Tackling chronic respiratory disease in low-resource settings

Brakema, E.A.

CHAPTER

FACILITATORS AND BARRIERS TO THE IMPLEMENTATION OF IMPROVED SOLID FUEL COOKSTOVES AND CLEAN FUELS IN LOW-INCOME AND MIDDLE-INCOME COUNTRIES: AN UMBRELLA REVIEW

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SUMMARY

2.6 billion people rely on solid fuels for cooking or heating. Accelerating access to cleaner solutions is critical to reduce the negative effects of solid fuel use. Despite abundant evidence on how to implement these solutions, previous attempts have been disappointing. An overview of the evidence is lacking and translation of the evidence to practice is limited. We conducted an umbrella review using eight databases to consolidate evidence on factors that influence the implementation of improved solid fuel cookstoves and clean fuels in low-income and middle-income countries, weigh the level of confidence in existing evidence, and develop two practical implementation strategy tools. We identified 31 relevant reviews consisting of 13 systematic and 18 narrative reviews, covering over 479 primary studies. We found 15 implementation factors supported by the highest level of evidence. Regarding improved solid fuel cookstoves these included 'cost', 'knowledge & beliefs about the innovation', and 'compatibility'. For clean fuels these included 'cost', 'knowledge & beliefs about the innovation', and 'external policy & incentives'. The factors were synthesised into the Cleaner Cookstove Implementation Tool (CleanCIT) and the Clean Fuel Implementation Tool (CleanFIT). These tools can be used to optimise implementation, thereby improving health, environmental, climate, and gender equity outcomes.

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INTRODUCTION

Every day, 2.6 billion people use traditional solid and polluting fuels and rudimentary stoves to cook or to heat their homes, mainly in low-income and middle-income countries (LMICs).[1] These traditional technologies negatively impact health (leading to both chronic and acute ailments and to premature mortality), the environment (forest degradation and deforestation), and the climate crisis (emissions of greenhouse gases and black carbon).[2-4] Because many women have primary responsibility for cooking tasks, they bear a disproportionate share of the negative health risks from household air pollution. Additionally, women and children often spend several hours a day on cooking-related tasks including fuel collection, food-processing activities, cooking, and cleaning, resulting in time poverty (less time for education, rest and leisure, and income-generating activities).[2] Cleaner cooking interventions could offer a solution. In view of the negative effects on health, climate, and gender, opportunity costs of not transitioning to cleaner cooking solutions (including deaths, disability-adjusted life years, carbon prices, and women's time) are estimated at US$2.4 trillion per year.[2] Cleaner cooking solutions include improved solid fuel cookstoves (subsequently referred to as cleaner cookstoves) and clean fuels. Cleaner cookstoves are defined as any improvement from an open fire, traditional inefficient

stove, or a kerosene stove. They include improved wood stoves, pellet stoves, and briquette stoves. Clean fuels include electricity, liquefied petroleum gas (LPG), natural gas, biogas, solar cookers, and alcohol fuels, and their corresponding technologies.[5] Clean fuels are expected to have the largest impact on health, environment, climate, and gender equity and are therefore critical to achieving substantial gains.[6] Cleaner cookstoves, on the other hand, generally have limited effects on household air pollution, as emission levels often remain above the WHO-Air Quality Guideline levels.[5] Nevertheless, as clean fuels are unlikely to be widely available in the near future, cleaner cookstoves are needed in the interim.[2,7]

Successful implementation, defined as the sustained (more than one year of use after acquisition) and predominant use of cleaner cooking solutions, is crucial to achieving health, environmental, climate, and gender equity improvements.[3,7] Decades of experience has shown that the implementation of cleaner cooking interventions is both challenging and complex.[7] Even where transition is achieved, uptake is often only partial (also referred to as stacking).[8] A successful implementation process requires the involvement of multiple sectors including, amongst others, the social, environmental, political, health, and financial sectors. Furthermore, the involvement of multiple stakeholders is needed, such as intended users and local groups, local and national governments, financial institutions, commercial enterprises, and non-governmental organisations. Besides, a successful implementation process requires careful attention to contextual factors on a micro-level (e.g. household factors), meso-level (e.g. wider context-specific conditions), and macro-level (e.g. policies). Implementation science provides a multi-sectoral and systematic approach to this challenge.[7,9] Identifying and pragmatically structuring factors that enable or limit implementation can improve understanding of the implementation process, which in turn may lead to improved evidence-based implementation strategies that accelerate the widespread access to cleaner cooking interventions.[7]

To date, hundreds of studies have assessed the implementation process of cleaner cooking interventions and dozens of literature reviews have been conducted. However, the implementation success of cleaner cooking interventions is generally considered poor.[10,11] Although a plethora of evidence exists, an up-to-date overview is lacking and there is little translation of academic evidence to help guide implementation in practice. Therefore, in this umbrella review we consolidated all available evidence from existing literature reviews covering factors that influence the acquisition, initial adoption, and sustained use of cleaner cookstoves and clean fuels in LMICs. Furthermore, we weighed the level of confidence in the evidence for these factors and translated our findings into two practical tools for developing evidence-based implementation strategies for future cleaner cooking interventions. In conducting our umbrella review, we address the following question: which factors enable or hamper acquisition, initial adoption, and sustained use of cleaner cookstoves and clean fuels with corresponding technologies in LMICs and what is the level of confidence in the evidence supporting these factors?

METHODS

This umbrella review (review of systematic and narrative reviews) was part of a broader review conducted by Brakema et al.[12] as part of the Horizon 2020 Free Respiratory Evaluation and Smoke exposure reduction by primary Health cAre Integrated gRoups (FRESH AIR) project.[13] The study was registered with PROSPERO (CRD42018088687) and a peer-reviewed study protocol is available.[14] Due to a lack of reporting standards for umbrella reviews (currently under development[15]), we followed the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) reporting standard.[16]

Panel 1: Search strategy and selection criteria

Sources: PubMed, Embase, Global Health Database, Cochrane, PsycINFO, Emcare, Web of Science, and CINAHL

Date or language restrictions: None

Search terms: (Synonyms of) implementation, LMICs, and interventions targeting chronic lung health, including cleaner cooking interventions (for full details, see appendix pp 2-3)

Inclusion criteria: Reviews were included if they

- Reported on facilitators and/or barriers to the implementation (acquisition, initial use, or sustained use) of cleaner cookstoves or clean fuels
- Were systematic and narrative reviews that covered quantitative, qualitative, or mixed-methods studies[17]
- Were peer-reviewed
- Regarded rural or urban settings in LMICs (as defined by the World Bank classification[18])
- Addressed a switch from either traditional cookstoves or kerosene stoves (hence, changes from one clean fuel to another clean fuel, from a cleaner cookstove to a clean fuel, or from a cleaner cookstove to another cleaner cookstove were excluded)

Exclusion criteria: Factors were excluded if they were solely based on hypothetical interventions or speculations

Search strategy

Reviews were originally identified during a search conducted in a broader review by Brakema et al.[12] The search was developed together with a certified librarian (panel 1). The search was performed on the 23rd of October 2017 and updated on the 10th of July 2019. Two experts in the field of cleaner cooking (researchers and members of the clean cooking implementation science network; see acknowledgements) were consulted to identify relevant reviews up to the 13th of January 2022. Full details, including the search strategy, are available in the protocol and appendix pp 2-3.[14]

Selection criteria

Selection criteria are provided in panel 1. Because we anticipated limited evidence in the literature concerning implementation factors that influence sustained use, we also included acquisition (purchase or installation) and initial adoption (use for less than one year from acquisition) in this review.[19] A distinction was made between cleaner cookstoves and clean fuels, as we expected that the factors determining implementation success of each would differ. The protocol stated that articles would be excluded if they focused on legislation at a national governmental level.[14] Nevertheless, we decided to include these articles as we felt we could not neglect the central role that governments play in implementing national policies and strategies that prioritise cleaner cooking, in developing and enforcing regulations and standards, and in enlarging and investing in infrastructure.[2] Review selection, including title and abstract screening and full-text screening, was conducted using independent verification by two or more authors.

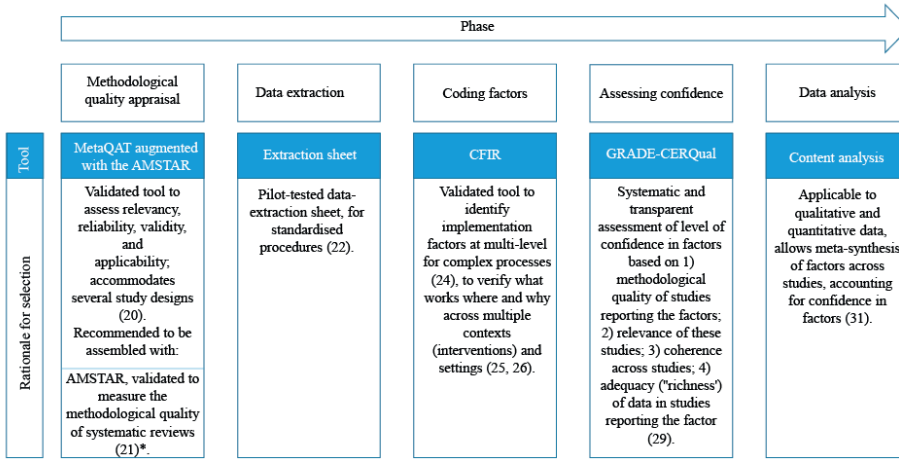

FIGURE 1: Tools applied in each phase, adapted from Brakema et al.[12] and reproduced from Boudewijns et al. with permission from BMJ Publishing Group Ltd[14].

Quality appraisal and data extraction

Reviews were appraised and data were extracted and analysed in five steps using validated tools (Figure 1). Two researchers conducted all steps independently and a third researcher was consulted to resolve any disagreements. First, the methodological quality of the reviews was appraised using the Meta Quality Appraisal Tool (MetaQAT).[20] This tool is validated to assess the relevancy, reliability, validity, and applicability of studies, and accommodates several study designs. The tool was augmented with the Assessment of Multiple Systematic Reviews (AMSTAR) tool

(see appendix pp 4-10 for further details).[21] The MetaQAT/AMSTAR tool contains descriptive rather than numeric appraisals and is designed to document relevant information to enhance transparency. The results of the quality appraisal provided the basis for assessing confidence in the evidence during step four. This approach accounted for risk of biased recommendations from narrative reviews during the meta-synthesis. Second, data on descriptive review characteristics and factors influencing the implementation of cleaner cooking interventions were extracted using standardised data extraction forms and were summarised in tables (appendix pp 11-21).[22] We did not distinguish between facilitators and barriers, as reversed facilitators can often be interpreted as barriers and vice versa.[12,23] Both modifiable (e.g. fuel accessibility) and non-modifiable factors (e.g. age) were extracted.

Evidence synthesis

The third step involved the coding of factors that influence the implementation of cleaner cooking interventions using the Consolidated Framework for Implementation Research (CFIR).[24] This is a validated tool to identify implementation factors for complex processes from a multilevel perspective, in order to verify what works where and why across multiple contexts and settings (appendix pp 22-70).[24-26] The CFIR is recommended for use in environmental health areas.[27,28] The framework includes five domains, each including several constructs: 1) intervention characteristics, 2) outer setting, 3) inner setting, 4) characteristics of individuals involved, and 5) the implementation process.[24] During the fourth step, confidence in the evidence of the extracted factors was calculated using the Grading of Recommendations Assessment, Development, and Evaluation-Confidence in the Evidence from Reviews of Qualitative research (GRADE-CERQual) tool.[29] The GRADE-CERQual can be applied to several fields, including environment and international development.[30] This tool consists of four domains: methodological limitations, relevance, coherence, and adequacy. For each of these domains, we assigned a score per included review, ranging from one point (substantial concerns) to four points (no to very minor concerns).[29] A score for coherence was not assigned, as the fit between the data was taken into account during the content analysis (step five). The score for the methodological limitations was based on the reliability and validity category of the Meta-QAT/AMSTAR tool; the score for relevance was based on the relevance category of the Meta-QAT/AMSTAR tool; and the score for adequacy was based on the data sources (appendix p 71). The content analysis allowed for meta-synthesis of factors across reviews while accounting for confidence in factors.[31,32] This step was conducted separately for factors influencing the implementation of cleaner cookstoves and clean fuels. Reviews that did not distinguish between factors for cleaner cookstoves and clean fuels were included in both analyses. For each factor (categorised by the CFIR), we determined a score by multiplying the score for the quality of the review in which the factor was mentioned (step four) by the number of reviews in which the factor was mentioned (appendix pp 72-81). To account for varying levels of reporting detail across reviews, each CFIR construct was taken into account only once for each review, even though various implementa-

tion factors were coded to the same CFIR construct (e.g. age and household composition are different implementation factors, but we used the same CFIR construct 'other personal attributes' for both). Finally, we calculated the overall level of confidence in the factors by totalling the scores of the three domains. Hence, higher score indicates higher adequacy, relevance, and/or quality of the review, and/or a higher frequency of the factor. The implementation factors supported by evidence with the highest level of confidence, including the level of evidence and practical examples, were consolidated in a comprehensive overview.

Different systematic reviews may include the same primary studies, resulting in double counting of certain evidence. Therefore, a matrix of primary studies included in systematic reviews was prepared to gain insight into double counting of primary studies.[33] Because narrative reviews often do not present the studies included, narrative reviews were not included in the matrix (appendix pp 82-112).

Role of the funding source

The funders had no role in study design, data collection, data analysis, data interpretation, or writing of the article.

RESULTS

From a screening of 9111 unique articles, 31 reviews were included, of which 13 were systematic[6,23,34-44] and 18 were narrative[3,8,45-60] reviews (Figure 2). The systematic reviews included 479 unique primary papers. The included reviews were published between 1992 and 2022 and were conducted in a variety of geographical settings. Twelve reviews reported factors affecting the implementation of clean fuels, including electricity, LPG/bottled gas, biogas, solar cookers, and alcohol fuels (ethanol and methanol). It should be noted that two reviews included kerosene as a clean fuel.[36,53] Eighteen reviews described implementation factors concerning (a wide variety of) cleaner cookstoves, seven reviews reported separate factors for cleaner cookstoves and clean fuels, and eight reviews did not differentiate between cleaner cookstoves or clean fuels. Details of the included reviews are provided in Table 1 and appendix pp 7-20.

Quality appraisal

Twenty-two articles achieved a high score for relevance in the MetaQAT, nine articles achieved a medium relevance score, and none had a low score (appendix pp 7-10). The reliability of the included articles varied, with eleven articles achieving a high score, ten a medium score, and ten a low score. The main reasons underlying low or medium reliability were unclear reporting of methods and lack of information on data sources. In terms of validity, seven, fifteen, and nine articles achieved a high, medium, or low score, respectively. Lower scores were often due to risk

of bias, methodological flaws (e.g. no duplicate data extraction and no assessment of the quality of included studies), or unclear reporting of analytical methods. The applicability score was high for seventeen articles and medium for fourteen articles. The kappa with linear weighting was 0.56, indicating moderate reviewer agreement. The systematic reviews had limited overlap in the primary studies they had included (see appendix pp 82-112).

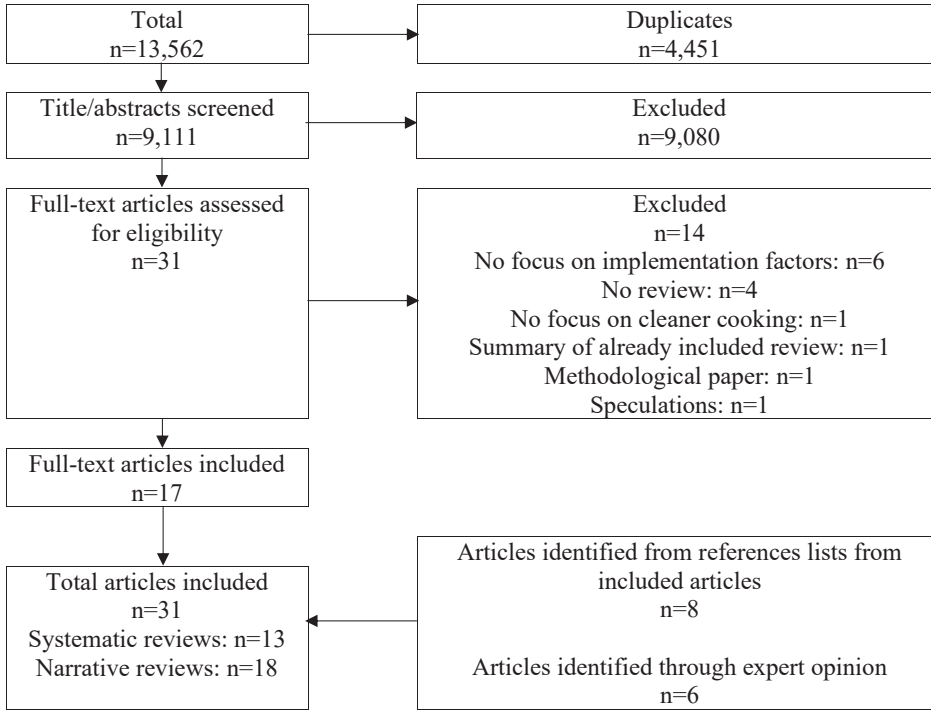

FIGURE 2: Diagram outlining study selection

Implementation factors and the Cleaner Cookstove Implementation Tool (CleanCIT)

We found that the influence of factors on successful implementation varied markedly depending on the technology being introduced and the specific context. The 15 factors (CFIR constructs) for which the level of confidence in supporting evidence was highest, based on our content analysis, were summarised in a practical tool (CleanCIT) (Figure 3). Examples of each factor are included in appendix pp 113-114, and a full list of factors for each CFIR construct is included in appendix pp 29-49. The three factors with the best supporting evidence for an influence on implementation accounted for 19% of the sum scores of the content analysis and are described below.

TABLE 1: Characteristics of the included reviews

First author, year [reference]	Study design	Intervention[1]
Barnes, 1993 [45]	Narrative review	**Stove:** Improved cooking stoves (different types)
Bonan, 2017 [46]	Narrative review	**Stove:** Improved cookstoves (all kinds of innovation) **Fuel:** Electricity connection (on-grid, off-grid and decentralized power provision both micro photovoltaic and home solar system, and improvements in the quality of the electricity supply)
Clemens, 2018 [47]	Narrative review	**Fuel:** Biodigester implementation through market development (Africa Biogas Partnership Program)
Energy Sector Management Assistance Program (ESMAP), 2020 [34]	Systematic review	**Stove and fuel (no distinction):** Modern Energy Cooking Services (transition is treated as any upward movement from a baseline cooking system to an improved one, as defined by the studies and programs evaluated)
Furszyfer Del Rio, 2020 [43]	Systematic review	**Stove:** Improved cookstoves
Gall, 2013 [48]	Narrative review	**Stove:** Improved cookstoves
Gill-Wiehl, 2021 [49]	Narrative review	**Stove and fuel (no distinction):** Improved biomass stoves, biogas, LPG, electricity, ethanol, natural gas, solar oven/cooker
Goodwin, 2015 [35]	Systematic review	**Stove and fuel (no distinction):** Cleaner cooking interventions
Guta, 2022 [44]	Systematic review	**Stove:** Improved biomass stove **Fuel:** Electric stove, LPG, biogas, solar cooker/heater, and ethanol
Karanja, 2019 [50]	Narrative review	**Stove and fuel (no distinction):** Clean bioenergy cookstoves (improved biomass stoves, biomass gasifier stoves, biogas stoves, and ethanol stoves)
Khandelwal, 2017 [51]	Narrative review	**Stove:** Improved cookstoves
Kowsari, 2011 [52]	Narrative review	**Stove and fuel (no distinction):** Modern energy systems
Leach, 1992 [53]	Narrative review	**Fuel:** Modern energy sources (among others LPG/bottled gas, kerosene, electricity)
Lewis, 2012 [36]	Systematic review	**Stove:** Improved cookstoves **Fuel:** Clean fuels (kerosene, LPG, electricity, or solar)
Lindgren, 2021 [61]	Narrative review	**Stove:** Biomass improved cookstoves (e.g. rocket, forced air, gasifier or top lift updraft stoves, addition of a chimney) **Fuel:** Solar cookers
Martinot, 2002 [55]	Narrative review	**Stove:** More efficient biomass stoves **Fuel:** Renewable energy (biogas stoves and solar cookers)
Mittal, 2018 [37]	Systematic review	**Fuel:** Small-scale biogas plants

First author, year [reference]	Study design	Intervention[1]
Puzzolo, 2016 [6]	Systematic review	**Fuel:** Clean fuels (LPG, biogas, solar cooking, and alcohol fuels)
Puzzolo, 2019 [56]	Narrative review	**Stove and fuel (no distinction):** Clean fuels: electricity (grid and photovoltaic), LPG, alcohol fuels (ethanol/methanol), biogas, compressed biomass pellets
Quinn, 2018 [57]	Narrative review	**Stove and fuel (no distinction):** LPG, biogas digesters and stoves, ethanol, compressed biomass fuels (pellets and briquettes); all meeting the ISO Tier-4 standard for emissions
Rehfuess, 2014 [23]	Systematic review	**Stove:** Improved solid fuel stoves
Ruiz-Mercado, 2011 [3]	Narrative review	**Stove and fuel (no distinction):** Clean fuels and cookstoves
Shankar, 2014 [58]	Narrative review	**Stove:** Improved cookstoves
Shankar, 2020 [8]	Narrative review	**Stove:** Biomass pellets **Fuel:** LPG, electric/induction cooking, ethanol, biogas
Sharma, 2017 [59]	Narrative review	**Stove:** Improved cookstoves (forces draft gasification and natural draft combustion/gasification)
Shen, 2015 [38]	Systematic review	**Stove:** Clean cookstoves **Fuel:** Clean fuels
Stanistreet, 2014 [39]	Systematic review	**Stove:** Improved solid fuel stoves
Thomas, 2015 [40]	Systematic review	**Stove:** Improved stove interventions
Thurber, 2013 [41]	Systematic review	**Stove:** Improved biomass cookstoves
Van der Kroon, 2013 [60]	Narrative review	**Fuel:** Modern forms of energy (e.g. electricity and LPG)
Vigolo, 2018 [42]	Systematic review	**Stove:** Improved cooking stoves

1 Bold text = paper included in analysis of cleaner cookstoves, clean fuels, or both.

The factor associated with the highest level of evidence regarding implementation was cost. High initial costs, lack of access to credit, and ongoing costs for maintenance were reported as key barriers to the acquisition and sustained use of cleaner cookstoves in several reviews. As the price of a cleaner cookstove is comparatively high relative to the purchasing power of a lower income household (and compared to traditional stoves that are produced at no cost), reviews recommended considering ways to facilitate the purchase. Addressing affordability constraints, e.g. by community lending schemes, price incentives, or free repairs, could to some extent address the high upfront costs. Evidence supporting a role for subsidies was inconsistent, with some reviews reporting that subsidies facilitated adoption, while others reported that adoption rates for cleaner cookstoves did not increase.

The second best supported factor was knowledge & beliefs concerning the innovation. Reviews showed that a higher level of education is generally positively associated with the adoption of cleaner cookstoves. A lack of prior knowledge about available cookstoves or the consequences of cooking with traditional and inefficient stoves inhibited the transition. Programs that used behaviour change techniques, including shaping knowledge and social support, reported higher adoption rates than those without. Public cooking demonstrations, training sessions, and campaigns are useful tools for communicating the advantages of cleaner cookstoves to a community. It is recommended that all implementation efforts anticipate the value that end users place on cleaner cookstoves, including safety, cleanliness, home improvement, and short-term health benefits.

The third best supported factor influencing implementation was compatibility. Many programs failed to accommodate the fact that the specifics of cooking vary by culture, geography, season, fuel type, local practices, and cooking needs. Several reviews reported that cleaner cookstoves suitable for the preparation of local dishes were preferred. Examples of facilitators of implementation included the suitability of the stove to meet the household's cooking demands, the ability to accommodate multiple fuels, fuel sizes and pot types, the fit of the stove in the typical kitchen space, technologies that did not affect the taste of food, and compatibility with current cooking schedules. A few reviews indicated that the additional energy services obtained from traditional stoves, such as heating and lighting, was a factor hindering adoption of cleaner cookstoves. Furthermore, a cleaner cookstove needs to be compatible with cultural practices, traditions, and beliefs.

Other factors associated with high confidence in the level of evidence included design quality & packaging, relative advantage, physical ability to change, delivery infrastructure, external policy & incentives, other personal attributes, access to knowledge & information, available resources, peer pressure, needs & resources of users, engage innovation participants, and reflecting & evaluating. In total, 44 factors (constructs) are included in the CFIR, of which 37 were reported to influence the implementation of cleaner cookstoves in various reviews (Figure 4).

Implementation factors and the Clean Fuel Implementation Tool (CleanFIT)

The 15 constructs supported by evidence with the highest level of confidence are summarised in the CleanFIT in Figure 5. Practical examples of each factor are included in appendix pp 115-116, and a full list of factors for each CFIR construct is included in appendix pp 50-70. The three factors with the best evidence for influencing implementation of clean fuels and corresponding technologies, covering 21% of the total sum scores of the content analysis, are described below.

Factors best supported by evidence in descending order	Description
	Consider initial and regular costs of the cleaner cookstove, including limited access to credit
	Take into account individuals' attitudes toward and value placed on the cleaner cookstoves as well as familiarity with facts and principles related to the cleaner cookstove
	Ensure compatibility between the local context (e.g. cultural and environmental conditions) and the cleaner cookstove
	Secure that the quality, including the presentation and assemblage, of the cleaner cookstove is good
	Ensure that there is a perceived advantage of the cleaner cookstove as compared to the traditional stove
	Understand the economic and non-economic factors within a household that determine the individual's ability to change
	Ensure that the infrastructure for delivery and maintenance of the cleaner cookstoves is available, of high quality, and reliable
	Understand and support external strategies to spread cleaner cookstoves, including policies, subsidies, regulations, legislation, and standards
	Take into account other personal traits, including the age and gender of the individual
	Facilitate access to knowledge and information about the cleaner cookstove and how to use it
	Secure sufficient resources for the implementation process and ongoing operations
	Be aware of the role that peers and social networks play in the decision to adopt the cleaner cookstove, in positive or negative ways
	Explore and accurately prioritise the needs of intended users
	Engage the end-users in the development, implementation, and use of the cleaner cookstoves
	Ensure feedback about the progress of the implementation and the quality of the cleaner cookstoves

FIGURE 3: The CleanCIT, evidence-based implementation strategy tool for cleaner cookstoves; the order reflects the level of evidence for the factor (not its importance). Practical examples are provided in appendix pp 113-114 (photo used with permission of copyright owner and the individual pictured)

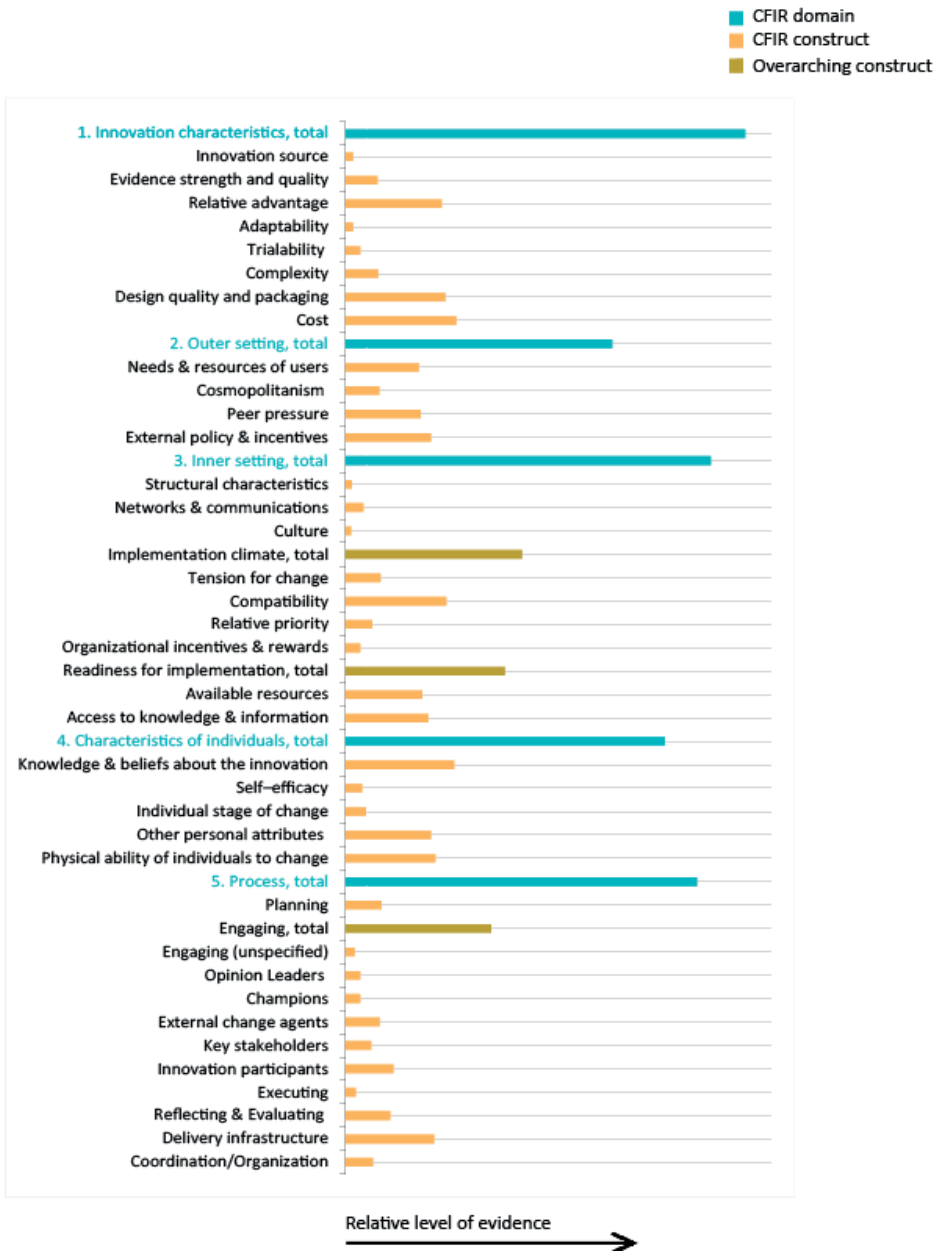

FIGURE 4: Overview of implementation factors per domain and relative levels of evidence for the factors for cleaner cookstoves. Bar sizes indicate the relative certainty as to whether the factor influences implementation, CFIR (overarching) constructs are described in appendix pp 22-27 and at https://cfirguide.org/.

Factors best supported by evidence in descending order	Description
	Consider initial and regular costs of the clean fuel and corresponding technology, including limited access to credit
	Take into account individuals' attitudes toward and value placed on the clean fuel and corresponding technology as well as familiarity with related facts and principles
	Understand and support external strategies to spread the clean fuel and corresponding technology, including policies, subsidies, regulations, legislation, and standards
	Understand the economic and non-economic factors within a household that determine the individual's ability to change
	Ensure that the infrastructure for delivery and maintenance of the clean fuel and corresponding technology is available, of high quality, and reliable
	Take into account other personal traits, including the age and gender of the individual
	Ensure compatibility between the local context (e.g. cultural and environmental conditions) and the clean fuel and corresponding technology
	Secure that the quality, including the presentation and assemblage, of the clean fuel and corresponding technology is good
	Secure sufficient resources for the implementation process and ongoing operations
	Ensure that there is a perceived advantage of the clean fuel and corresponding technology as compared to the traditional fuel/stove
	Be aware of the role that peers and social networks play in the decision to adopt the clean fuel and corresponding technology, in positive or negative ways
	Facilitate access to knowledge and information about the clean fuel and corresponding technology and how to use it
	Minimise the perceived difficulty of the intervention, such as the radicalness and intricacy required to implement
	Understand the degree to which stakeholders perceive the current situation as intolerable or needing change
	Explore and accurately prioritise the needs of intended users

FIGURE 5: The CleanFIT, evidence-based implementation strategy tool for clean fuels; the order reflects the level of evidence for the factor (not its importance). Examples are provided in appendix pp 115-116 (photo used with permission from owner and person on the picture)

Similarly to the analysis of cleaner cookstoves, the factor associated with the highest level of evidence regarding implementation was cost. Affordability constraints concerning the upfront capital costs of the clean fuel technology, ongoing fuel costs, and maintenance were all reported as barriers to successful implementation. Monetary incentives, including subsidies, were often reported to increase adoption, although they may also limit adoption upon withdrawal. Several reviews recommended ensuring access to credit and avoiding lumpsum payments. The main role of fuel prices was to cause a shift between fuels among those households that use several fuels, with fuel price differentials being more likely to result in a 'backward' substitution than an 'upward' transition.

The second best supported factor was knowledge & beliefs regarding the innovation. As seen with the adoption of cleaner cookstoves, several reviews identified a positive relationship between education level and a switch to clean fuels and corresponding technologies. Knowledge and awareness of the benefits of using clean fuels enabled adoption. Perceptions of cleanliness (e.g. no soot/ash), home improvement, and safety were often mentioned as highly valued by end users.

External policy & incentives was the third best supported factor influencing implementation. This includes external strategies to promote the adoption and use of clean fuels and corresponding technologies, including policies, subsidies, regulations, legislation, and standards. Examples were policy changes that lead to higher income levels or financial support targeted to the poor, a government's commitment to the provision of infrastructure, as well as market and trade policies, including supportive and effective instruments for regulation, certification, and standardisation. Furthermore, the need for collaborative action to promote behavioural change and/or to create a conducive policy environment was highlighted.

Other factors well-supported by evidence included physical ability to change, delivery infrastructure, other personal attributes, compatibility, design quality & packaging, available resources, relative advantage, peer pressure, access to knowledge & information, complexity, tension for change, and needs & resources of users. In total, we identified 36 factors (constructs) in the reviews that influence the implementation of clean fuels and corresponding technologies (Figure 6).

Similarities and differences between the implementation of cleaner cookstoves and clean fuels

Most factors supported by a high level of evidence were found to influence the implementation of both cleaner cookstoves and clean fuels, although we found some differences in the level of supporting evidence. For example, external policy & incentives was supported by a higher level of evidence for clean fuels compared to cleaner cookstoves. This could be due to the influence

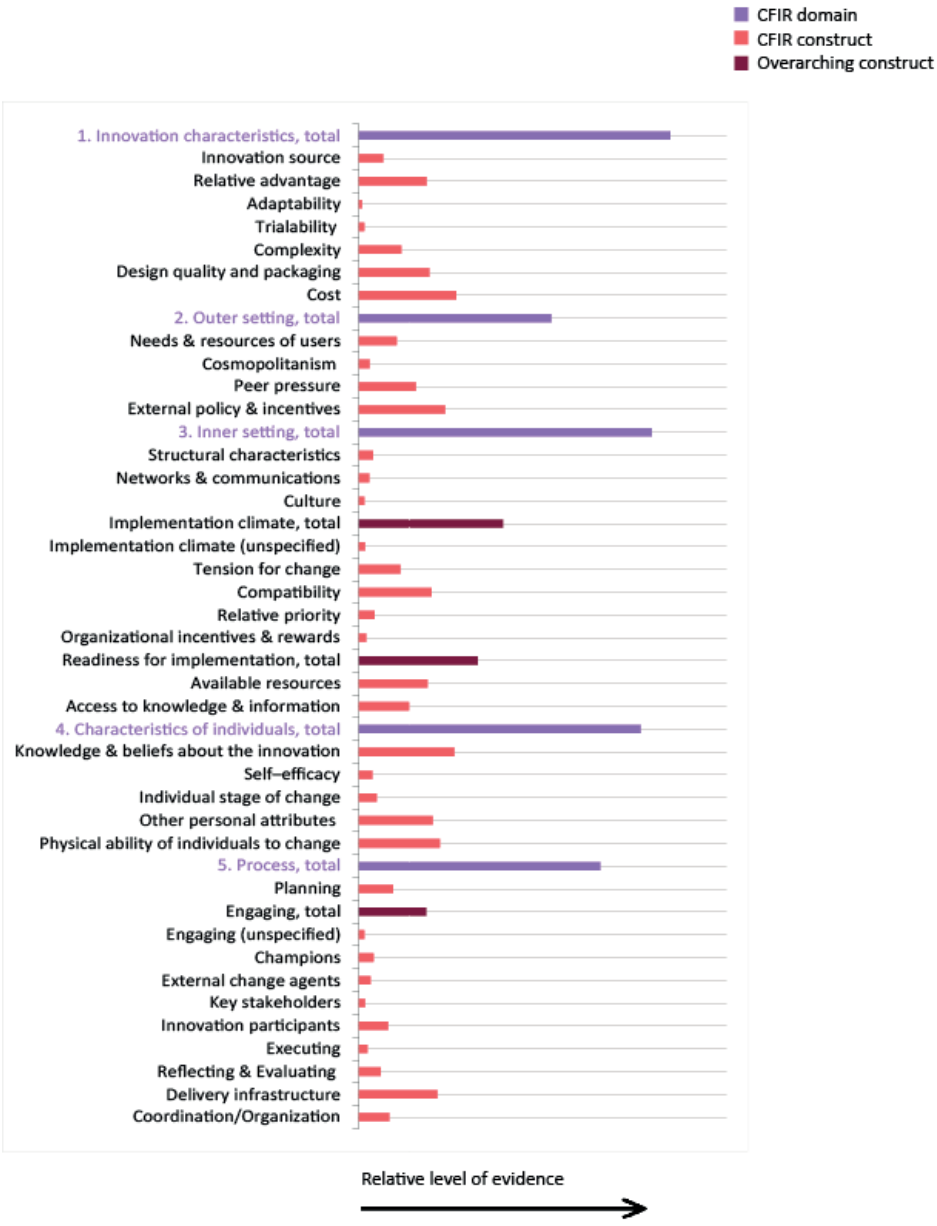

FIGURE 6: Overview of implementation factors per domain and relative levels of evidence for the factor for clean fuels. Bar sizes indicate the relative certainty as to whether the factor influences implementation. CFIR (overarching) constructs are described in appendix pp 22-27 and at https://cfirguide.org/.

of policy tools on upfront costs and recurrent fuel costs, which are often relatively high, and due to the regulations and standards needed to promote a safe and sustainable supply of clean fuels.

Conversely, compatibility was supported by a higher level of evidence in the case of cleaner cookstoves. An explanation for this difference could be that we have learned from mistakes made during implementation efforts of cleaner cookstoves (which have a longer history) and consequently compatibility is more carefully considered during the implementation of clean fuels and corresponding technologies (this does not imply that it is unimportant, but rather that it has already been taken into account).

DISCUSSION

Summary of findings

In this umbrella review, we aggregated and weighed the level of confidence in evidence found in 31 systematic and narrative reviews covering 479 primary studies on factors critical to the implementation success of cleaner cooking interventions in LMICs. Our results demonstrate that a range of factors synergistically influence acquisition, initial adoption, and sustained use, indicating that a comprehensive approach to cleaner cookstove and clean fuel implementation is needed. The 15 factors supported by the highest level of evidence were consolidated in the CleanCIT and the CleanFIT, including examples of their influence in practice.

Interpretation of results

The level of confidence in evidence supporting a particular factor should not be interpreted as a prioritisation of the relative importance of a factor and neither should it be seen as an indication of order in the steps of implementation. Rather, it simply represents the relative certainty as to whether a factor influences implementation. We would argue that all factors included in the tools should be properly addressed or at least considered. Conversely, the absence of a factor does not necessarily imply that the factor is not important, but may simply indicate a lack of available evidence. We therefore advocate that missing evidence will be obtained in future studies. It should also be noted that the presentation of evidence in reviews is dependent on the methodologies used and on the perspective of the researcher, implementer, and end user.

Considerations

The factors identified here should be clearly addressed or at least considered during the development of evidence-based implementation strategies for cleaner cooking interventions. The tools developed in the course of this study will help programmes avoid neglecting important factors, such as local needs, financing options, or after-sales support, when designing implementation strategies, all of which were shortcomings encountered in earlier programmes.[34] These tools will help accelerate the large-scale implementation of cleaner cooking interventions but should not be interpreted as a guarantee of successful implementation. Facilitators and barriers for implementation are highly dependent on contextual factors, but due to the nature of

the study we were not able to distinguish between different regions or countries. Tools and reports to assess the current state of household energy in specific regions or countries are readily available, for example the Clean Household Energy Solutions Toolkit (CHEST).[62] Some of the factors mentioned can be tackled by small, local organisations, while others require the involvement of (inter)national institutions or governments. For example, shaping knowledge through marketing messages, word of mouth, or practical demonstrations can be carried out by a local implementer.[43] Meanwhile, energy policy and regulations regarding the production and distribution of energy carriers and energy appliances are the responsibility of local or national institutions or governments.[52] We decided to include all factors in the tools, regardless of the organisation that can tackle those, to urge implementers to at least consider how these factors could influence their implementation strategy. This underlines the importance of a multilevel stakeholder approach and a system-wide perspective regarding cleaner cooking interventions. Factors influencing acquisition, initial adoption, and sustained use were not distinguished in this study, but it should be noted that the extent to which the factors influence the one or the other may differ. The same applies to large and small-scale implementation. Finally, in line with the pledge "to leave no one behind" in the Agenda for Sustainable Development 2030, we recommend at least considering equity in relation to gender, socioeconomic status, and the urban-rural divide. These issues are further elaborated on in a study by Puzzolo.[6]

Strengths and limitations

Commitment to implementation research is a prerequisite to enhance health in the face of increasingly harmful environmental trends.[9,63] To the best of our knowledge, this is the first review of reviews to have consolidated and weighed evidence on factors critical to the successful implementation of cleaner cooking interventions. However, bridging the gap between research and practice requires more than evidence alone.[63] Therefore, we developed two new evidence-based implementation strategy tools. These tools provide a practical overview of factors influencing the implementation of cleaner cookstoves and clean fuels, as well as presenting the level of supporting evidence, together with examples of how these factors impact implementation. By adhering to the PRISMA reporting standard, the study was rigorous in design and execution,[16] and reproducibility and transparency were ensured throughout the entire process by use of validated tools applied by two independent researchers. The study included an extensive literature search, with no date or language restrictions, and although the search was originally conducted in July 2019, consultation of experts allowed us to identify relevant publications up to January 2022. We decided to include both systematic and narrative reviews in this umbrella review, as only a fraction of all literature is captured by systematic reviews. Double inclusion was addressed in systematic reviews, but was not possible in the case of narrative reviews. Unfortunately, grey literature sources (such as policy reports) were not included, although we acknowledge that these contain important data. Previous literature has highlighted the challenge of identifying data in non-academic literature.[34] In addition, while specific names of fuels (e.g.

biogas or ethanol) were not included as search terms, we do not expect that this has led to a review being missed. Finally, kerosene, a relatively efficient fuel but with significant health risks, was considered a clean fuel by two reviews.

Recommendations for implementation initiatives

To those contemplating the challenge of implementation, we would stress that hundreds of papers have been dedicated to this complex subject. Therefore, we strongly advocate the design of a comprehensive strategy regarding implementation of cleaner cookstoves and clean fuels. This strategy should consist of a multilevel stakeholder approach and a system-wide perspective. The CleanCIT and CleanFIT (Figures 3 and 5) developed in this study suit this purpose. In collaboration with stakeholders, we now plan to further develop these tools as an inclusive online interactive platform, and recommend pilot-testing of the tools and, if successful, their subsequent promotion to regional and global initiatives. Lastly, we advise continuous monitoring of the effectiveness of any implementation strategy, together with the adoption of necessary improvements. The Reach, Effectiveness, Adaption, Implementation, and Maintenance (RE-AIM) framework is a suitable tool for assessing the effectiveness of a certain strategy.[7]

Recommendations for implementation research

Collating data from numerous fragmented studies, we have distilled clear recommendations that can be used to improve current practice, and we are therefore confident that this umbrella review will boost the implementation of cleaner cooking. For future research, we recommend the use of standardised methods and structured reporting, e.g. the Standards for Reporting Implementation Studies (StaRI) statement[64]. Echoing a common recommendation, we urge clarification of the definitions 'adoption' and 'sustained use', as these are used interchangeably in many reports.[61] For example, The Adoption Index developed by the Clean Cooking Alliance can be used to quantify rates of adoption.[65] Furthermore, several reviews have indicated that exclusive use of cleaner cooking solutions is unusual and that fuel stacking (the use of multiple stoves and/or fuels) is common practice.[8,57] As stacking reduces the potential benefits of cleaner cooking interventions, we advise to offer (a range of) cleaner cooking solutions to meet the household's diverse cooking demands.[66] Furthermore, in addition to paying attention to the uptake and sustained use of clean cooking solutions, we also recommend focussing on the suspension of solid fuels and traditional stoves. A recent systematic review highlighted the differences in factors that influence household uptake and sustained use of less polluting fuels and stoves versus those that influence use and suspension of solid fuels.[44] We recommend future studies to assess the role of stacking in their research. Objective measurements regarding the use of fuels and technologies, for example by stove use monitors, may help to better understand the adoption process and the impact of the use of one or multiple cleaner cooking solutions.[3] In this review, we merged data on a variety of clean fuels (electricity, LPG, natural gas, biogas, solar cookers, and alcohol fuels). However, we would recommend to separately review the role

of implementation factors with regard to these specific fuels when more evidence becomes available. Further studies are needed to better understand implementation factors influencing sustained use, as existing reviews often have short follow-up and therefore only cover the acquisition and initial adoption of cleaner cookstoves or clean fuels. Finally, the reliability of the strategy tools deserves further research, with special attention for the prioritisation of the importance of known factors.

CONCLUSION

With 2.6 billion people using traditional fuels and stoves daily, and climate crisis as the greatest threat to public health in the 21st century,[67] there is an urgent need to accelerate the implementation of cleaner cooking interventions. The evidence presented in this umbrella review supports a comprehensive approach to the development of evidence-based implementation strategies, including at least the 15 factors identified here, and argues for a multilevel stakeholder approach and a system-wide perspective. This umbrella review, and especially the CleanCIT and CleanFIT, will serve as a useful basis for the planning and delivery of cleaner cooking interventions. This, in turn, may facilitate significant health gains, less forest degradation and deforestation, mitigating effects on our climate, and gender equity.

Key messages

- Expediting access to cleaner cooking is crucial to mitigate the effects of solid fuel use on health, environment, climate, and gender equity.
- Of the dozens of literature reviews conducted on how to implement cleaner cooking interventions, comprising hundreds of studies, few have been translated into practice and the implementation success of cleaner cooking interventions is generally considered poor.
- Our study identified and consolidated the facilitators and barriers that need to be addressed to improve the successful implementation of cleaner cooking solutions, weighed the level of confidence in the existing evidence, and developed two practical implementation strategy tools to bridge the gap between academic evidence and practice.

The Cleaner Cookstove Implementation Tool (CleanCIT) and the Clean Fuel Implementation Tool (CleanFIT) serve to improve the inclusion of important factors during implementation strategy development and hence avoid waste of scarce resources; this, in turn, may accelerate large-scale implementation of cleaner cooking interventions.

Contributors

EvAB conceptualized the study and together with EsAB, elaborated the concept and design. Title and abstract screening were conducted by EvAB and DV. EsAB and MT or CH conducted the full-text screening. Methodological quality appraisal, data extraction, coding of factors, assessing of confidence, and data analysis were conducted by EsAB and MT or CH, supervised by EvAB. DV made the matrix for double counting. EsAB wrote the first version of the manuscript and developed the figures. EvAB supervised the various stages of the writing of the manuscript. DV, RMJJvdK, NHC, BK, and OCPvS critically reviewed the paper. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication. JP Bayley has edited the manuscript. He was funded by Maastricht University and Leiden University Medical Center.

Declaration of interests

EsAB is part-time employed at the Dutch Spark for Clean Cooking Solutions. Other authors declare no competing interests.

Data sharing

The results of the quality appraisal, data extraction, and CFIR coding are documented on more than 310 pages. These are available from the corresponding author on reasonable request.

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Supplementary information:

Provided with the online version of this publication.

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