or partial nature of these case studies.

The management and the energy transition in the Global South has totally different parameters than in the so-called developed countries, which is also expressed in the way energy is consumed. The food sector is energy consuming both in the Global North and South, and is directly connected to the equipment used for the food storage and cooking, with researchers suggesting new strategies to reduce their environmental impact [20,21], or comparing several approaches to stochastically predict the temporal energy consumption of low-load appliances [22]. These works are primarily focusing on developed countries when the problem also exists in the Global South, with researchers examining the typologies and determinants of energy for cooking sources among households in Ghana [23], and others investigating and analysing the programmes which explore alternative approaches to address cooking energy concerns in the Global South [24].

Nevertheless, it is commonly recognized that the cooking methods in the Global South are not sustainable, and at the same time, the share of energy spent for cooking in the households is big. For instance, in Kenya, 98% of the energy spend in a household goes on cooking and hot water, when for the same activities a household in Spain spends the 50% [25]. Additionally, cooking is one of the principal energy demands for rural communities in the Global South, mainly met by crude use of biomass and kerosene with high indoor air pollution. Moreover, the current cooking practice is responsible for 3 to 4 million premature deaths annually and partly for climate change [26]; whereas, rural communities also have lower resilience to the detrimental consequences of climate change [27]. Therefore, the work focuses on proposing policy recommendations to drive a transition toward the reliance on clean fuels and technologies for cooking in rural communities in the Global South in recognition of the urgent need to develop adequate policy pathways that aim to present governments in the Global South with options to effectively drive the clean energy cooking space in their respective countries [28].

Thus, the broad objective of the presented study is to develop policy pathways for overcoming barriers to the uptake of clean cooking technologies for sustainable energy access in rural communities in the Global South. To achieve this, it explores the existing clean energy technologies—solar, wind, biomass, and small hydropower—that could support clean cooking technologies in rural communities. Additionally, it aims to map the explored technologies with clean cooking by mitigating the identified barriers to clean energy uptake in rural communities in the Global South (including cost assessment and financial sustainability of the technology, policy, culture, etc.).

2. Methodology

Figure 1 shows the steps and interactions involved in the methodology of the current work. The methodology begins with the literature review of the relevant studies on clean cooking technologies and clean energy access for the Global South. The literature is focused on clean cooking technologies, end-use, technology diffusion and existing policy. After that, literature targeting Fiji, Ghana and Nigeria were used to represent the Global South to validate the literature review. The choice of Fiji, Ghana and Nigeria was inevitable because of access to data. Though the sampled countries used for the validation study might be judged as limited, it could be considered the first approximate solution in the space of the Global South. After this, clean cooking policies were suggested by mapping technology, affordability, accessibility, climate action, business model and local capacity by addressing health, environmental, and sociocultural impacts associated with existing cooking services.

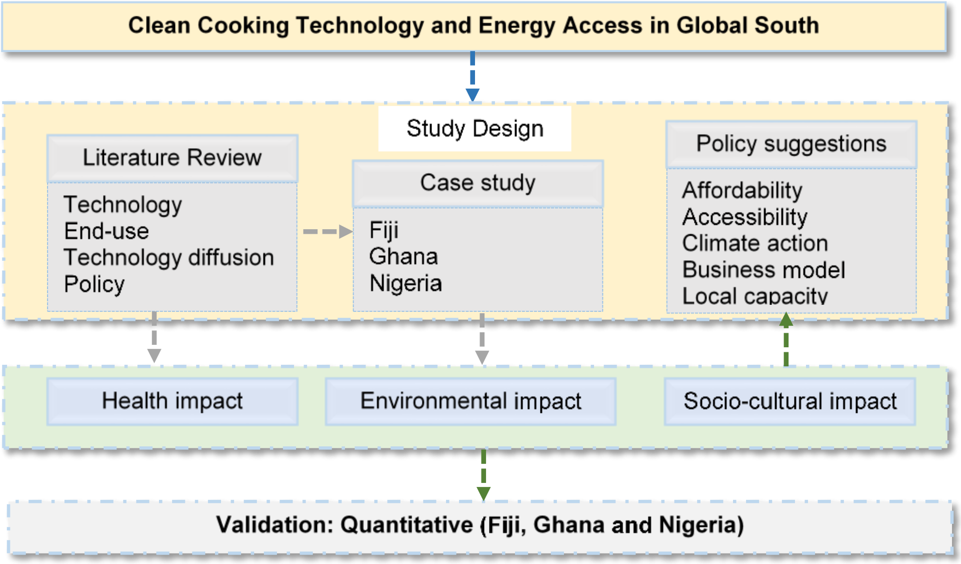

Figure 1. Structure of the methodology. The top box deals with the research question. The box that follows deals with the study design. The literature review and the case study outputs can be categorized into the items in the third box. The outputs are systematically analysed to suggest appropriate policies in the context of the items in the box (policy suggestions). The entire process is then subjected to a validation study using the three countries. The arrows show the flow of information.

The validation study focuses on a stakeholder assessment, as shown in Figure 2, using a five-step approach, which is relied upon to determine the communication method and approach of engagement with different groups. The framework consists of the following five steps:

Step 1: Defining a list of stakeholder groups and their potential risks in the penetration of clean cooking technology. This step addresses a logical and useful categorization of potential stakeholders with differing interests.

Step 2: Identifying specific individuals under each category and their specific interests. In this step, a table of individuals with their respective contact details, affiliations, and specific interests was developed and included sections to monitor the engagements' progress.

Step 3: Stakeholder assessment—analyzing stakeholders' relative potential interest in the outcomes of this study, and their power to influence decision-making around its subject (Figure 2).

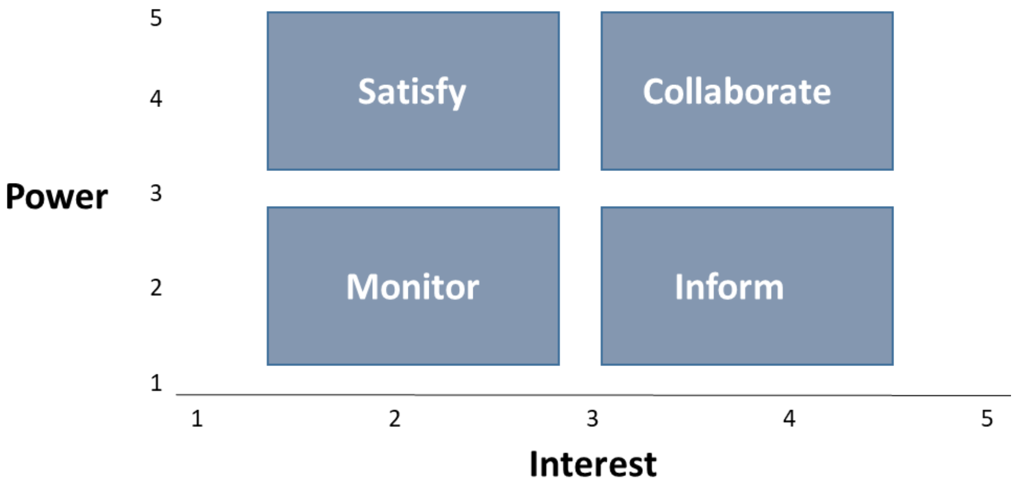

Figure 2. Stakeholder assessment.

Step 4: Attributing communication method based on Step 3 in accordance with Figure 3.

Step 5: Developing of a communication management plan following the communication method adopted for respective stakeholders.

Figure 3. The attribute communication method based on stakeholder ranking.

In order to ensure that the validation is appropriate, desirable and viable, three online questionnaires were designed to capture three categories of key stakeholders with distinctive and complementary interests in clean energy access for cooking: (i) End-users, (ii) Energy Suppliers and (iii) Interest Groups in rural communities in Fiji, Ghana and Nigeria. The end-users are defined as the people in rural communities who use fuels and cooking technologies. Their interest in shifting towards clean cooking fuels and technologies is envisioned to improve health and living conditions, empower women, educate children, and provide reliable and safe energy access. The energy suppliers are the stakeholders who supply fuel and clean cooking technologies to the rural communities, such as government departments/ministries, public authorities, energy service companies, financial institutions, and clean fuel suppliers. Finally, interest groups are organizations (non-government organizations, community-based organizations, women groups, etc.) interested in climate action, gender equality, reducing poverty, and health and safety. The responses are analyzed to conduct a comparative study across the three countries examined.

2.1. Literature Review

The literature review starts with the presentation of works targeting technologies used to provide energy to remote rural settlements to meet their energy end-use, with clean cooking in focus, in the context of the Global South. In this context, clean fuels and technologies are defined as those that limit the emission of particulate matter, carbon dioxide and/or carbon monoxide with no health impact [29]. The works related to environmental and sociocultural impacts were systematically mapped in the same framework. Policy issues related to drivers, barriers and opportunities are presented in the context of the Global South. Going forward, an attempt was made to present some pertinent business models existing in the public domain.

2.2. Technologies and Energy End-Use

Several researchers focused on providing technologies that support energy cooking services in remote communities, which depend on biomass, coal, natural gas, Liquefied Petroleum Gas (LPG), biogas and electricity. There was a strong connection between available energy solutions in rural communities and the choice of cooking services. In most cases, energy for cooking comes from traditional biomass, kerosene, coals, or other oil-based fuels [30,31]. However, existing clean technologies are readily available to support modern clean cooking services in rural communities [32–34].

Huenteler et al. [32] focused on six renewable energy technologies to support Thailand's renewable energy target for 2021. It was stressed that local capacity and learning curve in renewable energy technologies has the potential to reduce the cost of energy from renewable energy technology to support clean cooking services. Similarly, Chauhan and Saini [34] presented some solutions to the barriers to implementing renewable energy technologies in remote communities, which include energy end-users, provision of an institutional regulatory framework for financial management, creation of a database for resource assessment, provision of online subsidy disbursement mechanism, the development of an energy-efficient system by considering demand-side management, the skilled workforce development, the development of standards for small scale renewable energy products and the system design considering future load growth. However, a study by Hansen et al. [35], corroborated by Frame et al. [36], showed that the effectiveness of Local Content Requirements (LCRs) in promoting local industrial development differs across countries and technologies as demonstrated in South Africa, Brazil, India and China.

Some researchers presented advanced renewable energy technology (hybrid energy system) to mitigate the unsteady supply of renewable energy sources (e.g., solar and wind) by introducing energy storage in the form of batteries [37], which, in some cases, is attributed to the high cost of energy [38]. The management of the use of batteries, their waste and their cost in hybrid systems are also discussed by Shezan [39]. Mohammed et al. [40] focused on hybrid systems regarding the drivers and specific benefits of hybrid renewable energy systems (HRES); a backup battery system for energy storage was essential for solar and wind. The diffusion of different non-hydro renewable energy (NHRE) technologies in developing countries was studied by Pfeiffer and Mulder [41]. It shows that NHRE diffusion accelerates with the implementation of economic and regulatory instruments, higher per capita income and schooling levels, and stable democratic regimes.

Diemuodeke et al. [38] focused on solar electric cooking technologies and presented technical and economic analyses of various electric cooking technologies in rural communities. It established the possibility of solar PV induction cookstove technology to fill the rural communities' clean energy cooking services gap. The study showed that cooking at 2 kWh/day, effective energy demand, is adequate for a household in a rural community (on average, 2 tons of fuel wood per year is needed by a Fijian household to cook three meals[31]). Additionally, it was revealed that the Levelized Cost of Energy (LCOE) fluctuates between 0.120–0.390 $/kWh from without-battery to with-battery induction cookstoves, which is cheaper than LPG cookstove (0.500 $/kWh).

The economic aspect of cooking was one of the main pillars of the study presented by Jewitt et al. [42]; that cooking technology is constrained by the interconnection of economic, access and spatio-temporal distribution of fuel cost, availability, service quality, and the sociocultural aspect of cooking practices. It also shows that fuel stacking is the ultimate in-meeting cooking demand because of the seasonality of some of the fuel sources. The implication is that change in seasonality caused by climate change will severely impact cooking. In the framework of clean cooking, Ozoh et al. [43] performed a cross-sectional and population-based survey, which focused on the choice of household cooking fuel and the attitudes towards using LPG in a densely populated town in the Global South. It shows over 90% of households were willing to accept LPG as cooking fuel without safety issues and high costs. A study by Black et al. [44] showed that biogas has huge potential to meet the cooking energy needs of off-grid households and the added benefits of biogas generation in the context of a circular economy-effective management of waste (especially agro-residues and wastes) and nutrient recovery. Buskirk et al. [45] study stressed that the continued use of firewood for cooking was directly connected to cost and, therefore, presents pathways to make solar PV electric cookstoves more economically competitive than firewood-based cookstoves. However, challenges include poor quality of solar PV in the market, high cost of verified solar products, lack of after-sales maintenance services, and limited access to credit financing sources [46].

2.3. Health Impacts

Poor air quality is attributed to health problems in communities or societies and many premature deaths [44,47,48]. In response to the adverse effects of the inefficient use of solid biomass for cooking on health, World Health Organisation (WHO) has set "Guidelines for indoor air quality: household fuel combustion" to help countries to identify key stakeholders and design and implement policies for household energy [29]. According to WHO Guidelines for indoor air quality—household fuel combustion 2012—clean fuel and technologies should have an annual average emission of fine particulate matter (PM2.5) of 10 $\mu g/m^3$ and a 24 h average carbon monoxide (CO) level to be 7 mg/m^3 [29]. Cooking fuels and technologies have been categorized into three levels by WHO—clean, transitional and polluting; solar, electric, biogas, natural gas, LPG, and alcohol fuels are considered clean cooking fuels and technologies. Transitional fuels and technologies provide some health benefits but do not achieve WHO emissions levels of PM2.5 and CO, e.g., improved biomass cookstoves that have ISO Tier 3 PM2.5 and Tier 3 or Tier 4 CO emission levels [29]. Coal and kerosene are considered to be polluting fuels and are strongly discouraged by the WHO Guidelines.

Tian et al. [49] have used the Chinese General Social Survey data to investigate the health effects of household cooking choices. They found that rural households depend more on solid fuels for cooking and thus bear a higher health risk. In Ghana, it is reported that more than 3000 children die each year due to acute lower respiratory infections, including pneumonia, caused by the use of solid fuels [50]. Similarly, Ortega et al. [51] carried out a detailed study on the health impacts of replacing kerosene lighting with renewable electricity in 13 countries in East Africa. They used comparative risk assessment methods to quantify various health problems of individuals exposed to particulate matter emitted by kerosene lighting in 2015. They presented estimates of the number of deaths and disabilities due to exposure in three different scenarios of households replacing kerosene lights with renewable energy: (i) 33%, (ii) 66% and (iii) 100%, which give 6218, 10092, 12723 avoidable deaths. Importantly, women and children are the most affected by the status quo, as more than half a million premature deaths per year were reported in sub-Saharan Africa in 2015 [29,52,53]. United Nations' Economic and Social Commission for Asia and the Pacific (ESCAP) [54] conducted a systematic review of 86 studies and found that 52 out of the 86 studies focused on improved biomass cooking stoves and reduced carbon monoxide levels, but impacts on pneumonia, blood pressure, and hypertension were statistically significant. The implication is that further research is needed to adequately address the impact of improved cookstoves on health [51].

2.4. Environmental Impacts

The environmental impact of clean cooking services is important for designing effective policy programmes. It also provides the policymakers with policy data and information to monitor emissions at the sectoral level for reporting at national and international levels. It is estimated that about two tons of fuelwood per year are needed by a Fijian household to cook three meals a day, where feedstock is sourced from mangrove swamps or community forests [31]. This implies that the continuous trend of traditional cooking with fuelwood (firewood) would severely impact climate change by raising the global temperature beyond the threshold because trees, which naturally effective for carbon sequestration, are indiscriminately sourced for cooking energy.

It is estimated that households' inefficient, traditional cooking fuel causes around 25% of global black carbon emissions. In addition, their use contributes to forest degradation, loss of biodiversity, and localized deforestation [55]. Urmee and Harries [56] report that the use of solar home systems (SHS) by rural, remote and maritime communities in Fiji has enabled households to live in a cleaner indoor environment. A 100 kW micro-hydro power plant installed in the highlands of Fiji has the potential to save 160 tCO_2e greenhouse gas emissions [57]. Similarly, mini biogas generators (each of 6 m^3 volume) installed in Bali, Indonesia, across 752 rural cattle farms with no electricity, can potentially avoid 1.92 ± 0.96 Gg of CO_2e GHG emissions [58].

A study in Ethiopia found that a solar electrified rural household has the potential to save 43.68 L of kerosene per annum and emission 107 kg CO_2 and 2.72 kg of black carbon per year per household relative to a non-electrified home [46]. They employed a cross-sectional survey method involving 605 sample households and a direct field investigation of 137 solar PVs and lanterns in four rural districts of Ethiopia. Corfee-Morlot et al. [59] also found that most of those without clean cooking access in sub-Saharan Africa rely on traditional biomass, causing deforestation and smoke and soot pollution, which in turn harms the local and global environment and human health.

2.5. Sociocultural and Economic Impacts

Multiple studies highlighted that cooking programmes could fall short if they do not consider social and cultural factors and do not involve women from the outset [52,60,61]. The political livelihood of rural communities, which is shaped by sociocultural stance, is expected to influence the adoption of cooking services. Shankar et al. [62] studied clean cooking solutions such as electric induction cooking, LPG, ethanol/methanol, biogas, compressed biomass pellets and briquettes. The study showed that substantial stove stacking (concurrent use of multiple cookstoves) was practiced in every programme, negating the efforts to transition households to cleaner fuel options. Ockwell et al. [63] presented socio-technical innovation pathways for transforming clean energy access space by 2030 in the Global South and the strong connection between energy access and clean cooking services. It shows that gender, the scale of technologies, political and economic status are important in the intervention for electric cooking. The study discussed portable solar lanterns and electric cookstoves, how the transformative clean energy technology should be lensed with social justice, especially in the area of gender factors in clean energy access, and how politics and political economy dynamics drive the success of interventions around new technologies at the rural community level.

Corfee-Morlot et al. [59] noted that while women are a primary beneficiary of clean energy, they have been under-represented in energy policy leadership and establishing and promoting related businesses. In addition, the authors highlighted the importance of placing women at the center of decision-making around energy access for cooking because they collect fuel, make household cooking decisions and have an intimate understanding of the family's cooking needs. Although both men and women are negatively impacted by a lack of access to clean and sustainable forms of energy, social inequalities, economic capability, and gender-defined roles ensure that women are often disproportionally affected by a lack of energy access [52]. The issue of acceptance has also been highlighted in a study; unwillingness to take the risk of switching, mainly if there was a previous bad experience with low-quality options [64]. This is consistent with the G20 Leaders' recommendation that the energy transition needs to span the power generation and the end-use sectors alike [52,59,65]. The number of hours that continue to be spent each year in biomass collection could have been otherwise spent more productively [52,55,66].

According to the World Bank, the estimated cumulative annual opportunity cost for continuing to use traditional fuels in sub-Saharan Africa is 3% of the region's $32 billion annual gross domestic product due to time lost to fuel collection and slow cooking, household expenditures on inefficient fuels and stoves, and increased health-related costs for households and health care systems [64]. As such, and given that 62% of economically active women are working in agriculture (over 90% in countries such as Burkina Faso, Malawi and Rwanda), improvements in the energy sector are predicted to benefit them the most [67]. Moreover, while clean cooking reduces the risk of illness or death from air pollution and saves time for women, research showed that electricity access also boosts female employment rates and improves education for children—most notably girls; since almost 60% of health facilities in sub-Saharan Africa have no electricity [67] while on average, just 34% of hospitals and 28% of health facilities in sub-Saharan Africa have reliable electricity access [29,64]. The mini-grids supporting modern energy cooking services could also power the health sector, providing better maternal health services and conditions [52,59].

It is shown that improved biomass cookstoves could reduce cooking time by 34% and the ability to reduce firewood usage by 54% [31]; both the time and firewood use reduction imply saving time in cooking services which could be directed towards productive social-cultural activities for improved wellbeing; for example, freeing up time for women to take up community level or income-generating activities, which in turn can improve gender equality. On the other hand, access to clean energy (with clean cooking in focus) can help raise millions from poverty and improve the rural poor's livelihoods [59,68]. It is also reported that children have better lights to study at night and help women with their daily choices—an observation also supported by Laufer and Schäfer [69]. Households can also enjoy other benefits of electricity, such as better entertainment and communication. Additionally, Urmee and Harries [56], corroborated by the Equator Initiative [57], found that Solar Home Systems (SHS) help in the facilitation of social gatherings and the ability to undertake activities during evenings that were not possible when using kerosene or benzine supported lighting.

It is shown for Asian-Pacific countries that access to electricity for cooking services could facilitate economic activity and provision of a range of essential services such as storage of food and vaccinations and access to information from the use of computers, televisions, radios, and mobile phones [70,71]. However, limited access to capital, mobility, and sociocultural restrictions often preclude a more prominent role for women in many modern renewable energy enterprises [72]. It is also proved that potential market and economic disruptions that might result from major shifts in energy policy require "redeployed, re-trained or compensated, and not left stranded" [64,67,73].

2.6. Current Situation in Ghana, Nigeria and Fiji

Several factors can either enable or hamper policy development for implementing clean energy technology in rural communities. In this section, the literature review was a more targeted review of the landscapes in Ghana, Nigeria and Fiji, which serve as the case study for the current work. The examined literature suggests that every region faces different challenges to the effective penetration of clean energy technology, especially in rural and remote communities. Still, fundamental challenges seem to be universal in the Global South context.

2.6.1. Ghana

Key challenges identified by the Ghanaian Energy Commission [74] in its Strategic National Energy Plan (2006–2020) included the overreliance on wood fuels (creating a risk of deforestation due to a projected increase in energy demands) and the lack of initiatives to exploit relatively abundant solar energy. The Ghanaian Ministry of Energy also published the Energy Sector Strategy and Development Plan in 2010 [75]. The Plan highlighted Ghana's development agenda and approached the challenge of increasing the supply of sustainable energy and building energy infrastructure as an integral part for its achievement. It set the target of achieving universal access to modern energy by 2020 while recognizing the major challenges of attracting the necessary investment, building local capacities, and implementing policy and regulatory reforms to ensure the sustainable development of the energy sector.

The Ghanaian government also published its Sustainable Energy For All Action Plan in 2012 [76]. In this document, the Government laid out the context within which Ghana prioritizes the acceleration of sustainable access to clean energy for households and productive uses. It recognizes the importance of effective and sustained access to energy in providing services to meet basic human needs, including heat, light, cooking and mechanical power. Moreover, the Ghana SE4ALL Country Action Plan [67], which recognizes the need for collaboration across government, civil society, the research community and the private sector, focuses on two main sources of clean energy/technology-LPG and Improved Cookstoves.

Notably, in 2010, 40.2% of households in Ghana used fuelwood as the main fuel for cooking, 33.7% used charcoal, and only 18.2% used LPG [76]. Ghana's National Energy Policy 2010 sets a target of achieving Universal Access to Electricity by 2020. It also set goals across various areas of the energy sector, including Renewable Energy and Energy and Gender. In addition, Ghana's Renewable Energy Masterplan (REM) [77] identified renewable energy as one of the options that could contribute to the overall energy supply mix and minimize adverse environmental effects. The Multiannual Energy Plan (MEP) set out 12-year targets to be implemented in three cycles (subject to review): the first (transition phase) running from 2019 to 2020, and the subsequent cycles running from 2021 to 2025 and 2026 and 2030, respectively [67,76,77]. The data from Ghana's Bureau of Statistics showed that households depend mainly on charcoal, wood and gas for cooking services, e.g., 34% and 33% of households use charcoal and fuelwood, respectively. For these fuels, traditional coal pots or three-stone fire stoves are used by 62% of households, whereas 12% use improved charcoal stoves and improved mud stoves. Additionally, 55% of urban and 85% of rural households use polluting fuels.

In Ghana, the 2010 National Energy Policy (NEP) and the 2010 Energy Sector Strategy and Development Plan (ESSDP) are the two documents that provide details on the country's specific goals and targets for cooking fuels and technologies [78]. According to the national energy policy 2010, the move towards clean cooking fuels and technologies, such as improved fuelwood stoves, are driven by the need to reduce deforestation and the negative health impacts of inferior cooking equipment [79]. With regard to LPG, the Energy Sector Strategy and Development Plan (ESSDP) planned to increase access from the current level of 6% of households to 50% by 2015 through the development of LPG infrastructure and pricing incentives to encourage distributors to expand their operations, especially to the rural and deprived areas [75]. However, as seen from the 2017 Ghana Living Standards Survey, this target was not reached, where only 25% of households used LPG.

2.6.2. Nigeria

Onuvae [80] reviewed the policy landscape around clean cooking in Nigeria and found that there is no standalone policy applicable to the subject. Rather, several official documents have policy guidelines that affect clean cooking. The Nigerian Economic Sustainability Plan (ESP) 2020 aims to mitigate the effects of a deep recession following the COVID-19 pandemic while addressing long-standing economic vulnerabilities as envisaged in the Economic Recovery and Growth Plan 2017–2020. Importantly, a cornerstone of the ESP is its focus on the gas (a transition fuel) sector to drive economic recovery and growth. It promotes domestic gas utilization by encouraging local manufacturing to support a transition towards LPG. More specifically, the ESP provided an "LPG Expansion Programme" built on the National Gas Policy of 2017 and was labelled as one of the "7 Big Wins" of the gas sector developed by the Ministry of Petroleum Resources and the Economic Recovery and Growth Plan.

Other relevant policy documents include (1) the National Energy Policy (2018), which focused on the efficient use of energy resources, and placed an emphasis on relying on efficient biomass cookstoves and other fuels and technologies for cooking, but failed to set clear targets or plans to achieve its aims; (2) the National Biofuel Policy (2007), which set a target for the Government to create an enabling environment for the achievement of 100% domestic production of biofuels consumed in Nigeria by 2020; (3) several policy documents aiming to encourage the use of renewable energy in cooking, including the Renewable Energy Master Plan (REMP) (2004 and 2012),which set targets for the use of renewables, especially clean biomass technologies for cooking, the national Sustainable Energy for All (SE4ALL) Action Agenda (2016), which pledges Nigeria's commitment to global sustainable development, the National Renewable Energy Action Plan (NREAP) (2016), the National Energy Efficiency Action Plan, etc. The NREAP aims to rely on providing improved cookstoves, efficient charcoal production and modern fuel alternatives for cooking, including LPG and ethanol gel fuel, to achieve its target of ensuring 100% clean-cooking-fuel coverage by 2030 without laying out concrete plans to achieve this.

Regarding the current cooking fuels and technologies used in Nigeria, according to the Bureau of Statistics, 51% of households use three-stone or open fire stoves, 14% use biomass stoves and 17% use kerosene. Clean fuels only make up 18% of the total households in Nigeria. Again, for Nigeria, there is a clear difference between urban and rural household cooking stove mix. For example, 36% of urban households use clean cooking fuel stoves such as LPG and electric, while the rest are kerosene, three-stone or open fire stoves and biomass stoves; whereas only 6% of rural households use LPG or electric stoves and 71% use open fire stoves and the rest kerosene and biomass stoves. Finally, it should be noted that the national electricity access in Nigeria is 149 kWh/person. About 65% of the total energy consumption is by the household, with cooking accounting for about 91% of the total domestic energy consumption [81], which amounts to about 88 kWh/person. In addition, access to clean cooking was very limited since, in 2016, just 4% of the total population had access to clean fuels for cooking [82].

2.6.3. Fiji

Fiji's policy landscape is supportive of using renewable energy and promoting energy efficiency measures in different sectors of Fiji. For instance, the 2006 national energy policy (NEP) of Fiji aimed to (i) strengthen the capacity for energy planning through appropriate policy, regulatory and implementation frameworks and effective and efficient management; (ii) enhance energy security through greater participation and collaboration within the industry; (iii) increase access to affordable and reliable electricity services; and (iv) research, promote and utilize renewable energy applications [83]. However, the policy landscape for cooking is not robust; about 50% of households use wood fuels. The 2006 NEP strategy recognized agricultural waste as feedstocks for biofuel production.

The 2013 draft NEP of Fiji has its targets aligned with the Sustainable Energy for All (SE4ALL) initiative of the United Nations. It targets (i) 100% of the population to have electricity access with zero use of fuelwood for cooking by 2030, (ii) improved energy efficiency by reducing the energy intensity to 0.077 Liters of fuel consumption per unit of GDP and reducing energy consumption to 0.209 kWh per unit of GDP by 2030, (iii) 100% electricity generation using renewable energy sources and 23% renewable energy share in total energy consumption by 2030 [82]. Ministries have used the draft 2013 NEP for planning their activities; however, the NEP is currently being reviewed. The NEP revision aims to focus on (i) renewable energy and grid power supply, (ii) energy efficiency, (iii) energy access and (iv) transport, with due recognition of clean cooking fuel and technology access.

Additionally, Fiji's Green Growth Framework (GGF) is a strategic planning document that provides plans for cooking fuels and technologies [84]. In its short-term action plan, the GGF plans to promote public education on energy-efficient technologies, especially in cooking. Fiji's Sustainable Energy for All (SE4All) [85] suggests exploring the use of biogas digesters for cooking, as Fiji's Department of Energy has already installed around 20 digestors. Moreover, Fiji's SE4All recommends the introduction of improved cookstoves in the medium-term timeline as no such programs currently exist. In addition, it further recommends the use of fossil fuels (LPG and kerosene) and electricity [85]. However, it should be noted that kerosene is a polluting fuel and should not be encouraged to be used.

Fiji's National Development Plan aims to provide electricity access to 100% of its population by 2021, generate 100% of electricity using renewable resources by 2036 and eliminate all wood consumption for cooking by 2036 [86]. More recently, Fiji's Low Emission Development Strategy is targeting net-zero emissions by 2050 and phases out open fire stoves and wood stoves by 2030, which will be replaced by LPG and electric stoves [87]. Furthermore, in terms of fiscal incentives and policies, Fiji has zero import duty on the import of renewable energy and energy efficiency equipment; it provides a 5-year tax holiday to investors who invest in clean energy projects. The current cooking fuels and technologies used in Fiji, as sought from the Bureau of Statistics, showed that in the past decade, cooking fuel usage in households has changed significantly. Compared to 2007 census data, in 2017, LPG usage had increased from 28% to 38% of households, while woodstoves and open fire stoves have reduced from 42% to 21%. In addition, more households are using electric stoves for cooking, with the share increasing from 4% in 2007 to 15% in 2017. From 2017 census data, 57% of the total households in Fiji use clean cooking fuels, while in 2007, it was just 38%. One of the reasons could be due to the reduction in LPG prices and improvement in the social status of households. Again, there is a disparity between rural and urban households' use of fuels for cooking. In 2017, 63% of rural households used open firewood stoves and kerosene stoves, whereas 28% of urban households used open firewood stoves and kerosene.

2.7. Business Model Review

The lack of energy and, most importantly, clean energy technology access in rural communities has been attributed to several factors spanning from policy and development to financing. However, the financing mechanism has been identified as a key challenge to the uptake of clean energy technologies in rural communities [88]. In a related study, Bensch et al. [89] reviewed the supply chain for clean energy access in Kenya and reported that inappropriate business models hinder clean energy penetration in rural communities. In the view of Glemarec [88], rural communities' uptake and sustainability of clean energy technology hinge on the business model's economic viability. Hence, developing an appropriate business model for clean energy uptake is as important as developing the technology.

Currently, there is no universally accepted business model for clean energy technology uptake. A literature review in this field shows pockets of contented business models

[88–92]. Therefore, this work attempts to offer alternative business solutions to promote clean energy access in rural communities. The existing business models can be grouped into three main headlines: incentive-driven [91,93], government-driven [91,92] and private-sector-driven [88–90]. The incentive-driven models are anchored on external interventions by NGOs, grants, subsidies, tax-wavers, and other free packages. The government-driven business model places the responsibility for the clean energy uptake on both the central government and the rural communities, which is the most used approach in rural communities in the Global South [92]. However, the sustainability of this model is a challenge because the communities often cannot maintain the technology due to the financial implications [88]. The private-sector-driven is more profit-oriented, which involves private energy entrepreneurs developing clean technology and using various methods to sell the technology to rural communities. Although this approach relieves the already financially constrained governments' budget, it is often expensive for the rural communities who live below the poverty line. In view of the foregoing, this study recommends a blended approach to the three existing business models. Therefore, for effectiveness and sustainability, in the context of rural community cooking space, this work proposes that the initial life of the clean cooking business should be government-driven and, thereafter, followed by incentive-driven at the mid-life of the business (say, 25% technology penetration) and private-sector-driven at the late-life (say, 45% technology penetration).

3. Validation

The answers from the questionnaires synthesized the findings from the literature and allowed for initial analysis and basic decoding for the development of policy pathways for mapping clean technologies with energy access in the Global South. The results validate the three key stakeholders, namely (i) End-users, (ii) Energy Suppliers and (iii) Interest Groups.

3.1. End-Users

The responses from Fiji, Ghana and Nigeria show that households rely on various fuels and cooking technologies for cooking, which support the narratives presented in the literature. The responses show that fuelwoods and open-fire are the dominant cooking fuels and cooking technology, respectively. However, there was evidence of the acceptance of liquefied petroleum gas (LPG) cookstoves, especially in urban settlements. Respondents also overwhelmingly (96%) indicated that they only rely on one cooking technology in a day, which they attributed to the availability of the technology.

Regarding the acceptance of new cooking technology, the respondents (87%) overwhelmingly show a willingness to accept clean cooking technologies that could support their socioeconomic development. Regarding the acceptability of clean cooking technologies, respondents are willing to use biogas, LPG and electric cookstoves once they are available and affordable. Other motives inferred from respondents to support the acceptability of the clean technologies were their ease of use/reliability, environmental friendliness and they were less hazardous.

Most respondents were positive about shifting away from fuelwood because of some perceived advantages by the respondents, e.g., saving time from fuelwood collection and freeing up more time for other chores and studies. However, few respondents (less than 15%) believed that clean cookstoves could lead to increasing costs for cooking and undesirable cooking outcomes. In addition, the respondents gave insights into the benefits of the time gained from using alternative fuels for women and children in their community; 38% of the respondents thought a shift would free-up time for education, 27% thought it would support women empowerment, and 23% saw a value in increased social and community activities. In comparison, only 10% thought the time gained would be used for recreational activities (Figure 4).

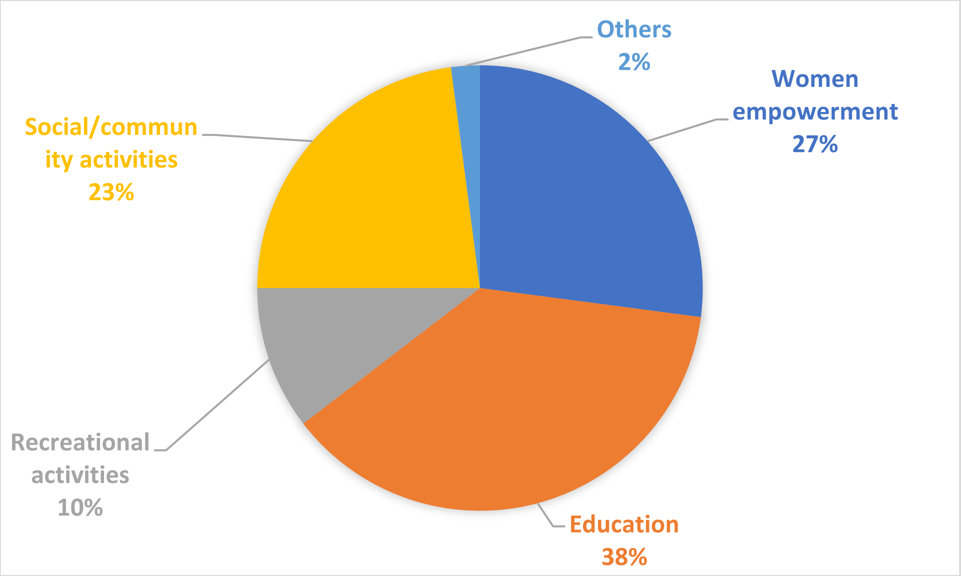

Figure 4. How the time gained from using alternative fuels could benefit women and children in the community.

Furthermore, the respondents gave insights about perceived major barriers to shifting towards cleaner energy access for cooking in their communities; 56.5% of the responses indicated maintenance costs as the main barrier, followed by set-up costs (17.5%) and refuelling costs and the underdevelopment or inadequacy of current energy markets (13% each) (see Figure 5).

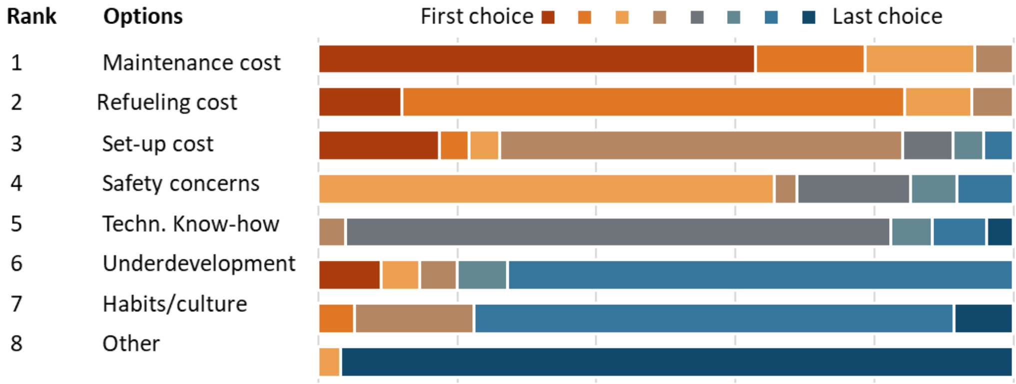

Figure 5. Main barriers for shifting towards cleaner energy access for cooking.

3.2. Energy Suppliers

The respondents quasi-unanimously thought that a shift towards clean energy access for cooking in rural communities in their respective countries is of utmost importance; about 78% of the respondents indicated the “highest” level of importance, whereas 22% indicated “very high” levels of importance. In terms of which technologies/fuels could be more readily implemented to supply cooking energy for rural communities, the improved cookstoves and solar/electricity power generation were perceived by 35% of the respondents as most readily available, whereas 23.5% of the respondents opted for biogas, and nearly 6% for LPG (see Figure 6). On a more granular level, the responses revealed a clear lack of homogeneity in what suppliers perceived as solutions that could soon be relied upon to afford clean energy access for cooking in rural communities. This is reflective of a lack of prioritization and certainty due to the inexistence and/or inadequacy of current policies in the examined countries and a reliance instead on open/unregulated markets for energy/technology production, which affirmed the position of the existing literature

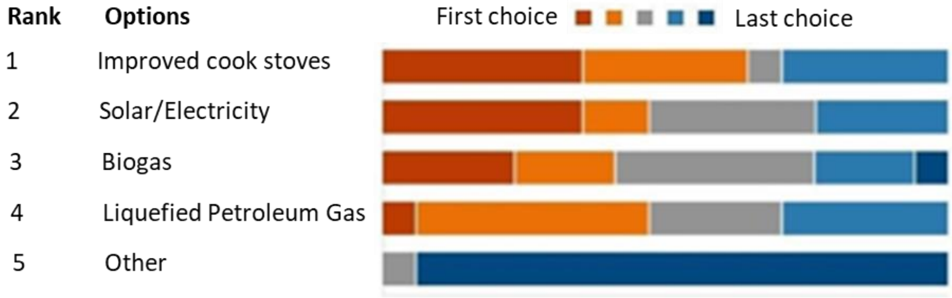

Figure 6. Technologies/fuels that can be more readily implemented to supply cooking energy for rural communities.

In terms of the key cost factors of shifting towards cleaner technologies/fuels for cooking in rural communities, the respondents' first choices were split as follows production costs (39%); transport/distribution costs (17%); other costs, including capacity building and purchasing power/financing (17%); importation costs (11%); safety measures (11%) and marketing (5.5%). Examined individually, a lack of consistency similar to the one concerning the most readily available technologies/fuels is noted in the responses provided regarding each of the cost factors, as reflected in Figure 7.

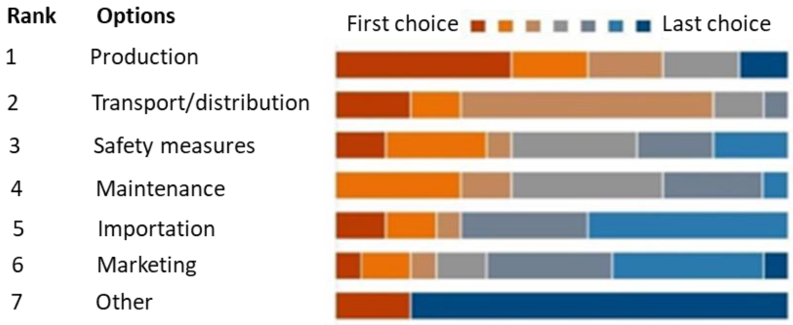

Figure 7. Key cost factors of shifting towards cleaner technologies/fuels for cooking in rural communities.

The energy supplies perceived benefits in the shift towards cleaner fuels/technologies for cooking in rural communities as 47% indicated improved health and conditions in rural communities, 47% indicated reduced costs for end users, and 6% indicated meeting energy and environmental policy targets (Figure 8).

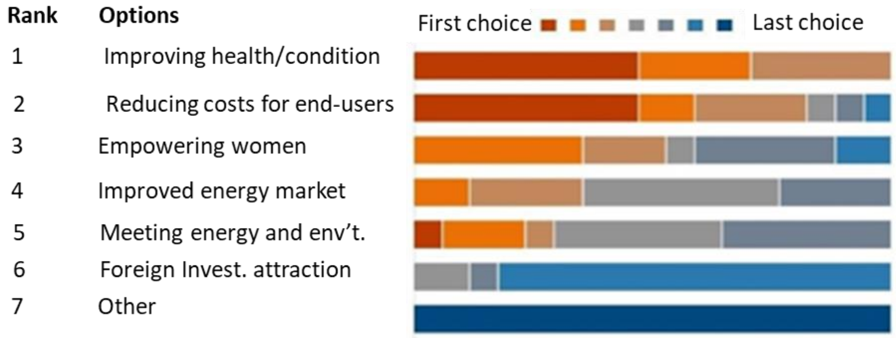

Figure 8. Most important potential benefits of shifting towards cleaner fuels/technologies for cooking in rural communities.

Focusing on technologies for clean cooking, the suppliers also rated the readiness levels for their employment in rural communities, using a 1–5 rating system where 1 is the lowest and 5 is the highest level of readiness: 16.7% provided a rating of 5, 22.2% a rating of 4, 22.2% a rating of 3, 33.3% a rating of 2, and 5.6% a rating of 1. In addition, the respondents gave insight into the interconnection between adopting cleaner energy technologies for cooking in rural communities: 61% affirmed that existing policies are important in transitioning to cleaner energy cooking (see Figure 9). In addition, respondents gave insight about the sources of the cooking systems used: 61% indicated the systems were imported, 16.7% indicated locally manufactured, and 22.2% indicated a combination of imported and locally manufactured systems. Furthermore, respondents perceived end-users purchasing capacity, health and safety, sustainability and longevity, and local capacity as concerns in taking an investment decision.

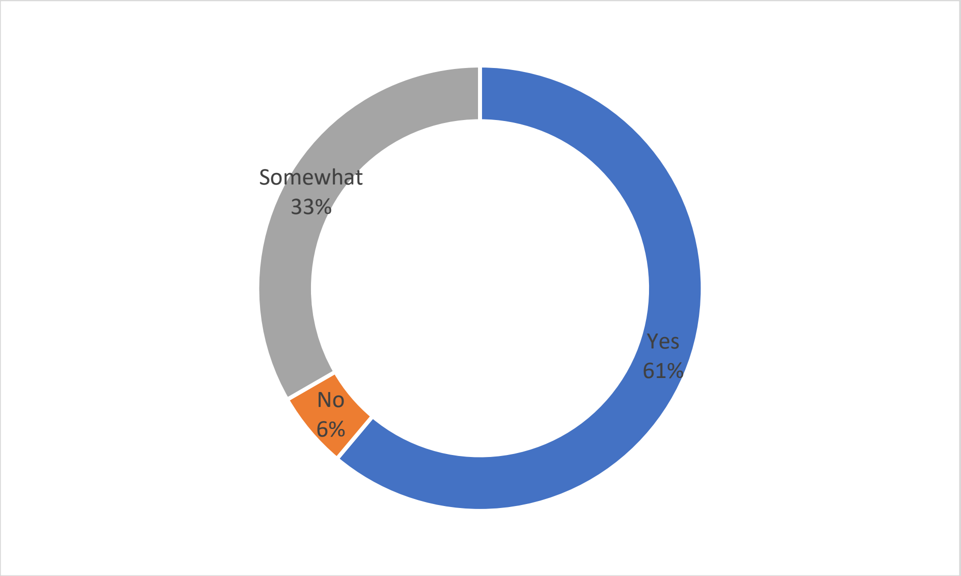

Figure 9. Interconnection of policy and cleaner energy technologies for cooking in rural communities.

3.3. Interest Groups

The interest groups identified some key barriers to shifting from dirty cooking services to clean cooking services: 33% of the respondents thought end-user behaviours/response to new fuels/technologies constitutes the biggest hurdle, followed by 25% that it is instead due to lack of investment, and 25% considering that it is due to the unavailability of technologies/energy sources. Only 8.3% of the respondents thought the inadequacy of existing policy frameworks was the main barrier to such transition (Figure 10).

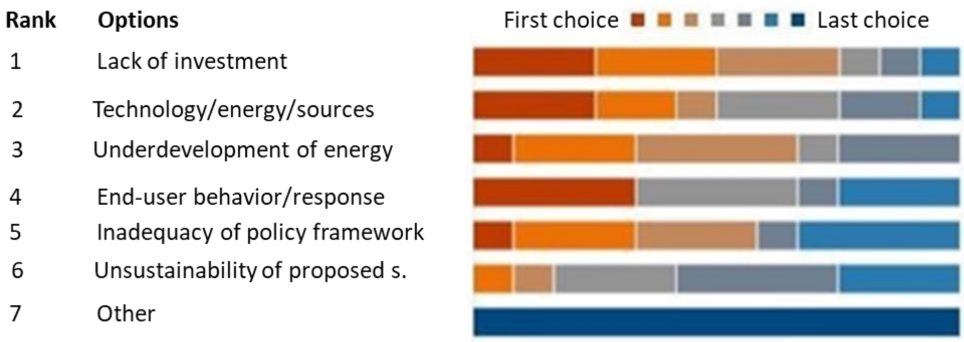

Figure 10. Main barriers impeding a shift towards cleaner energy access for cooking in rural communities.

The responses by the interest groups suggest that there have been some initiatives to support the transition to clean cooking through education of rural dwellers on available clean cooking technology, e.g., biogas and electric cooking, and international collaborative projects to reduce carbon emissions. Unsurprisingly, the success rate of the initiatives by the respondents was 55%, which was attributed to a lack of coherent policy targeting the clean cooking transition, lack of funding, lack of awareness of the effects of current/alternative cooking practices, setting up/maintenance costs, lack of education/knowledge from end-users in terms of employing new technologies, and the necessity to import materials. However, insight was also made regarding the key drivers for the success of the clean cooking initiative, which include foreign or local investment, political affiliations, the scarcity of current fuels (firewood), projects being led by international organizations (NGOs), and the availability of local materials/technologies. In addition, the respondents opined that local capacity building, training, and partnerships in the clean cooking project were necessary to drive the clean cooking space. Furthermore, the responses indicate that the awareness of the health and social impacts of current cooking practices in the countries examined was low, with an average rating of 45% awareness. Surprisingly, the level around the benefits of shifting towards cleaner fuels for cooking was above average—55% awareness level—with Fiji having 60% awareness. Specifically, improved health in rural communities was ranked as the perceived main benefit of implementing a shift towards cleaner energy access to meet clean cooking demands (see Figure 11).

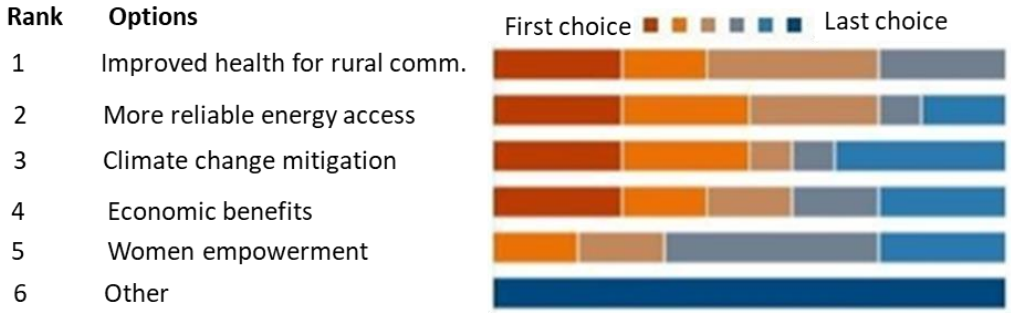

Figure 11. Main benefits of implementing this shift towards cleaner energy access.

4. Clean Cooking Policy Pathways

It is shown that a lot of people rely on the environmental and health degrading traditional use of biomass for cooking, with 20%, 70% and 73% of the share of the population of Fiji, Ghana and Nigeria, respectively, relying on fuelwood for cooking. However, it could be inferred from the literature, and corroborated by responses from questionnaires, that appropriate and coherent policy was a culprit in holding clean cooking to ransom. It, therefore, shows the imperative for developing policy pathways to drive an accelerated transition to clean/cleaner cooking in rural areas through tackling key barriers that are frequently highlighted by the literature (and validated by the qualitative data) on the subject and benefiting from existing strengths in the three countries examined. The challenges identified in the study could be broadly summarised into four:

(i) The supply chain of cleaner fuels to rural areas;
(ii) Affordability of cooking fuels and technologies in rural areas;
(iii) Lack of awareness of clean cooking technologies and its benefits;
(iv) Lack of gender mainstreaming in energy access.

To address the challenges, the policy pathways are proposed to present individual governments and partnering international development organizations with broad options to effectively drive the clean energy cooking space in respective countries in the Global

South. This is done with an awareness of the concurrent imperatives of improved economic empowerment and general wellbeing of rural communities, especially women and children:

(a) Integrating gender considerations into clean cooking policies and initiatives—Governments should recognize women's important role in clean cooking fuel and technologies uptake by rural communities. Policies must put women at the centre of clean cooking technologies uptake and strategize ways to increase participation in clean cooking initiatives, especially in leadership and technical roles.

(b) Prioritizing clean cooking fuels and technologies in National Policies, Strategies and Action Plans. Governments must explicitly state their position on clean fuels and technology access and ensure that this position is consistently supported in cross-cutting sectoral policies (e.g., growth, investment, education, etc.). A clear direction in national energy policy documents and related plans will provide certainty for suppliers and end-users and promote activities, programs, and projects undertaken by local governments, departments, and ministries.

(c) Increasing and designing new financing options and risk-reducing mechanisms for suppliers of clean fuels or technologies. Governments, financial institutions, and the private sector need to collaborate to discuss strategies to support the private sector in reaching remote rural communities. For applicability, governments must investigate financing options such as concessional loans, subsidies, tax holidays, and others.

(d) Establish a public body or governmental agency to regulate, provide guidance, and support with tapping into existing international funds for clean energy projects in rural communities in the Global South and ensuring their adequate employment through defined monitoring and auditing practices.

(e) Mobilize funding for clean cooking fuels and technologies for (i) uptake by end-users, (ii) research and development to reduce the costs of clean cooking technologies, (iii) programs and projects to be delivered by public bodies and institutions. This will make fuel and technologies for cooking affordable to end-users.

(f) Allocate resources to civil society organizations (CSOs), faith-based organizations (FBOs), community-based organizations (CBOs), and small-scale providers of clean fuel or technology. Governments or local governments should collaborate with CSOs, CBOs and FBOs to encourage clean cooking initiatives. These organizations can promote improved biomass cookstoves, provide training, support the storage of cookstoves, and raise public awareness of the risks posed by current cooking practices and the benefits of a transition towards cleaner fuels/technologies. As part of their training programs, communities should be encouraged to replant trees and woodlots to ensure sustainable use of resources.

(g) Governments should financially incentivize energy suppliers to supply clean energy to rural and remote communities—this can be done through tax rebates and government subsidies, and other financial mechanisms.

(h) Collect information and data on clean cooking demand in rural communities. Government departments can collaborate with academic institutions and Bureaus of Statistics to collect household fuel and energy demand, income levels, and other relevant data that can inform more targeted enabling policy for clean cooking fuel and technology access in rural communities.

(i) Design and implement a well-intended and well-designed educational intervention programme aimed at postgraduate studies targeting clean energy access for cooking services in rural and semi-rural communities to promote aggressive adoption.

(j) National energy policies should address lopsided subsidy intervention and competing demand for unproductive and environment-degrading uses of agro-residues and wastes. In this effort, Governments should, for example, ensure consistency in supporting biomass to biogas cookstove intervention and programmes.

(k) Governments should elaborate and adopt policies that empower government agencies and public bodies to develop quality assurance and quality control programmes to ensure the compliance of all components of clean energy systems with internationally acclaimed standards to boost their durability and preserve their functionality.

In order to have a clearer approach, the above policy pathways are summarized in Table 1.

Table 1. Summarization of the key points of each proposed policy pathway.

Policy Pathways		
Type	**Policy No.**	**Key Points**
Gender	A	Integration of gender considerations into clean cooking policies—recognition of women's important role in clean cooking fuel and technologies uptake by rural communities.
Fuels	B	Prioritization of clean cooking fuels and technologies in National Policies, Strategies and Action Plans.
Financing	C	Increase and design of new financing options and risk-reducing mechanisms for suppliers of clean fuels or technologies.
	E	Mobilization of funding for clean cooking fuels and technologies.
	G	Financial incentivization of energy suppliers to supply clean energy to rural and remote communities.
Regulation	D	Creation of a public body to regulate, provide guidance, and support with tapping into existing international funds for clean energy projects.
	F	Allocation of resources to CSOs, FBOs, CBOs and small-scale providers of clean fuel or technology.
	J	Addressing of lopsided subsidy intervention and competing demand for unproductive and environment-degrading uses of agro-residues and wastes.
Information	H	Collection of information and data on clean cooking demand in rural communities.
Education	I	Design and implementation of an educational intervention programme aimed at postgraduate studies targeting clean energy access for cooking services in rural and semi-rural communities.
Quality Assurance	K	Elaboration and adoption of policies that empower the development of quality assurance and quality control programmes.

5. Conclusions

While some of the cooking practices are known to induce climate change, the consequence of climate change has been shown to have a substantial impact on the livelihood of the rural communities, e.g., flooding and desertification have increased the hours the women/girls used to collect fuel wood (firewood). Therefore, this study presents the mapping of policies with clean technologies for the cooking space of rural communities in the Global South for sustainable development. The study presents the barriers, opportunities and drivers associated with clean cooking space in the rural communities in the Global South as derived from literature and validated qualitative data. The connection between clean energy and cooking services was identified with possible health impacts. The policy issues related to drivers, barriers and opportunities are presented in the general context of rural communities in the Global South. The distribution of cooking technologies established from a literature review was presented and validated by engaging with stakeholders associated with the cooking space in Fiji, Ghana and Nigeria.

The study shows huge potential for clean cooking technologies in rural communities. However, conscious intervention to link end-users and clean cooking technologies lies in the policy and business domains. To this end, an attempt was made to present broad base policy pathways for adopting clean cooking services in the rural community for sustainable development. The policy pathways harmonize the major stakeholders in the cooking space: the Government, Non-Governmental Organizations (NGOs), clean energy developers, business services and end-user. In addition, a business model in the context of rural community cooking space is proposed: the initial life of the clean cooking business should be government-driven and, thereafter, followed by incentive-driven at mid-life of the business (say 25% technology penetration) and private-sector-driven at the late-life (say 45% technology penetration). It is expected that the effort made in this work could be advanced by investigating the detailed techno-economic parameters of clean cooking technologies that could be influenced by the policy pathways established in connection with the sociocultural factors associated with energy services.

The study was constrained by data availability. The choice of Fiji, Ghana and Nigeria was inevitable because of access to data. Though the sampled countries used for the validation study might be judged limited, it could be considered the first approximate solution in the space of the Global South. Future studies should extend the sample size to cover greater parts of the Global South.

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Nomenclature

SDG	Sustainable Development Goal
LPG	Liquefied Petroleum Gas
IEA	International Energy Agency
LCR	Local Content Requirements
HRES	Hybrid Renewable Energy Systems
NHRE	Non-Hydro Renewable Energy
LCOE	Levelized Cost of Energy
WHO	World Health Organisation
CO	Carbon Monoxide
ESCAP	United Nations' Economic and Social Commission for Asia and the Pacific

RCT	Randomized Control Trial
REM	Renewable Energy Masterplan
NEP	National Energy Policy
ESSDP	Energy Sector Strategy and Development Plan
REMP	Renewable Energy Master Plan
NREAP	National Renewable Energy Action Plan
GGF	Green Growth Framework
NGO	Non-Governmental Organization
SHS	Solar Home System
SE4ALL	Sustainable Energy for All
CSO	Civil Society Organisation
FBO	Faith-Based Organization
CBO	Community-Based Organization

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