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REVIEW

Domestic energy consumption, theories, and policies: a systematic review

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Abstract
This article examines the evolution of residential energy usage over time. This objective was accomplished by conducting a systematic review of 75 studies spanning three decades. First, the theoretical foundation of household energy consumption models, household sources, energy measurement tools, and energy policies across three continents was examined. The results demonstrated that both top-down and bottom-up strategies have significant utility in estimating residential energy consumption, but the combination of the two approaches plays a crucial role. The article also revealed that the Niche-breath tool for analysing fuelwood consumption is a novel instrument whose use has yet to be fully explored. Additionally, various energy policies enacted across three continents: Europe, Asia, and Africa, were examined. The research revealed that household energy consumption policies in the UK, China, Thailand, and Ghana have, to some extent, been implemented, in contrast to Nigeria and Cameroon, which have yet to realize a significant aspect of their renewable energy potentials due to poor implementation of their respective strategies. Furthermore, Cameroon lacks a proper up-to-date renewable energy policy document as of the time of this study. It is evident that energy transformation and climate change are global issues, underscoring the critical importance of increasing research activities and policy efforts in developing nations. The study concludes by recommending that evolving and innovative studies on social treatments, energy management, and energy poverty, as well as those concerning climate and energy ingestion, may represent the frontier of research.

Keywords Renewable energy · Energy consumption · Modelling approaches · Household sector · Household energy tools

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1 Introduction

The critical role energy plays in enhancing production, competitiveness and income cannot be overemphasis, and this is seen through its solid wall backing to creative activities and the creation of industrial investment environment, agriculture and commerce (Adamu et al., 2020). Certain poverty-level threshold can be effectively crossed when modern forms of energy are easily accessed. Invariably, this access brings about the economic growth promotion, creation of employment opportunities, increased communal facilities, and anthropological expansion (Balsalobre-Lorente et al., 2023).

Domestic energy consumption is a central component of the global energy landscape, impacting both individual households and the broader socio-environmental context. The way in which energy is utilized within homes has significant implications for energy efficiency, sustainability, and overall quality of life (Cardoso et al., 2017).

Domestic energy consumption encompasses the energy used within households for various purposes, including heating, cooling, lighting, cooking, and powering appliances. It represents a complex interplay of factors, influenced by household demographics, geographic location, cultural practices, technological advancements, and energy policies. The need to scrutinize and understand this multifaceted phenomenon is underscored by its profound implications for energy security, climate change mitigation, and resource management (Ghilardi et al., 2016; United Nations Framework Convention on Climate Change (UNFCCC) 2015; Usman & Nichol, 2018; Yiran et al., 2020).

Wang et al. (2023), Bonjour et al. (2013), Shah et al. (2023a), Anenberg et al. (2012), Al-Sulaiti et al. (2022), Boateng et al. (2021) noted that the residential sector worldwide typically relies on consuming fuels, biomass (e.g. wood, charcoal), which negatively impacts their climate, health, and livelihoods. Individual households are at a greater risk of exposure to health-threatening levels of fine particulate matter (PM2.5) due to the usage of infesting fuels (Hussain et al., 2021), making them susceptible to numerous infectious and quasi-respiratory and cardiovascular disorders (Yu, 2020). The Global Burden of Disease (GBD) study linked 3.6 million yearly deaths to household air pollution (HAP) in 2019. Murray et al. noted that when polluting fuels are burned, long-lived (e.g. CO2) and short-lived (e.g. black carbon) climate-altering pollutants are emitted (Anenberg et al., 2012). Black carbons consist primarily of dark particulate matter with strong visible light absorption characteristics (Kypridemos et al., 2020). It is estimated that household biomass fuel combustion contributes between one-third and one-half of all global anthropogenic black carbon emissions (Bruce et al., 2015). Unsustainable harvesting of wood for cooking and charcoal manufacturing can contribute to deforestation, a rise in atmospheric CO2, and the loss of biodiversity (Kypridemos et al., 2020).

While there exists a substantial body of literature on domestic energy consumption, a noticeable gap persists (Ghilardi et al., 2016; United Nations Framework Convention on Climate Change (UNFCCC) 2015; Yiran et al., 2020; Wang et al., 2023; Bonjour et al., 2013; Shah et al., 2023a). The existing research often focuses on specific aspects or regions, resulting in a fragmented understanding of the broader landscape. This fragmentation limits the development of holistic solutions and comprehensive policy frameworks to address domestic energy consumption challenges. Moreover, the dynamics of energy use within households are evolving rapidly, driven by technological innovations, changing lifestyles, and global energy transition efforts. Consequently, there is a pressing need for an updated, integrated, and comprehensive review that synthesizes the diverse insights scattered throughout the literature.

In the past, researchers have predominantly emphasized the impact of household energy consumption on health and the environment. Only an hand full limited number of earlier research have delved into the exploration of domestic energy consumption with the aim of comprehending its theories, various sources, consumption modelling techniques, tools for analysing household fuel consumption, and policies (Balsalobre-Lorente et al., 2023; Cardoso et al., 2017; Ghilardi et al., 2016; Shah et al., 2023a; Anenberg et al., 2012; Hussain et al., 2021). As such, this research gives a thorough review of household domestic energy use.

For the purpose of this review this paper adapts an all-encompassing delineation of domestic energy. Domestic energy is the energy used at home, for cooking (i.e. in form of Liquified Petroleum Gas, biomass, and kerosene), heating and to power devices and appliances (i.e. electricity from either hydro, solar, or wind) (Sulaiman et al., 2017).

This essay reveals the result of the complex factors that pilot household energy consumption, so as to identify the gap in literature, for critical research.

1.1 Theoretical contribution

In this review paper, the primary focus revolves around the critical analysis of existing theories, modelling techniques, and analytical tools pertaining to domestic energy consumption. The central aim is to evaluate their efficiency and applicability in the context of real-world data and scenarios.

Furthermore, this paper conducts a comprehensive examination of diverse sources of energy within domestic settings, considering the complexities of utilization. By scrutinizing these sources, the paper contributes to a more holistic understanding of the multifaceted nature of domestic energy consumption.

One noteworthy aspect of this review paper is the in-depth analysis of energy consumption policies across three distinct continents. This comparative examination not only provides valuable insights into the variations and commonalities in energy policy approaches but also contributes to the theoretical discourse on the effectiveness of these policies in shaping domestic energy consumption behaviours.

In essence, this review paper plays a crucial role in the academic landscape by critically assessing and synthesizing existing theories, modelling techniques, and analytical tools relevant to domestic energy consumption. Additionally, its exploration of various energy sources and its comparative analysis of energy policies across continents contribute significantly to the existing theoretical frameworks in the field of domestic energy consumption.

1.2 Structure of the review paper

This is divided into five sections. The paper begins by introducing the review and the theoretical contributions of the paper. Section two outlines the aim of the review, while section three presents the Data and Methodology. Section four provides the results and discusses them. Finally, the paper concludes with section five, which addresses the conclusion aspect.

2 The review

2.1 Aim

The primary objective of this review is to explore household domestic energy sources and consumption among urban poor. The secondary objective is to identify the characteristics of energy consumption in poor urban households, whether the improvement of the energy consumption pattern could help reduce energy lost and environmental degradation.

3 Data and methodology

According to Kitchenham and Charter (2007), systematic literature reviews are a common operational strategy for reviewing pragmatic evidence that spans a wide range of fields and typically combines results of the investigations (qualitative and quantitative). This method of review is typically employed to determine whether or not approaches have been effective in addressing a particular communal issue (Li et al., 2022; Shah et al., 2023a).

This systematic literature assessment follows (Sorrell et al., 2020) recommended stages for enhancing the evidence base for energy policy. This systematic literature assessment commence with a glaring design of study interrogations to be tackled, followed by in-depth examination of accessible body of research. Following the application of unambiguous standards for annexation or segregation of studies, the quality of the annexed studies is evaluated by adopting crystal-clear and standardized techniques, in which the output is abridged and merged in an unbiased order prior to their publication to suitable audience (Li et al., 2022). For this systematic review, each study's evidence of efficacy was evaluated based on the quantitative and/or qualitative outcome measures data reported in that study.

3.1 Research queries

The resolve of this study is to present an appraisal of environmental impacts of household domestic fuel consumption. The study aims to help ascertain how household domestic energy consumption can help shape forthcoming energy policies. To clearly reach the resolves and goal of this systematic review following the recommendations of Sorrell et al. (2020) the research questions were drawn as follows:

RQ1: What domestic energy consumption causes significant environmental sustainability and degradation?
RQ2: Which theories, models and conceptual frameworks are used to inform household domestic energy consumption?
RQ3: What is the predominant household domestic energy consumption type?
RQ4: Which techniques and activities are used to measure household domestic energy consumption?
RQ5: What are the dominant household energy policies across five countries in three continents?

3.2 Search parameters

Relevant literatures were searched for on three major databases (i.e. ScienceDirect, Web of science, and Scopus). These databases contain varieties of published research ranging from the field of social sciences, business, and built environment, with more than hundred million archives. Primary search parameters encompass publicized documents (in English only formats) prior to December 2021 and after 1990.

Specific search terms were searched across selected (three) catalogues, ensuring a comprehensive analysis of works in the systematic review. Likewise, wildcards and synonyms search terms were used. For instance, "energy OR LPG Or electricity" AND "consumption OR depletion OR reduction". Reports and unpublished studies were searched for grey literature. Also, advanced Google search function was used for parameters search. Duplicate results were removed and the most relevant papers were identified.

3.2.1 Inclusion and exclusion criteria

This review's search strategies guaranteed that only the most relevant literatures were acquired, and the review's inclusion and exclusion criteria weeded out any extraneous material (see Table 1). Households, rather than businesses, offices, or dorm rooms; English-only papers; works published before December 2022 but after 1990; publications focused on empirical work, rather than laboratory experiments, constitute the core group of study focus.

3.3 Study quality

The risk of bias in the Cohort Studies was evaluated using the Cochrane Risk of Bias assessment technique (Cochrane RoB) (Stern, 2019), where the risk of bias was rated from "low" to "high" for each area of study. In addition, the author provided an overall rating for each study based on their evaluation of the available data.

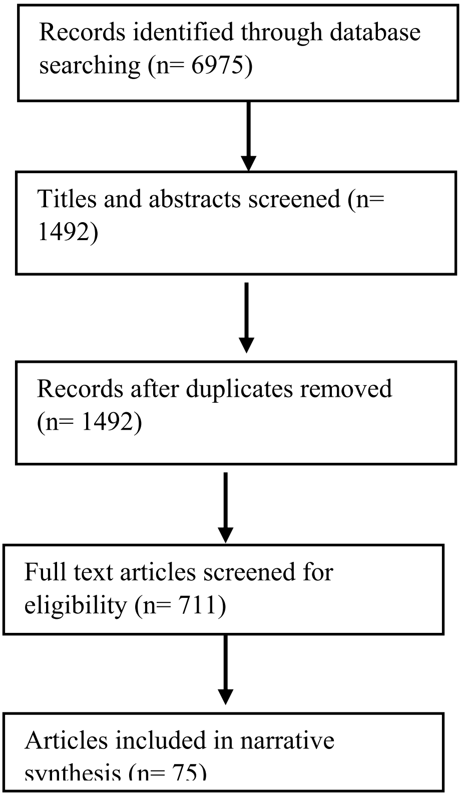
In this way, the strategy of data extraction and critical evaluation in the work was methodically formed by the screening of the source literature (Hafeez et al., 2023; Iorember et al., 2022). To get the largest possible sample of papers, the paper welcomed research using any methodology (Spencer et al., 2003), and the final search string yielded 6975 abstracts (Web of Science). In total, 6975 abstracts were submitted, 75 of which met the criteria for further review (see Fig. 1).

Articles were found by abstract screening, and pertinent data were extracted using a standardized form. Full articles were examined as part of this procedure to verify their

Table 1 Inclusion and exclusion variable

Emphasis	Inclusion	Exclusion
Consumer cluster	Households and homes	Spaces for business, work, and living
Language	English	Prior to 1990, speakers of languages other than English (LOTE)
Time Frame	3 Decades	Journal Articles, Editorials, Conceptual Reviews,
Paper types	Journal articles	Formative and Statistically Sound Laboratory Experiments
Method types	Empirical	Spaces for business, work, and living

Fig. 1 PRISMA flowchart



applicability to the study question as a whole. Mixed Methods Appraisal Tools were also used to evaluate each (Pluye et al., 2018). To begin with, this instrument was created to combine qualitative, quantitative, and mixed-methods research, making it appropriate for this evaluation. After the data extraction process was complete, the quality of each article was assessed. As a result, the following three conditions were satisfied by every article: first, deciding on a specific research question to investigate, second, collecting evidence that is relevant to that question, and third, deducing a reasonable conclusion from that investigation (Hafeez et al., 2023; Shah et al., 2023a). After verifying that 75 articles met the requirements, this evaluation was completed (see Fig. 1). Additionally, descriptive statistics were used to examine these papers.

4 Results and discussion

4.1 Introduction to findings

This systematic review recognized 4 germane domestic energy sources for annexation across 75 papers. Three of these sources had 15 published papers that explored diverse study queries (Al-Bajjali & Shamayleh, 2018; Hammeed et al., 2016; Heltberg, 2005; Jones & Lomas, 2016). These energy sources were diverse in their influence on outcomes, theories or models, and also significantly different across geographic location. In the succeeding subdivisions the paper presents the outcomes of the systematic analysis, responding to the four identified study enquiries.

4.2 Journals and field statistics

Seventy-five papers reviewed systematically, with just 46 (i.e. 61%) appearing in just six academic journals (Table 2). Table 2 reveals that the three leading journals in the field of energy research are Energy, Energy Policy, and Journal of Cleaner Production, accounting for more than half of the total studies. Not only has that, but the number of publications in the last four years nearly caught up to the total for the previous decade. Evidence suggests that research into residential energy use has flourished in recent years, making it a promising subject for academics to study.

4.3 Household energy theories

Of 75 papers reviewed, five papers revealed that the stronghold of any meaningful research is theories, without which the success of such work is marred. These five papers also revealed three relevant theories: Energy Ladder Theory, Energy Stacking Theory, and Energy Leap Frogging Theory (Arnold et al., 2006; Hiemstra-Van der Horst & Hovorka, 2008; Murphy, 2001). Energy Ladder theory is based on the view that as household income increases, there tend switch to energy sources that are more efficient than the previous. Energy Stacking theory on the other hand explains that households those not completely switch energy source with respect to income, but there tend to use different energy sources complimentarily. For examples, household that uses Electricity for cooking tends use Liquified Petroleum Gas (LPG), interchangeably as purchasing power increases. This is evidence in most Nigerian households.

4.3.1 Energy ladder

The actions of Utility maximizing neoclassical consumer are mirrored by households, according to Energy Ladder Model. And by implication, households tend to move to stylish energy carriers as income increases (Hosier & Kipondya, 1993). Central to this transition

Table 2 Top 5 most productive journals

Source	Publication period			
	2015–2019	2020–2022	Total	Relative frequency (%)
Energy policy	5	7	12	16
Energy	4	8	12	16
Energy economics	3	5	8	10.6
Journal of cleaner production	4	6	10	13.3
Journal of renewable and sustainable energy	1	3	4	5.3
Total	17	29	46	61.2

(i.e. energy ladder model), in energy consumption is fuel switching, referred to as transposition of one fuel by another. As a move up the energy ladder occurs, simultaneously fuel used experiences a move outwardly (Heltberg, 2005). The physical characteristics; ease of use, cleanliness, speed of cooking, and efficiency of usage are the criteria for which energy ladder fuel are been ordered based on household preference (Hiemstra-Van der Horst & Hovorka, 2008). A linear movement with three distinct phases is used to describe the system of ascending the energy ladder. Energy ladder is of the assumption that when socioeconomic status of families changes progressively, they tend to abandon more polluting, less efficient, and less costly fuel choices for better ones. In the third and fourth phase of the ladder, households' fuel switches to LPG and electricity (Heltberg, 2005).

The efficiency and cost of highly placed fuels are noteworthy, as such there require lesser labour and produces lesser pollutant per units of fuel consumed (Shah et al., 2023b). At a cross-country-level comparison, the correlation that exists between economic growth and modern fuel uptake is positive. This suggests that as industrial progress of a country occurs, its dependence level on electricity and petroleum increase with a compensate reduction in the demand for biomass (Hosier & Kipondya, 1993). Furthermore, a micro-level comparison reveals that a strong relation between income and fuel choice exists too (Abbas et al., 2022; Gupta & Köhlin, 2006; Pluye & Hong, 2014). Conversely, energy ladder hardly assumes that there exists such a strong relationship between income level and fuel choices.

Projected dynamics of demand based on income for fuel wood are either grossly insignificant, low, or positive (Cooke et al., 2008). Numerous studies have shown the significant of fuel wood as an energy source in households that are in both rural and urban, with varying income levels (Brouwer & Falcão, 2004; Hiemstra-Van der Horst & Hovorka, 2008; Mirza & Kemp, 2009). A typical example is Botswana, where fuelwood is the most preferred energy source, that transverses the entire income spectrum, despite commercially available alternate energies. On the other hand, there exist other poor houses that uses contemporary fuels (e.g. electricity and LPG) (Brouwer & Falcão, 2004; Zhuang et al., 2022). However, both of these studies were conducted in urban and rural areas. Little to no studies have focused on energy consumption of people stuck between these two spectra (i.e. the urban poor).

They are always a mismatch of energy pattern between the rich and the poor, which is based on the huge per capital differences between the income (i.e. low and high) households (Elias & Victor, 2005), suggesting that the notion of attribution of fuel wood as identity of the poor is not entirely true, as various other factors play important roles (Hiemstra-Van der Horst & Hovorka, 2008).

Evidence from empirical studies shows that income is indeed a significant factor influencing fuel choice (Abbas et al., 2022; Arnold et al., 2006; Brouwer & Falcão, 2004; Brouwer & Falcão, 2004; Cooke et al., 2008; Gupta & Köhlin, 2006; Hiemstra-Van der Horst & Hovorka, 2008; Hosier & Kipondya, 1993; Mirza & Kemp, 2009; Murphy, 2001; Pluye & Hong, 2014; Shah et al., 2023b; Zhuang et al., 2022). However, it is important to note that the association among salary and fuel choice is not always straightforward. For instance, some studies found that higher income does not always result in a shift to cleaner energy sources, suggesting that other factors, such as infrastructure, access to technology, and cultural preferences, also play a role in fuel choice (Brouwer & Falcão, 2004; Mirza & Kemp, 2009).

While the energy ladder theory provides a useful framework for understanding fuel choice dynamics, it is important to approach its application with caution. The theory may oversimplify the complex dynamics involved in fuel choice decisions, and multiple factors beyond income need to be considered when designing policies and interventions to promote the adoption of cleaner and more sustainable energy sources (Brouwer & Falcão, 2004).

4.3.2 Energy stacking

Energy transition is devoured of sequentially simplified and disjointed steps, but rather consists of multiple fuel use (Arnold et al., 2006; Brouwer & Falcão, 2004; Davis, 1998; Heltberg, 2005; Leach, 1992; Martins, 2005; Nascimento et al., 2015). Adaptation of new fuels and technologies by households serves as alternate, rather than a complete replacement, is dependent on growing income (Elias & Victor, 2005). Furthermore, the unidirectional notion of fuel switching is erroneous, as it has been uncovered that households switch forth and back (i.e. modern to traditional), and vise vastly as the need arises (Arnold et al., 2006; Masera et al., 2000). Research conducted by Wickramasinghe (2011) found that in Sri Lanka, semi-urban household areas that had adapted LPG reverted back to traditional sources based on increased LPG prices. The development of alternative models explains that energy transition procedure is based on the various pragmatic observations. Rather than fuel preference, energy demand ladder plays a vital role determining household fuel choice (Foley, 1995). The services energy provides is the primary drive of energy demand. Household biomass reliance for heating and cooking is key at a subsistence level of development. And as household income increases, the appliance purchasing power also increases which invariably requires specific energy sources. As such, diversification of energy demand (including modern sources) becomes key. However, in other to meet the basic household energy needs, biomass fuel becomes quite indispensable, with addition of other fuel choices to accommodate their changing life style needs (Hiemstra-Van der Horst & Hovorka, 2008).

On the contrary, multiple fuel model was proposed by Shah et al. (2023b) to canter fuel switching postulations. He stated that rather than switching, choices are made by households from a wide range of energy choices at varying level on the ladder theory. This wide range of options could be a representation of fuels from either or both upper and lower parts of the ladder, in which this process is referred to as fuel stacking. It is abnormal to find households that switch completely from one energy type to another, but would moderately use another source in addition to the present. This scenario is commonly witnessed in some households in Abuja, Nigeria, where households usually add cooking fuels (i.e. LPG and stove types), without completely abandoning the use of fuel wood. At first glands there appears to be a similarity between energy demand model and multiple fuel model when compared. The major disjoint between these two models is that in multiple fuel model for a specific use, numerous fuels are used. Thence, it is not usually the case for multiple fuel use to have a direct relationship with numbers of household appliances. There is an increasing support for multiple fuel model (Heltberg, 2005; Hiemstra-Van der Horst & Hovorka, 2008; Mekonnen & Köhlin, 2008; Mirza & Kemp, 2009; Jürisoo et al. 2019). Numerous factors have been revealed to clear the mist around fuel stacking behaviour in households. One of such argument is that fuel stacking is as integral aspect of poor livelihood (Davis, 1998). As such the irregularity and variability of income flows characteristics of households most times prohibit the consumption of regular modern energy sources. Thus, strategically mapped out budget is well placed in other to exploit fuel security. Another argument is of the view that fuel stacking is conditional behaviour that is based on fuel supply problem (Hosier & Dowd, 1987; Shah et al., 2023b; Soussan et al., 1991).

In most cases, the irregularities and unreliability of the supply nature of modern fuel are low. As such, households are conditioned to have one or two backup fuel (Hosier & Dowd, 1987). Also, another argument puts fuel stacking behaviour as a function of irregularities in energy prices, which mare household affordability of such energy (Hosier & Dowd, 1987). Conclusively, another argument for fuel stacking is based on the role of culture and tradition influence on preventing complete transition to modern energy sources (Murphy, 2001; Shah et al., 2023b).

Studies on household cooking energy stacking have examined various aspects related to fuel choice, consumption patterns, and factors influencing energy stacking behaviour. For example, the study by Choumert-Nkolo et al. (2019) explores different measurements and correlates of energy stacking behaviour in Tanzanian households. They analyse the factors that drive households to use multiple energy sources for cooking.

Additionally, research by Bisu et al. (2019) investigates cooking energy consumption patterns in Bauchi metropolis, Nigeria, to determine whether households follow the energy ladder model or engage in energy stacking. The study considers the influencing factors behind cooking energy choices and their implications.

The relevance and implications of fuel stacking and energy switching models are explored in the study by Ali and Megento (2017), focusing on urban and peri-urban households in Arba-Minch town, Southern Ethiopia. The findings shed light on the low-rate of energy transition prospects in household energy use.

It is important to note that fuel stacking can serve as a transition phase toward clean cooking practices (Hosier & Dowd, 1987). However, there remains a need to better understand the dynamics between fuel stacking and the adoption of clean cooking technologies, as discussed in the study by Price et al. (2021) in Cambodia, Myanmar, and Zambia.

Other studies have highlighted the prevalence of fuel stacking, especially with the use of traditional biomass fuels like wood (Mekonnen & Köhlin, 2008; Soussan et al., 1991). Shen et al. (2022), Zhu et al. (2018) provide insights into the substantial use of multiple energy types and the increasing prevalence of fuel stacking in rural China.

Overall, the theory of household cooking energy stacking recognizes that households often rely on a combination of energy sources for cooking, reflecting the complexities of fuel choices and the need for a nuanced understanding of household energy transitions.

4.3.3 Leap frogging theory

In most developmental studies, leapfrogging theory suggests that lessons from the familiarities of developed nations, and the channel through which scientific generations to implement most modern expertise and sidestep different ecologically mortifying phases of the Kuznets arc by developing countries (McGranahan, 2008; Munasinghe, 1999). As such, developing countries can bank on the negative experiences of the developed ones, and by so doing the environmentally destructive trails would not be threaded and a more sustainable future would be built concurrently. Leapfrogging theory proposes the development of household energy, through fast induction of modern sources in a cost-effective manner and by so doing counter degradation caused by the traditional ones (Lenssen & Flavin, 1996).

Stove distribution programmes, stove subsidies, and promotional campaigns are typical example of technological experiences transference, in which emphasis is placed on the poor household affordability (Lenssen & Flavin, 1996). The model then proposed a direct move to advanced energy from traditional. As such, the environmental and health challenges attached to the transitional fuel are totally avoided. The proposed introduction of developed imported technologies in leapfrogging is based on the credence that developing national is constrained in terms of creation skills and crippled capacity to decimate local innovations. Technical, organizational, and institutional are the limitations as categories by Murphy (2001). From the technical knowhow lens, technologies can be challenging when it comes to manufacture, keeping cost-efficient, safe and durable. Through the organizational lens, resources to effectively disseminate technologies are not available in most countries. The institutional lens reveals that technological adoption is usually constrained by social structures in place Community resource allocation traditions and gender-based roles may be the two factors that might for example influence the categorization of improved cooking tools as non-significant (Murphy, 2001). As such, it is assumed that by moulding machineries overseas, such constraints can be defected. As a major criticism to this model, (Murphy, 2001) claims that a misconception of leapfrogging model in most cases is that contemporary cooking machineries are moulded overseas and disseminated in the developing nation in a top-down method. Though most of these machineries are prevalent certain portion of the world, they mostly fail to meet the conditions such as social, culture, and economic that are principal in the local community context.

One key implication of household cooking energy leap frogging is its potential impact on health outcomes, as discussed by Lenssen and Flavin (1996). Transitioning to cleaner cooking fuels can improve self-rated and others-rated health. Additionally, the analysis by Munasinghe (1999) highlights the relevance of household size, economic growth, and saturation of energy appliances in understanding energy efficiency in developing countries.

Barriers to household cooking energy leap frogging are explored in studies such as Lenssen and Flavin (1996). They identify factors such as fuel availability, affordability, infrastructure constraints, and the influence of traditional and cultural practices as significant barriers to transition. Munasinghe (1999) emphasizes the need to understand the reasons behind the slow transition to clean energy for cooking in Nepal for effective policy interventions.

Policy interventions can support smoother energy transitions. Munasinghe (1999) discusses the cost and externalities associated with household cooking, emphasizing the importance of addressing energy poverty and multiple fuel use. Lenssen and Flavin (1996) explore different planning scenarios, including low carbon emission and efficient cooking scenarios, as policy interventions for sustainable energy planning.

In summary, household cooking energy leap frogging offers opportunities for improving health, reducing environmental impact, and enhancing sustainability. Understanding the dynamics, barriers, and implications of leap frogging can inform targeted policy interventions to facilitate a successful transition to cleaner and more efficient cooking energy sources.

4.4 Household domestic energy sources

Among the 75 studies on household energy consumption that were analysed, 42 demonstrated that the characteristics of households play a significant effect on the choice of home fuel in developing nations. Almost all previous studies concluded that family size is a major factor in deciding which fuel to utilize (Murphy, 2001; Shah et al., 2023b). As the average number of people living in a home rises, many make the transition to alternative fuels like charcoal, fuelwood, and liquid petroleum gas (LPG) (Ngui et al., 2011a).

Large households with a high proportion of women have been shown in studies by Kroon et al. (2013), Narasimha and Reddy (2007) to have less opportunities to collect firewood, leading to an increased prevalence of fuel stacking as a result. Heltberg (2005) investigated the variables of fuel switching using data from household surveys in Brazil, Guatemala, Ghana, India, Nepal, Nicaragua, South Africa, and Vietnam. According to the results of his research, the number of people living in a home influences which fuel is used, but does not cause a changeover. He said that larger families were more likely to employ a combination of biomass and non-biomass fuels. Studies on energy consumption have also factored in the average degree of education of the home's inhabitants. Studies by Emagbetere et al. (2016), Adriana (2019) in Brazil, in urban Nigeria (Abdullahi et al., 2021; Ouédraogo et al., 2017), are selected illustrations which highlight the significance of learning/mindfulness in sinking the need for customary fuels such as charcoal and firewood. Households that have higher education exposure, tend to be more mindful of the deleterious impacts of biomass fuels consumption (Ouédraogo et al., 2017). Long-term strategies to address and manage firewood use may include education, as highlighted by Ouédraogo et al. (2017). According to Abdullahi et al. (2021), fuel availability and user friendliness are two crucial factors. Choice can also be fuelled by adjusting for factors such as race and location. For instance, Adriana (2019) showed that the dynamics that influence fuel choice are drastically dissimilar for rural and urban Nigerian households.

4.4.1 Biomass

Based on household preference (i.e. cleanliness, ease of use, cooking speed, and efficiency), biomass is ranked the lowest (Hiemstra-Van der Horst & Hovorka, 2008), in a theory called the "*Energy Ladder*". Lighting, cooking, heating, and electrical appliances are the numerous purposes in which household energy is required and there often referred to as household energy consumption. These are the energy (fuel wood, muck, agricultural remains, kerosene, charcoal, electricity, and LPG) expended to meet household needs (Kadiri & Alabi, 2014). There are two main classifications of household energy utilization: solid fuels and non-solid fuels (International Energy Agency, 2002). The solid fuel is made up of the fossil fuels (coal and peat) and biomass; and the non-solid fuels (kerosene, LPG and electricity). According to International Energy Agency (2002), a large share (i.e. about 30 to 40%) of the world's total energy consumption is used by built environment.

Around the world, household has the highest significant energy intense segment (Wang et al., 2011). This segment accounts for the major portion (65%) of energy usage (Oyedepo, 2012). Energy Commission of Nigeria (ECN) estimated in year 2003 that around 60% of Nigeria population relied on fuel wood for catering and other domestic routines. The figure rose to 72% in 2004.

About 2.5 billion individuals depend on fuel wood for their household necessities in developing countries (International Energy Agency, 2006), this corroborated the claim of ECN on Nigeria's fuel wood consumption. A World Bank report in year 2007 indicated that in Asia, (74%) households adopt use customary energy sources (in biomass form). The condition is similar in Nigeria; (70%) household adopt customary energy sources. While rural households predominantly utilize biomass fuels compared to their urban counterparts, it is noteworthy that a significant number continue to rely on fuelwood, wood remnants, and charcoal to meet their cooking energy needs (Maduekwe, 2014).

However, in the consumption of energy by households, different low ranked energy sources on energy ladder such as charcoal and wood have been known to cause health challenges and environmental degradation (Aderemi et al., 2009). For example, the consumption of customary biomass is liable for indoor air contamination, green house gas (GHG) secretions and forest depletion (Muller & Yan, 2018; Toole, 2015). According to an estimate by World Health Organization (WHO, 2010), over 1.5 million premature yearly death is caused by indoor air pollution from consumption of solid fuels. Energy ladder has been used by several scholars to theorize household energy dynamics in developing countries (Alem et al., 2016; Arthur et al., 2010; Gu et al., 2015; Ugochukwu et al., 2021; xxxx). Different variables that steer household energy consumption have been discovered by these studies (Ugochukwu et al., 2021; Čomić et al. 2021). Even so, income plays a key role in moulding fuel choices.

Energy requirement and poverty-linked issues have also been examined by numerous studies using diverse methodologies and estimation procedures. A study by Pachauri and Spreng (2004) discovered that efficient energy access translates into a high level of energy consumption, which generates usefulness such as upgraded indoor air value, increased time for industrious or frivolous activities and time free collecting biomass energy. When electricity access is guaranteed, standard of livelihood increases sharply (Jackson, 2005). Also, correlation between modern energy consumption and Gross National Product (GNP) per capita is strong (Jackson, 2005).

4.4.2 Electricity

The importance of electricity consumption on economic development cannot be overemphasized; however, it is of specific significance also for homes. Based on the concept of sustainable development, which is an integral aspect of rational use of resource, electricity is not an exception. Electricity has witnessed a significant trend in growth of consumption over the world. The prediction of consumption of electricity is of great importance for development of energy strategies.

Many studies have examined the evolution of power infrastructure in both established and emerging economies. Smith et al. (2014) found that among the 62 factors influencing home electricity usage in industrialized nations, 13 are socioeconomic factors, 12 are connected to the home itself, and 37 are influenced by the appliances within the home. Kim (2018) also looked at the energy consumption patterns of the highest and lowest consuming families in South Korea. His findings revealed important differences in socio-demographic characteristics, residential settings, and consumer preferences between the two samples. Electricity consumption in the Hawaiian Islands was also studied by Yalcintas and Kaya (2017), and their findings showed that different islands have different electricity consumption configurations, highlighting the importance of lifestyle, household size, and dwelling type. Unlike more developed nations, emerging nations do not conduct as many of these kind of studies. Babatunde and Enehe (2011) carried out a study in Nigeria and found that socioeconomic factors (such as the number of rooms in a house, the size of a family's home, and the number of hours that electricity is on) play a significant role in determining household electricity consumption. Ye et al. (2017) also offered evidence that household income and electricity fee are significant determinants of electricity consumption volume in low-income countries like South Africa. Their research also revealed that households with more people and larger dwellings in urban locations tend to use more electricity due to the higher number of electrical appliances in use. The GDP, rate of urbanization, economy structure, and collective water ingestion were found to be significant and positively associated to electricity consumption in a study conducted by Al-Bajjali and Shamayleh (2018) in Jordan, while electricity fees were found to be significant and negatively associated with electricity consumption. Overall, it is safe to say that every nation, at every stage of development, faces its own set of challenges that drive up electricity demand.

4.4.3 Liquefied petroleum gas (LPG)

Liquefied petroleum gas (LPG) is widely available in most of sub-Saharan Africa, albeit with limited availability in several nations. High marks have been given to the reliability and effectiveness of this energy method, which has the potential to improve climate, environment, health, and development (Hussain et al., 2021). LPG is a clean burning cooking fuel that could improve people's health, the environment, and economic growth (Hussain et al., 2021). Several governments in sub-Saharan Africa, notably those of Ghana, Kenya, Nigeria, and Cameroon, have made it a priority to provide their citizens with LPG in order to reduce the negative impacts of biomass use on the environment and the economy (Leeuwen et al., 2017). To tackle deforestation, pollution, and sustainable energy threat problems, the government of Cameroon aims to expand LPG use from its current level of roughly 20% of the population to 58% (18 million people) by 2030.

Social and economic factors, which have not been heavily planned for so far, drive the adoption and maintenance of LPG use (Lewis & Pattanayak, 2012). Musibau et al. (2020) conducted research on the consumption of LPG as a gastronomy energy source among rural families and found that, despite a high level of awareness of the health risk related with the use of the substitutes as compared to switching to LPG, there is a low level of usage of LPG. Their research also showed that factors like as price and household income play a crucial effect in determining LPG consumption. In conclusion, the ability to pay, as measured by income and the value of energy sources, plays a crucial influence in determining residential energy use.

4.5 Energy consumption modelling techniques

These methods can be broken down into two basic categories: top-down and bottom-up approaches. These groups correspond to the hierarchical perspective of data inputs related to the overall residential area. In order to characterize energy ingestion to aspects of the whole housing sector, top-down models use predicted total inhabitant sector energy consumption and other important criteria. Bottom-up models analyse energy consumption patterns of clusters or individual families, and then extrapolate the findings to characterize an entire region or country. Figure 2 displays and discusses some examples of bottom-up and top-down approaches to modelling residential energy consumption.

4.5.1 Overview of the top-down approach

These models approach the domestic segment as an energy port and do not separate energy ingestion on household bases. Variables commonly utilized by top-down energy models include; climatic conditions, rate of housing construction/demolition, macroeconomic indicators (employment rates, price indices and Gross Domestic Product (GDP), and number of units.

in the residential sector and projected appliance ownership. Econometric and technological are the two major groups that lie under top-down models. Price (of energy and appliances) is the bases on which the econometric sub-sect lies. On the other hand, the total housing stock (appliances ownership trend) is the base on which technological

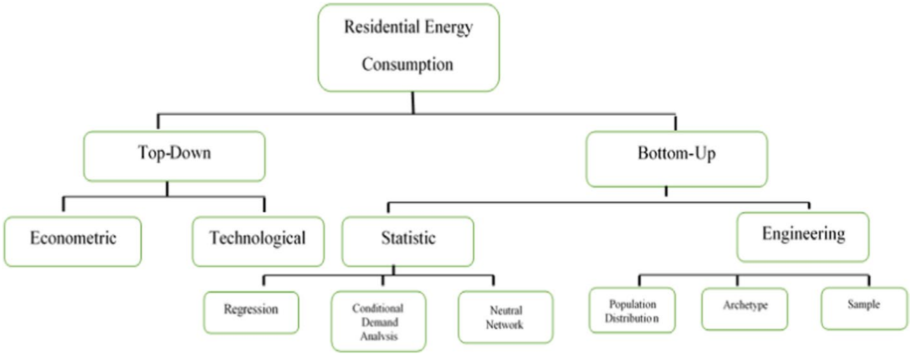


Fig. 2 Residential energy consumption models, adopted from IEA (2002)

models are characterized. Noteworthy, it is the fact that there are models that utilize both characteristics from these models (technological and econometric).

The equilibrium framework that stabilizes historical and estimated (based on inputted variable) energy consumption is the base on which top-down models operate. The usefulness of top-down modelling lies on its capacity to utilize cumulative data on momentous domestic energy ideals that provides inertia to the model.

Based on the fact that the energy sector hardly experiences paradigm shifts, a prejudiced model offers a good projection proficiency for slight deviances from the status quo. For illustration, if lodging units are augmented by 2% in construction, a subsequent upsurge in inhabitant energy ingestion of 1.5% can be predicted using top-down mode, based on the fact that novel households are energy effectual. However, if there was 10% increase in development, difficulty would arise in the use of top-down model as the base for dissemination of housing stock. It is a drawback, to rely on top-down models, has there is no intrinsic competency to model intermittent development in machinery. Besides, the absent of detail concerning the energy consumption of distinct end-uses omits the model ability of detecting key regions for precision of decline in energy consumption.

4.5.2 Bottom-up approach overview

These embody the entire models that consume input records from hierarchic level fewer than that of a segment as a whole. This approach can be used to describe the energy depletion of specific end-users, distinct households, or clusters of households and are then generalized to characterize the region or nation centred on illustrative encumbrance of the exhibited trial. These variability of data inputs results in the group and sub-groups of the bottom-up method are presented in Fig. 1. The statistical approaches are based on historic data and peculiar regression analysis approach used in household energy ingestion, which are unique to end-users. When the establishment of linkage between users and their respective energy consumption is made, the statistical analysis can be made. The Engineering methods (EM) on the other hand exhaustively quantify the energy ingestion of end-user based on power ranking, equipment usage, and systems or thermodynamics and heat transference.

4.6 Tools for analysis of household fuel consumption

4.6.1 Niche breath and redundancy

The classical research of Hardesty (1972, 1975) has made significant contributions to analyses of the association between the use of natural resources and humans, with a particular importance on the perception of niche breadth. This is a bottom-up approach and efficient tool for assessing the relative intensity with which populations utilize the elements in their environments. The theory incorporates the tenets of multidimensionality (i.e. several scopes can be investigated in the research of resource consumption, or a single scope can be analysed throughout a certain time period) (Hardesty, 1972, 1975). As a result, communities with greater niche breadth imply greater multiplicity or uniformity in utilization of the investigated magnitudes. But populations with the most selective resource scope will exhibit a narrower niche width (Hardesty, 1972, 1975).

This notion has been used to analyse the expenditure of resources associated with dietary diversity (Branco et al., 2010; Hanazaki & Begossi, 2000). This demonstrates that when wild resources become scarcer, niche diversity expands, especially when populations have access to external supplies (Hanazaki & Begossi, 2000; Silva & Begossi, 2009). Numerous ethno-biological analyses have evaluated the concept of ecological redundancy in socio-ecological systems in which several species provide the same function. Currently, the Utilitarian Redundancy Model (URM) is being used to evaluate the redundancy of specific socio-ecological structures in order to analyse usable structures and develop unified preservation and bio-cultural management approaches (Cortés-Borda et al., 2015). However, only Rosen et al. (2008) have successfully employed these methodologies in their investigation of fuel wood usage in rural areas.

Fuel Niche Breadth is represented by Equation:

$$\text{Fuel Niche Breadth} = 1/\sum_{i}^{n}(pi)^2 \tag{1}$$

where ‘pi’ is the proportion of the total subsistence donated by resource ‘i’ in a given dimension.

Results from various studies have shed light on the analysis of niche breadth and redundancy in different ecological contexts. For instance, research on sharks in South Brazil revealed higher trophic redundancy and patterns of niche overlap (Jawad et al., 2023). Another study demonstrated that niche and neutrality exist on a continuum from competitive to stochastic exclusion (Jawad et al., 2023). Purposeful clusters were used to appraise niche occupation and redundancy in the analysis of moth diversity (Uhl et al., 2021). The concept of functional niche was defined as the area occupied by a species in a multidimensional functional space (Uhl et al., 2021). Invasive species were found to have a broader ecological niche compared to native species (Uhl et al., 2021). Analysis of dominant phytoplankton species in Lake Wuchang involved measures such as niche width, overlap, and association coefficients (Zihao et al., 2022). However, only Zihao et al. (2022) as applied the concept of niche breadth and redundancy for the analysis of fuelwood.

4.6.2 Multinomial probit models

These statistical models utilize a bottom-up strategy. These models are utilized to explore the fuel choice of households. Various sources of fuel are appropriate for culinary, including firewood, coal, electricity, and liquefied petroleum gas (LPG). And according to the notion of fuel stacking, households typically choose between two or more fuels for cooking. As a result, standard Logit regression is unsuitable for analysis because it can only handle binary dependent variables. Some of the criteria for categorizing cooking fuels are cleanliness, efficiency, and convenience. However, household (e.g. catering culture makes electricity unsuitable for particular meal preparation) energy preferences cannot be easily categorized. The utility of a home is maximized by the selection of energy sources depending on its features and preferences. Multinomial logit (MNL) model can be applied to diverse-option and unclassified problems. It was utilized by Daioglou et al. (2012) to investigate culinary and heating fuel preferences in developing nations. The MNL is expressed as:

$$In\frac{P(Y=j)}{P(Y=J)} = \infty + \beta X + t + p + \varepsilon$$

where $P(Y=j)$ denotes the likelihood that the household selects fuel j as the key cooking fuel, and X represents the vector of descriptive variables that may stimulate the fuel choice. The

descriptive values include housing circumstances, year and province dummy variables, and household socio-economic status. The regression coefficient β exposes the consequence of the descriptive factors on the logarithm of the likelihood quotient between the j fuel type and J fuel type, amid which J type fuel is the baseline group, j$\neq$J. t and p signify time (year) and province effects, respectively, and ε is error term. Dependent variable = Cooking fuel form. Main cooking fuels are in five groups: firewood, coal, gas, electricity and others.

Multinomial probit models are often used to analyse discrete choices made by individuals in various fields, including market research, electoral studies, and economic analysis (Cardoso et al., 2017; Usman & Nichol, 2018). These models allow for flexibility in examining complex choices involving multiple alternatives and attributes (Usman & Nichol, 2018). However, the computational cost of estimating multinomial probit models can be high, especially when using Markov chain Monte Carlo methods (Balsalobre-Lorente et al., 2023). As a result, multinomial logit models may be preferred in empirical studies due to their computational ease and ability to accurately predict outcomes (Ghilardi et al., 2016; Shah et al., 2023a).

Despite the challenges in estimation, there have been efforts to develop optimal design strategies for multinomial probit models. For example, it has been shown that locally D-optimal designs for multinomial probit models with independent utilities can consist of counterintuitive choice sets (Graßhoff, 2020). This highlights the importance of carefully selecting choice sets in order to obtain meaningful results in empirical choice experiments (Graßhoff, 2020).

In addition to analysing discrete choices, multinomial probit models can also be used for multiclass classification problems (Son, 2023). Variational Bayesian methods have been proposed as an alternative to Markov chain Monte Carlo for estimating multinomial probit models, offering computational advantages (Son, 2023). Furthermore, there have been advancements in prior specifications and correlation structures for multivariate multinomial probit models, allowing for more flexible and accurate analysis of nominal data (Liesenfeld & Richard, 2010; Zhang et al., 2008).

Overall, multinomial probit models provide a valuable tool for analysing discrete choices and multiclass classification problems, although their estimation can be computationally demanding. Researchers continue to explore optimal design strategies and alternative estimation methods to overcome these challenges and improve the application of multinomial probit models in various fields.

4.6.3 Stove performance testing

This is a top-down technological model approach. This particular test method can be used to evaluate wide range of metrics ranging from fuel efficacy, cooking period, thermal efficacy, ease of use, and pollution. In other to improve design and efficiency, keep stakeholders and potential abreast of critical issues, guide actualization of decisions and provide backing for carbon credit process, stove performance test method can be applied on stove initiatives (Micheal et al., 2017). The Volunteers in Technical Assistance project (Baldwin, 1986), which was later restructured by University of California, Berkeley and Aprovecho Research Center for the Shell Foundation's Household Energy and Health Program, developed three main stove performance test methods; Kitchen Performance Test (KPT); Water Boiling Test (WBT); and Controlled Cooking Test (CCT).

Analysis of stove performance testing has provided valuable insights into the efficiency, emissions, and overall functionality of various stove designs in different contexts. These studies have employed standardized laboratory testing methods to evaluate stove performance and compare it to traditional stoves or other improved stove technologies.

For example, laboratory efficiency tests using the Water Boiling Test (WBT) protocol consistently demonstrate that improved stoves have better fuel efficiency compared to traditional three-stone fires (Baldwin, 1986; Micheal et al., 2017). Additionally, studies have assessed performance indicators such as duration of boiling water, average fire power, specific fuel consumption, and energy efficiency (Micheal et al., 2017). The performance testing of stove technologies has also been conducted in real-world settings. Results have shown that pellet-fed gasifier stoves can approach the performance of gas stoves during in-home use (Baldwin, 1986). Furthermore, field evaluation of a gasifier stove in Ethiopia demonstrated increased thermal efficiency, reduced emissions of PM2.5 and CO, and significant fuel and cooking time savings compared to traditional three-stone stoves (Micheal et al., 2017).

In summary, performance testing of stoves has provided valuable data on fuel efficiency, emissions, thermal efficiency, and cooking time savings, allowing for the comparison and improvement of stove technologies in both laboratory and real-world settings.

4.6.4 Mofuss (modelling fuelwood savings scenarios)

Effects on local vegetation as a result of fuelwood harvesting are spatially and dynamically simulated within Mofuss environment. The goal of the model is to carry out a comprehensive measurement of decline in woody biomass as a result of unsustainable use from external interferences that depletes fuelwood demand. The model as the capacity to forecast fuelwood harvest locations overtime, by basing it predictions on fuelwood access. Vegetation is a function of harvest that is based on wood extract quantity and forest regrowth function (Soares-Filho et al., 2010). The uncertainties that are associated with input parameters are inbuilt in the model. For example perceived and predictable sequence in forest loss and gain unconnected to fuelwood harvesting are accounted for in the model. Also, rooms are created to accommodate meeting fuelwood demand through by-products of land clearing activities and as such fuelwood supply map is constantly adjusted (Adusah-Poku & Takeuchi, 2019; Hernández et al., 2020; Middlemiss et al., 2019; Roy & Das, 2018; Soares-Filho et al., 2010; Thomson et al., 2019; Xian et al., 2020). The only shortfall of the model is based on the fact that it is not developed to accommodate fuel stacking. As it can only be used in areas where fuelwood is the major energy sources excluding charcoal (Shah et al., 2023b). The key primary purposes of Mofuss as highlighted by Shah et al., 2023b are fuelwood harvesting pressure on prevailing biomass sources projection; vegetation disturbance estimation in terms of AGB growth; and intervention consequences estimation.

Results from the analysis of household MOFUSS (Modelling of fuel wood savings scenarios) suggest several findings.

First, there is a significant relationship between choosing fuel wood as an energy source and household living circumstances such as marital status, education level, and age (Hussain et al., 2019).

Second, the use of wood fuel in cooking is associated with increased risks of squatness of gasp, fever, cough, acute respiratory infections (ARI), and severe ARI, compared to charcoal fuel (Adams et al., 2015).

Third, the short-term financial constraints during crises like the COVID-19 pandemic can impact household savings and consumption levels (Adhikari et al., 2021).

Fourth, there may be variations in the relationship between inflation and household-saving behaviour across different countries (Amewu et al., 2020).

Fifth, households using wood or animal dung as primary cooking fuel have a higher risk of acute respiratory tract infections (ARI) compared to those using cleaner fuels (Duressa et al., 2018).

Sixth, fuel stacking behaviour, which involves multiple fuel use among households, has been observed (Yu et al., 2022).

Seventh, household income has been identified as a determinant of saving behaviour, with a significant increase in income tending to raise the rate of household savings (Mu'azu et al.,., 2021).

Eighth, there is a need for new methodological approaches for collecting and analysing data on wood fuel consumption in households (Ngui et al., 2011b).

Ninth, savings may be challenging or not an ideal scenario in certain household contexts (Abbas, 2020).

In conclusion, the implementation of gasifier cook stoves that produce biochar leads to enhanced energy efficiency and improved indoor air quality within rural households (Martins, 2005).

4.6.5 Long-range energy alternatives planning system (LEAP)

This is a complete, unified, scenario-based energy environment modelling tool that is used to project energy demand, source and pollution at the local, national, regional or intercontinental levels. This approach combines both bottom-up and top-down approach. This model supports a broad area of multiple modelling approaches; ranging from bottom-up, end-use account to top-down, and it makes provision for a variety of simulation, accounting, and optimization methodologies (Heaps, 2017). The flexibility of using different variety of input data is also put in place (Heaps, 2017).

One key implication of household cooking energy leap frogging is its potential impact on health outcomes, as discussed by Amankwah (2018). Transitioning to cleaner cooking fuels can improve self-rated and others-rated health. Additionally, the analysis by Wu (2021) highlights the relevance of household size, economic growth, and saturation of energy appliances in understanding energy efficiency in developing countries.

Barriers to household cooking energy leap frogging are explored in studies such (Schunder & Bagchi-Sen, 2019). They identify factors such as fuel availability, affordability, infrastructure constraints, and the influence of traditional and cultural practices as significant barriers to transition. Malla (2021) emphasizes the need to understand the reasons behind the slow transition to clean energy for cooking in Nepal for effective policy interventions.

Policy interventions can support smoother energy transitions. Balmer and Hancock (2019) discuss the cost and externalities associated with household cooking, emphasizing the importance of addressing energy poverty and multiple fuel use. Adhikari et al. (2021) explore different planning scenarios, including low carbon emission and efficient cooking scenarios, as policy interventions for sustainable energy planning.

In summary, household cooking energy leap frogging offers opportunities for improving health, reducing environmental impact, and enhancing sustainability. Understanding the dynamics, barriers, and implications of leap frogging can inform targeted policy involvements to facilitate a successful alteration to cleaner and more efficient cooking energy sources (Table 3).

4.7 Domestic energy policy review

As already identified, uncontrolled energy usage can cause severe environmental pollution. This conscience has led various countries to take drastic actions that come in form of policies. Policies are consciously set guidelines that sharp various sectorial actions. In other to gain proper insight into these policies, six major countries (UK, China, Nigeria, Ghana, Cameroon and Thailand) were selected across three continents (Europe, Asia, and Africa) (see Fig. 3). The selection of these countries was based on three factors. Firstly, these countries are among the most populous countries in the world, with significant energy demand to support their economic and social development. As such, they are likely face energy-related pollution challenges.

Secondly, these countries have diverse energy profiles and different levels of development, which can provide insights into the effectiveness of various domestic energy policies in addressing pollution. For example, China and Thailand are both major coal consumers, while UK has diverse energy mix that includes renewable sources. Nigeria, Cameroon, and Ghana, on the other hand, are major oil producers, but also have significant renewable energy potential.

Thirdly, these countries have different levels of institutional and policy frameworks for addressing energy-related pollution, providing opportunities for comparative analysis of domestic energy policies. For example, UK has a well-established regulatory framework for addressing pollution, while Nigeria, Cameroon, and Ghana are still developing their regulatory frameworks.

Overall, the selection of these countries is based on energy demand, diverse energy profiles, and different levels of institutional and policy framework.

Table 3 Characteristics of tools for analysis of household fuel consumption

Tools	PROS	CONS
Niche breath and Redundancy	1. It can be used to carry out cluster analysis of population and resource consumption	1. The result of the analysis is dependent on other indexes, and as such there in the shortfalls of such tools
	2. It is a universal tool. Because it involves a multidimensional analysis. That is different environmental resource consumption can be analysed in relation to adjourning population	
	3. It as a temporal capability. As such, the various analysis can be within a defined time range	
Multinomial Probit Models	1. Highly suitable for investigating households that uses two or more cooking energy sources	1. Its estimation is based on probability of household fuel choice. And in some cases such probability might be wrong
	2. It is also suitable for study of household whose energy source is not ordered	
Stove Performance Testing	1. Highly suitable for testing multiple metrics; fuel efficacy, thermal efficacy, cooking period, easiness of use, and pollution	1. It is an uncontrolled household-level test
	2. It is usually used to compare various stoves interventions	2. This method ignores stove/fuel stacking at household level. It subsumes fuel use from other sources while focusing at one source
	3. They are usually conducted in an highly controlled environment, as such result is highly accurate	
MOFUSS	1. It is highly suitable for estimating carbon footprint of household fuelwood consumption	1. It is only suitable for the estimation of fuelwood exploitation
	2. It provides a more detail spatial and temporal estimation approach for household fuelwood	2. It is more spatially inclined
LEAP	1. It has scenarios rooted on exhaustive recording of the various forms of energy expended by residential sector using numerous fuel types	1. It flexibility of data makes it liable to garbage-in and out error in result
	2. It can accommodate various scenarios with varying factors	
	3. It applicability is broad, which ranges from household, transportation sector, industrial sector, institutional sector among others	

Table 3 (continued)

Tools	PROS	CONS
	4. It is suitable for different types of energy estimation 5. It can be used to estimate greenhouse gas emission from various energy consumption 6. It is flexible in data requirements. Characterization of the energy system can be as detailed or rough as required, depending on data availability	

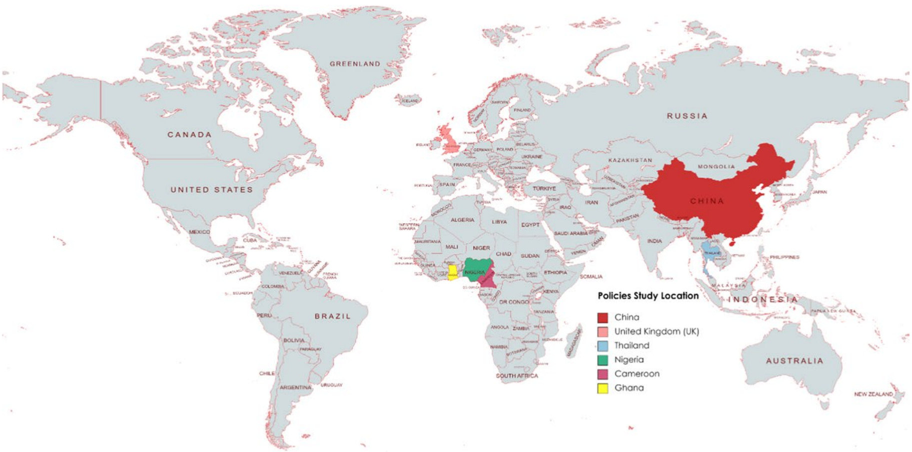


Fig. 3 Countries in which household policies were examined

4.7.1 UK energy policies

The UK has an ambitious target of achieving net-zero greenhouse gas emissions by 2050, and a significant portion of this goal will be met through the increased deployment of renewable energy sources. The country has made significant progress in recent years in increasing the share of renewable energy in its electricity mix, driven by a combination of policy support and market forces.

The primary policy instrument for promoting renewable energy in the UK is 'Renewables Obligation (RO)', which was introduced in 2002 and is currently the country's main support mechanism for large-scale renewable electricity projects. According RO, energy suppliers are obliged to source certain percentage of the electricity they supply from renewables, gradual increase over time. RO has been successful in driving the deployment of renewable energy, particularly wind power, but has been criticized for its lack of cost-effectiveness and lack of flexibility.

Another important policy is the Feed-in Tariffs (FiT) scheme, which was introduced in 2010. This scheme provides financial incentives for individuals and organizations to generate their own renewable energy and feed any excess back into the grid. The FiT scheme has been particularly successful in promoting the deployment of small-scale renewable energy projects, such as rooftop solar panels.

The UK government has also invested in research and development to support the advancement of new technologies and to reduce the costs of renewable energy. For example, UK government has provided funding for the development of offshore wind technology, which has led to significant cost reductions in recent years.

UK government has set a target to reach net-zero greenhouse gas emissions by 2050 and to phase out the use of coal for electricity generation by 2025. To achieve this, UK government has set a target to upscale the quantity of renewable energy in the energy mix to 30% by 2020, and to 60% by 2030. These targets are expected to drive significant growth in the renewable energy sector in the coming years.

There exists a legal obligation under the European Union (EU) law for the UK to generate an average of 20% of all its energy needs from renewable energy sources by 2020. In addition, it has been lawfully required as far back as 2008 to make eighty percent decrease in national climate-change emissions by 2050. Through a law amendment made in year 2019, there is aim to achieve net zero carbon emission by 2050 (Démurger & Fournier, 2011). A range of policy instruments, including initiatives such as the Green Deal, Change Levy, Feed-in-Tariffs, and the Energy Efficiency Opportunities Scheme, alongside advancements in construction and design standards like building control regulations and mandatory energy labelling through Energy Performance Certificates (EPC) and Display Energy Certificates, have been enacted and periodically revised (Démurger & Fournier, 2011).. A summary of these policies framework is shown in Table 4. The introduction of Minimum Energy Efficiency Standard (MEES) in UK was made in year 2011 and is based on the removal of market buildings/properties rated "G" and "F". Based on the 2015 yearly report of the Department of Energy and Climate Change, an average of 200,000 units of leased commercial stocks in England and Wales (representing 8% of non-domestic buildings had an EPC rating of F) and a further 10% of non-domestic buildings had an EPC rating of G.

In summary, the UK has implemented a range of policies to promote the use of renewable energy, including the Renewables Obligation, Feed-in Tariffs and research and development funding. These policies have been successful in increasing the amount of renewable energy generated in the country and reducing the costs of renewable energy technologies. The UK government is determined to increase the percentage share of renewable energy in the energy mix and to reach net-zero greenhouse gas emissions by 2050.

4.7.2 China energy policies

China has been actively promoting the use of renewable energy in recent years as a means to address energy security and environmental challenges. The country has set ambitious targets for the deployment of renewable energy, with a goal to increase the share of renewable energy in the primary energy mix to 20% by 2030 (Ratinen & Lund, 2015).

To achieve these targets, the government of China has implemented a number of policies and programs aimed at promoting the development of renewable energy. One key policy is the Renewable Energy Law, which was first implemented in 2005 and has been updated several times since then. The law sets targets for the deployment of various types of renewable energy, including solar, wind, and hydropower, and includes a number of incentives to encourage the development of renewable energy projects.

Another important policy is the National Energy Administration's (NEA) "Top Runner Program", which was introduced in 2009. The program aims to promote the use of high-efficiency and low-emission technologies in the power generation sector by providing financial incentives to power companies that use these technologies.

To support the implementation of these policies, the government of China has established a number of institutions and programs. In the growth and execution of energy strategies in China, National Energy Administration (NEA) was established. The NEA is also responsible for the promotion of clean energy technologies and the administration of financial incentives for renewable energy projects.

In addition to these policies, China has also implemented a number of programs to support the improvement of renewable energy. One key program is the "Golden Sun" program, which was launched in 2009. The program provides financial incentives to solar power projects and aims to increase the deployment of solar energy in China. Another important program is the "Wind Power Connection and Grid-Price" program, which was launched in

Table 4 UK energy policies overview

S/N	National policy	Description
1	FiT—Feed-in-Tariff	This policy ended in year 2012. The policy was targeted at achieving improved energy efficiency through distribution of low energy light bulb and insulation of loft bulb
2	Green Deal	Under this policy, owner occupiers are eligible to household energy bills loan, in other to pay for home energy-efficiency improvements
3	Warm Home Discount	This policy tackles the problem of finance, by providing support for fuel poor households from the suppliers of electricity and gas
4	CRC—Carbon Reduction Commitment	The policy enshrined that beginning from year 2012, large commercial organization that consumes more than 6000MWh electrical energy must recompense CO_2 tax which was initial fixed at £12/ton

Source: Adopted from Lu et al. (2020)

2010. The program aims to improve the connection of wind power projects to the grid and to provide a stable revenue stream for wind power developers.

All over the world, building (i.e. residential/public) energy consumption is the major sector that threatens sustainable development and this trend is projected to upturn in the subsequent years. From the establishment of first building standard in 1986, the Chinese government as set up various systematic standard design for new development within varying climatic zones (Ratinen & Lund, 2015) (see Table 5). And it has been noted that those standards are updated at varying intervals over the years. The 13th Five Year Plan on energy development was issued by National Development and Reform Commission (NDRC) of China, in which it is the basic framework of China's energy policy from 2016 to 2020 (Lu et al., 2020). The enhancement of the energy demand and supply structure stands as a crucial structural pillar within China's 13th Five-Year Plan. This plan is aimed at addressing the challenges posed by the existing renewable energy policy, which has historically emphasized facility construction while overlooking usage considerations.

Thus, it could state that the Government of China (GoC) has prioritized renewable energy as is evidence from the deferent policies it has been enacting from 1996 Brightness Program (solar PV) up to the 14th 5-year plan for renewable energy development. Which is part of the GoC efforts to promote clean energy consumption (see Table 5). It could thereby be noted that the GoC has a focus and persistent efforts in terms of renewable energy policy enactment and implementation, which has made the Country the world leader in terms of adaptation renewables.

4.7.3 Nigeria energy policies

Nigeria is a country that has abundant renewable energy resources, including solar, wind, hydro, and biomass. However, for a long time, the country has primarily relied on fossil fuels to meet its energy needs, which has resulted in a significant carbon footprint and negative environmental impacts. In recent years, Nigeria has begun to shift towards a greater use of renewable energy through various policies and initiatives, which will be discussed in this summary.

One key policy that has been implemented in Nigeria is the Renewable Energy Master Plan (REMP). The REMP was developed in 2011 by the Nigerian Federal Ministry of Power, with the goal of increasing the percentage of renewable energy in the country's overall energy mix from the current 5% to 30% by 2030. To achieve this goal, the REMP includes targets for the deployment of solar, wind, hydro, and biomass power. The plan also includes the development of transmission infrastructure and the establishment of a Renewable Energy Fund to support the deployment of renewable energy projects.

Another important policy that has been implemented in Nigeria is the Renewable Energy Development Fund (REDF). The REDF was established in 2013, with the aim of providing low-cost financing to renewable energy projects. The fund is managed by the Central Bank of Nigeria (CBN) and is open to both public and private sector investors. The REDF plays a crucial role in providing financial support to renewable energy projects, and in this way, it helps to reduce the cost of financing and encouraging investors to take on renewable energy projects.

The Nigerian government has also introduced various fiscal incentives to support the development of renewable energy projects. These incentives include tax holidays, import duty exemptions for renewable energy equipment and other benefits that help to reduce the cost of doing business in the renewable energy sector. A feed-in-tariff (FiT) system was introduced

Table 5 China energy policies overview

Legislation	Year	Protocols, Schemes and Subsidies
	1996	Illumination Scheme (solar PV)
Legislation on Energy Efficiency	1997	
	2002	Township Electrification Program (solar PV)
	2003	Initial competitive tender phase for land-based wind energy initiatives
	2004	Sustainable Energy Efficiency Strategy
Green Energy Legislation	2005	Leading Sequence for Renewable Energy Industry
	2006	1. Classification of High-Tech Products for International Trade 2. Electricity Market Regulations Regarding Pricing and the Distribution of Costs 3. Generation Using Non-Conventional Sources of Energy (Provisional) 4. Regulations Involved in the Production of Electricity Using Renewable Sources of Energy 5. Provisional Policies Regarding the Administration of the Renewable Energy Development Special Fund 6. Provisional Guidelines for the Administration of the Renewable Energy Building Special Fund 7. Views on the Implementation of Policies on Finance that Backs the Development of Biochemical Engineering and Biomass Energy, with Specify Focus on Elastic Deficit Subsidy for Biomass Energy 8. Public Notice Concerning the Quota Transaction Plan and the Renewable Energy Generated Electricity Subsidy 9. Notice Regarding Tariff Adjustment for Grid Power
Revised Energy Conservation Law	2007	1. The United States Department of Energy's National Climate Change Program 2. The Eleventh Five-Year Plan for Progress in Energy Research and Development 3. Provisional Renewable Energy Tariff Surcharge Reallocation Policies 4. Requirements Placed on Grid Operators Regarding the Purchase of Electricity Produced from Renewable Sources 5. The Regulation Enterprise Income Tax Law implementation 6. Non-Grain Biochemical Engineering and Biomass Energy Provisional policies 7. Administration of the Funds, Including Their Distribution and Awarding 8. Raw Materials Biochemical Engineering and Biomass Energy Provisory Policies
	2008	1. The Eleventh Five-Year Plan for the Development of Renewable Energy
Revised Renewable Energy Law	2009	2. Provisional Policies for the Industrialization of Equipment Used to Generate Electricity from Wind Energy

Table 5 (continued)

Legislation	Year	Protocols, Schemes and Subsidies
	2010	3. Administration of Unique Funds
	2011	4. Modification of Favourable Import Tax Treatment Policies for Electricity Produced by Large-Scale Wind Energy
Draft Climate Change Law	2012	5. Equipment for the Generator, Essential Components, and Raw Materials
	2013	6. Important Announcement Regarding the Grid Power Tariff Adjustment
	2016	1. The initial implementation of a feed-in-tariff program for onshore wind energy
	2021	2. The first round of concession bidding for onshore solar PV projects has been located

Source: Adopted from Lu et al. (2020)

by government for renewable energy, in which prices of electricity generated from renewable sources are fixed. The FiT is intended to provide a stable revenue stream for renewable energy developers and attract investment in the sector. The implementation of this policy aims to provide a stable revenue stream for renewable energy developers, which in turn encourages more investment in the sector.

Furthermore, the Nigerian government has also supported the growth of renewable energy through the establishment of the Rural Electrification Agency (REA). The REA was created in 2005 to increase access to electricity in rural areas through the deployment of off-grid renewable energy systems. The REA has implemented several solar home systems and mini-grid projects, with the aim of reaching 3 million households by 2030. This policy is important as it addresses the issue of lack of access to electricity in rural areas and provides an alternative source of energy that is clean, sustainable, and affordable.

Nigeria recently has experienced a tremendous developments in the renewable energy sector. According to the International Renewable Energy Agency (IRENA), Nigeria has the potential to generate 12 GW of solar power, 10 GW of wind power, and 6 GW of hydropower. Moreover, the Nigerian government has been taking steps to increase the share of renewable energy in the country's total energy mix.

In addition, the Nigerian government has also been investing in the expansion of projects and infrastructures of renewables. The Nigeria Renewable Energy Access Project (REAP), which is supported by the World Bank, aims to increase the share of renewable energy in the national energy mix by deploying off-grid renewable energy solutions in underserved and unserved communities. The project is also providing technical assistance to the Nigerian government to improve the regulatory environment.

Another policy implemented by the Nigerian government to promote renewable energy is the National Electric Power Policy (NEPP). The policy aims to increase the share of renewable energy in the country's energy mix and improve the efficiency and reliability of the power sector (NERC, 2005). The policy also aims to attract private sector investment in the power sector and to create a level playing field for the expansion of renewables.

Despite these policies and efforts, the share of renewable energy in Nigeria's energy mix remains low. According to a study by Adeniyi (2017), the main barriers to the development of renewable energy in Nigeria are lack of finance, lack of technical expertise, and lack of government support. The study also suggests that the government should provide more incentives for private sector investment in renewable energy projects and improve the regulatory framework for the development of renewable energy projects.

In conclusion, Nigeria has a high potential for renewable energy development, but the country's energy sector has been heavily reliant on fossil fuels. The government has implemented policies such as the National Renewable Energy and Energy Efficiency Policy (NREEEP) and the National Electric Power Policy (NEPP) (Table 6) to promote renewable energy and increase the share of renewables in the country's energy mix. However, the share of renewable energy in Nigeria's energy mix remains low and more needs to be done to improve the sustainability of the projects. To overcome the barriers to the development of renewable energy, the government should provide more incentives for private sector investment in renewable energy projects and improve the regulatory framework for the development of renewable energy projects.

Table 6 Nigeria energy policies of targeted sector overview

S/N	National Policy	Description
1	Oil & Gas	This policies dedicated to the necessary security agencies that should address oil infrastructural sabotage It also put in place necessary to efficiently retrieve and transmit associated gases for domestic and industrial use
2	Environment & Renewable energy	The policy was set to pursue sustainable energy mix and by so doing reduce reliance on fossil use Establishment of a well-trained, distinct and strong for EIA Tax exclusion for operator of renewable energy Creation of access to funds and open arcade to stakeholders in the renewable energy sector Energy effectual cooking gear subsidization

Source: Authors construct, 2022

4.7.4 Cameroon energy policies

Cameroon is a peculiar Country which is totally different from several other Africa Countries such Nigeria, as no clearly defined guidelines regarding renewable energies. However, mostly hydropower is the only renewable energy source that as an enacted law in Cameroonian parliaments (Mus'ud et al., 2015). Strategies has been put in place by Cameroonian government to transform it electricity sector, coupled with a handful of actions to facilitate the utilization of renewable energies, without fiscal incentives (Ngnikam et al., 2016). In order to make ease the availability of modern and clean energy to rural dwellers of Cameroon, Rural Electrification Agency was created by Cameroonian Government. This agency is saddled with responsibilities of providing backbone and allotment of licenses for electricity generation for isolated communities.

Two prominent Cameroon-based companies established Cameroon Renewable Energy Fund (CREF) in other to provide both funding and expertise for the improvement of renewables (hydropower and biomass) so as to improve contemporary energy facilities provision in the country (Ngnikam et al., 2016). Cameroon is determined to become a fore player of renewable energy-producing country by year 2035. Under this vision, Universal access to electricity for all (i.e. Cameroonians) is the one of the utmost target, which is to be achieved by making noteworthy development in the energy sector, renewables in particular (EUEI-PDF., 2013).

Cameroon, in its 2035 vision, aims at becoming an emerging country. With this vision in mind, universal access to electricity for its citizenry is one of its targets to be achieved through significant investment in energy sector (EUEI-PDF., 2013).

According to EUEI-PDF. (2013), the strategy paper on growth and employment comprising of energy goals with an execution period between 2010 and 2020 is targeted at improving the security, reducing the cost of energy supply and simultaneously improving energy facilities and structuring of the stakeholders. Also, the paper aims at achieving 3000 MW of installed hydropower capacity by 2020. According to the Energy Sector Development Plan 2030 (Manjong et al., 2021) in regard to energy access, a long-term policy has been setup by Cameroon with a goal of meeting the rural electrification rate (20%) and improved overall total (75%) by year 2030. Renewable energy policies are still in the planning phase with the aim of increasing the share of renewable energy (power and heat generation inclusive) by involving private capital in the delivery of energy (Cameroon, 2013). Special measures have been employed in Cameroon energy and renewable energy sector so as to attract private capital. These measures are in form of; reduction with regard to import tax for equipment manufacturer's as well as cost measures with subsidies in form of Rural Energy Fund (70%).

According to MINEPDED (2016), Lighting Africa (2012), agencies in the state actively involved in the organization of Cameroon energy sector are as follows:

- Ministry of Energy and Water (MINEE) comprising of renewable energies department are charged with the responsibility of designing and actualization of national energy policy, and simultaneously delivering administrative and technical oversight.
- The Environment Ministry is saddled with the responsibility of advancing renewable energy sector's sustainable development.
- Rural Electrification Agency (AER) is charged with task of supporting and executing rural electrification Cameroon rural area, while managing the its Energy Fund.
- The Electricity Regulatory body (ARSEL) regulates the electricity sector by fixing its rates and standards.
- Electricity Development Corporation (EDC) is saddled with the building and maintenance of hydroelectric projects.

4.7.5 Ghana energy policies

Ghana has been actively pursuing renewable energy policies in recent years as a means to address energy security and climate change challenges. The country has set ambitious targets for the deployment of renewable energy, with a goal to increase the share of renewable energy in the energy mix to 10% by 2020 and 30% by 2030 (Adaramola et al., 2017; Mensah & Adu, 2015).

To achieve these targets, the government of Ghana has implemented a number of policies and programs aimed at promoting the development of renewable energy. One key policy is the Renewable Energy Act, passed in 2011, which established a legal and regulatory framework for the development of renewable energy in Ghana. The act includes provisions for the development of feed-in tariffs, net metering, and the creation of a Renewable Energy Fund to support the deployment of renewable energy projects.

Another important policy is the National Renewable Energy and Energy Efficiency Policy, which was launched in 2015. The policy aims to increase the share of renewable energy in the energy mix, improve energy efficiency, and promote the use of clean energy technologies. The policy includes a number of specific targets, such as increasing the share of renewable energy in the energy mix to at least 10% by 2020 and 30% by 2030, and reducing energy intensity by 20% by 2030 (Table 7) (Gyamfi et al., 2015).

To support the implementation of these policies, the government of Ghana has established a number of institutions and programs. One key institution is the Energy

Table 7 Renewable energy policies and strategies of Ghana. Adapted and modified from Gyamfi et al. (2015)

S/N	Renewable energy source (RES)	Policy	Renewable energy source target	Year of enactment
1	Renewable Energy Act	The feed-in tariff, RE purchase obligations, the institutionalization of Green Energy financing fund, tax exemptions	Heat and Power from RE	2011
2	National energy policy	Non-indication of policy types Challenges of Energy sector challenges with government objective to overcome such challenges were identified	Encompasses all energy sources, including waste-to-energy, solar, hydroelectric power, geothermal, various renewable energy sources, electricity generation, bioenergy, and biofuels for transportation	2010
3	National Electrification Initiative	Research, development, and deployment (RD&D), research initiatives, technology deployment and dissemination,, economic mechanisms,, fiscal/ financial incentives, grants, and subsidies	Wind, Onshore, bioenergy, biomass for power, multiple Renewable Energy sources, Electricity Generation, solar, wind	2007
4	Ghana Energy Development Access Project	Economic tool, economic rewards, credit financial mechanisms, Monetary incentives, funding and financial aid/support,	Wind, solar, solar PV	2007
5	Strategic National Energy Plan 2006–2020	Policy endorsement, strategic design	Policy support, strategic planning	2006
6	Renewable Energy Service Program (RESPRO)	Financial mechanisms, Capital Injection, Development investments	Solar, Solar PV	1999
7	Tax and duty exemptions	Economic instruments, fiscal/ financial incentives, tax relief, economic instruments, fiscal/ financial incentives, Taxes		1998

Source: Authors construct, 2022

Commission, which is responsible for the regulation and oversight of the energy sector in Ghana. The commission is responsible for the development of policies and regulations related to renewable energy and energy efficiency, as well as the promotion of clean energy technologies.

In addition to these policies, Ghana has also implemented a number of programs to support the development of renewable energy. One key program is the Renewable Energy Fund, which was established in 2011 to support the deployment of renewable energy projects in Ghana. The fund provides financial support to projects through grants and loans and is aimed at reducing the cost of capital for renewable energy projects.

Another important program is the Rural Electrification Project, which is aimed at increasing access to electricity in rural areas of Ghana. The project includes the installation of mini-grids and off-grid systems, which rely on renewable energy sources such as solar and wind power. To date, the project has helped to provide electricity to over 1,000 communities in rural areas of Ghana (Adaramola et al., 2014; Ahiataku-Togobo, 2012; Caballero et al., 2013).

In addition to these policies and programs, Ghana has also implemented a number of other measures to promote the development of renewable energy. For example, the government has established a number of tax incentives to encourage private investment in renewable energy projects. These incentives include a tax holiday for renewable energy projects and the exemption of import duties on renewable energy equipment.

Moreover, the government has also implemented a number of capacity-building programs to support the development of the renewable energy sector in Ghana. These programs include training and education programs for engineers, technicians, and other professionals involved in the renewable energy sector.

In conclusion, Ghana has implemented a number of policies and programs to promote the development of renewable energy in the country. These policies and programs include the Renewable Energy Act, the National Renewable Energy and Energy Efficiency Policy, the Renewable Energy Fund, and the Rural Electrification Project, among others. These policies and programs have helped to create a favourable environment for the development of renewable energy in Ghana and have made significant progress in augmenting the proportion of renewable energy within the energy blend and enhancing energy efficiency. However, there is still a long way to go before the country can achieve its ambitious targets for renewable energy deployment. To continue progress in this area, it is important for the government to continue to implement policies and programs that support the building of REs, as well as to provide the necessary funding to ensure their success.

4.7.6 Thailand energy policies

Thailand has been actively promoting the usage of REs in recent years as a means to address energy security and environmental challenges. The country has set ambitious targets for the deployment of renewable energy, with a goal to increase the share of renewable energy in the energy mix to 20% by 2036.

To achieve these targets, the government of Thailand has implemented a number of policies and programs aimed at promoting the development of renewable energy. One key policy is the Alternative Energy Development Plan (AEDP), which was first implemented in 2012 and has been updated several times since then. The AEDP sets targets for the deployment of various types of renewable energy, including solar, wind, and biogas, and includes a number of incentives to encourage the development of renewable energy projects.

Furthermore, Thailand Ministry of Energy is a government organization saddled with the responsibility of Restructuring and management of its energy sector according to their Act of Parliament (2002). Also established was the National Energy Policy Council (NEPC), which has the right to bestow energy operating licenses and the issuance of energy pricing regulations. The major legal support for the Thailand energy sector is provided by the Energy Industry Act (2007). The legal documents aim at encouraging the use of renewable energy in consideration of quality and affordable pricing. Another focus of this document is on renewable energy and domestic energy resource development for economic, social, and environmental sustainability, in consideration of energy import dependency reduction. Another notable energy policy is the 15-Year Renewable Energy Development Plan (REDP) that focuses primarily on the promotion of ethanol and biodiesel as sources of energy. This which is expected to upturn the cost of agricultural products while reducing the energy importation. In terms of the environment and natural resource laws, there are a number policies that have been enacted in Thailand; Land Code (1954), Factory Act (1969 revised in 1992), Agricultural Land Reform Act (1975), Public Health Act and Hazardous Substances Act (1992) and Community Forest Bill (2007). In the aspect of global commitments, Thailand signed the multilateral environmental agreements concerning to bioenergy in 1995. It also joined the United Nations Framework Convention on Climate Change (UNFCCC) in 1994, and in 2003, it joined Convention on Biological Diversity. The Royal Thai Government currently implements its policies, which have been able to solve several urgent energy problems, improved the life of Thai people by basing its actions on three key disciplines; Energy security: Provision of alternative energy forms, as such increasing the power consumption and lessening over dependence; Economy: Retaining affordable electricity generation price and achieving efficiency; Ecology: reduction of environmental and social effects electricity generation, by reducing to the barest minimum carbon dioxide intensity (see Table 8). Haven, looked at the dominant energy policies in Thailand and the compensating sustainable energy development level, it could be concluded that the country as achieved to a great extent its goals. In comparison today Nigeria, Ghana, and Cameroon, Thailand can be said to have implemented significant aspects of its renewable energies policies (Table 9).

Table 8 Renewable energy policies and strategies of Thailand

S/N	National Policy	Description
1	Sustainable energy	Encourage the use of renewable energy in consideration of quality and affordable pricing Development of renewable energy for social, economic and environmental sustainability Reduction of import fuel dependency Promotion of ethanol and biodiesel
2	Improved quality of Life	Increased numbers of alternative energy sources Increased price of agricultural products Improved transport efficiency and greenhouse gas emissions reduction Increased energy market integration

Source: Authors construct, 2022

Table 9 A brief overview comments on the successes and shortfalls of renewable energy policies of each country reviewed

Countries	Successes	Shortfalls
UK	The nation has made remarkable strides in augmenting the proportion of renewable energy in its electricity composition	Despite progress, the UK still heavily relies on fossil fuels and has yet to fully phase out coal power
	The UK has established a robust framework for supporting the development of renewable energy projects, such as the Renewable Obligation, the Feed-in Tariff and the Renewable Heat Incentive	The country also faces challenges in meeting its ambitious renewable energy targets, particularly in the transportation sector
China	China has made significant investments in renewable energy over the decades, particularly in solar and wind power, and has become a global leader in the sector	However, China still heavily relies on coal and faces challenges in integrating large amounts of renewable energy into its grid
	The country also, just like UK, has a strong focus on research and development in the renewable energy sector	The country also faces challenges in addressing environmental degradation and air pollution caused by its heavy use of fossil fuels
Thailand	Thailand has set several ambitious targets for renewable energy and has made headway in improving the ratio of Res in the mix, particularly in the use of solar and biomass energy	Thailand, similar to UK and China, still relies heavily on fossil fuels, particularly natural gas, and faces several challenges, mainly financing and overall public acceptance in meeting its renewable energy targets
Nigeria	Surprisingly, Nigeria, which is a growing nation, has also set increasingly ambitious goals for renewable energy and has made headway improving the ratio of Res in the mix, particularly combining hydro and solar energy source	Just like UK, China, and Thailand, Nigeria also heavily relies on fossil fuels, particularly fossil fuel and faces challenges in meeting its renewable energy targets particularly financing. This has resulted in several environmental degradation faced by the country
Cameroon	Cameroon, similar to Nigeria, has also set increasingly ambitious targets for renewable energy and has made progress in increasing the share of renewable energy in its electricity mix	However, the country still relies heavily on fossil fuel for it household energy source, and faces challenges in meeting its renewable energy targets tied primarily to financing and governmental will to implement stated policies. As a result, the country is confronted with challenges of addressing environmental degradation
Ghana	Ghana, like is counterpart African countries (Nigeria and Cameroun), is making increasing strides in enactment of ambitious policies for renewable energy and has made progress in increasing the share of renewable energy in its electricity mix	However, the country still relies heavily on fossil fuels, particularly oil, and faces challenges in meeting its renewable energy targets

Source: Authors construct, 2022

4.8 Reviewed energy policies of countries: differences and similarities

This section examines the differences and similarities in energy policies among five countries: Ghana, Cameroon, Nigeria, the UK, and Thailand, which were highlighted in the preceding section.

Among the five countries, each has distinct policies addressing various energy sources, with the exception of Cameroon, whose policies primarily focus on hydroelectricity. Previous discussions revealed that Ghana, Nigeria, and the UK have implemented feed-in-tariff (FiT) Acts. However, Ghana's FiT is more comprehensive, encompassing RE acquisition responsibilities, the institution of an RE fund, and tax exemptions. In contrast, Nigeria's FiT Act concentrates on renewable energy by guaranteeing fixed prices for electricity generated from renewable sources. Additionally, Nigeria's FiT aims to provide a stable revenue stream for renewable energy developers and attract investment in the sector. The UK's FiT Act, on the other hand, targets improved energy efficiency through the distribution of low-energy light bulbs and loft insulation.

Similarly, both Nigeria and Ghana have well-established national energy policies. However, Ghana's National Energy Policy does not explicitly outline policy types for different energy sources; it primarily highlights challenges within the energy sector and government objectives to overcome them. In contrast, Nigeria's National Energy Policy aims to increase the share of renewable energy in the country's energy mix, without disregarding underlying problems. The policy also aims to attract private sector investment in the power sector and create a level playing field for the improvement of REs projects.

Furthermore, in order to achieve the renewable energy goals set by these five countries, different boards and research bodies have been established by their respective governments. The Ghanaian government, for instance, established the National Electrification Scheme Research, Development, and Deployment (RD&D), which focuses on research programs, technology deployment, and providing financial incentives, grants, and subsidies to renewable energy investors. Similarly, the Cameroonian government created the Rural Electrification Agency (REA) to facilitate access to modern energy services in rural communities. Additionally, the Nigerian government also established the Rural Electrification Agency (REA) with the aim of increasing electricity access in rural areas through the deployment of off-grid renewable energy systems.

Moreover, the governments of Nigeria, Ghana, Thailand, and China have developed various energy plans for their respective countries, all with the common objective of improving the planning, implementation, and support of renewable energy. However, Nigeria's Renewable Energy Master Plan (REMP) is more comprehensive than Ghana's Strategic National Energy Plan and Thailand's 15-year Renewable Energy Development Plan (REDP), which focuses solely on biodiesel as an energy source. Furthermore, China's Energy Conservation Plan provides a more comprehensive roadmap for achieving an energy sustainable society compared to Nigeria's Renewable Energy Master Plan (REMP).

4.9 Implications derived from reviewed energy policies

Renewable household energy policies play a momentous role in promoting sustainable development and addressing the challenges of climate change. Drawing from the policies of China, UK, Thailand, Nigeria, Cameroon, and Ghana, several implications can be derived:

1. Implement ambitious renewable energy targets: China's renewable energy policies have been successful due to their ambitious targets. Setting and implementing clear and ambitious renewable energy targets can drive investment, research, and development in the renewable energy sector. This approach has been adopted by the UK, which aims to achieve net-zero emissions by 2050.

2. Provide financial incentives: Financial incentives are crucial to incentivize households to invest in renewable energy technologies. These incentives can include tax credits, grants, and subsidized loans. China's efforts to provide generous subsidies for renewable energy installations have resulted in significant growth in renewable energy capacity. The UK also offers various financial incentives, such as the Feed-In Tariffs (FITs), to encourage renewable energy adoption.

3. Create supportive regulatory frameworks: A supportive regulatory framework is essential for the successful deployment of renewable energy technologies in households. This includes streamlining the permitting process, revising building codes to include renewable energy requirements, and implementing net metering policies that allow households to sell excess renewable energy back to the grid. Thailand's Net Energy Metering program has been effective in promoting renewable energy adoption in households.

4. Develop public–private partnerships: Collaboration between the government and private sector can accelerate the deployment of renewable energy technologies. Policy initiatives that promote public–private partnerships and provide incentives for private investment in renewable energy projects can contribute to the growth of the renewable energy sector. Ghana's Renewable Energy Act encourages public–private partnerships to promote renewable energy development.

5. Strengthen awareness and education: Raising awareness and educating households about the benefits of renewable energy is crucial for widespread adoption. Awareness campaigns, educational programs, and capacity-building initiatives can inform households about the importance of renewable energy and how to access it. Nigeria has recognized the importance of awareness and education in promoting renewable energy choices among rural communities.

6. Support research and development: Investing in research and development (R&D) is essential to drive innovation in renewable energy technologies. It is important to allocate funds for R&D, encourage collaboration between research institutes and industry, and provide grants for renewable energy research projects. China has made significant investments in renewable energy R&D, contributing to technological advancements and cost reductions in the sector.

7. Strengthen grid infrastructure: Reliable grid infrastructure is necessary to support the integration of renewable energy into the electricity system. Policies should focus on improving the grid capacity, upgrading transmission and distribution infrastructure, and implementing smart grid technologies to accommodate the increased penetration of renewable energy. This is particularly important in countries like Cameroon, where grid infrastructure may need to be expanded or upgraded to facilitate the integration of renewable energy sources.

8. Promote energy efficiency: Energy efficiency measures should go hand in hand with renewable energy policies. Improving energy efficiency in households can reduce overall energy demand and complement the benefits of renewable energy technologies. Policies can include energy efficiency standards for appliances, energy audits for households, and incentives for energy-efficient building designs. Thailand has integrated energy efficiency measures into its renewable energy policies.

9. Foster international collaboration: Collaborating with other countries and international organizations can provide valuable knowledge exchange, capacity-building opportunities, and financial support for renewable energy projects. Developing partnerships with countries like the UK, which has demonstrated leadership in renewable energy deployment, can facilitate the transfer of best practices and experience sharing.

In conclusion, drawing from the policies of China, UK, Thailand, Nigeria, Cameroon, and Ghana, it is evident that implementing ambitious targets, providing financial incentives, developing supportive regulatory frameworks, fostering public–private partnerships, strengthening awareness and education, supporting research and development, strengthening grid infrastructure, promoting energy efficiency, and fostering international collaboration are crucial implications for renewable household energy policies.

4.9.1 Robustness test

Cronbach's alpha is usually applied to evaluate the dependability of test choice. This technique is adopted when internal regularity is existent in a test (Cronbach, 1951). Cronbach's alpha assesses the extent to which a set of items gauges a solitary, uni-dimensional dormant construct. The nearer to 1 the α denote the strength of the relationship. The test within the study reveals that the result is within the limits of 0.75 to 0.83 with one Cronbach's alpha above 0.90.

In adopting this, a pre-test was ran in the four study sites, in which 75 identified studies were tested. This analysis was carried out to test the reliability of the research instruments; the result showed a Cronbach alpha of 0.83 and this affirms its reliability (Table 10).

4.9.2 Study limitations

Certainly, here are the limitations associated with a review on domestic energy consumption, which assessed and synthesized existing theories, modelling techniques, and analytical tools while conducting a comparative analysis of energy policies across continents:

Data Availability and Quality: One notable limitation is the dependence on available data for analysis. Variations in data quality and accessibility across different regions and countries may introduce biases or limitations in the comparative analysis of energy policies and consumption patterns.

Temporal Dynamics: Domestic energy consumption is subject to temporal fluctuations influenced by factors like economic conditions, technological advancements, and policy

Table 10 Quantification of reliability by applying Cronbach's alpha

Case processing summary			
		N	%
Cases	Valid	75	100
	Excluded	0	0
	Total	75	100
Reliability statistics			
Cronbach's Alpha	Cronbach's Alpha of Standardized Items		Number of Items
0.832	0.841		5

changes. The review may not capture the full spectrum of these dynamics, potentially leading to a static representation of energy consumption trends.

Scope of Theories and Models: The review's focus on existing theories and models may inadvertently exclude emerging theoretical perspectives or modelling techniques that could offer fresh insights into domestic energy consumption. This could limit the comprehensiveness of the analysis.

Generalizability: While the comparative analysis of energy policies across continents is valuable, it may not always account for the unique cultural, economic, and social contexts of individual countries within those continents. Thus, the findings might not be universally applicable.

Policy Implementation and Enforcement: The review may not delve deeply into the nuances of policy implementation and enforcement, which can significantly impact the effectiveness of energy policies. Understanding the practical challenges in enforcing policies is crucial for a comprehensive analysis.

Evolution of Policies: Energy policies are subject to change over time. The review may not capture the evolution of policies within the selected continents, potentially leading to an incomplete picture of policy effectiveness.

Limited Focus on Alternative Energy Sources: Depending on the emphasis of the review, there might be a limited exploration of alternative and REs sources, which are becoming increasingly significant in domestic energy consumption. This could be a potential gap in the analysis.

Interactions with Global Factors: The review may not extensively explore how global factors, such as international agreements and geopolitical influences, affect domestic energy policies and consumption patterns.

Methodological Challenges: Assessing and synthesizing diverse theories, models, and policy approaches from different regions and disciplines can pose methodological challenges related to standardization and comparability.

Publication Bias: There might be a bias towards published literature, potentially excluding valuable insights from unpublished reports or grey literature, which could impact the comprehensiveness of the review.

Despite these limitations, a review of this nature provides a valuable foundation for understanding the complexities of domestic energy consumption and policy dynamics across continents, with the potential to guide future research and policy development.

5 Conclusion

Household energy consumption has been a subject of interest for researchers and policy makers for many years. It is a complex issue that is influenced by various factors such as income, demographics, and behaviour. In order to effectively design and implement policies aimed at reducing household energy consumption, it is important to have a clear understanding of the various theories and policies that have been developed in this area. In this comprehensive systematic review, we have explored the intricate landscape of domestic energy consumption, theories, and policies across diverse regions, encompassing the UK, China, Thailand, Nigeria, Ghana, and Cameroon. Our journey through these geographical contexts has unveiled unique patterns, challenges, and policy responses that underscore the significance of understanding domestic energy consumption within a global context.

Our analysis has revealed several key insights specific to each region:

UK: The UK has made substantial progress in reducing domestic energy consumption through energy efficiency measures and renewable energy adoption. Yet, challenges persist, particularly related to fuel poverty and the need for more inclusive policies.

China: Rapid urbanization and economic growth have led to a surge in energy demand within Chinese households. The government's multifaceted approach, combining technological innovation, regulatory interventions, and public awareness campaigns, has proven instrumental in shaping energy consumption patterns.

Thailand: Thailand's transition toward sustainable energy use is marked by a strong emphasis on promoting energy-efficient appliances and alternative energy sources. However, addressing disparities in energy access and affordability remains a pressing issue.

Nigeria: Nigeria faces complex challenges related to energy access, affordability, and reliability. Policies geared toward expanding access to clean energy sources and improving energy infrastructure are crucial for achieving sustainable domestic energy consumption.

Ghana: Ghana has exhibited a commitment to renewable energy integration, particularly in rural areas. Yet, there is room for enhancing energy efficiency and developing targeted policies to address disparities in energy access between urban and rural populations.

Cameroon: Cameroon's diverse energy landscape includes biomass, hydro, and fossil fuels. The government's efforts to diversify energy sources while ensuring affordability and accessibility have yielded positive results. Continued investments in infrastructure and sustainable practices are essential.

As we conclude this review, we must acknowledge that domestic energy consumption remains a dynamic field with several frontiers for future research:

Technological Innovation: The ongoing development of smart home technologies, IoT devices, and advanced energy management systems presents opportunities to gain deeper insights into energy consumption patterns and devise more effective interventions.

Behavioural Economics: A deeper understanding of the psychological and behavioural aspects that influence energy use within households can inform the design of targeted interventions and policies.

Data Analytics: Harnessing the power of big data and advanced analytics can facilitate real-time monitoring, prediction, and optimization of domestic energy consumption, enabling more responsive policies.

Cross-Regional Comparisons: Comparative studies across diverse regions can offer valuable insights into the transferability of policies and the role of cultural, social, and economic factors in shaping energy consumption.

Policy Evaluation: Rigorous evaluation of the impact of energy policies on domestic consumption behaviours, energy affordability, and environmental outcomes is essential for refining existing strategies and developing evidence-based policies.

In conclusion, this review has shed light on the multifaceted nature of domestic energy consumption, encompassing theories and policies across distinct regions. While progress has been made, domestic energy consumption remains a critical global challenge, requiring innovative solutions and concerted efforts. The frontiers of research outlined herein beckon researchers, policymakers, and practitioners to embark on a journey toward a more sustainable, efficient, and equitable domestic energy future. Through collaborative endeavours and interdisciplinary approaches, we can address the complexities of this vital field and chart a course toward a more sustainable and energy-resilient world.

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Declarations

Conflict of interest The authors have no conflicts of interest to declare.

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