

The Importance of Time-Saving as a Factor in Transitioning from Woodfuel to Modern Cooking Energy Services: A Systematic Map

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Abstract: Over half of the world's population lack access to modern energy cooking services (MECS) and instead rely on locally harvested biomass for fuel. The collection and burning of such biomass for cooking have significant negative social, health, economic and environmental impacts and is a major sustainability challenge. The adverse development impacts from households' continued dependence on polluting stove-and-fuel combinations are significant. Household Air Pollution (HAP) from biomass fuel use accounts for some 4.3 million premature deaths each year, disproportionately affecting women and children. Fuel harvesting and use represent a significant time burden for women and girls. Time savings can be realized through multiple pathways. Understanding the importance of timesaving as a factor in the adoption of clean cooking is thus important in informing the design of cookstove programs and their marketing approach. The systematic evidence evaluation of drivers of and barriers to adoption of modern energy systems undertaken for the World Bank's Energy Sector Management Assistance Program (ESMAP) was further analysed to create a systematic map of evidence relating to time-saving attributable to the adoption of modern energy systems by traditional fuel users. The umbrella ESMAP evaluation comprised 160 studies, of which 48 are relevant to the current systematic map. Time-saving was gained from (i) a switch from collection to buying fuel; (ii) urban market utilization; (iii) reducing collected fuel quantity; (iv) reducing the distance to fuel collection sites; (v) and reductions of meal preparation time were found as the key drivers/enablers of cleaner energy adoption across the evidence base. Perceptions and recognition of the time-saving benefits of cleaner fuel adoption across studies were reported to be understood for: (i) fuel efficiency; (ii) fuel collection time; (iii) buying fuelwood; and (iv) better household economics. Relatively few studies report on what the time saved was used for; however, those that do investigate timesaving use found that additional time was used for: (i) additional income generation; (ii) professional development; (iii) more cooking (iv) other domestic activities (e.g., learning to sew); (v) eating out; and (vi) leisure activities. While many studies speculate that time is taken away from education, none state that saved time was used for education, beyond employment opportunities or overarching claims of professional development.

Keywords: systematic map; wood fuel; modern cooking energy services; gender; time-saving



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1. Background

Over half of the world's population lack access to modern energy cooking services (MECS) and instead, rely on locally harvested biomass for fuel [1]. The collection and burning of such biomass for cooking have significant negative social, health, economic and environmental impacts and is a major sustainability challenge. The adverse development

impacts from households' continued dependence on polluting stove-and-fuel combinations are significant. Household Air Pollution (HAP) from biomass fuel use accounts for some 4.3 million premature deaths each year, disproportionately affecting women and children [2]. Fuel harvesting and use represent a significant time burden for women and girls [3,4]. A substantial share of cooking wood fuel is harvested unsustainably, resulting in deforestation, soil degradation, biodiversity loss and indirect CO₂ emissions through land-use change. It is estimated that residential wood fuel use contributes up to 58% of global Black Carbon (BC) emissions and 1 gigaton of carbon dioxide equivalent (CO₂e) emissions per year [5]. The progress on achieving modern cooking energy for all as envisioned in Sustainable Development Goal (SDG)7 is reported as too slow and off-track [1,6]. To accelerate this progress there is a need to develop a comprehensive understanding of factors that enable or limit the transition to clean cooking.

Previous studies, including systematic reviews, have been consistent in locating supply- and demand-side enablers and barriers such as availability and affordability of clean cooking options, appropriateness of the solutions, user-perceived benefits amongst others [7–9]. A critical question however remains; on whether the factors that motivate households to adopt clean cookstoves and the realisation of those benefits, can be a determinant of continued use (sustained adoption) or peer influence that is an important driver of widespread adoption. A systematic evidence evaluation of MECS transition programs conducted by ESMAP (ESMAP, 2021) revealed a high failure rate of those programs. Specific details of the programs selected for the evaluation using a protocol-driven approach can be accessed on the interactive systematic map of the study (freely available at <https://energydata.info/apps> (accessed on 30 June 2021))—the first ever produced from studies in the field of modern cooking energy. This consistent failure of cookstove programs to achieve the purported health, fuel use efficiency, time savings and other goals makes it necessary to evaluate the potential influence of the cookstove program's performance on adoption. This remains an important area of evidence gap.

Amongst the key impacts of lack of access to MECS is time poverty that primarily affects women, thus strong linkages are drawn between SDG 7 on clean cooking and SDG 5 on achieving gender equality and empowering all women and girls [1,9]. A global study by McKinsey and Company (2015) reports that 75% of the world's total unpaid work (e.g., cooking, firewood collection, and fetching water) is done by women [10]. The unpaid work associated with domestic cooking falls includes time spent gathering fuel, cooking and cleaning. World Bank data from more than 70 time-use surveys across various geographies shows that fuel collection is a significant time-opportunity cost for rural households, with up to 6 h per day spent on these activities in some settings [1,11]. In this paper, we use time savings as an entry point for analysis of drivers of cookstove adoption; a stark departure from previous studies that have paid less attention to this outcome. Unlike health or climate benefits that have been prioritised by other studies, time savings would be more easily perceived by the end-users, hence the outcome could potentially influence their behaviour. Furthermore, several studies have shown time savings to be amongst the important reasons people cite for adopting clean cooking [12].

Time savings can be realized through multiple pathways. The first pathway which has been subject to most investigations is through fuel savings. An efficient stove with improved heat transfer efficiency would thus imply fewer trips for collecting fuelwood. While this pathway is highly relevant in rural settings, it may not be relevant for urban settings where the principal fuel is charcoal whose supply chains are well developed and is delivered right to the user's doorstep. This is one of the cited challenges for getting urban households to transition to alternative fuels like LPG (Liquid-Petroleum-Gas) that requires travelling to the refill points [9]. A second pathway is time savings through the increased cooking speed of efficient stove technologies, which has also been used in many marketing campaigns for clean cookstoves. In addition to the thermodynamics of the stoves, multiple burners that allow users to prepare several dishes simultaneously enhances the speed of cooking and is valued by users [13]. A third pathway is through cleanliness; if the new

stove reduces time spent in cleaning pots and kitchen spaces. Time savings can however become attenuated if the stove is difficult to light, entails a lengthy fuel preparation process (such as cutting wood in small pieces, or preparation of feedstock for biogas digesters) and if fuel for the new stove has to be sourced far. Each of these pathways offers an opportunity for enhancing the time savings benefit. Understanding the importance of timesaving as a factor in the adoption of clean cooking is thus important in informing the design of cookstove programs and their marketing approach.

It should be stressed, also, that the SDGs primarily linked with deforestation or forest degradation are SDG 1 (no poverty), SDG 2, SDG 7 (affordable and clean energy) and SDG 9 (industry, infrastructure and innovation). All of these have strong connections with Goal 7 of the SDGs, which in rural settings amongst poor communities mostly means traditional energy from forest resources. To expand energy access, it is crucial to enhance energy efficiency and to invest in renewable energy, while taking account of forest loss and degradation.

2. Research Questions

2.1. Primary Research Question

What is the evidence base for time-saving as a driver for adoption for cleaner cookstoves and fuels (Modern energy cooking services) amongst wood fuel/traditional fuel users?

2.2. Secondary Research Questions

Do people who switch from traditional wood stoves or fuels report the time savings benefit?

What is the reported use/value of time saved from the adoption of MECS by wood-fuel users?

3. Method

3.1. Stakeholder Engagement

Full details of the method adopted to select and analyse studies related to the umbrella review question of drivers and barriers to adoption of MECS were published by ESMAP (2021) [9]. Following good practice for systematic evidence evaluation [14,15], two workshops, in the UK and Kenya, were held to engage relevant stakeholders in the questions developed by ESMAP (2021) from which the current review is further developed. The UK workshop comprised mostly academics with expertise in modern energy cooking systems. The Kenya workshop comprised mainly policymakers and practitioners from non-governmental organizations (NGOs) and the private sector involved in modern energy systems. The workshops provided input for the search strategy. Both stakeholder meetings suggested a very comprehensive list of potential sources of studies, including organizations, networks and communities of interest with published or archived relevant evidence. It was agreed that these organizations would be contacted by email to request grey literature and requests would also be sent to publicize the project in relevant networks and news alert services.

A 19-person Advisory Group comprising people at the workshops and other relevant practitioners also guided the method for the umbrella review.

3.2. Definition of the Question

Using an adaptation of the well-established Population/Intervention/Comparator/Outcome (PICO) framework developed for systematic review methodology, the following elements were derived:

Population: Users at a large-scale level that have experienced a technology transition from a baseline/traditional level, or been exposed to a program promoting a transition (large-scale defined as national, sub-national, regional, state, district, city, town, area of high population density).

Intervention: a technology program or intervention implemented at scale.

Comparator: no technology program or intervention was trialled at scale.

Outcomes: data reporting uptake of the technology (in numbers of people or density of uptake) and information on factors driving or inhibiting the uptake.

Context: woodfuel or charcoal or other traditional fuel users.

For the purposes of the current study, an additional element was added to further define the set of studies assessed. This uses ‘Context’, which is frequently used in systematic reviews of studies that contain qualitative data (or mixed quantitative/qualitative data).

3.3. Search Strategy

The following bibliographic databases and aggregators were searched:

Clarivate Analytics Web of Science™ Core Collection <http://apps.webofknowledge.com/> (accessed on 19 December 2019).

Elsevier’s SCOPUS <http://www.elsevier.com/online-tools/scopus> (accessed on 19 December 2019).

CAB Abstracts: <http://www.ovid.com/site/catalog/databases/31.jsp> (accessed on 19 December 2019).

Google Scholar: <https://scholar.google.co.uk/> (accessed on 19 December 2019).

Websites of organizations and networks are listed in Supplementary Material—Annex 1.

A search string was developed and tested iteratively against a test set of documents (details are in Annex 1), resulting in the following search string that was optimized for Web of Science and amended as necessary for CAB Abstracts and Scopus. Note that the terms reflect the broader context of the umbrella review, which embraced sectors and technologies other than cooking and heating.

(barrier OR driver OR constraint) AND (initiative OR intervention OR technology OR microgrid OR “energy conversion” OR “energy program” OR “modern energy” OR “energy transition” OR cooking OR ((cook* OR stove OR cookstove OR cook-stove OR woodstove OR wood-stove) AND (fuel OR ethanol OR “LPG” OR “LP gas” OR “liquid petroleum gas” OR “liquefied petroleum gas” OR “liquefied petroleum gas” OR Biogas OR Biodigester OR Bio-digester OR Solar)) OR electrification OR “clean energy” OR “cleaner energy” OR sanitation OR toilet OR “clean water” OR “mobile phone” OR smartphone OR telecom*)) AND (“pathways to change” OR transition OR uptake OR adopt OR rollout OR scale-up)) AND (rural OR sub-urban OR urban OR national OR regional OR sub-national OR city OR district OR state OR rural OR peri-urban OR periurban OR community OR neighbourhood OR national OR ngo OR community OR neighbourhood OR village OR scale)).

3.4. Article Screening

Bibliographic information of articles retrieved from the searches was downloaded to EndNote [16] reference management tool and duplicates removed. The set of articles was uploaded into Colandr [17], an open-source tool created to incorporate computer assistance for screening and metadata extraction. Articles were screened sequentially for relevance at the (1) title, (2) abstract and (3) full text. After the title and abstract screening stages, reviewers downloaded the accepted articles for full-text screening. Reasons for not including articles at full-text are reported based on PI(C)O framework—e.g., article rejected because Population was wrong, or article rejected because no Outcomes were reported. All screeners (GP, WH, LP) used Cohen’s kappa to test for consistency of decision-making during the screening process by screening batches of 100 records and comparing results. Differences of assessment were discussed and the process repeated at the title and abstract stage. The full-text screening was subjected to kappa testing for 5 records after considerable discussion, involving discussions of data extraction at the same time.

3.5. Inclusion Criteria

In order to be included in the systematic map, articles had to meet the following criteria:

Population: participants in a large-scale (e.g., village, regional, national) technology or fuel change program. Transitions to electricity for cooking were limited to studies from low- and middle-income countries (LMICs). (<https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2020-2021> (accessed on 19 December 2019)) The rationale for this was the desire to focus on the transition from biomass to cleaner cooking, which is critical for achieving SDGs in LMICs. The decision to limit this aspect to LMICs was taken after considering that there is a huge, historical literature on transitions from coal to gas and gas to electricity in European and North American countries, which is not the focus of the current review. The search was not adjusted to accommodate this limit, but the screening process excluded studies from higher-income countries in this category.

Intervention: restricted to large scale ‘program’ aimed at producing a technology change (any sector). Within the programs, all studies where groups of individuals (households, villages, areas) are studied were included. Studies reporting individual choices outside an obvious program were excluded. Large-scale electrification studies from non-LMICs were not assessed in the current study.

Outcome: one of three outcome measures had to be present for studies to be included: (i) data reporting positive/negative/neutral changes to social, economic or environmental variables as a result of the programme or intervention; (ii) reported measures of uptake or sustained use (iii) drivers and/or barriers to change, was supported by tabulated results or qualitative results that indicated the number of respondents.

Context: studies considered transitions from woodfuel, charcoal or traditional fuel to modern energy systems.

3.6. Data Extraction and Coding

The coding and extraction template comprised 64 extraction/coding elements organised into 17 categories and sub-categories: Article metadata (author, date of publication, journal, DOI/URL, abstract, etc.), Population details (including location details—country, whether rural, or urban—and numbers affected by the intervention), Intervention details (including the sector, funders and implementers, dates, aims, baselines and transition objectives), Study design and Critical appraisal proxies (missing data), measured outcomes of the transition (listed under Social, Economic, and Environmental), and drivers and barriers in 9 thematic categories.

The framework for compiling the reported barriers and drivers was taken from domain areas highlighted in previous literature as being necessary for successful transitions at scale, which was well suited to the current review [7,18,19]. The thematic categories were: Characteristics of setting; Knowledge, Perception & information; Technology characteristics; Financial, tax and subsidy; Regulation, Legislation & standards; Market development; Programmatic & policy mechanisms. Two other categories were added to the current review—Poverty, Gender.

These map onto the familiar Dahlgren-Whitehead (1991) “rainbow” model which shows the relationship between an individual, their environment (social, political, ecological), and health [20]. The current review is not focused on health, but it is a key outcome of cleaner energy use and the model usefully puts into context the different levels at which our analytical framework operates on the individual making a transition (Figure 1).

3.7. Narrative Reporting of Time-Saving

Examination of the results reported in the included studies revealed a dearth of quantitative information. The current systematic map will therefore include a section of all accounts of time-saving in the studies included. These may be supported by data in tables and figures but may also be taken from qualitative accounts in the individual studies. By including these data, the systematic map is not excluding qualitative information of potential significance for decision-makers.

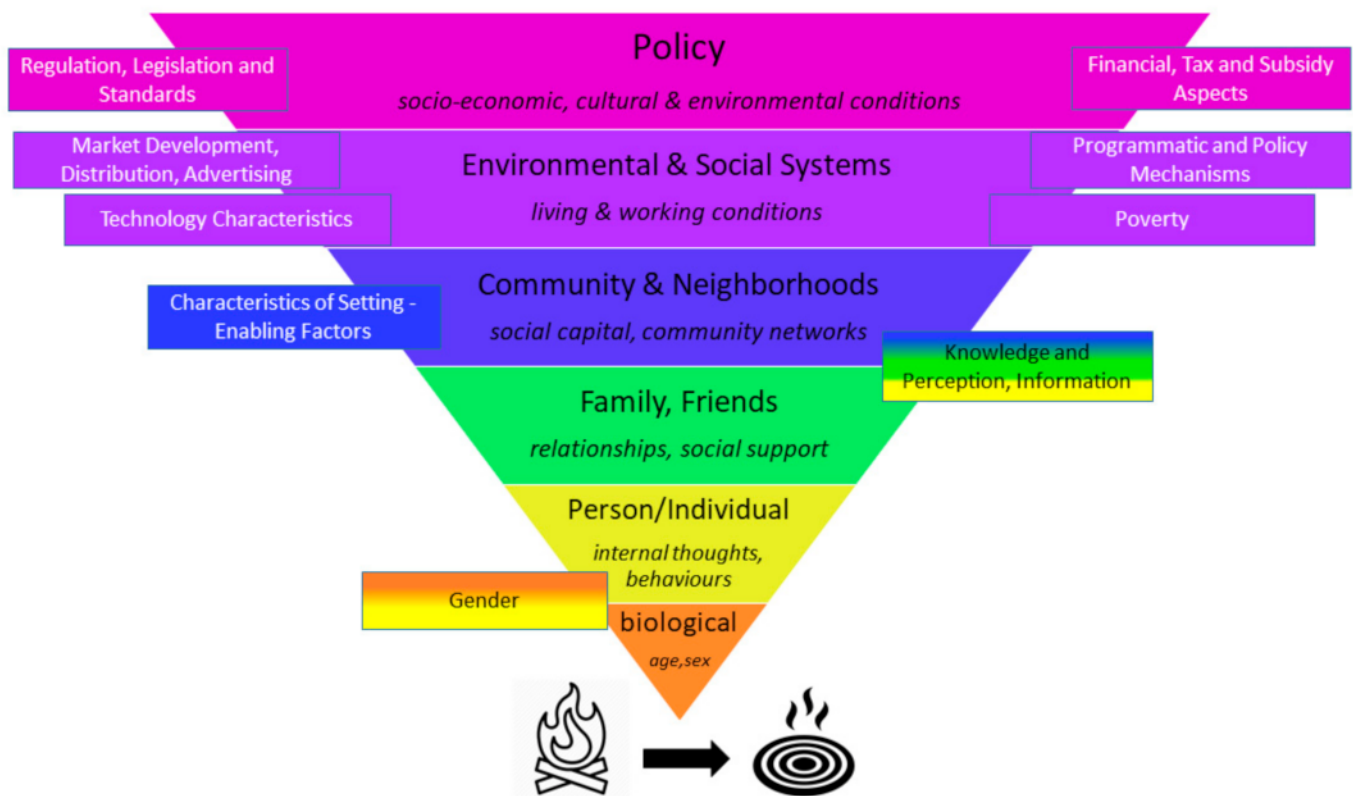


Figure 1. A modified Dahlgren–Whitehead model of the relationships between an individual and her environment.

4. Results

A total of 41 articles presenting 48 studies were retrieved from the ESMAP (2021) evidence base, after iterative screening and applying inclusion criteria (Figure 2). These studies are viewable on an online interactive map (<https://oxsrev.github.io/evidencemaps/woodfuel/> (accessed on 20 August 2021)) and details of each study, with coding and data extracted, are reported in Supplementary Material—Annex 2. Figure 3 shows a screenshot of the interactive map.

4.1. Article Details

The breakdown of article types shows journal articles as dominant at 77.1% (Figure 4). Articles were published between 1997–2019. The years with more than 5 articles published include 2012, 2018, and 2019. A decrease in the number of articles examining the influence of time-saving as a transition driver can be seen from 1997–2011, and an increase between 2015–2019 (Figure 5).

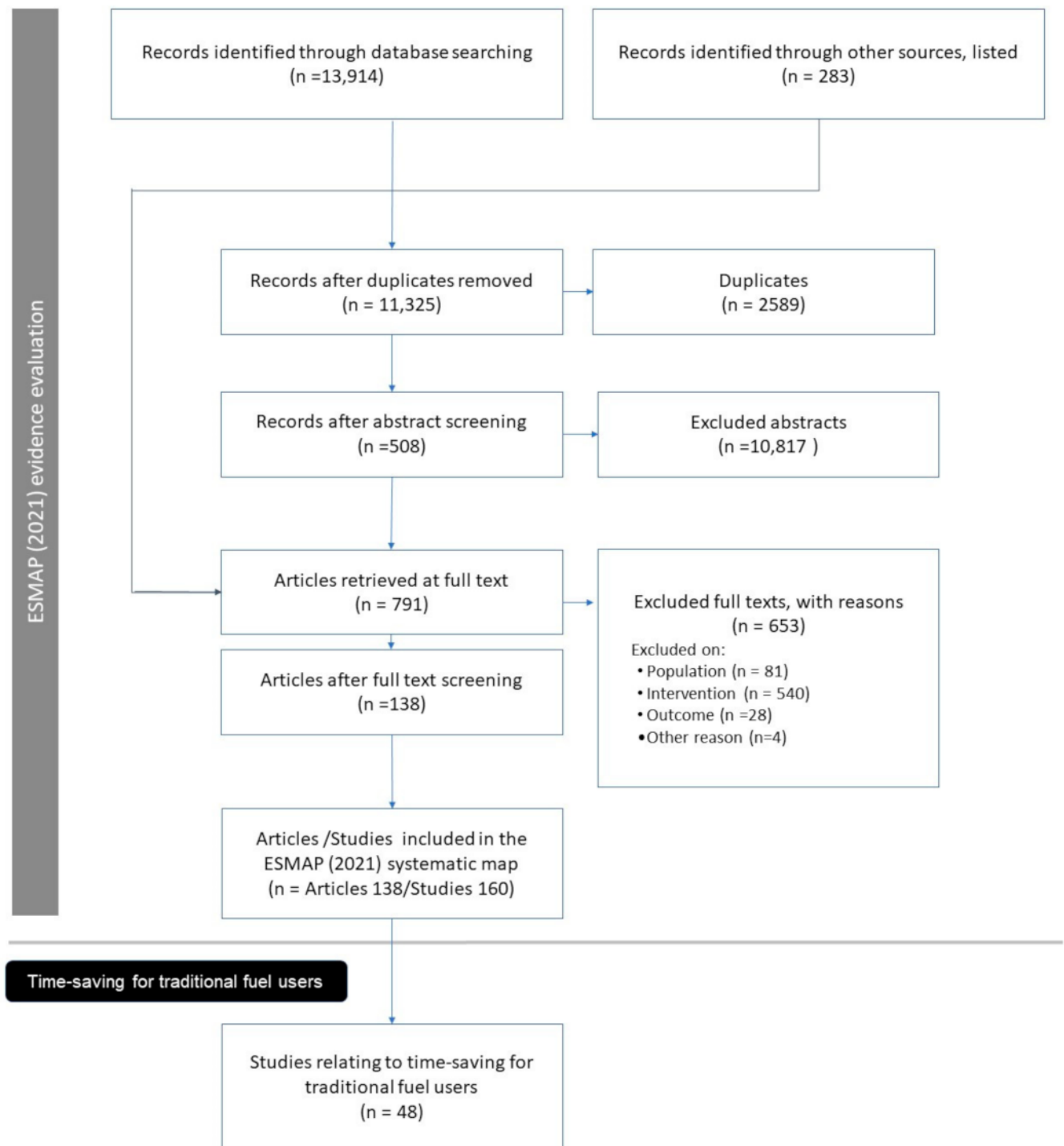


Figure 2. A flow chart of studies included in the systematic map. Adapted from Haddaway et al. (2017) [15].

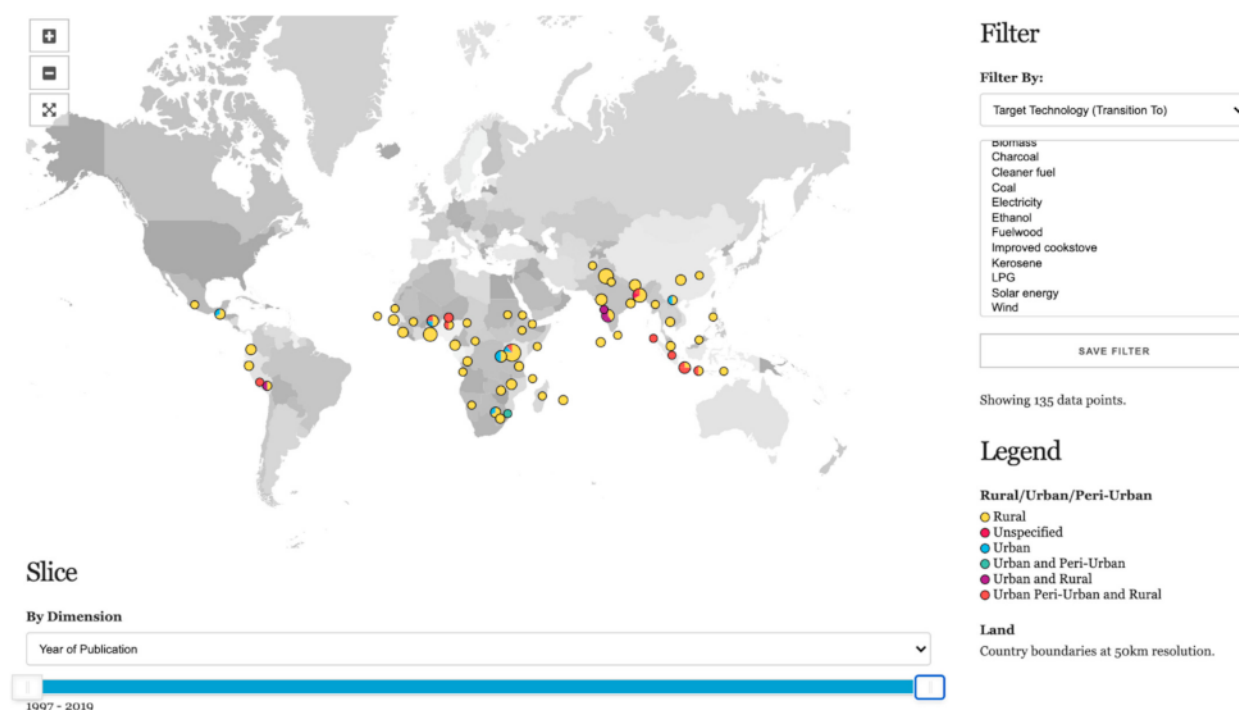


Figure 3. Interactive visualization of the 48 studies comprising the evidence base <https://oxsrev.github.io/evidencemaps/woodfuel/> (accessed on 17 August 2021).

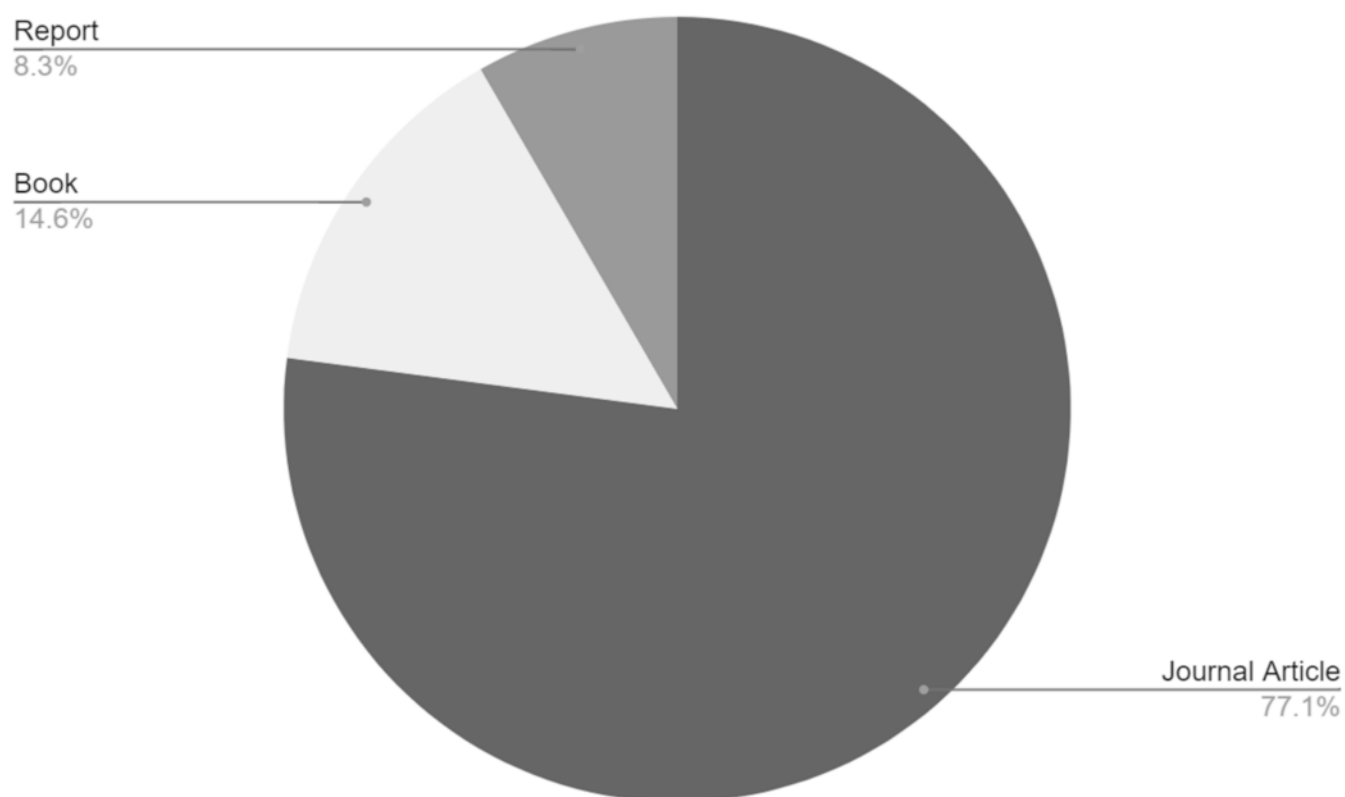


Figure 4. Reference type from which studies in the evidence map were found.

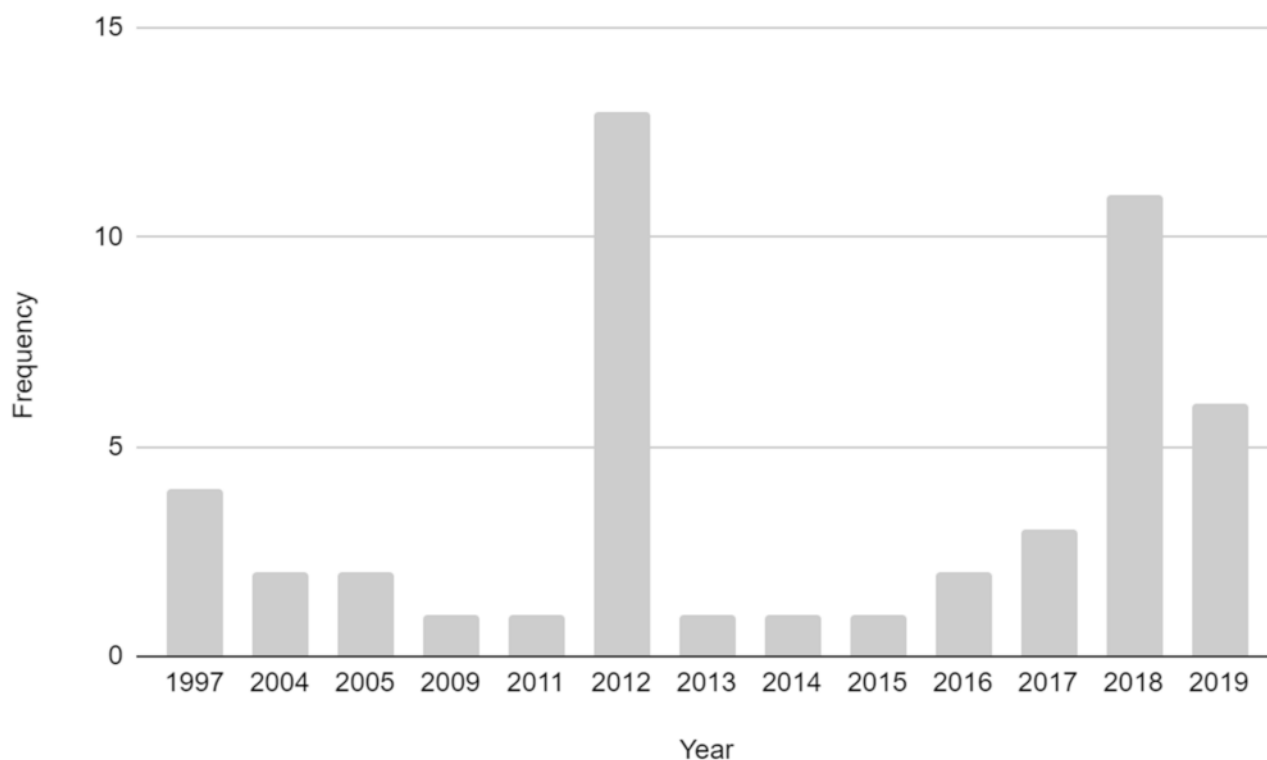


Figure 5. Year of study publication.

Study data collection techniques included 7 study designs with the most popular being surveys (39.6%) and mixed methods (25%). Several studies did not report data collection techniques (10.4%), applying a narrative descriptive overview instead (Figure 6).

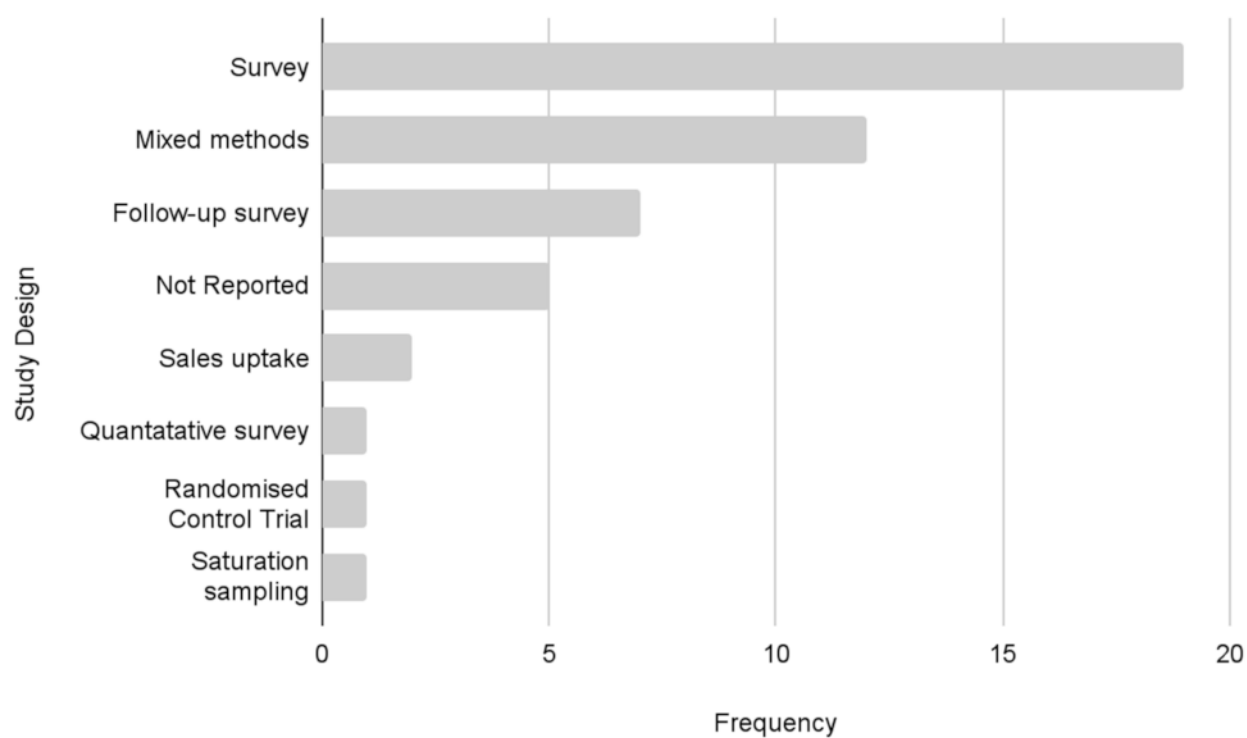


Figure 6. Study design and data collection methods.

4.2. Population Details

A total of 24 countries are represented in the evidence base across Latin America, Africa, and Asia. The most studies are reported from India (18.8%), Peru (10.4%), and Niger (8.3%) (Figure 7).

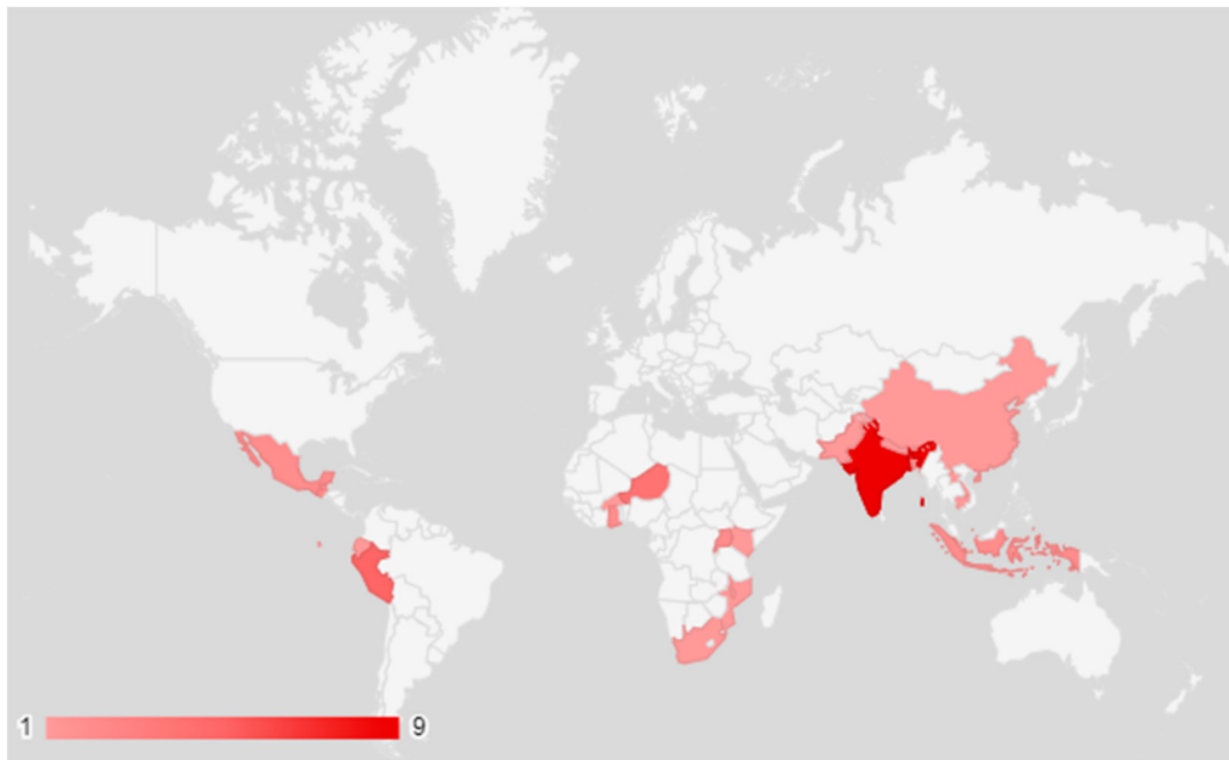


Figure 7. Geographic distribution of the evidence base.

Over half of the studies were conducted in rural regions (58.3%) with relatively few from urban areas (14.6%). Studies presenting (i) urban, peri-urban, and rural programs; (ii) urban and rural; and (iii) urban and peri-urban composed just over a quarter of the evidence base (25.1%) (Figure 8).

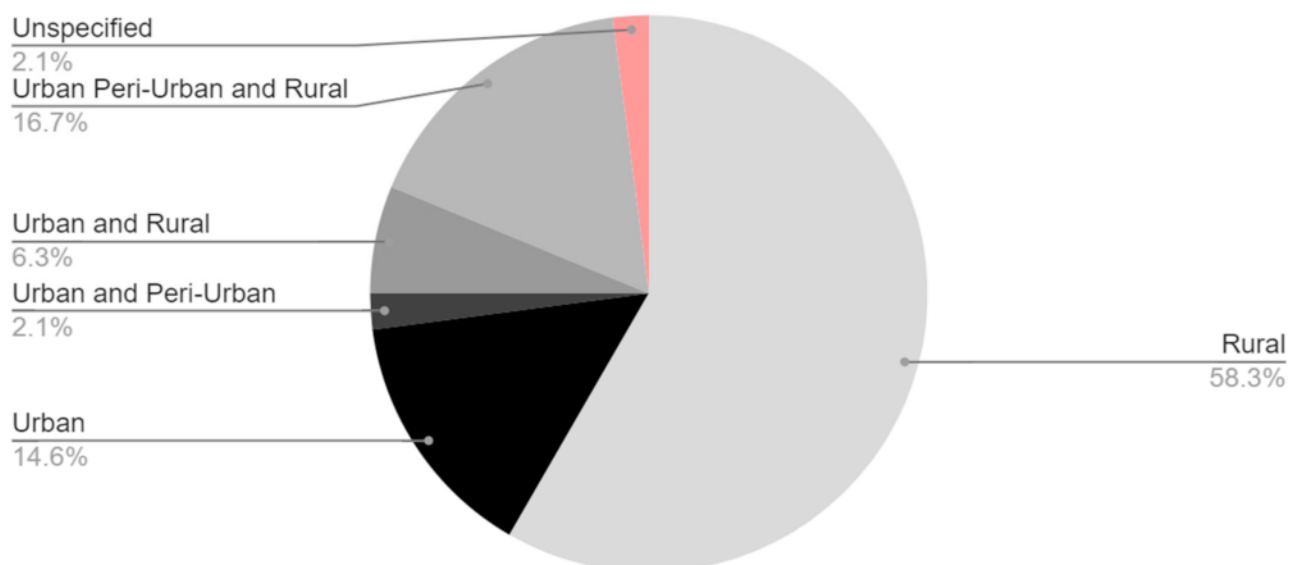


Figure 8. Study setting—Rural/Peri-Urban/Urban.

Studies primarily reported on programs that impacted less than ten thousand people (65.6%). The most common programs examined the impact on populations of <1000 people (31.3%), and between 1000 to 10,000 people (34.4%) (Figure 9).

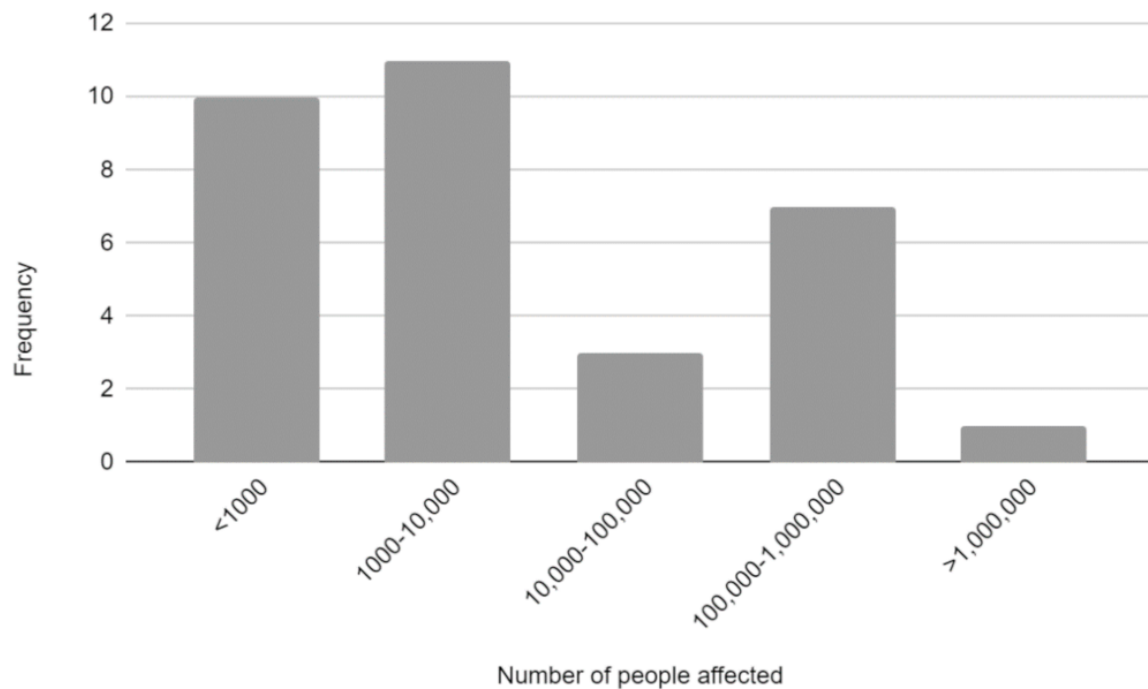


Figure 9. Grouped sizes of populations impacted by programmes presenting evidence of time-saving.

4.3. Timing and Duration of Studies

The overall length of the studies ranged from 1 month to 8 years (Figure 10), with 67% of studies lasting at least one year. The most common period of time for a study duration to last was 1 year (35%). Length of time since the intervention was implemented ranged from less than one year to 9 years; however, 26 studies did not report this important information.

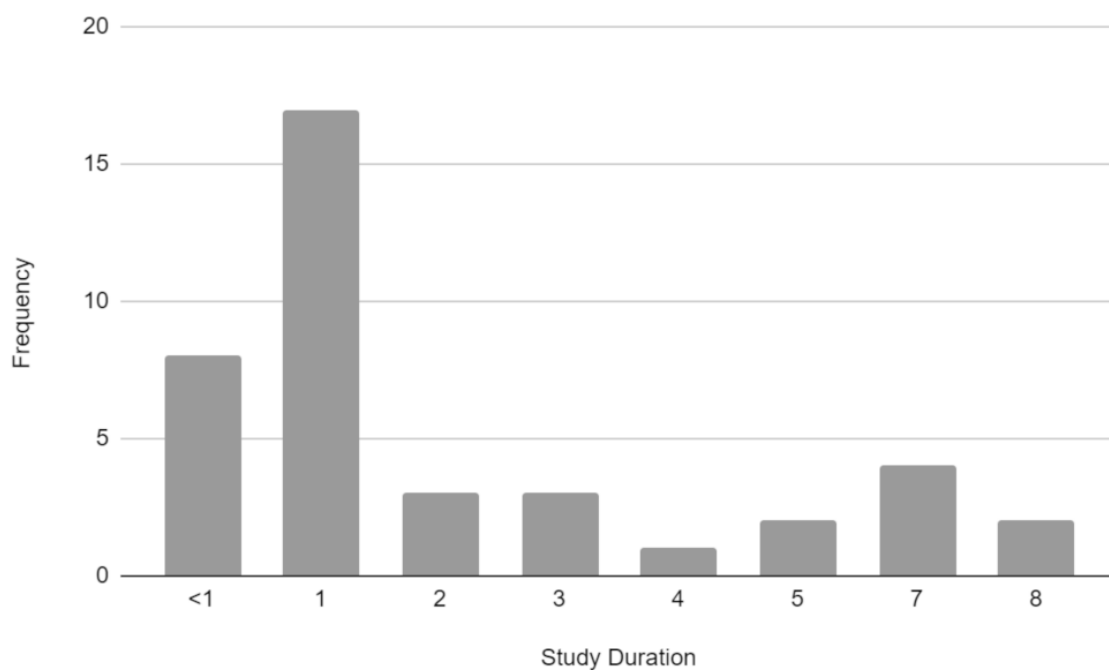


Figure 10. Frequency and duration of studies.

4.4. Fuel Use Characteristics (Showing Baseline to Target Fuel)

Most transitions of fuel were reported as fuelwood to LPG, or kerosene. LPG was the most common fuel transition (Figure 11). Note that 27 studies examined transitions from traditional biomass cookstoves to improved cookstoves without a change in baseline fuel.

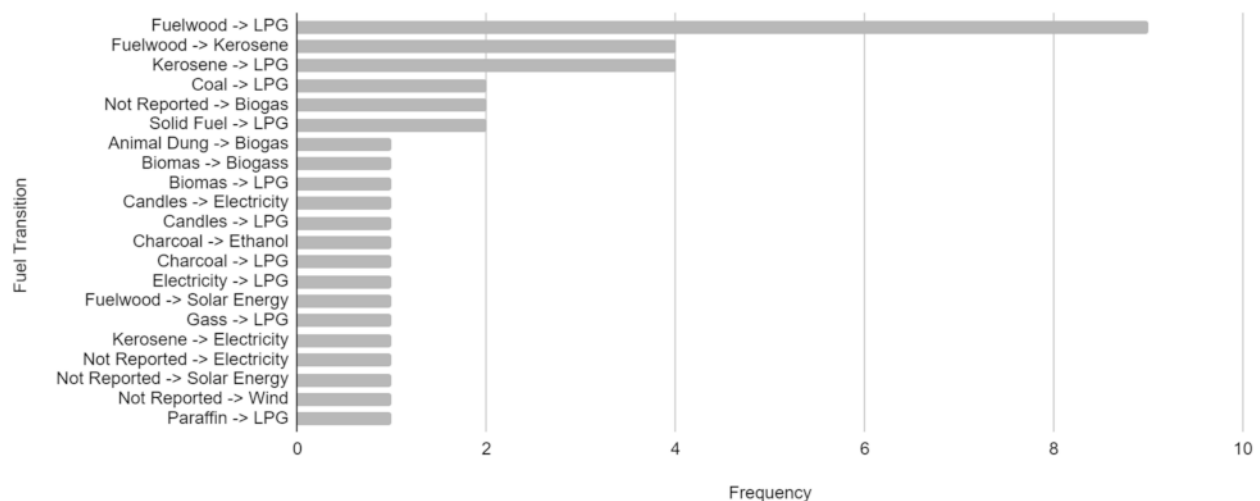


Figure 11. Characteristics of fuel use and transitions from evidenced programmes.

4.5. Possible Bias of Study Data

Around two-thirds of studies have complete data sets or missing data are accounted for, compared with a third of the evidence base where articles have not accounted for missing data and are therefore classified as potentially biased (Figure 12).

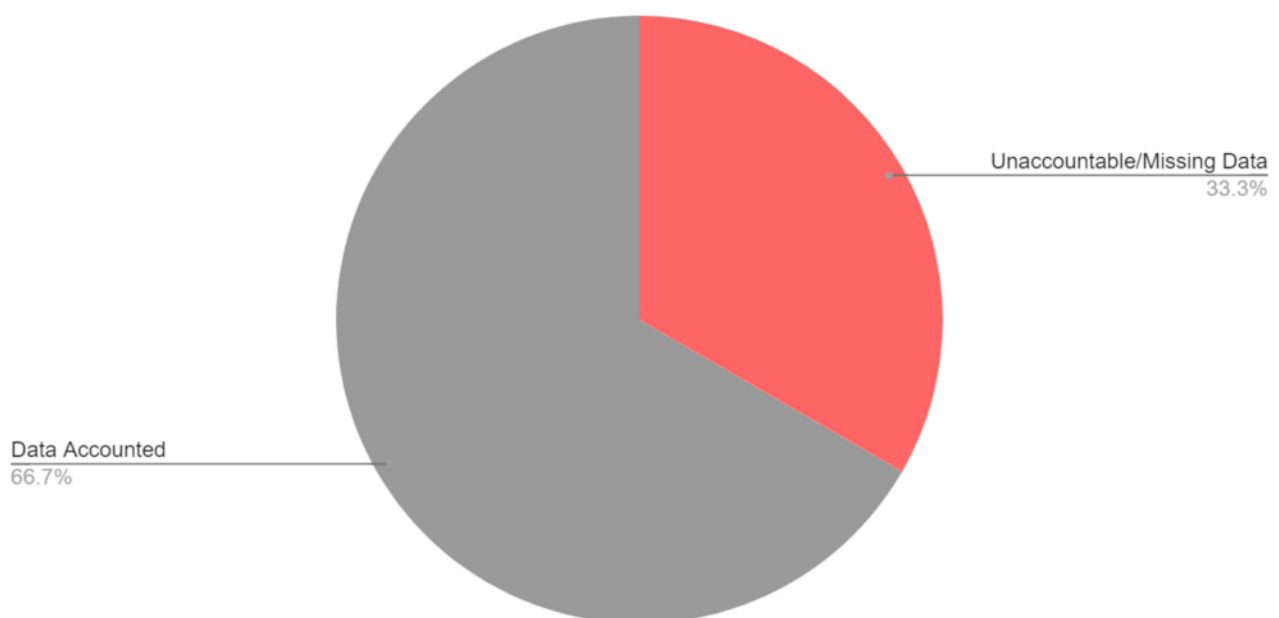


Figure 12. Reporting and accountability of data in studies.

5. Narrative Reporting of Time Saving

As explained in the Method (above), this section includes qualitative information from the included studies. Time-saving is both directly and indirectly reported across the 48 studies. Measures of timesaving have been grouped under two main categories: (i) time

saving as a driver/enabler or perceptions of time-saving following the adoption of MECS; and (ii) reported use of the saved time as a result of MECS adoption.

5.1. Time-Saving as a Driver/Enabler of MECS Adoption

Yasmin and Grundmann (2019) report that biogas adoption in Pakistan has had a positive impact on reducing drudgery, especially of women, and has promoted gender equality [21]. Time spent collecting fuelwood is particularly high in fuelwood scarce areas, where women and girls have to walk several miles to collect fuelwood. As a result of this demand, many girls drop out of school and women have less time for their children and other household activities.

Barnes et al. (2012) reported that rural women in Bangladesh and India that adopted the improved biomass cookstoves through intervention programs spent less time cooking and substantially less time collecting fuel. More than half an hour's time savings are reported in fuelwood collection, and a consequent reduction in drudgery [22].

Mobarak et al. (2012) found that financial, fuel and time costs of cookstoves dominate household decision-making in Bangladesh and that there are significant time costs associated with collecting fuel when using a traditional cookstove [23].

Sovacool & Drupady (2011) report from a study in Grameen Shakti, Bangladesh that improved cookstoves facilitate shorter cooking times. One participant from their survey stated, "I can save time, make money, and watch my children all at once." [24].

Hanna et al. (2016) reported mixed results with regard to time-saving as a perceived benefit of using an improved stove in a program in rural Orissa, India [25]. The program subsidized the construction of improved wood stoves to 15,000 households over 5 years. The study assessed 2575 of these households between 2005–2007. The self-reported satisfaction ratings show that time saving was a factor both as a reason to recommend the improved stove and a reason why it should not be recommended. The authors conclude that the satisfaction results, which do not commit the households to anything, are likely tainted by social desirability bias, and point to the limitations of self-reports generally and especially in trying to learn about how individuals value new technologies.

Wilson et al. (2018) found that women from Kalahandi, India reported one of the primary benefits of using an improved electric cook stove was that total meal preparation time was reduced [26].

Dendup & Arimura (2019) provide an indirect assessment of time savings, by assessing variables such as household size and distance to fuel collection point and its impact on clean fuel adoption in Bhutan [27]. Time-saving aspects are inferred from the convenience of obtaining fuels and the cost/value of people's time. Their finding indicates that households with more members and who live far from the clean fuel source are less likely to adopt a clean fuel. However, the household distance from the forests was not found as significant. This result is suggested to be due to the abundance of firewood in rural Bhutan, with around 70% of the country covered in forests.

Christiaensen and Heltberg (2014) reported that almost all (98%) of the rural small-holder farmers in China who had adopted biogas said biogas saved them time in cooking [28]. This was mostly women's time: women in households with biogas saved on average 1.2 h per day in cooking time. Adopters also nearly unanimously (99% of biogas users) reported time savings from having to collect less of other fuels. Women in households with biogas reported time savings of 24 days per year on average, men saved 10 days, and children saved 4 days.

Usmani et al. (2017) in a pilot study of 59 households in rural Cambodia explored whether drudgery of collecting and preparing biomass fuels is borne by women and children, who have less time to devote to education and income-producing activities as a consequence [29]. Household visits and diary checks accompanied by incentives were found to reduce the total amount of time spent collecting solid fuels.

Lee et al. (2015) found from a survey of traditional wood fuel users and LPG adopters in Indonesia, that the time it took to access a forest positively impacted people's preferences towards fuelwood use [30].

Astuti et al. (2019) found from their interviews of 44 households from across Indonesia that people did not have time to find firewood despite the abundance of wood in their area [31]. One participant reported "We cannot use firewood until we cut it into smaller pieces. It takes time". The authors also report that cooking using a firewood stove requires more time than using Kerosene.

Pachauri et al. (2013) report that time devoted by women and young children to obtaining traditional fuels restricts educational and economic opportunities across South Asia, Pacific Asia, and sub-Saharan Africa [32]. LPG stoves are reported to be around four times more efficient than biomass stoves, and hence, require fuel to provide the same amount of energy for cooking. Time could be saved by women and children through the adoption of LPG stoves, due to this time no longer needing to be spent on collecting solid fuels.

A contradictory result was reported by Dickinson, et al. (2019) in an improved stove program in rural Ghana that targeted 200 households [33]. Field tests showed that the amount of cooking time required to prepare a given mass of food was similar across all stoves using the same type of fuel, although there were some differences when meal-type was considered.

Foley et al. (1997) discuss the time implications of switching from collecting fuelwood to buying it in the context of rural to urban transitions in Niger (Niamey, Zinder, and Maradi) [34]. A survey of people reveals that growing and collecting fuelwood takes a substantial amount of time and effort. Urbanisation provides opportunities to buy and sell fuelwood and other fuels at the market. While establishing and running these markets is time-intensive, time is ultimately saved by offering the option to buy fuel instead of collecting it. The option of buying fuel combined with a shift to a more urban dietary pattern was found to have saved time, particularly for women. And that women recognised the benefits of timesaving relating to buying fuel wood, kerosene and LPG instead of collecting fuelwood.

Asante et al. (2018) report on the time-saving benefits of LPG stoves in Nkoranza North, Ghana [35]. Before LPG stoves women could spend more than two hours on cooking; however, with LPG stoves the time spent for cooking was found to be drastically reduced because LPG stoves produced immediate and constant heat.

Toonen (2009) reports that the use of improved cookstoves in Ouagadougou, Burkina Faso reduced the amount of time that is spent when cooking [36]. Time saved on gathering firewood is reported as a positive effect of the cookstove program. The Authors findings suggest that men appreciate the benefits of time-saving and encourage their wives to use the time saved to develop (more) economic activities.

Okello (2005) in an evaluation of an improved wood stove program in Kenya reports that users of the improved stove (Upesi stove) saved up to 10 h per month in collecting fuelwood [37]. He further notes that collecting fuelwood was a major driver in the adoption of fuel-saving wood-burning improved stoves. The author argues that such time savings would be an important factor in enabling women in rural areas of western Kenya to participate in the economy as stove makers and marketers of the Upesi stove.

However, it should be noted that Vulturius et al. (2017) report from their survey of 20 people in Kenya, that there were complaints concerning the additional amount of time taken to use the improved cookstoves to cook food [38].

Person et al. (2012) report that women and children from Nyanza, Kenya spend a great deal of time and labour collecting firewood [39].

Clemens et al. (2018) report that one of the most valued benefits of using improved cookstoves was saving time and/or money from interviews conducted across Kenya (61%), Tanzania (86%) and Uganda (69%) [40].

Levine et al. (2018) working Kampala and Barara survey of households reports that households in Uganda in 2010 understood the value of time-saving using improved fuel-efficient cookstoves [41]. These improved cookstoves made more efficient use of charcoal and biomass.

Seguin et al. (2018) found that reduced cooking time was among the most discussed reasons as to why improved cooking stoves were adopted in urban Rwanda [42]. One participant stated “The time I used to spend preparing meals using charcoal has decreased. Before, it could take three hours to cook beans, while now I only use an hour”.

Jagger et al. (2019) reported that the simultaneous use of other cooking technologies in addition to the improved energy system (renewable biomass pellets and a fan-micro-gasification stove) in 144 urban households in Rwanda was the most likely explanation for observing no significant reductions in total cooking fuel expenditures and primary cooks’ time spent cooking in the study [43].

Jagger and Jumbe (2016) report from a sample size of 383 households across 44 villages in Malawi, that improved cookstoves saved time when cooking (87.8%) and reduced the time spent collecting wood (98.9%) [44]. They also found that household decision-makers prioritized the value of their own time above the value of others in the household who collect fuel, including children.

Mudombi et al. (2018) found from their survey of 418 households that a large proportion of ethanol stove users in Maputo, Mozambique saved time cooking compared to those who cooked with charcoal [45].

Kimemia et al. (2016) report on the benefits of issuing free LPG equipment and subsidizing monthly refills in Atteridgeville Township, South Africa [46]. These included time-saving, lower health bills, and better household economics. Time-saving was reported as the greatest area of impact (an overall 93.6% of respondents reported ‘improved greatly’ to ‘improved somewhat’) as many users found LPG cooks faster than electricity.

Troncoso et al. (2019) found a complex picture with regard to time saved in a study in 2017 of transitions from fuelwood to LPG in two communities that had recently urbanised in Mexico [47]. Amongst the 177 respondents (of 190 randomly selected), there were claims that the use of LPG reduced cooking time and fuel collecting time and also use of fuelwood reduced cooking time. Cooking with firewood represented around 50 additional hours per month for cooking-related activities by women. Traditional practices and traditional food also presented an additional time burden, with 23–47% of productive time used to make up to 7 kilos of tortillas per day. It was noted that in one of the two townships, men decide what fuel is used, despite having no involvement with cooking. The study points to a need to investigate further the time claims and the use to which time saved could be put by women in these types of communities.

Catalan-Vazquez et al. (2018) report from their interviews in Quineceo, Turicuaru, and Mojonera, Mexico that women value time-saving when cooking [48].

The Joint United Nations Development Programme (UNDP)/World Bank Energy Sector Management Assistance Program (ESMAP) Case Studies Report (2004) from Guatemala between 1976–2002 that communities perceived time-saving as a benefit of the use of improved stoves for fuelwood [49]. The main aim of this study was to explore the potential for a national improved cookstove program and although reducing fuelwood use and improving indoor living conditions are the primary objectives of such an initiative, further research on how time saved could contribute to social benefits, particularly for women in Guatemala.

Gould et al. (2018) found from the results of their questionnaire of 5000 households in Carchi, Ecuador that LPG stoves allowed for better time management of cooking tasks including time savings from fuelwood collection; however, delivery times of LPG are reported as being long and unreliable, which participants from the survey described as a significant time burden [50].

Calzada and Sanz (2018) found in a survey of 221,390 participants from Hua manga, Peru that switching from biomass to an LPG stove saved time spent cooking and collecting fuelwood [51].

Ortiz (2012) suggests that innovations that improve the energy supply used for cooking may free up time, improve health conditions and/or reduce the cost associated with the provision of energy for cooking, or even contribute to improved sanitation from evidence collected across Peru and Laos [52].

Keese et al. (2017) report in a study from Cuzco, Peru that gathering wood takes time away from school and other productive activities for women and children, and purchasing wood is a financial drain on poor households [53]. They found that if a cookstove was mechanically effective and if people believe that they will save time collecting fuelwood, then they would be more likely to adopt a new stove.

5.2. Use of Saved Time

Pal & Sethi (2005) report that time saved through improved cookstoves (0–5–1.0 h/day) was used for income generation and leisure (rural Haryana, India) [54].

Foley et al. (1997) report for Niger that saved time from collecting fuelwood was used to develop employment opportunities for women, which in turn increased the value of their time [34]. This was found to have positive feedback on the amount of time they would spend on collecting fuel, and preparing foods compared to eating out at small cafés and kiosks serving ready cooked food].

Okello's (2005) improved woodstove program in Kenya reports that time saved was used for additional income generation, leading to improvement in standards of living [37].

Toonen (2009) reports that spare time created by improved cookstove adoption in Ouagadougou, Burkina Faso was used for other activities such as learning to sew and alphabetisation lessons [36].

Jagger et al. (2019) found that participants who signed contracts for the improved energy system in Rwanda showed a significant reduction in time spent cooking, most of which was subsequently devoted to non-agricultural activities [43].

Yadoo et al. (2012) demonstrate the time-saving benefits of infrastructural investment for women [55]. Investing in rice and flour mills has allowed women to process extra crops with the additional time resulting in additional income in Pokhari Chauri, Nepal.

Christiaensen and Heltberg (2014) observe that one-quarter of biogas adopters in rural smallholder farms in China reported that their time savings were used for more leisure, while the remainder used it for household chores and income-generating activities [28]. These benefits were considered to be important drivers of transition to biogas from fuelwood.

Calzada and Sanz (2018) report from their survey of 221,390 in Huamanga, Peru that time saved is used for child care, other domestic activities and engaging in professional activities [51].

Pollard et al. (2018) report in their study from Puno, Peru, that people that cooked with an LPG stove saved time, which allowed them to cook faster and more often [56].

6. Discussion

This study has analysed two related questions on time savings as a driver of the adoption of MECS through systematic evidence synthesis. In addition to evaluating whether studies report time savings as a motivation for MECS adoption, we also evaluated the reported value of time saved by assessing where it is directed. If a high value is placed on time then it would follow that a technology that saves time would have an appeal. Even though the role of time savings is not isolated from other reported drivers of adoption of MECS such as fuel efficiency or health, the distinct ways in which it becomes realized, and trade-offs that occur between the benefits warrants analysing it as an independent driver and offering specific recommendations based on it.

On the first outcome, the evidence is overwhelming, with nearly all the studies reporting time-saving as a direct or indirect motivation for adopting MECS. The results show clearly that traditional fuel and stoves users perceive the time burden of fuel collection and inefficient cooking and many studies reported the need to reduce this burden as a reason given by the participants for adopting the interventions. How the saved time is utilized once it has been realized; however, generated incomplete and mixed findings. Very few studies tackled this question, and the few that did provided no actual data to back up the claims that the saved time is used for education, leisure, income generation activities and a range of other portended uses. The exceptions are Calzada and Sanz [51] who report leisure, household chores and income generation as the activities the time savings are directed towards. Filling this evidence gap is important in ensuring that realistic assumptions are made on the value of clean cooking interventions. While no study reported a negative impact of time savings, a few studies observed that the time saved went into other domestic chores, including cooking and childcare; suggesting neutral effects on women's time poverty [57].

Despite the strong evidence that time-saving was one of the goals for adopting clean cookstoves, very few studies quantified the time savings that resulted from the interventions. The few studies that quantified the results present wide ranging results of 30 min savings per day to 120 min savings per day, which did not necessarily vary by intervention type. It is not surprising that few studies have quantified time savings; the same weakness is observed with studies assessing health and other benefits of cookstove interventions. Field measurements of cookstove performance by Smith et al. have revealed a threshold of exposure reduction [58] above which there would be no value promoting cookstoves for health benefits. Based on these thresholds ISO standards for cookstoves [59] were developed, focusing on health and climate benefits. A similar threshold may need to be established for time savings, given that it has a stronger appeal to users as a driver of adoption than the other benefits, and a trade-off between the multiple goals of cookstove programs may be necessary since the "triple benefits" of improved health and time savings for households, conservation of forests and associated ecosystem services, and reduced greenhouse gas emissions, have proven elusive to achieve at a cost affordable to users according to Jeuland and Pattanayak, 2012 [60].

Although the weakness of these studies does not allow us to make concrete recommendations for policy and practice, the fact that this is the first comprehensive assessment of time savings as a driver of adoption of clean cooking solutions allows us to make the following tentative recommendations, which require further research to validate.

- (1) Cookstoves do not need to realise high-end benefits like climate and health protection to warrant promotion. The overwhelming evidence that time savings are an important driver of adoption should lead to the design of technologies that maximise these benefits through multiple pathways such as multi-burner stoves that allow for simultaneous cooking, technologies that do not come with additional time burden, and solutions that make it easy to access and process fuels to be used on those stoves.
- (2) The fact that there is no evidence from this study on the value of saved time should not be interpreted as evidence of absence. More qualitative studies are needed to be able to identify a potential range of benefits of the saved time to emerge from the participants themselves. In one such investigation (Ochieng et al., 2020) a strong link emerged between time savings from the adoption of clean cookstoves and the ability of school-going children to have their meals on time and not miss lessons or bedtime [13].

It is noteworthy that there are very few studies that appear to integrate problems of deforestation with the problems faced in incentivizing people to transition from traditional fuels to modern energy systems. Of those in the current evidence base, Lee et al. [30] argue that collecting fuelwood in Lombok, rural Indonesia, is a symptom rather than a driver of deforestation and forest degradation. Foley et al. [34] report the environmental impact of fuelwood cutting in Niamey, Zinder, Maradi, and Tahoua in Niger during the 1970's was

viewed as a major cause of deforestation and that concerns were expressed surrounding the effects of deforestation on the sustainability of local agricultural systems. Clemens et al. [40] found from their survey of half a million households that donor finance and subsidies for biogas helped to reduce deforestation across Kenya, Tanzania, and Uganda between 2009–2017, through reductions in fuelwood consumption. Pal & Sethi [54] report fuel shortages in rural areas of Haryana, India due to deforestation. It would be beneficial to bring together the two ‘silos’ of work on these important topics.

Key recommendations

1. Undertake primary research to understand the following questions, which represent significant evidence gaps:
 - i. Is time-saving a driver or enabler of adoption to modern energy?
 - ii. Do people adopting improved cookstoves and/or modern energy sources realize the time savings benefit?
 - iii. How do people spend the time they save?
2. Improve the integration of programs and interventions on deforestation prevention and forest restoration with those on transitions to modern energy systems. The evidence bases for these two key SDG concerns.
3. Use the evidence base compiled here to explore the possibility of producing a decision-making model about the benefits to women’s lives of adopting modern energy cooking systems in different contexts and regions.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/f12091149/s1>, Annex 1—Evidence sources and test set of documents. Annex 2—Extracted data and coding of all included studies in the evidence base.

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