Analysis of the Drivers and Barriers for Transition to Modern Energy Cooking Services (MECS)

A systematic evaluation of the evidence

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ACRONYMS AND ABBREVIATIONS

Abbreviations in common use
CSV - Comma-Separated Values
ESMAP - Energy Sector Management Assistance Program
ICS – Improved Cook Stove
LMIC – low- and middle-income countries
LPG – Liquid Petroleum Gas
MECS – Modern Energy Cooking Services
NGO – Non-Government Organization
RCT – Randomized Controlled Trial
SDG – Sustainable Development Goals
UN – United Nations
USB – Universal Serial Bus
WB – World Bank

Abbreviations used in our data analysis
AE – Aesthetics
AP – Air Pollutants
AS – Aspiration
AW – Awareness
CC – Choice
CH – Characteristics of Setting
CO – Convenience
CS – Cost Saving
DT – Decision-Taking
DE – Deforestation
DR - Drudgery
ED – Education
EM – Emissions Within Homes
EP – Employment
FP – Fuel Price
FU – Fuel Use
FT – Financial, Tax and Subsidy Aspects
GE – Gender
GH – Green House Gas Emissions
HH – Human Health and Wellbeing
HY – Hygiene
IG – Income Generation
IN – Inflation
IT – Information Technology
KP – Knowledge and Perception, Information
LE – Leisure
MD – Market Development
OT – Other
PO – Poverty
PP – Programmatic and Policy Mechanisms
RL – Regulation, Legislation and Standards

SA – Safety
SC – Supply Chain
SU – Subsidies
TC – Technology/Fuel Characteristics
TP – Technology Performance
TS – Time Saving
WP – Willingness to Pay

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SUMMARY AND KEY MESSAGES

The need for transition to modern cooking energy

Over a third of the world's population rely on traditional biomass fuels for cooking with significant health, environment and social impacts. Transitioning this population to modern energy cooking services is part of the Sustainable Development Goal 7 which aims to ``ensure access to affordable, reliable, sustainable and modern energy for all". There has been very minimal success with past cookstove programs which has been attributed to the failure of the programs to take into account important supply and demand side considerations such as cost, ease of use, availability of fuel and parts, sociocultural values and other such considerations. A lot of the documented barriers have been highly context specific, reflecting the scale under which they were analyzed – often at individual and household levels. As most development organizations move away from a predominantly project-by-project approach—which lacks the scale and speed to achieve universal access by 2030 in low-access countries (IEG World Bank Group 2015) - to sector-wide frameworks and engagement plans needed for implementing rapid access scale-up, there is an urgent need to understand what drivers and barriers operate at this scale, and what it would take to transition 3 billion people from traditional to modern cooking energy.

Systematic evidence synthesis

Systematic mapping, as opposed to systematic review, was employed in this study given the broad, multifaceted question that needed to be explored, incorporating multiple interventions, populations and outcomes. Despite assessing over 14,000 articles from a wide range of sources, the final set of studies did not yield sufficient data for meta-analysis. The body of evidence presented here, however, is a robust assemblage of literature relevant to the research question, and can therefore be used to make statements about what was found in the evidence and where evidence gaps exist. In addition to rigor and objectivity, a further strength of the systematic evaluation process is that files of all articles evaluated at each stage of the process are available for scrutiny, so there is always the possibility of re-evaluation from this wider library or potential evidence.

The barriers and enablers of transition to modern cooking energy

Had the evidence base been stronger, an evidence synthesis of this topic might have been able to provide decision-makers with very specific information on which set of drivers and barriers to focus their efforts on to be able to transition large populations to MECS and meet the SDG 7 target. Conclusions of this nature are not however possible from the current evidence base for several reasons. First, the nature of the evidence base is fragmented, comprising a broad range of interventions targeting a variety of outcomes, implemented at different scales and in different regions across the globe. Rarely in this study were we able to find multiple studies assessing the same set of populations, interventions and outcomes to allow us to link certain drivers with certain program outcomes. Secondly, most of the studies were assessed as liable to bias (largely through unaccountable missing data, or the use of unverifiable secondary data), and although several mentioned the drivers and barriers of success, they did not incorporate any verifiable data on the outcomes that would enable us to link them to the drivers. Third, clean cooking is a complex intervention which by itself makes it very difficult to attribute an outcome to a single driver or barrier. This, coupled with the low methodological quality of literature that emanated from our extensive search, makes drawing conclusions about what works and what does not in an intervention program difficult. Many systematic reviews are inconclusive and reinforce the

message that there is uncertainty, but greater openness about uncertainty can help challenge the prevailing culture and create the right environment for thinking of ways to resolve the uncertainty.
The following findings and recommendations acknowledge the uncertainty in the current evidence base.

Key outputs and findings

This study has brought together a diverse body of knowledge on the drivers and barriers to transition to modern cooking energy. The current report includes an open-access interactive systematic map of 160 studies selected from over 14000 articles in the global databases of research, using transparent inclusion criteria agreed by a broad range of experts in the field. The systematic map is the first to be produced of studies in the field of modern cooking energy and it has been designed in such a way as to allow additions over time, should the community of interest want to access ongoing evidence. From the assembled data, further analyses on the drivers and barriers can be run focusing on various elements such as countries, region (rural or urban), type of cooking energy and technology, amongst others. The map also allows for filtering based on quality of the studies.

The exercise has also generated a csv file of 657 publications that passed the initial screening stages and may have some relevant information on the topic, but were rejected at full-text screening, having failed to meet the full agreed criteria set for this review. An additional csv file lists articles rejected at Title and Abstract stage (see Supplementary material).

Important findings from this task include the following; many of them warranting further investigation:

- Select characteristics such as young demographic, higher level of education, and higher levels of household income encourage MECS adoption; while their counterparts often negate it. Financing solutions that address affordability constraints as well as targeted education and after sales support can therefore drive adoption. Similarly, higher-level policy changes that lead to higher income levels or targeted financial support to the poor to overcome financial barriers can drive large-scale transition to MECS.
- Ease of access to traditional cooking fuels that were often reported as cheaper, easily available and "traditional" was a major barrier for transitioning to MECS. For transition to happen modern energy sources have to counter the strong dependence on traditional fuels, by offering better and reliable services. Notable success was seen where policies were designed both to promote MECS but at the same time limit dependence on traditional fuels.
- There was evidence that peer influence was an important factor encouraging adoption. The peers served as an important validation step prior to adoption of MECS in addition to being the important first source of stove information. It is therefore important that technologies introduced adequately meet the early adopters' needs to avoid cascading effects of negative experience with a program.
- The evidence points to an important role of women in the MECS value chain, with success reported when programs were promoted through women's groups compared to traditional marketing channels. Male influence on the adoption showed some evidence of an overall negative effect. The role of gender requires further probing, particularly on how women's involvement in a MECS program affects their time use, which they are reported to attach very high value to.
- Technological characteristics were important, with functionality having more prominence as a driver than technology performance (e.g. on IAP reduction and fuel use). Durability and reliability of new technology was found to be an important driver of uptake, with the most important reason for discontinued use and non-adoption being breakdown of technology.

The evidence base shows that users are willing to pay more to have good quality options, and practicality matters more than efficiency.

- Follow-up by implementers after initial adoption to monitor and record program successes and weaknesses and respond to users' feedback over an extended period of time was an important driver, particularly for those technologies that were substantially different from traditional ones and required steep learning. Lack of follow-up was a major barrier to transition.
- Lack of appreciation of benefits of clean cooking systems was reported, but only in some settings as most programs entailed awareness-creation components. Generally, NGO programs achieved this very well in comparison to the few private sector initiatives reported in the evidence base that struggled to overcome this hurdle prior to distribution of technologies. As this barrier affects the entire sector, the role should be supported by governments, who could incentivize partnerships between the private sector and NGOs, a model that was reported to work well in some programs.

  While a number of NGO-led programs reported success in terms of distributing large numbers of cookstoves and getting households to adopt them, many of the initiatives were not sustained for lack of market-based approaches for sustaining the programs, with many failing after the initial pilot period. This further emphasizes the important role of partnerships with the private sector that could help in sustaining these interventions beyond the NGO financing cycles.

Evidence gaps

- There was a clear evidence gap in understanding MECS transitions in urban settings. Given the growing trend of rapid urbanization, particularly amongst the youth, an opportunity exists for understanding their behavior and exploring whether their experiences of modern energy for cooking can be harnessed as a force to influence families they have left in rural areas. The evidence points to a strong role of networks and channels of communication, including person-to-person knowledge transfer.
- The evidence base covers the role of subsidies as a driver of MECS adoption well, but it does not distinguish between short-term and long-term transition effects. There were a few reported instances of earlier subsidies discouraging adoption – suggesting the need to sustain subsidies once introduced if the primary goal is to achieve an energy transition. Further studies are necessary to fully unpack whether such subsidies are sustainable, and what alternative policy measures can overcome the major barrier of poverty that is reported as limiting transition across all settings.
- There is need for further research on what, amongst the wide range of benefits attached to MECS, can motivate transition. Although users report multiple benefits of new cooking systems, it was not entirely clear from this evidence base whether those factors informed their decision to transition to MECS and stay in the transition. We find in this evidence some technologies that in later evaluations were shown to have failed in performance, yet user perceptions of the technologies remained favorable and their use continued. The knowledge of what users value would allow for design of technologies that respond to those needs, and to use that type of information in marketing them.
- Creating awareness of benefits of MECS cannot be left to the private sector alone: there is a role for the public sector.

1. BACKGROUND

Over a third of the world's population – nearly three billion people - rely on traditional biomass fuels such as charcoal and wood for cooking. These fuels are typically burnt on inefficient stoves, leading to high levels of pollution that are responsible for around four million premature deaths each year, disproportionally affecting women and children (WHO 2018). The practice also contributes to considerable environmental degradation (34% of biomass fuel harvested is unsustainable), significant atmospheric pollution (1.9–2.3% of global greenhouse gas emissions, 25% of global black carbon emissions) and significant time burden for women and girls who partake in the domestic roles of fuel harvesting and use (Batchelor et al 2019, Bailis et al 2015). Access to modern energy cooking services (MECS) is thus an important contributor to development, and is part of Sustainable Development Goal 7 which aims to "ensure access to affordable, reliable, sustainable and modern energy for all".

While the energy access target is very ambitious in its scale, there remains a dearth of evidence on how to achieve large scale transition to modern cooking energy. Instead most of the prior evaluations on the topic have been based on small-scale and experimental studies, that are informative for pilot projects, but not large-scale transformation of the world's cooking systems as envisioned by the 2030 agenda. Unlike electricity access where progress has been made in recent years (global electrification rate reached 89% in 2017 from 83% in 2010), the population relying on biomass has remained constant over the decades, and the absolute numbers has increased in sub-Saharan Africa (World Bank 2018). According to the SDG 7 tracking report, progress on transitioning to modern cooking solutions is too slow, and 2.2 billion people will remain without access in 2030 (United Nations Department of Economic and Social Affairs, 2018). This concern has now led to an overall scale-up of ambition, with increased focus on national scale programs. ESMAP for instance has recently announced a USD 500 million Clean Cooking Fund that will leverage World Bank Group and other sources of finance including private sector investments to catalyze transition to modern energy cooking services.

Empirical studies on the barriers and enablers of transition to clean cooking technologies and fuels, which have been the subject of three systematic reviews (Puzzolo et al 2016, Stanistreet et al 2014, Lewis & Pattanayak 2012), have identified a large array of inter-related contextual factors which could reflect the scale under which many of the studies were conducted – often at individual and household levels. Evidence from small-scale programs may limit generalizability to large scale transition programs. Most past reviews in the cooking sector have also been restricted to low- and middle-income countries (LMICs), which limits the breadth of knowledge available on the topic: evidence from higher-income countries who have experienced transitions to cleaner cooking may be highly relevant to the design of transition programs in lower-income countries. The broader social and environmental benefits of the transitions could lead to policies that tackle supply side challenges, but the effects of these could be outweighed by households' perceptions of private benefit from making the switch, that drives the demand for clean cooking solutions (Pattanayak et al 2019, Jeuland et al 2018). This suggests a need for a more holistic understanding that integrates evidence at various scales, to provide a tailored pathway for transition for the 3 billion that lack access to modern cooking energy. Basing the current policy decisions on a sound evidence base would help to tackle one of the key barriers to transition that have characterized the past 50 years of the cooking sector development: of policies that do not take into account both the supply and demand side barriers such as upfront cost of technologies, cooking preferences and aspirations.

The challenge of transitioning to new technologies and systems is not unique to clean cooking. Learning from the barriers and drivers of transition in other sectors that have a longer history with similar

adoption challenges (e.g. Water, Sanitation and Hygiene) is therefore necessary; especially on the long-term transition pathways and sustainability factors that are yet to be experienced in the clean cooking sector. Similarly, new emerging sectors that have been highly successful in achieving large scale transitions in LMICs (e.g. mobile telephony and IT) can provide useful insights for modern cooking energy, particularly where the technologies can be bundled in innovative ways to overcome traditional hurdles such as supply and distribution (e.g. use of IT platform to distribute ethanol).

The current review seeks to explore the drivers facilitating, and barriers preventing, transition to modern cooking energy and link these with enabling (or hindering) factors. The assessment of the published and grey literature takes a systematic approach to gathering, mapping and evaluating the published evidence base (Collaboration for Environmental Evidence 2018). The review forms a core component of the broader MECS research program[1] that is aimed at generating an understanding of the holistic system of cooking and its transition pathways, and to find solutions to the barriers to scaling. The term *Modern Energy Cooking Services* adopted in this review considers the multi-dimensionality of energy access, which is more than cleanliness (attainment of efficiency and exposure reductions) as the transition endpoint; but also encapsulates attributes of convenience of the fuel and technology system, its availability, safety, and affordability (ESMAP, 2015).

This report follows guidance on best practice for reporting systematic evidence evaluation developed by researchers in the conservation and environmental science (Haddaway et al 2017). A detailed methodology is presented in Annex 2 to facilitate readability of this report. The principles of systematic review methodology are described below to highlight how a systematic review differs from a traditional literature review, and helps explain how the findings should be interpreted.

1.1 Systematic evidence evaluation

Systematic reviews and systematic maps are now widely-used in sectors of society where science can inform decision making and have become a recognized standard for accessing, appraising and synthesizing scientific information. The need for rigor, objectivity and transparency in reaching conclusions from a body of scientific information is evident in many areas of policy and practice, from clinical medicine (where systematic review methodology was first standardized) to environmental management, education, and social justice. International development is no exception and there are many urgent problems for which a reliable source of evidence is needed on which to base actions. Many of these actions will be controversial and/or expensive and it is important that they are informed by the best available evidence and not simply by the assertions or beliefs of special interest groups and by literature search that is tailored to individual knowledge or to what is easily available. For evidence synthesis to be credible, legitimate and reliable standards regarding its conduct need to be clearly defined.

The question posed in the current report lends itself to a systematic synthesis approach, and the two most commonly-used types of synthesis are the Systematic Review and the Systematic Map. Systematic mapping is particularly valuable for broad, multifaceted questions that can include multiple interventions, populations or outcomes (see Table 1 for definitions of these terms).

[1] https://www.mecs.org.uk/about/

Table 1 Key elements of a systematic evidence synthesis

Question element	Definition
Population (of subjects)	Statistical samples or populations of subject(s) to which the interventions will be applied, or exposed to described conditions (e.g. households in rural village targeted for efficient cookstove roll-out).
Intervention	Policy, action or environmental variable impacting the populations or to which the subject populations are exposed. (e.g. a program to make subsidized efficient cookstoves available)
Comparator	What the exposure or intervention are compared to. Either a control with no intervention/exposure or an alternative intervention or a counterfactual scenario. (e.g. a study comparing different levels of subsidy)
Outcome	Consequences of the intervention or exposure. All relevant variables that can be reliably measured. (e.g. measured views of the population about factors that encouraged uptake of the efficient cookstove)

The approaches to planning and conducting Systematic Reviews and Systematic Maps are similar in many ways but as forms of evidence synthesis they differ in their outputs. Systematic Reviews usually aim to answer a question by synthesizing findings of individual studies in order to produce an aggregate measure of effect or impact, mostly through statistical analysis (often meta-analysis). Systematic Maps do not aim to answer a specific question, but instead collate, describe, and 'map' findings in terms of distribution and abundance of evidence, often configured in relation to different elements of a question. Systematic mapping follows the same rigorous processes as systematic reviews to evaluate relevant evidence and minimize the potential biases and lack of transparency of traditional literature reviews (James et al 2016).

Systematic reviews and maps share the same initial steps and differ primarily in their analytical approaches and outputs. Table 2, adapted from CEE (2018), shows some of the key differences between the two closely-related approaches. In systematic mapping, the evidence is presented in a searchable database and can be accompanied by an interactive geo-map, with clearly defined elements that are coded similarly across the body of evidence collected through an extensive search of multiple sources (including academic journals and other sources of information, such as organizational databases, collections of theses, unpublished reports, and publications suggested by stakeholders interested in the review question).

As systematic maps may include multiple populations, interventions or exposures, the database usually enables cross-tabulations of the data to be carried out to explore the evidence base thoroughly. It then becomes possible to identify trends and knowledge gaps and evidence clusters. In further contrast with systematic reviews, systematic maps are unlikely to include detailed extraction of study results or statistical synthesis of results. The mapping process involves rigorous (i) searching for evidence, (ii) selection of relevant evidence ('filtering'), and (iii) presentation of key elements of individual studies in the evidence set ('coding').

Table 2 Main differences between systematic reviews and systematic maps (adapted from CEE 2018)

Key component	Systematic Review	Systematic map
Protocol	Required	Required
Systematic searching	Required	Required
Systematic study selection	Required	Required
Critical appraisal	Required, to ensure robustness of the review answer – directly influences the data synthesis and interpretation steps	Optional (possible if study validity indicators can be captured using the coding method, but unlikely in practice) – does not influence mapping process itself
Data coding & data extraction	Required, Meta-data coded and outcome measures (e.g. effect sizes) extracted.	Required for coding of metadata (e.g. type of study, Population type, Intervention description, etc.), but extraction of outcomes is optional and comes with a caution about 'vote counting', since strictly-regulated meta-analysis is not being conducted.
Data synthesis approach	Aggregative, seeking an unbiased answer with known precision; could involve meta-analysis	Exploratory; may include coding and sub-group analysis (i.e. examining subsamples of the population separately)
Outputs	A quantitative or qualitative answer with an indication of uncertainty and any threats to validity. May include estimate of variance caused by external factors.	A description of the evidence base, showing the distribution and abundance of evidence across different elements of the question. A stand-alone database of studies showing the coding and data extraction elements may be provided. An interactive geo-map may be constructed, based on the database of coded studies.

The Systematic map approach is most suited where the research question requires a descriptive overview of the evidence base, where the question is open-framed such as 'what interventions have been used to increase uptake of improved cookstoves?', or where the question is closed-framed but there are multiple subject populations, interventions and outcomes to consider such as 'what are the impacts of different marketing strategies on uptake of improved cookstoves?' Systematic mapping is a useful exercise to assess where there may be evidence gaps, and, conversely, where there may be sufficient evidence for further statistical synthesis of subsets of the evidence. Systematic mapping can cover the breadth of evidence needed for policy- or practice-relevant questions of the type under consideration in the current report.

The current study used a systematic map approach as opposed to systematic review, given the broad scope of questions it sought to answer and the desire to explore the entire evidence base available, without limiting the set of studies only to those reporting data that could potentially contribute to a meta-analysis, or similar statistical analysis. The method for the systematic mapping was guided by input from two stakeholder meetings and by an Advisory Group. The body of research identified by the systematic mapping approach provides a robust sample of research identified as being most relevant to the research question by a rigorous, transparent synthesis process. This differs from a conventional literature review where the body of research is usually selected based on individual knowledge or other criteria that is prone to bias. This body of literature reports on possible drivers and barriers of MECS

transition for a range of outcomes, resulting from a wide range of interventions in the clean cooking sector, and other sectors that are informative of transitions in this sector. The factors (broadly Drivers or Barriers) are thematically grouped into the following 10 categories: i) Characteristics of the Setting, ii) Knowledge, Perception, and Information, iii) Technology Characteristics, iv) Financial, Tax and Subsidy Aspects, v) Regulation, Legislation and Standards, vi) Market Development, vii)Programmatic and Policy Mechanisms, viii) Poverty, ix) Gender, and x) Other.

For the type of questions investigated in this review, it is not possible to infer which of the reported factors could be causally attributed to transition to MECS; but trends and evidence gaps are discussed.

2. METHODOLOGICAL APPROACH

2.1 Stakeholder engagement

Following good practice for systematic evidence evaluation (CEE 2018, Haddaway et al 2017), two workshops were held to engage relevant stakeholders in the systematic map. The first Stakeholder meeting was held at Loughborough University on 30th October 2019. It comprised 15 participants, mostly academics with expertise in modern energy cooking systems, transitional pathways and theories of change. This meeting discussed the complexities of modern energy uptake, understanding transition in the context of cooking energy and the goals of a MECS transition for outcomes such as health, climate and development. The second stakeholder meeting was held in Nairobi on the 8th November 2019 against the backdrop of the Clean Cooking Forum 2019, to engage with mainly policy makers and practitioners from NGOs and private sector. The review question and the scope of the review developed at Loughborough were further discussed by 21 participants. Search strategies and relevant terminology to include in database searching were suggested by stakeholders. The meeting provided a list of over 100 terms to consider for inclusion in the database search strategies. 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 report of the stakeholder meetings is included in Annex 1.

2.2 Advisory Group

The systematic map was also guided by a 19-member Advisory Group (see Annex 1) that represented a broad range of expertise in research, policy, and practice. The Advisory Group were engaged in varying degrees throughout the systematic map process, including in the refining of the review question, providing feedback on the Protocol that set out clearly all the methods to be used in the review, review of data extraction sheets and review of the final report.

2.3 Review question

A core component of the MECS program is a Transition Pathways analysis to provide the evidence for understanding how and when modern energy cooking services transitions can happen; and find solutions to barriers to scaling. Guided by input from two stakeholder meetings and the Advisory Group, the broad review objectives for this study were distilled into to the following researchable question:

What factors are critical to achieve a large-scale transition towards sustained use of modern energy with particular reference to cooking in Low- and Middle-Income Countries?

In addition to the cooking sector, consideration was given to examining what factors have been considered critical to large-scale, sustained technology transitions in three other selected sectors (sanitation, telecommunications and clean water) that may provide insights for modern energy cooking transitions in Low- and Middle-Income Countries. These other sectors were not intended to be as comprehensively covered as modern energy for cooking; rather the aim was to find out whether there are studies that could provide insights from large-scale programs that may be useful in developing

strategies for modern energy transitions. The set of search terms that were used to assess this body of literature was by necessity much less detailed than those for the cooking energy that formed the principal question.

Definition of the question

Using the well-established 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[2] (large-scale defined as national, sub-national, regional, state, district, city, town, whole village, area of high population density).
- Intervention: a technology program or intervention implemented at scale
- Counterfactual: in a review of drivers/barriers there may be few studies that consider a control group who were not exposed to the intervention. This element was not made a necessary precondition for included studies, but was to be recorded if present in study design, including features of before/ and quasi-experimental studies.
- Outcomes: data reporting uptake of the technology (in numbers of people or density of uptake) and information on factors driving or inhibiting uptake

2.4 Searching for the evidence

Details of the search strategies and their testing are included in Annex 2.

Publications related to drivers of and barriers to MECS transitions were searched in online bibliographic databases (covering academic journals, conferences, theses, books, and other reports) and on the websites of relevant organizations. These were assessed in a series of systematic filtering stages by a team of reviewers using the methods summarized below, and described in full in the Protocol to arrive at a final set of publications which comprise the systematic map of evidence relevant to the research question. The methods and protocol were developed in collaboration with stakeholders and the Advisory Group.

The number of articles retrieved from these searches are shown in Figure 2. By the final stage of screening (full-text), articles were assessed to identify if there were multiple studies reported within one article. The identified studies were subsequently treated as separate entries for coding, data extraction and mapping, each one with a separate unique identifying number. This is a powerful use of the systematic review methodology, to allow all research strands of a published article to be considered and only those which meet the review criteria to be considered for analysis.

[2]In this report transition is treated as any upward movement from a baseline cooking system to an 'improved' one, as defined by the studies and programs they evaluated. The review team did not seek to provide a definition of the terminology as it was expected to vary by programs, studies and settings. The decision was reached following stakeholder consultations that accepted that the definition could not be hard wired in a research that relies on secondary data from multiple studies that do not follow a standard definition or terminology.

2.5 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 LMICs. The rationale for this was the desire to focus on 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 consideration 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 'programs' 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 (either reported in the study or widely known, such as a national cookstove program or policy) were excluded. Large-scale electrification studies from non-LMICs were not be assessed in the current study.

Counterfactual: pilot searching revealed very few papers with counterfactuals or controlled research designs, therefore presence of a control in the research was not a requirement of inclusion, but was recorded if present in the study design**.**

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, where supported by tabulated results or qualitative results that indicated number of respondents. We note that our question relates to a sustained transition, but discussions with stakeholders identified significant problems in trying to pre-define what constituted sustained use. The use of fuel stacking is a well known phenomenon amongst communities moving towards modern energy systems and it was not felt to be useful or informative to exclude studies reporting fuel stacking as an outcome on the grounds that this represented no transition or not a sustained transition. Presence of stacking was therefore coded amongst the outcome measures.

Language of article**:** articles that could not be processed at full-text due to language limitations of the team were recorded as 'excluded' and the language reported - these amounted to only 3 studies-2 in Croatian and 1 in Chinese. Studies suggested through a call for grey literature that were wholly in Chinese were set aside and not analyzed for the current report. We had expected to assess studies in French, Spanish and Portuguese at full-text, but none were retained after abstract screening, having failed to meet inclusion criteria. All studies in the final set were therefore in English.

Type of publication: no restriction was placed on type of publication, except for power-point presentations, which were sent as part of the call for grey-literature. These were rejected.

Date: no restriction was placed on date of publication.

Research design: no restriction was placed on research design.

2.6 Article screening

Bibliographic information of articles retrieved from the searches were downloaded to EndNote reference management tool and duplicates removed. The remaining set of articles were uploaded into Colandr[3], an open-source tool created to incorporate computer assistance for screening and metadata extraction. Colandr semi-automates the synthesis process, but it continues to retain significant user oversight to ensure transparency. The machine-learning capability of the screening tool has been shown to reduce time spent on screening considerably (Cheng et al 2018). Literature retrieved was screened sequentially for relevance in three stages: at title, abstract and full text. After title and abstract screening stages, reviewers exported the accepted articles from Colandr into Google Drive for full text screening, coding and data extraction. Reasons for not including articles at full-text were recorded (based on PICO framework – e.g. article rejected because Population was wrong, or article rejected because none of the three types of Outcomes were reported).

2.7 Compiling data sheets for the evidence map

The coding and extraction template devised for the present work comprised 79 extraction 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, use of secondary 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 (Bruce et al 2006). This framework was also adapted by Stanistreet et al (2014) and Puzzolo et al (2013; 2016) and was found to be well suited to the current review during preliminary testing of the coding template. The thematic categories were: Characteristics of setting; Knowledge, perception & information; Technology characteristics; Financial, tax and subsidy; Regulation, legislation & standards; Market development; Programmatic & policy mechanisms. Three other categories were added to the current review - Poverty, Gender, 'Other' (drivers and barriers that did not fit in neatly into any one of the named categories) – to give a total of 10 categories. These map onto the commonly-used Dahlgren-Whitehead (1991) 'rainbow' model which shows the relationship between an individual, their environment (social, political, ecological), and health. 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] Colandr is the product of a collaborative partnership between the Science for Nature and People Partnership Evidence-Based Conservation working group, DataKind, and Conservation International (https://www.colandrapp.com/about)

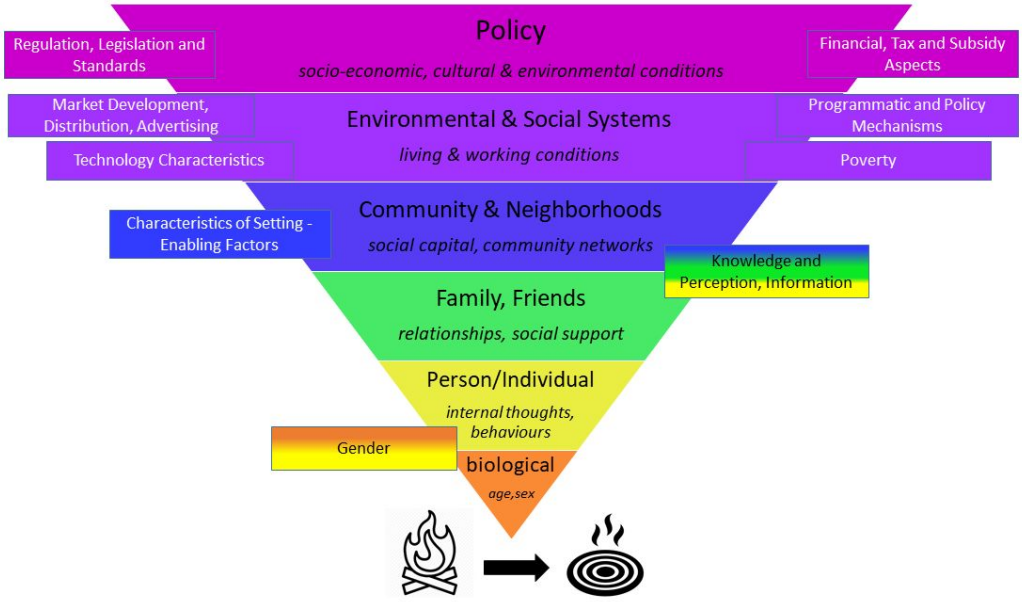


Figure 1 Modified Dahlgren-Whitehead model of relationships between an individual and her environment

Some data were coded in more than one category, and given the possibility of considerable overlap between categories for some types of information, the thematic categories were not all used for analysis; other groupings emerged from the evidence which better suited analysis (see Results). A column for adding relevant notes was available.

While this coding structure was useful for data extraction, it was adapted for data analysis and narrative reporting to embrace themes that emerged from within and across coded elements as discussed in later sections.

2.8 Quality of Studies

In addition to capturing the size of the population affected by the intervention or program, number of replicates in comparative studies was captured, together with two measure of time – duration of study and time since project implementation when outputs were assessed. A number of other characteristics were recorded for each included study that could be used as a proxy for quality measures. Applying critical appraisal (sometimes referred to as quality assessment) is a time-consuming process, with no single method of determining quality accepted by the systematic review community (CEE 2018). Schemes that are used for critical appraisal of randomized control studies in the medical field do not translate well into reviews of complex social or environmental topics and there is a danger that reviewers, in attempting to apply quality assessments that are neither transparent nor replicable, are adding reviewer bias to other biases inherent in the primary data (Frampton et al, in press). The timescale for the current review made critical appraisal unfeasible and it is important to note that it is not a requirement of systematic maps, or where meta-analysis is not undertaken (see Table 2), where minimizing risk of bias is extremely important for robust statistical analysis. Quality features documented as part of the coding process were: whether the study was part of a synthesis paper (i.e.

did not report primary data); whether the study reported missing data, and if such missing data were accounted for, and whether secondary data were used, which could not be independently verified.

3. RESULTS

This section presents the findings of the evidence synthesis. The results are reported in four sub-sections.

The first part focuses on quantitative analysis of the evidence base as a whole, including characteristics of included and excluded studies, main sources of the evidence, information about quality of included studies, and data relating to numbers of studies that fell into each of the data extraction categories. The results in this subsection are highly important in understanding the extent of the evidence available for policy or practice decision-making. It informs about the type of studies that have been conducted, pertinent to the questions considered of importance, and it shows where there are gaps in evidence and where trends over time may have responded more to funding priorities, research agendas, or other criteria other than importance of the topic. It also addresses the issues of study quality that is necessary in evaluating the strength of the evidence by assessing the study characteristics outlined above.

The second part presents the functionality of the systematic mapping tool of all studies that met the inclusion criteria. These studies all have data sheets that can be accessed from the interactive map. The interactive map forms a part of the current report, but can be used independently of the written report. It is freely available on this link [https://energydata.info/apps].

The third part focuses on the factors that drive or inhibit transition as reported in the 91 fully-coded studies included in the evidence base (and therefore on the interactive systematic map). These were initially grouped according to the 10 domains, and subsequently assessed in categories that reflected issues emerging from the evidence and which responded best to specific questions that motivated the review. This reflects an approach used routinely in qualitative systematic reviews (Finfgeld-Connett 2013).

The fourth section is a narrative reflection on evidence of drivers and barriers to MECS transition, which explores in greater depth findings of the 91 fully-coded studies.

The four sub-sections should be considered together as forming a robust assessment of the systematically-reviewed evidence base.

PART 1: THE EVIDENCE BASE - QUANTITATIVE DESCRIPTION OF DATA

3.1.1 Number of articles included and excluded at each screening stage

Figure 2 shows the number of articles examined at various stages of the review process. Articles obtained through the literature search, including articles searched through ‘snowballing’ (following references in relevant reviews or in references cited by included studies), or those suggested following the request for grey literature, were screened using the inclusion criteria. A total of 13,914 potentially useful articles were examined, out of which 791 were retrieved at full text. Of these, 658 were excluded. The retrieved articles often contained information on more than one separate study, and these were all given unique identifiers and coded separately in Data Sheets that capture the study information set out

in the method section. Although the inclusion criteria specified that data on Drivers and/or Barriers were a requirement, it was clear during screening that there were articles that contained detailed discussions on factors affecting transition but with no supporting data, and rather than exclude them entirely, they were included in the evidence base as partially-coded studies. There were 42 partially-coded articles and 91 fully-coded. Included papers are listed in the Annex. The 133 articles included at full-text yielded a final set of 160 studies.

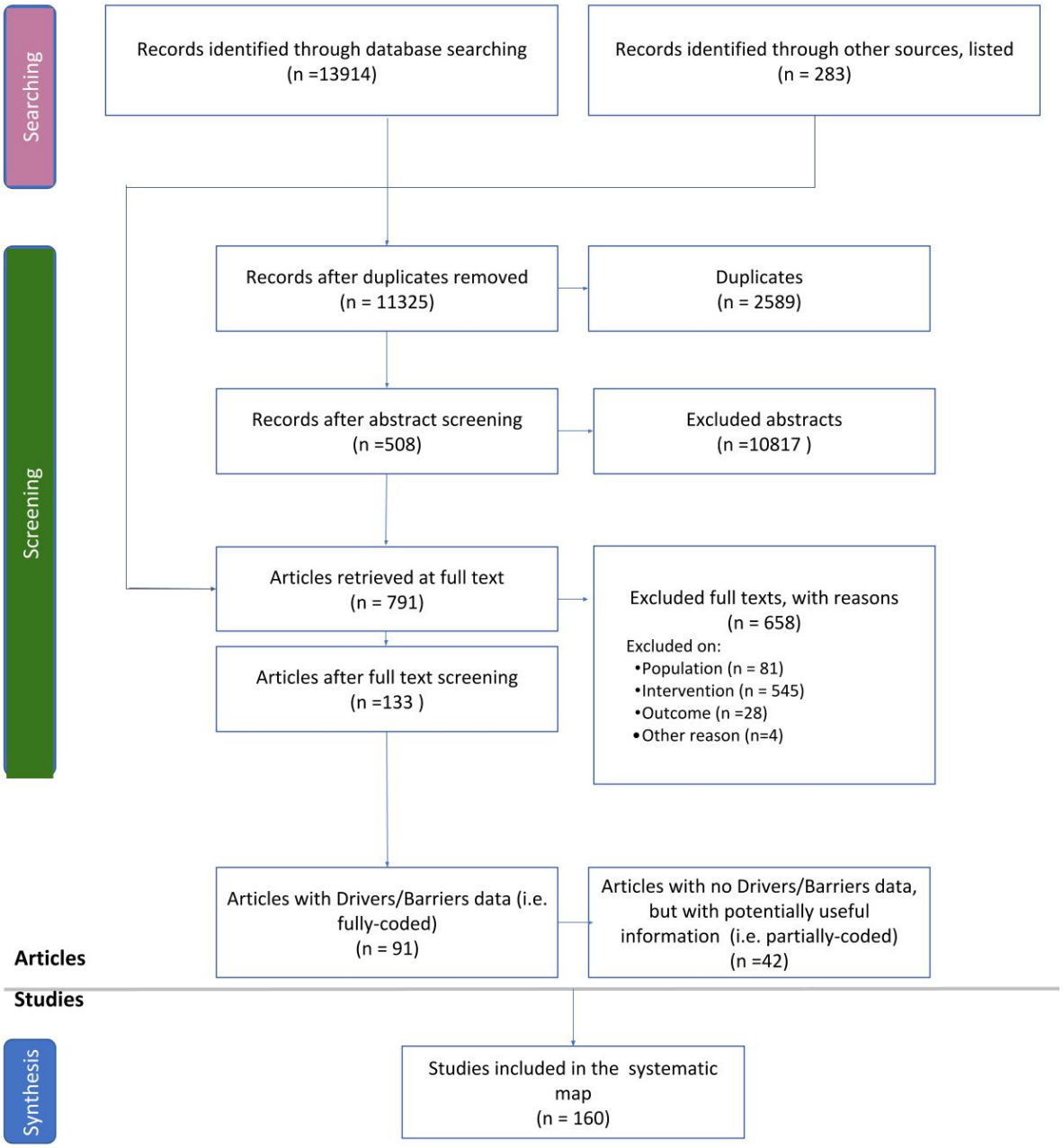


Figure 2. Flow chart showing numbers of articles and studies at searching, screening and synthesis stages.

3.1.2 Consistency of inclusion decisions

Consistency of screening between individuals engaged in screening was assessed in two rounds of screening of 100 articles, with the widely-used Cohen's kappa (Altman, 1991), which takes into account the level of agreement between screeners that would occur by chance. Agreement was high, which was unsurprising given that all members of the review team had attended both stakeholder workshops and follow-up discussions with experts taking part in the Clean Cooking Forum 2019 in Nairobi. Intense exposure to such a broad spectrum of experts from research, policy and practice, was hugely beneficial for the efficient completion of the review. The kappa figures of the first round and second round (following group discussion of differences of opinion on inclusion) are shown in Table 3. Following the second round of testing, screeners worked alone on records screened at Title and Abstract stage.

Table 3. Consistency of independent screening decision, using Cohen's kappa

	kappa	Standard Error of kappa	95% confidence interval
First round	0.668	0.076	0.520-0.817
Second round	0.872	0.039	0.795-0.948

3.1.3 Reasons for exclusion of articles at full-text

The numbers excluded for failure to satisfy criteria for Population, Intervention, Outcomes, and Various other reasons are shown in Table 4 below (and listed in a stand-alone csv file in the Supplementary material). Only one reason for exclusion was recorded, and this followed the order P-I-O-V. The high incidence of excludes based on lack of a large-scale program (the 'Intervention') does not mean that these studies had no reported results ('Outcomes' i.e. drivers and barriers) of potential interest; simply that the results could not be correlated with an activity that could be said to be an intervention of interest in this review. Where this relationship could be easily inferred without having to perform additional literature search (e.g. by reference made to a national cookstove program or policy) such studies were retained. All interventions that entailed experiments with participants outside an obvious program were excluded. Following feedback from independent reviewers, exclusions based on an original assessment of no evidence of the study being part of a regional or national program, were re-screened, and 6 studies were reassigned as 'included' in the evidence map. The issue of scale of the program was also often difficult to assess and inclusion was based on the presence of a description in the article of the program's ambition. As with any systematic review, these inclusion decisions can be contested, which is a strong reason to make available the file of excluded studies so that others can include these studies in subsequent analyses if required.

Table 4: Numbers of articles excluded at full-text screening and reason for exclusion

Key element	Number of articles excluded
Population	81
Intervention (programme)	545
Outcomes (results, drivers, barriers)	28

Various other reason	4

All articles excluded at full-text (658 in total) are listed in Supplementary material. Articles that could not be retrieved and were not therefore rejected, but were not included in the review, are also shown. The reason for making these files available for scrutiny is in keeping with best practice for systematic evidence evaluation. Subsequent review groups may want to examine potentially highly-relevant articles that, for one (documented) reason or another, did not satisfy the conditions for inclusion in the current review; and may also be able to locate the articles that this review team could not locate.

3.1.4 Characteristics of the included articles and studies

Articles

(i) Publication date

The number of articles included in the review by year of publication follows a slight upward trajectory, but this trend is not as steep in comparison to the trend in the overall population of published articles of potential relevance to this review, represented in Figure 2 by the total number of articles retrieved from the bibliographic databases before any screening. Neither is it as steep as the trend in all articles of potential interest screened at full-text. Possible explanations (as can also be inferred from Table 2 are i) proliferation of discussion articles about the subject of modern energy and clean cooking which are not reporting results of any particular programs designed to achieve energy transition; ii) discussion papers on specific programs that are not backed up by any evidence on the drivers or barriers to transition; and iii) studies focusing on a few individual households. The earliest year shown in Figure 3 is the earliest article included in the evidence map. Although older studies were retrieved by the searches, many were excluded at full-text screening for failing to meet the inclusion criteria.

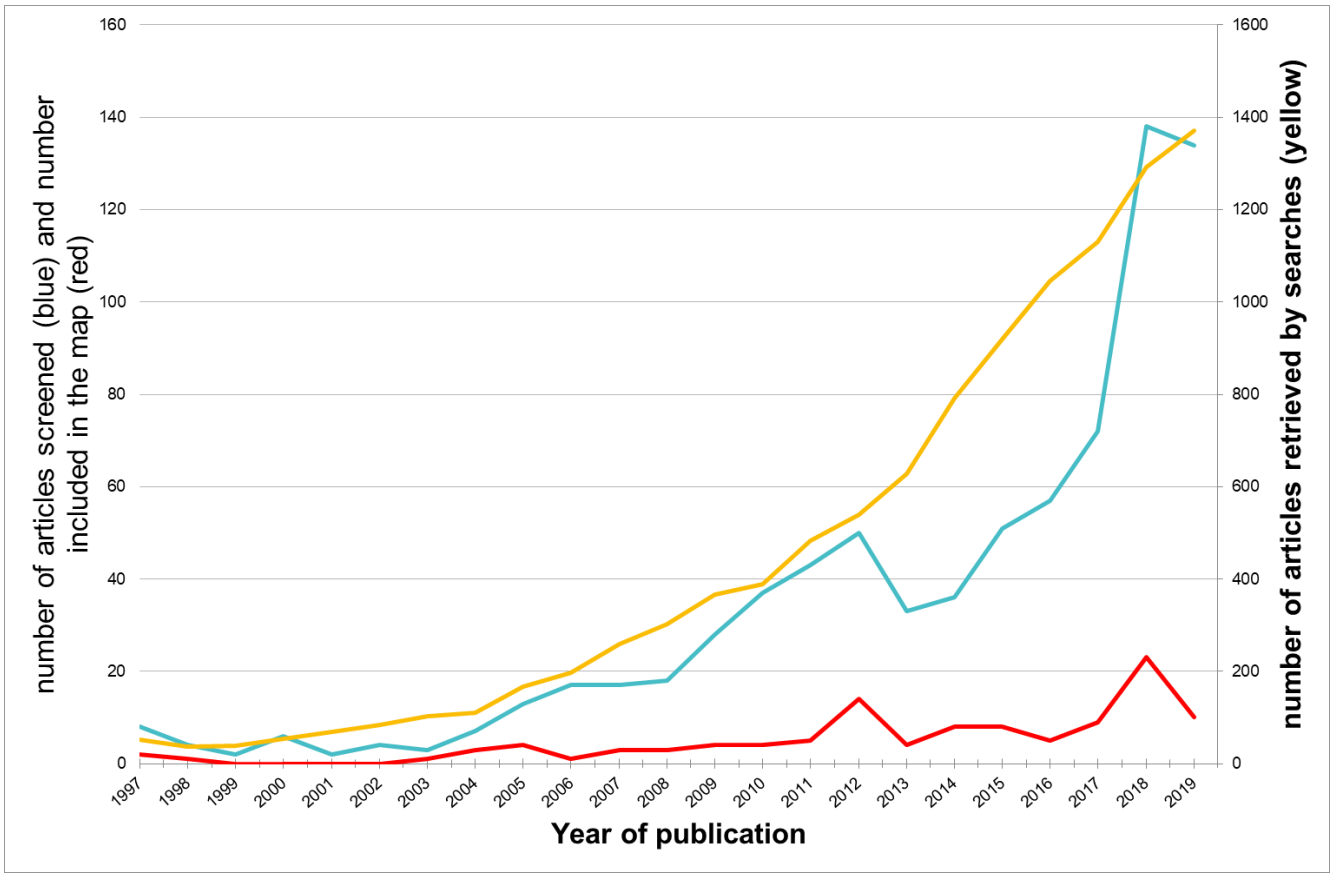


Figure 3 Number of publications by year (showing number included in evidence map, and for comparison – total number screened at full-text, and number retrieved from database searches (note: separate vertical scales)

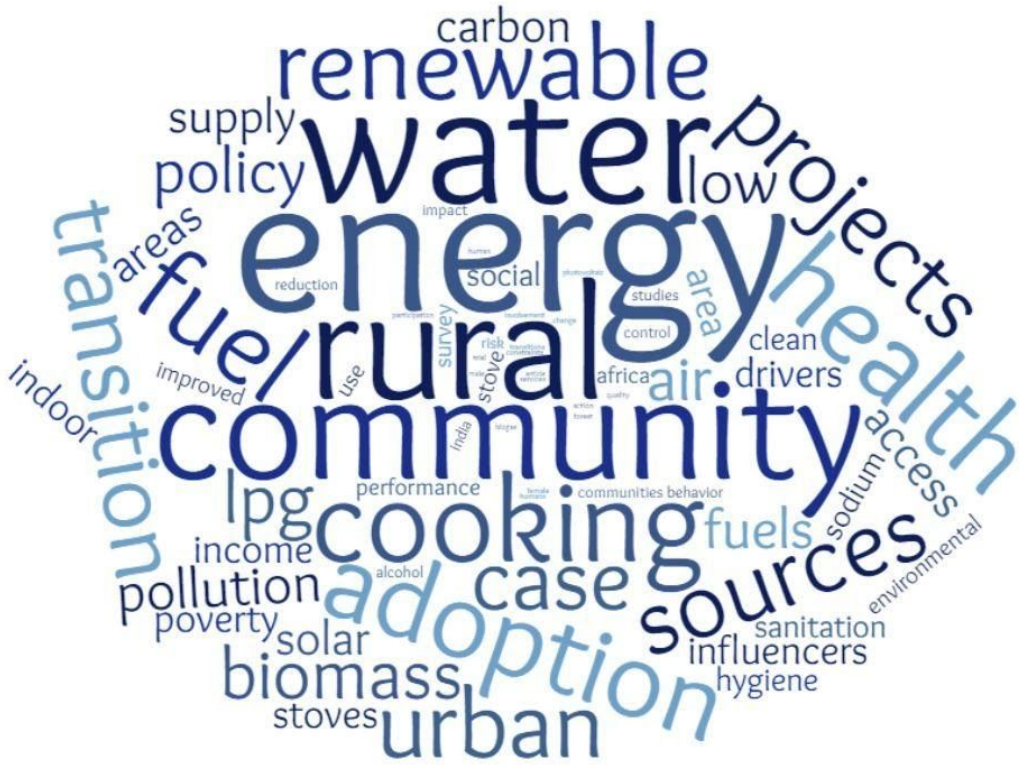


Figure 4 Prominence of different keywords assigned by academic journals to the set of included articles

(ii) Broad topics by keyword

Although not a strong analytical approach, highlighting the types of words used to index articles in academic journals can be useful to guide coding by reviewers. Figure 4 illustrates the frequency of words used as keywords in the included studies, as used in the academic journals which published each article retrieved from the bibliographic databases. Articles discovered through grey literature searching, or snowballing are not included as we did not write abstracts for papers nor add keywords where these were not available.

Studies

The following analyses refer to the separate studies within individual articles. Where relevant to the review question, studies were treated as individual entities with a unique identifying number and coded separately

(iii) Type of publication

Twenty studies in the evidence map were from synthesis papers, with results drawn from more than one piece of research, and incomplete research designs reported. Synthesis papers are typically not included in systematic reviews, because quality of the research is difficult to ascertain unless the original research is also located and screened. For this review however, it was agreed that synthesis articles would be included on the systematic map provided they reported on factors that affected adoption of change following programs promoting or supporting transitions in modern energy cooking services in low- and middle-income countries (LMICs). This was because the objective was to provide as much evidence as possible, which met inclusion criteria, and allow users of the systematic evidence map to decide

whether to filter these studies out or retain them when using the systematic map. Therefore, all synthesis papers that met the inclusion criteria, including those whose constituent papers could not be located were at least partially coded in the systematic evidence map. These can be filtered out in the interactive map, as a feature of transparent quality (see discussion on quality of evidence below).

The range of types of publication and sources are shown in Table 5 below. The vast majority of studies were from articles in academic journals. It is highly likely, given the topic of the current review, that there are more non-journal studies that could be assessed. These can be difficult to find, even using large-scale requests for grey-literature (see Annex 4). This is certainly an aspect that can be considered by future groups looking at evaluation reports of energy transition programs.

The included studies came from 48 different sources, with a dominance of two journals, which accounted for 66 studies. Table 6 shows journal publications for which there are 4 or more studies.

Table 5. Number of studies by types of publication

Publication type	Number of studies
Journal Article	139
Report	11
Book	8
Thesis	2

Table 6 Source of publications of studies included in the evidence base

Publication source	Number of studies
Energy Policy	35
Energy for Sustainable Development	31
Contemporary Social Science	9
Lancet Global Health	5
Boiling Point	4
Journal of Water and Health	4
Sustainability	4

iv) Geographical location of studies

(The evidence base is dominated by studies from India and China, but a total of 44 different countries are represented in the evidence base, of which the top 10 are shown in Table 6 below (note that multiple countries in one study are possible).

Table 7. Countries (top 10) where studies were undertaken

Country	Number of studies
India	25
China	16
UK	10
Kenya	9
Nigeria	6
Peru	6
Uganda	6
Indonesia	5
Mexico	5
Rwanda	5

There is under-representation of Brazil, Russia and countries of North Africa. Even though populations in these countries are not dependent on solid fuels for cooking, the search was not specific to studies about cooking with solid fuels and should have captured transitions in these countries. The under-representation may reflect a lack of programs implemented in these regions, a dearth of research on those programs, a limitation of the English-language search strategy (almost certainly for Russia) or some other reasons which needs due consideration.

(v) Setting of studies

Almost half of the studies were rural in setting. Many had multiple settings. Only 14% were wholly urban, which is undoubtedly an under-representation of the sector by the evidence base dominated by academic articles. The studies were dominated by those assessing households (62%, 101 studies); 19 studies assessed individuals, whereas only 5 studies assessed communities or villages within a transition program.

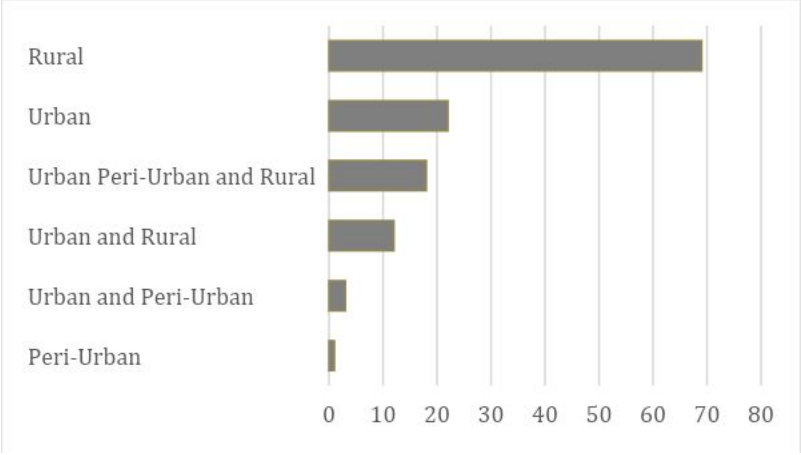


Figure 5 Study settings by number of studies

The number of 'units' studied (i.e. number of households or number of villages, etc.) ranged from 4 to 250,000, with a median sample size of 247.

vi) Quality of studies

As discussed above in 2.8, following good practice guidance for systematic maps, the included studies were not assessed for quality as an exclusion criterion. The review team did, however, record a number of characteristics of each included study that could be used as a proxy for quality. We included studies that are typically rejected in systematic reviews, e.g. synthesis papers, papers which rely on analysis using secondary data that are not easily verifiable, and studies with missing data (see Methods). Instead the quality features of these studies were documented as part of the coding process: whether the study was part of a synthesis paper, or used primary data; whether the study reported missing data, and if such missing data were accounted for, and whether secondary data were used, which could not be independently verified. The evidence base can therefore be interrogated for studies that meet the higher standard of transparency and repeatability (i.e. no occurrences of these factors). Excluding studies which 'failed' to meet these quality criteria would have reduced the size of the evidence based considerably, while introducing possible reviewer bias discussed in 2.8. Table 8 shows the number of studies with one or more of the potentially-low-quality proxies. The evidence map (described below) can allow for filtering out studies with these quality proxies and excluding them from independent analyses if required.

Table 8 Number of studies which had potential risk of bias or unreliability. Note these are not mutually exclusive: many studies had more than one adverse quality proxy

Quality proxy	Number of studies
Synthesis study	21
Data missing	45
Data missing and not accounted for	15
Use of secondary data	42

vi) Transition in other sectors of relevance to MECS

Despite applying the same inclusion criteria to articles from sectors other than cooking or modern energy, the vast majority of articles on sanitation, water availability and quality, telecommunications and other sectors were rejected for lack of clear evidence that the study was part of a large-scale program. Searching the file of excluded studies (see Supplementary material) for these keywords indicates how many studies relate to these different sectors. As excluded studies, they were not coded for the evidence base, however, so the precise number of articles by sector is not available. As discussed earlier, the reasons for exclusion by the reviewers can be contested and the value of providing access to the full list of excluded articles is a large benefit of the systematic evidence evaluation approach. The evidence base contained only 5 studies (from 2 key articles) – Wilson et al (2018) and Opryszko et al 2010. This disappointing lack of comparative studies from other sectors may be attributed to the high-level search strategy, but there were terms in the search which should have picked up relevant research about what drove the adoption of new technology, or what incentivized transitions. No relevant studies outside the modern energy for cooking sector were suggested by the wide request for grey literature either, but this is perhaps more easily explained by the fact that the stakeholder-suggested organizations were heavily dominated by those with a cooking focus. Wilson's study was in fact also cooking-focused as the intervention was an improved cookstove with the added presence of a USB charging port for household's mobile phones. The addition of this technology dramatically increased adoption of the cookstove, and this increased adoption was driven primarily by improved convenience and time-saving during cooking or cooking-and-charging, while charging-only as a mode of function carried with it perceptions of negative impact on emissions. Opryszko (2010) reported a small-scale, randomized control trial of a sanitation program in Afghanistan, which correlates positive health and well-being outcomes with transition to chlorinated water and associates higher uptake with higher economic status. The program could not be fully implemented in five villages for technical reasons, and this may have affected outcomes. This lack of evidence in the current map probably does not mean that evidence is lacking in the wider literature, but from the current systematic attempt to find relevant studies, there was an evidence gap.

vii) Sustainability of transition programs

Capturing sustainability of a transition is limited by a general lack of long-term research. An important factor that indicates to some extent the likelihood of the study to be useful in determining sustainability is to look at studies conducted over several years. The majority of studies which reported clear information on duration of study in the evidence base were conducted over 1 year or less (60%), while 26% lasted more than 2 years. Encouragingly, 18% were of 5 or more years' duration (Figure 6). This is entirely consistent with other systematic reviews, which have similarly found that short-term research dominates the literature. Data on years since the intervention (a very strong indicator of sustainability) were not well reported, but of the 35 studies with reliable information 21 had started more than 3 years

since the introduction of the transition program, compared with 13 which started one year or less after the program introduction.

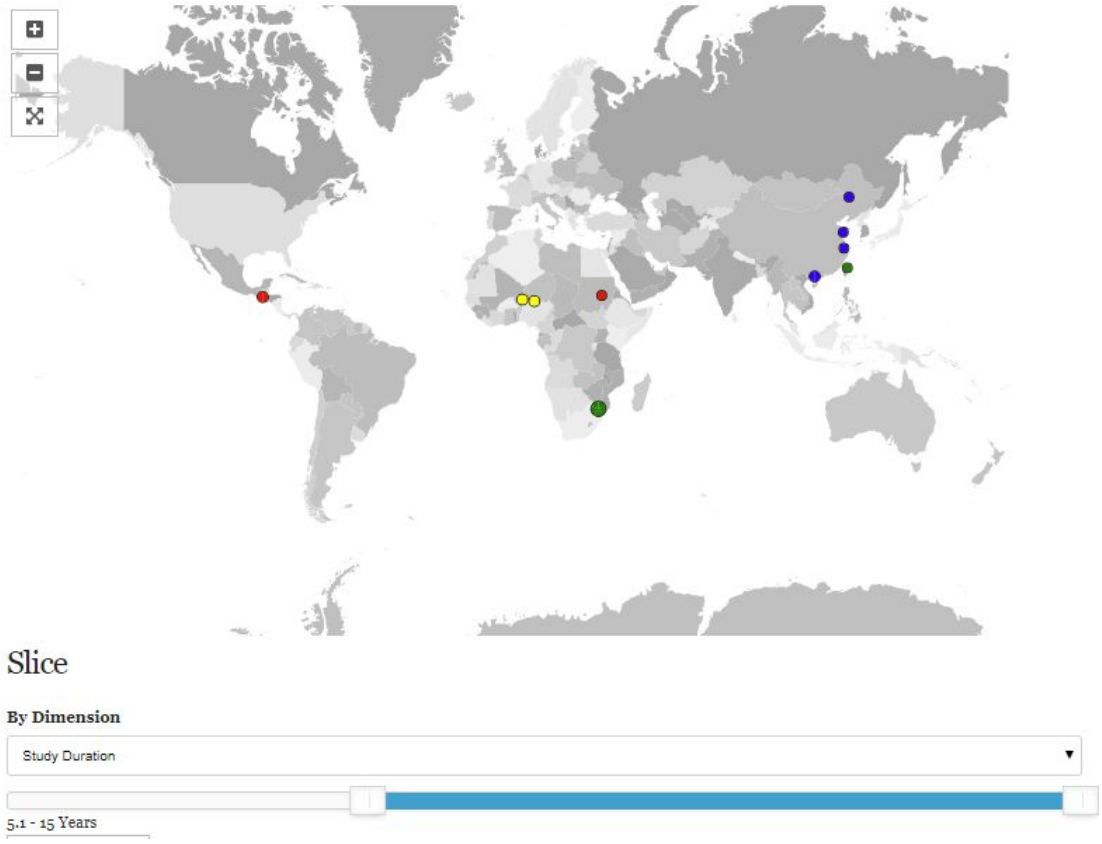


Figure 6 Studies that were carried out over periods of 5 or more years.

PART 2: THE INTERACTIVE MAPPING TOOL

Most of the information presented in this section is discernible from the visual map of the evidence base assembled from the data sheets (160 in total) described in the methods section. These have been linked in an interactive mapping tool that users can manipulate to find sets of studies filtered by selected data sheet criteria. Some of these studies had been conducted in more than one geographical location, and all locations are mapped. The map is therefore the richest source of information about the evidence base. It is operational at [https://energydata.info/apps]. Its functionality is described on the mapping tool page at the same location and in Annex 4.

The mapping tool is a visual representation of the Data Sheets in the evidence map. Studies are georeferenced and displayed as points on a global map as can be seen in Figure 7.

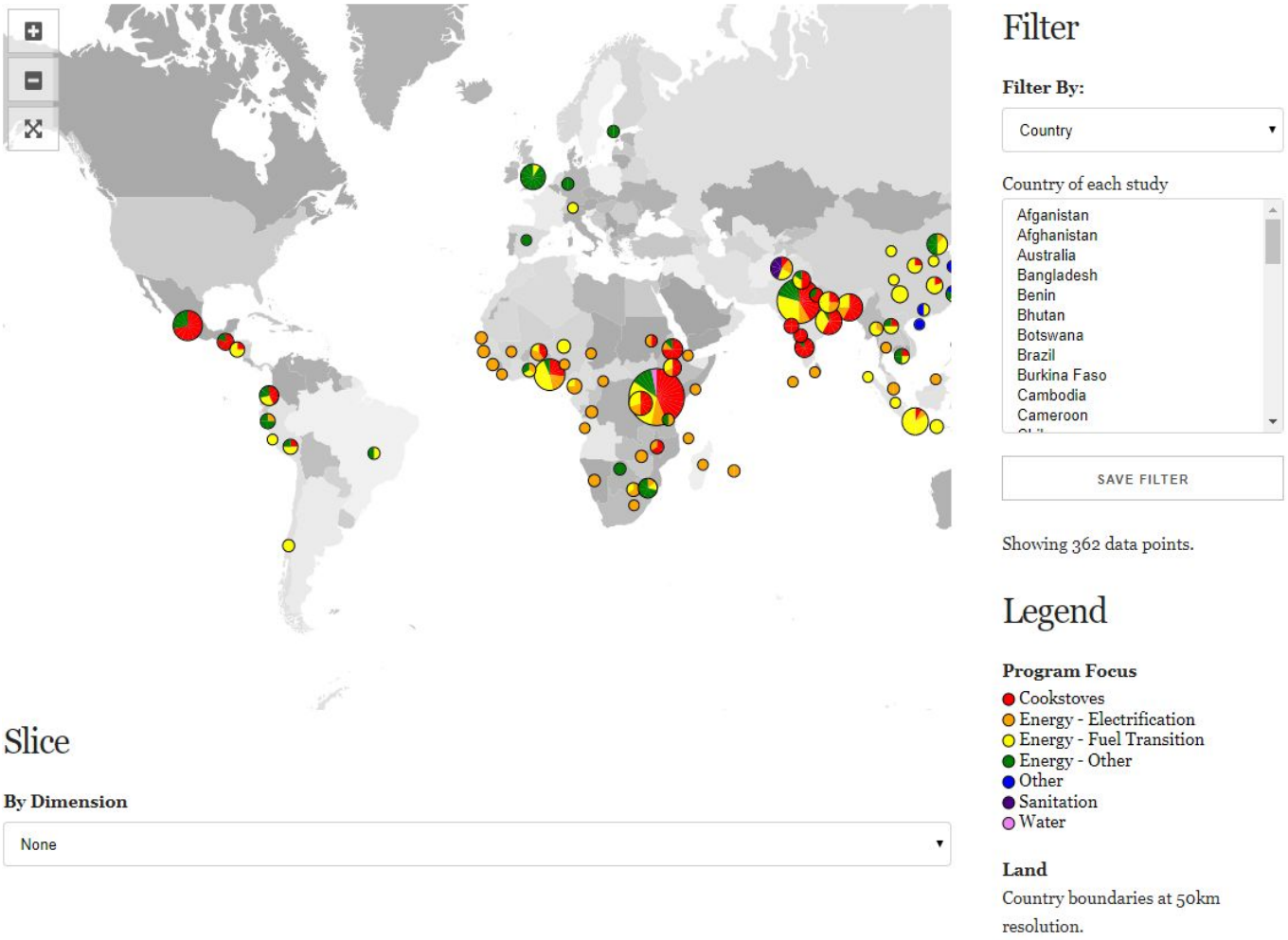


Figure 7 shows a screenshot of the entire evidence base plotted using a color code that represents the major focus of the programs for technology transition found in the evidence.

Sub-samples of studies can be viewed by applying the filters (for example quality criteria – Figure 8) and slices (for example dates of programs).

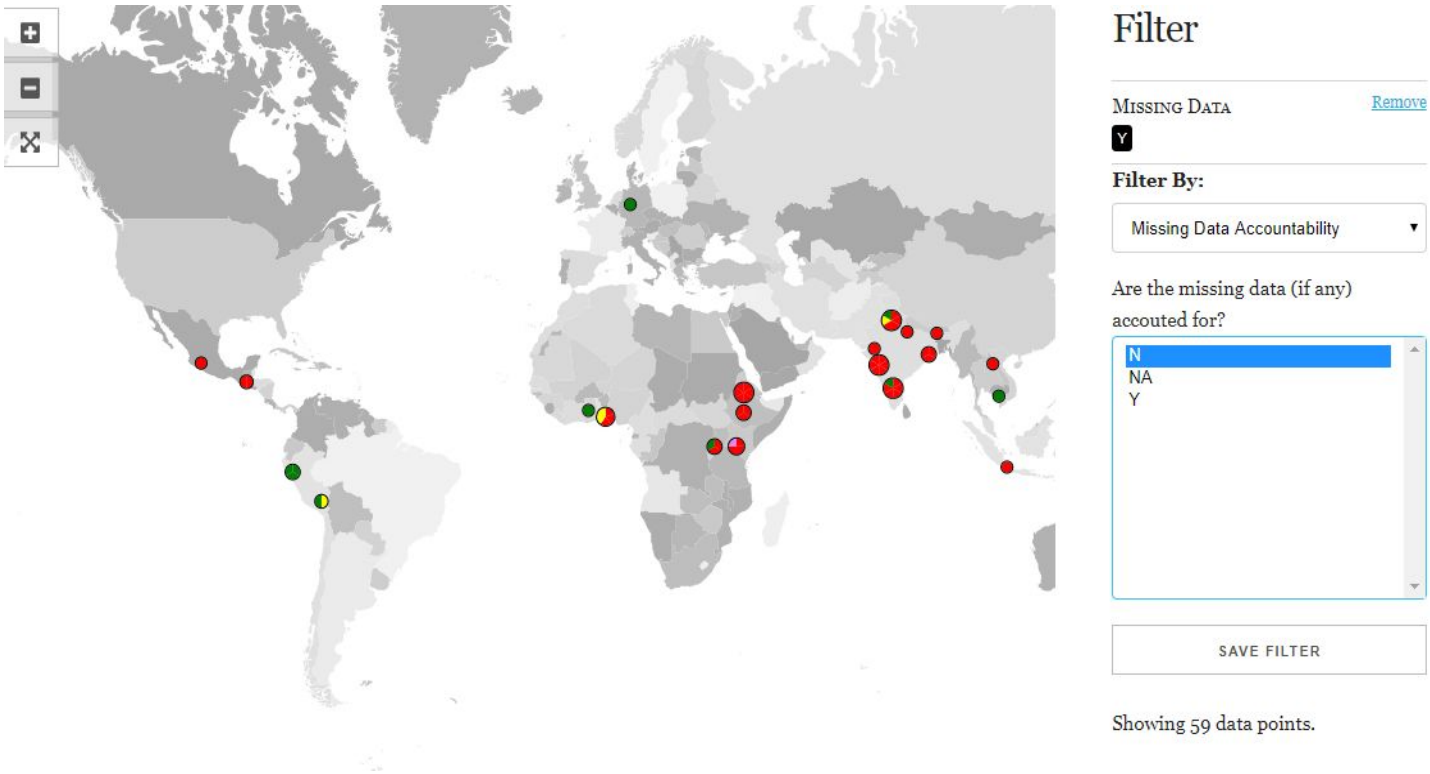


Figure 8 Map of studies where there is a risk of bias due to missing data that are not accounted for. Note use of filter to obtain this information from the mapping tool

The interactive mapping tool can also support, for instance, the discovery from the assembled evidence on urban vs rural transitions to MECS have occurred and in what years, as shown in Figures 9 and 10.

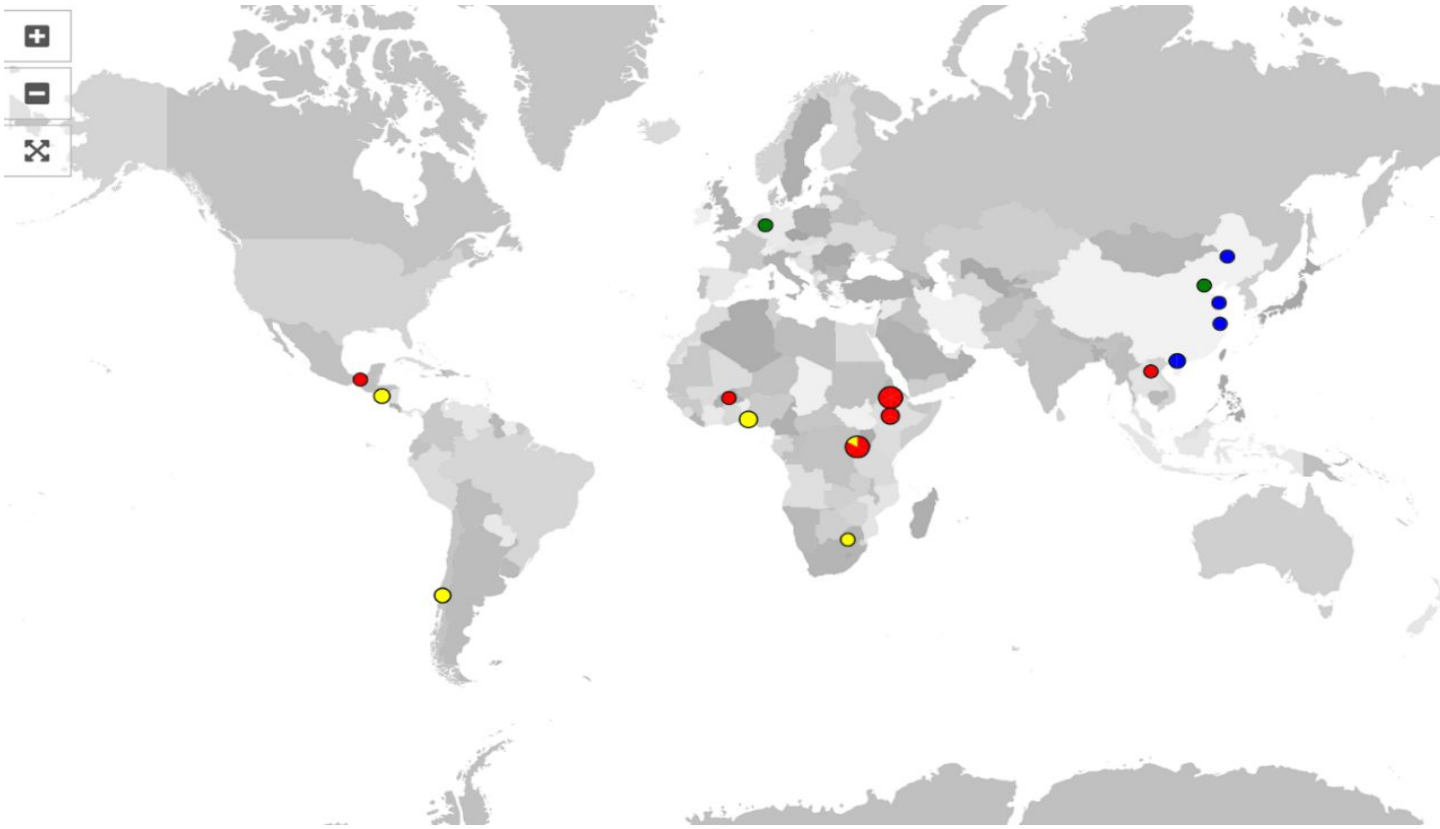


Figure 9 evidence from urban settings (note that many studies reported urban and rural, which can also be used as a filter)

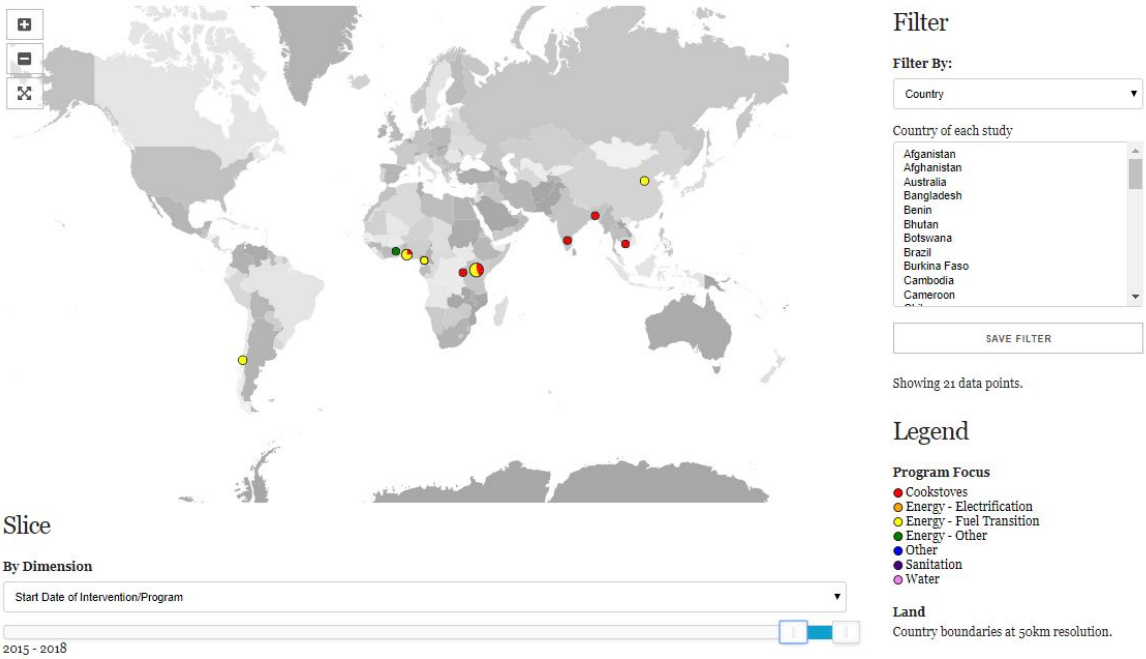
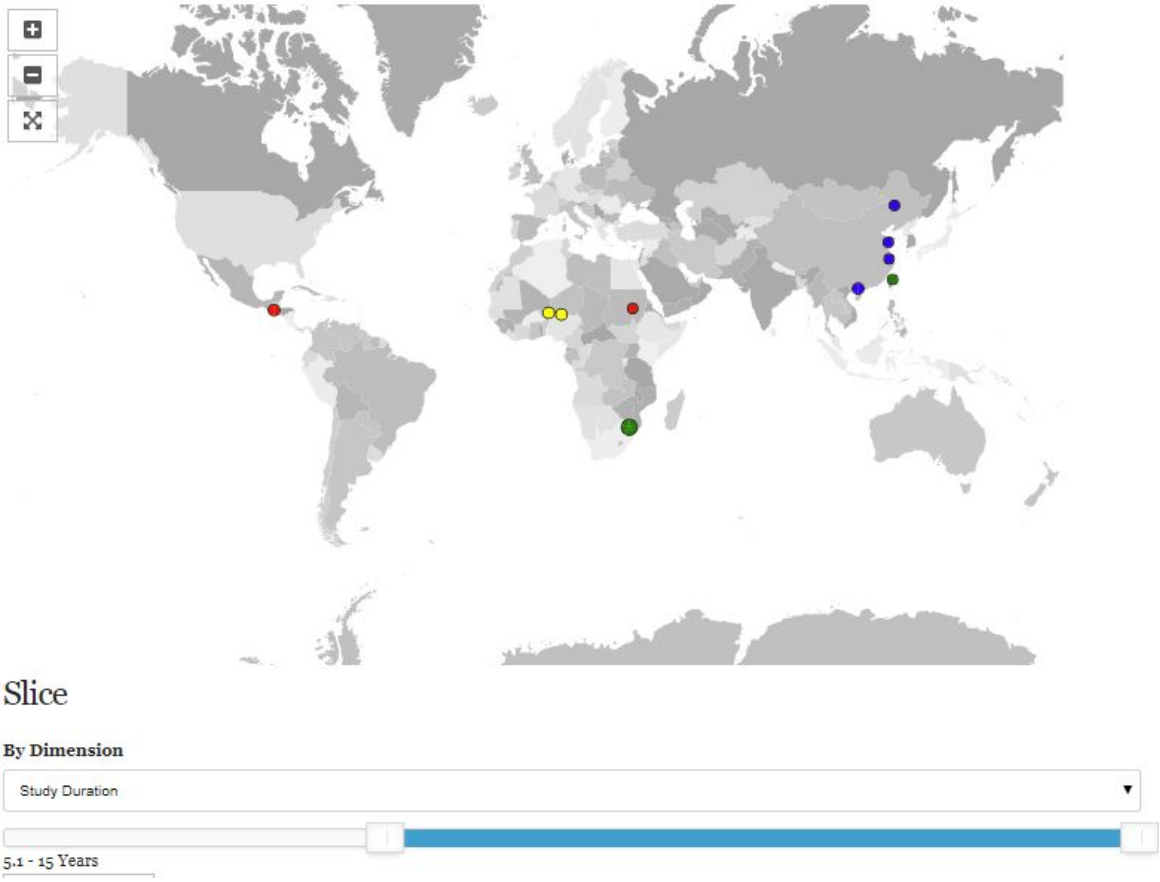


Figure 10 (i) cookstove studies that started from 2000 onwards, and (ii) from 2015 onwards.



PART 3: SYNTHESIS OF REPORTED FACTORS THAT DRIVE OR INHIBIT TRANSITION

This section presents the findings of reported factors that contribute to the key question about what may drive transition to cleaner energy systems, and what may act as a barrier to adoption or transition to cleaner energy systems with particular reference to cooking. The evidence base captures potential enabling factors as well as reported drivers of change. These factors were captured as positive, negative, or neutral in the evidence base, based on what was reported and not on independent statistical analysis. For interpretation, it is important to note that one factor can serve both as a driver and as a barrier depending on how it is characterized in the study. This is similar to interpretation applied by Puzzolo et al (2016), where the factors are not seen as discrete enablers and barriers, but as operating on a spectrum, "so that when present or satisfactory they are enabling, and vice versa".

Information on drivers and barriers to adoption of modern cooking energy (backed by reported results or data, including, importantly, qualitative reporting of perceptions of benefits or inhibiting factors) was extracted from the studies in the 10 main thematic categories (the initial 9 categories with an additional category of "other") explored by the review, with many of them having overlaps. For example, the topic adverse perceptions of new technology characteristics cuts across the domains Knowledge & Perception, Technical Characteristics and Market Development.

Overall these factors may help to explain what population characteristics determine adoption of MECS, where and when transitions have occurred, how the domain characteristics drive or impede large-scale transition amongst others.

In addition to assessing studies that contained data specifically on drivers or barriers, this section contains an assessment of studies that specifically reported success (or otherwise) of the transition program. Not all studies in our evidence base contained information on both these elements, and the tables of studies below reflect these minor differences.

3.3.1 Reported Outcomes of transition programs

Before delving into the reported drivers and barriers, we first present the perceived successes (positive outcome), failures (negative outcome) or neutral outcomes of the evaluated programs to achieve their intended goals, where these were supported by measurements or documented data. The results presented in this report are those reported by respective authors.

Transition level outcomes

Just under a quarter of the included studies (37) reported on success of transition (i.e. adoption and uptake of clean fuel or stove) as an outcome in itself, of which 35 also reported at least some data on success measures of the program and drivers or barriers to the transitions. Out of these, 21 are reported as programs targeting more than 1000 people. Adoption of the transition ranged from 5% of the total population affected by the program to 69%, in a very large-scale program targeting all regions of Indonesia in a change from kerosene to LPG (Thoday et al 2018). Other studies with high reported adoption rates were a very large-scale commercially-based distribution program of an advanced pellets gasifier stove in India (Thurber et al 2014) with transition rate of 45% in purposively-selected participants (compared with 16% in randomly-selected households), and in a program introducing an improved cookstove to communities of mainly indigenous people in Mexico who traditionally cook on open fires with no chimney (Pine et al 2011). A very large program in rural Hebei in China reported 30%

transition rates from coal to natural gas and electricity for heating (Nan et al 2018). A large-scale program of over 25,000 households in Ghana reported 30% success rate for households adopting improved wood or charcoal cookstoves in preference to their traditional stoves (Dickinson et al 2019). Three further programs with moderate (*c*. 30%) levels of uptake were for much smaller programs - in Rwanda (Jagger et al 2019) and Uganda (Levine et al 2018), both aimed at transitions from traditional cookstoves to improved solid fuel stoves. A large program biogas that targeted 500,000 people in rural Kenya, Tanzania and Uganda reported 5% uptake (Clemens et al 2018).)

Impact level outcomes

Transition outcomes can also be viewed as an intermediate outcome measure without which the programs would not realize the final desired impacts – such as improved health and wellbeing, increased household wealth, etc.–. Information on intended outcomes of the programs was therefore captured in three main categories – Economic, Environmental, and Social benefits. These three types of benefits have been reported to accrue from transition to modern energy for cooking. Even though health is a commonly reported outcome measure of cookstove programs, none of the interventions had only health as their goal, hence its inclusion with other social benefits of transition. These are all filters on the interactive map. The results are reported in Table 9.

The broad spectrum of studies included resulted in a large set of measured outcomes. The most frequently-measured positive outcomes of transitions to cleaner energy across programs were Human Health and Wellbeing (10 studies), Cost Saving (8 studies), and Deforestation (5 studies). Time Saving (TS), and Safety and Emissions Within Homes (EM) were reported as positive outcomes in 3 studies each. As expected, there were more studies reporting positive than negative outcomes, resulting probably from well-known publication bias that favors positive results (Frampton et al, in press). It is also possible that studies reporting new technology features may be over-represented compared with studies with whole-system evaluation, which may also suffer from publication bias (Newcomer et al 2015).

(i) Measured Social and Wellbeing Outcomes

The five most frequently-reported positive outcomes in this topic were Human Health and Wellbeing (HH) (29 studies), Time Saving (TS) (19 studies, with an additional 6 discussing Drudgery (DR)), Convenience (CO) (10 studies), Education (ED) (7 studies), and Safety (SA) (7 studies). In addition, benefits to Hygiene (HY), Awareness (of the objectives of the program specifically or the benefits of a transition in general) (AW), Gender (GE), Leisure (LE), Aesthetics (AE), Aspiration (AS), Choice (CC), and Decision-taking (DT) between them were discussed in 18 studies. Time Saving and Human Health and Wellbeing were also recorded as no change in one study each, and Human Health and Wellbeing and Safety were also recorded as negative in one study each.

(ii) Measured Economic Outcomes

The most frequently-cited economic benefits were Cost Saving (CS) (20 studies) and reduced Fuel Use (FU) (16 studies). Other beneficial factors reported related to Income (IN) (3 studies), Sustained Funding (SF), Employment (EP) and Willingness to Pay (WP) (2 studies each), and Income Generation (IG) and Subsidies (SU) (1 study each). Negatives were reported for Fuel Use and Cost Saving (2 studies each), and Fuel Price (FP), Fuel Use, Cost Saving, Supply Chain (SC), Technology Performance (TP), and Inflation (IN)

(1 study each). Fuel Use and Cost Saving were reported as having no change in response to the transition in a single study each.

(iii) Measured Environmental Outcomes

The two most frequently-cited environmental benefits were Emissions Within Homes (EM) (13 studies) and reduced Deforestation (DE) (11 studies). Forest degradation was not reported in any of the studies, which is almost certainly due to historic difficulties in discerning and quantifying degradation, resulting in a dearth of literature relative to that on deforestation (Sasaki and Putz 2009). One study reported an adverse effect on Deforestation, and one study each reported negative effects on Emissions Within Homes and Air Pollutants (AP). One study each recorded no effect on Emissions Within Homes and Green House Gas Emissions (GH) following the technology adoption.

Table 9 shows studies reporting measured outcomes of modern energy transition (KEY: positive "+" or negative "-"). Abbreviations are listed in Measured Outcomes sections i, ii and iii above.

First Author	Social/Health/Wellbeing	Economic	Environmental
Acharya 2017		IN-; FU-;	
Aklin 2018			
Alberts 1997a		CS/; FU+;	DE+;
Alberts 1997b		CS+; FU+;	DE+;
Andadari 2014		FU/	
Asante 2018	HH/		EM/;
Astuti 2019	CO+; HH+; HY+; ;	CS+; ;	EM+;
Banerjee 2016	DR+	FU+; CS+;	
Barnes 2012a	TS+; CL+; HH+	FU+	EM+ ;
Barnes 2012b	CL+; TS+	FU+	EM+ ;
Barnes 2012c	HH+; TS+; CL+;	FU+; FU+;	
Barnes 2012d	TS+;CL+; HH+	FU+	
Barnes 2012d	TS+ ; HH+;CL+	FU+; FU-;	EM- ;
Barnes 2012e	CL+; HH+; TS+	FU+	EM+ ;
Bielecki 2014			
Boso 2018		CS+	EM+;
Calvo-Gonzalez 2015	HH-		
Calzada 2018	HH+	SF+; SC-;	EM+;
Catalan-Vazquez 2018	HH+;CO+		EP+;
Chang 2018		SU+	
Christiaensen 2013	TS+; GE+; LE+; HH+; DR+	FU+; IG+;	EM+;
Clark 2017	CO+		EM+;
Clemens2018	HH+; DR+; CO+; HY+; TS+	CS+; FU+;	DE+;
Coelho 2018		FP-; FU+;	
Coyle 2005a	CO+; TS+	CS+	
Coyle 2005b	CO+; TS+; ED+	CS+	DE+; EM+

Dendup 2019	HH+; DR+;	IN+	
Dickinson 2019	TS/; TS+;	FU+; IN+	EM+;
Foley 1997a	HH+		DE+;
Foley 1997b	HH+		DE+;
Foley 1997c	HH+		DE+;
Foley 1997d	HH+		DE+;
Garland 2015a			DE+
Garland 2015b			DE+;
Hanna 2012	HH+		AP+; GH/
Jagger 2016	SA+; TS+; DR+		EM+;
Jagger 2018	AS+; HH+; HY+; TS+		EM+;
Jagger 2019	HH+; TS+		
Jeuland 2019	CC+	WP+	
Keese 2017	CO+; TS+	CS+	
Kuai 2020a	HH+		
Kuai 2020b	HH+		
Kuai 2020c	HH+		
Kuai 2020d	HH+		
Kuai 2020e	HH+		
Lee 2015			DE-;
Levine 2018a	ED+; TS+	CS+	
Levine 2018b	ED+; TS+	CS+	
Mobarak 2012	TS+	CS+	
Mudombi 2018	HY+; CO+; SA-; TS+;	IN-; CS-; CS+	
Nan 2018			EM+; EP+
Obueh 2008a	SA+	CS+	
Obueh 2008b	SA+	CS+	
Obueh 2008c	SA+	CS+	
Opryszko 2010a,b,c and d	HH+		
Ortiz 2012a,b,c and d	AW+		
Ozier 2018		WP+	
Patel 2016	CO+	CS+	
Pollard 2018	HH+;		
Sesan 2012	SA+		
Sovacool 2011	SA+; TS+	EP+; CS+;	EP+;
Toonen 2009	ED+; TS+		
Troncoso 2007	HY+; AE+; DT+	FU+;CS-; TP-	
Usmani 2017	DR+;	FU+; ;	
Vulturius 2017	GE+	SF+	
Wilson 2018	CO+; TS+		
World Bank 2004	ED+; TS+; GE+	CS+	

Yadoo 2012a	ED+; HH+; TS+	CS+; EP+;	EP+;
Yadoo 2012b	SA+; LE+; HH+; ED+;		
Yadoo 2012c	SA-;	CS/; ;	
Yasmin 2019		CS+	

*Note that only the first author and date is provided in the tables in section: full bibliographic details can be ascertained from the list of studies included in the review and on the evidence map in the Bibliography section.

3.3.2 Drivers and barriers of transitions by coded category

There were 91 articles from which at least some data on drivers and barriers were extracted *i.e. the fully-coded papers). The number of studies reporting drivers and/or barriers in each coded category is shown in Table 10.

Table 10 incidence of recorded drivers and/or barriers by coded category

Category	Driver/Barrier	number of studies
CH- Characteristics of Setting - Enabling Factors e.g. household characteristics, farm, uplands, lowlands. Confounding factors	Drivers	20
	Barriers	20
KP- Knowledge and Perception, Information	Drivers	22
	Barriers	17
TC- Technology/Fuel Characteristics - impacts based on measured data - e.g. time, safety, health	Drivers	21
	Barriers	19
FT- Financial, Tax and Subsidy Aspects - Did financial incentives (or lack thereof) lead to program success/failure?	Drivers	23
	Barriers	25
RL- Regulation, Legislation and Standards	Drivers	4
	Barriers	2
MD- Market Development (e.g. Distribution, advertising campaign)	Drivers	10
	Barriers	3
PP- Programmatic and Policy Mechanisms (e.g. Government leafleting, demonstrations, setting up networks, government promotion)	Drivers	11
	Barriers	17
PO- Poverty	Drivers	3
	Barriers	7
GE- Gender	Drivers	10
	Barriers	6
OT- Other	Drivers	8
	Barriers	13

It is clear from Table 10 that many of the studies contributed multiple aspects of knowledge of interest to the review question. Of the studies which had information on drivers and/or barriers, 49 studies yielded information on barriers or drivers in four or more categories. On average studies reported

Drivers and/or Barriers in 4 of the 10 categories. The highest number was 9, in the study by Gould et al (2018). Andadari, Mulder & Rietveld (2014), Troncoso (2007) and Astuti (2019) reported data in 8 categories.

The most frequently reported drivers were in the domains of FT (Financial, Tax and Subsidy Aspects) with 23 studies, KP (Knowledge, Perception, Information) with 22 studies, TC (Technology Characteristics) with 21 studies and CH (Characteristics of Setting) with 20 studies.

Barriers were most commonly reported in the domains of FT (25 studies), CH (20 studies) and TC (19 studies. KP and PP (Programmatic and Policy Mechanisms) had 17 studies each.

Several studies reported the same domain as both a driver and a barrier: TC (11 studies), CH (10 studies), FT (9 studies), KP (7 studies), PP (5 studies), GE- Gender (4 studies).

PART 4 NARRATIVE REFLECTIONS ON EVIDENCE OF DRIVERS AND BARRIERS TO MECS TRANSITION

This section delves deeper into the reported drivers and barriers. As discussed earlier, despite searching for articles from other disciplines, only studies on aspects of cleaner cooking, or modern energy for cooking, satisfied the inclusion criteria and were incorporated in the evidence base. The following section, therefore, deals only with modern energy for cooking. The discussion makes reference to particular studies that offered valuable insights on how certain factors played a role in facilitating or inhibiting transition to MECS, including some context specific information. However, users can interact with the complete picture of the evidence base of 160 coded studies using their own combinations of filtering criteria to determine which studies reported information of interest to them. We reflect on studies that discuss in detail drivers and barriers to MECS transition.

The section is organized according to the themes that emerged from the evidence base, and does not, therefore, follow our 10 *a priori* domains, which were useful for data collection, but less useful for qualitative analysis owing to overlap of issues. Six major themes emerged from the study that influence transition. These were (in no particular order) i) Population characteristics including poverty and wealth status; ii) Peer influence and trust embodied by the information source, iii) Competition with existing fuels and technologies; iv) Performance of the transition fuel and technologies relative to traditional ones, v) Cost of transition; vi) Socio-cultural perspectives and gender and vi) After sales support.

3.4.1 Population Characteristics

The evidence base shows a strong correlation between certain individual characteristics (e.g. age, education, socio-economic status) and MECS transition across programs and settings. This is despite the wide variation in the studies in terms of methodology, outcome measures, settings in which they are conducted and the interventions evaluated. A number of studies utilized logistic regression models to assess the influence of age, education, wealth status and other socio-demographic variables on MECS adoption, with the majority of them finding common results. While such modelling can be considered a limitation of the studies based on such model's assumptions, small sample sizes reported in some of these studies and inadequate control for confounding, the similarity of their findings is striking.

Additionally, the findings are highly consistent with those of qualitative studies that posed direct questions to respondents on what had driven or prevented them from making the transition to modern cooking energy. Income, age, education (knowledge) and other individual characteristics were always cited as drivers or impediments to adoption. For income in particular, an overwhelming number of studies find poverty to be a critical factor affecting transition, to the extent that some programs that had been touted as successful were in later evaluations found to have excluded the very poor who were their target groups (Troncoso et al, 2007, Urpelainen & Yoon, 2017). Urpelainen & Yoon observe the following on one of the programs:

> *Poverty distribution in both the SHS (solar home system) and ICS samples suggest that the dissemination of both technologies is currently not pro-poor oriented according to the definition of the German Federal Ministry for Economic Cooperation and Development (BMZ), as the proportion of poor people among the respondents is below the regional average of 48% in the research region.*

Programs that included interventions to tackle income barrier demonstrated some success. The evidence on population characteristics including wealth status as a driver or impediment of MECS transition is thus very compelling and a key finding emerging from this evidence base.

Clarke et al (2017) report household stove use to be negatively associated with age of the main cook, household socioeconomic status amongst other variables. In Cameroon, Pope et al (2018) also find an association between LPG use and wealth status (household head with secondary and tertiary education, with access to mains water and household sanitation and with income above national average, asset ownership), with the exception of age which showed no relationship with adoption in rural settings. For the peri-urban setting however, age was negatively associated with LPG use. Thurber et al (2014) report a strong correlation between adoption and usage of LPG with household income and age. Troncoso et al (2019) report a strong correlation between use of firewood and socioeconomic stratum, with those in the lowest stratum preparing 81% of their meals with firewood compared to 40% households in the high-income stratum who mainly use LPG. In Gould & Urpelainen (2018). older cooks are reported to use the intervention less than the younger cooks, which the authors note was unsurprising. Mudombi et al (2018) who assessed adoption of ethanol cooking fuel by wealth status, using a multidimensional poverty index found adopters to have the lowest poverty, followed by those who adopted the technology and abandoned it, and finally the group who never adopted it. Beyene & Koch (2013) finds that wealth increases the rate of adoption of the Mirt stove, but does not affect the adoption of the Lakech stove in Ethiopia. According to the authors, the Mirt stove is large in size and requires a lot of space, while the Lakech stove is simple and easily mobile, and, therefore, does not require additional space. Thus, it was not surprising to the authors that those with their own homes and separate kitchens reported higher rates of adoption of Lakech stoves.
Yasmin & Grundmann (2019) found that wealthy farmers are more likely to adopt biogas technology.Education was also a predictor of biogas adoption, similar to what Hafeez et al (2013) found on adoption of the same technology in Bangladesh (in addition to income, farm size and number of cattle Li Jian (2009) found that formal education levels of the biogas users were higher than those of the overall village population, although there were some sub-groups where this relationship did not hold true. In another study on biogas, Amir et al (2019) grouped respondents into two categories based on their monthly income: those at a lower income level (PKR up to 15,000) and those at a higher income level (PKR 15,001 to 33,000). Households in the higher income category were significantly more likely to adopt the technology. Kishore et al (1998) found the literacy status of household heads to have a positive influence on the demand for biogas. Suliman (2013) reports asset poverty, low educational

achievement and low status as deterrents of adoption of clean fuels. The influence of age was not significant but is noted as positive, with more years of formal education of the household's head increasing the likelihood of adoption.

A few studies however present some contrasting findings, particularly on biogas technology adoption. In Walekhwa et al (2009) biogas non-users are reported to have larger households and to rear more livestock, although they did have lower income (not significant) and number of cattle compared to adopters. Monthly household income earning patterns were similar between biogas users and non-users in this region. In Pakistan, Amir et al (2019) found age and education level of household head to have a significant negative relationship with biogas technology adoption, with the younger and less educated household heads being more likely to adopt the technology. This finding on age is consistent with Christiaensen & Heltberg (2013) R., who find the probability of biogas adoption to be higher with younger household heads in China. The result on income is however consistent with other biogas studies, showing higher probability of adoption with increasing income, except for households whose income came from remittances.

The common findings on age, income and SES reported above for clean fuels are also reported for populations adopting ICS, although we find some contracts that would be expected given the diversity of technologies that are included as ICS. The ICSs evaluated by the studies range in quality and price, from simple stove designs that mimic traditional cookstoves, to advanced gasifier types that entail establishment of fuel supply chains.

In Rwanda, Jagger et al (2019) found that households adopting the pellets improved stove had more assets, and higher per capita hygiene expenditures. Education level however had only a modest correlation with the stove's adoption in rural areas. Inayatullah Jan (2011) using regression analysis, reports that education and household income were the most significant factors that determined a household willingness to adopt improved biomass stoves. In contrast to these findings, Alvarez et al (2004) found the socioeconomic characteristics of non-stove users to be similar to those of stove users. Nonetheless, the non-adopters reported lack of the required cash payment (45% of the stove cost) as the reason why they did not participate in the project. In Haryana, India, Barnes et al, 2012however found the influence of income to be on the opposite direction, with most improved stove users being low-income households and with lower literacy levels. The setting is however unique with high penetration of LPG that was the main fuel for wealthier households. The income gradient was also reflected in the type of ICS used, with the less expensive single-pot stoves used mainly by low-income households while better-off households used both single- and two-pot stoves. Mobarak and Miller (2013) report on a program that offered two choices of stoves. Women with at least some education were more likely to choose the healthier chimney stove than the efficiency stove.

Troncoso et al (2007) explored and found no significant relationship between education and age and level of adoption, but a positive correlation was found with socioeconomic level. The authors however note that their sample sizes were too small. In urban Ethiopia, Beyene & Koch (2013) used survival analysis to explore not just the outcome of adoption but also the speed at which it occurs. They found education, income and wealth to be important contributors to adoption. However the speed of adoption was influenced by income only, and for just one of the technologies. Unlike other studies finding positive relationship between LPG use and income, Thompson et al (2018) report that households with higher median incomes used wood- fueled stoves (both improved chimney stoves, or planchas and open fires) more hours per day, but did not increase gas stove use, compared to those households below the median. Agurto Adrianzen (2009) found the proportion of households with

secondary education and above to be significantly higher for adopters than for not adopters. The adopters are also reported to have more assets than non-adopters. These findings are however surprising as the stove cost was fully subsidized.

The important role of SES also emerges when looking at other programs that entailed free stove distribution or heavily subsidized ones. In a stove replacement program that entailed 100% subsidy, income, education and other factors were found to not influence adoption (Boso et al, 2019). The only significant factor was age that had a positive relationship with enrolment in the stove replacement program, whose goal was to improve indoor air quality. In another free stove distribution program, Gould & Urpelainen (2018) find a negative association between household SES and intervention use. In South Africa (Kimemia & Annegarn, 2016)) where one of the few successful large-scale stove transitions is reported (from solid fuels and paraffin to electricity in the low-income suburbs), one of the reported driving factors was rising income levels.

Other commonly cited driver or barrier of transition was family size, which had mixed results for different technology types. For instance, Yasmin & Grundmann (2019) and Troncoso et al (2019) report family size to have a negative effect on LPG adoption. Agurto Adrianzen (2009) reports it to have a negative effect on ICS adoption, while Amir et al (2019) and Kishore et al (1998) report it to have a significant positive effect on biogas adoption. In the case of LPG, cost was reported as the barrier, as it was too expensive to cook for large families using LPG. For biogas, labour availability was the underlying factor. ICS adoption is also explained as being limited by labour availability, but for wood processing unlike biogas where labour shortage meant no one to tend to the plant.

The findings of the studies cited above (largely quantitative) are supported by findings of qualitative studies that offer insights as to why those relationships exist. These studies show the influence of age and education to be particularly strong when the intervention is completely new, substantially different from the old technology and therefore requires a lot of learning. In such situations some people opted out of the technology. The following excerpts from the studies illustrate this point.

> *"... my daughter insisted on buying a gas stove after I got ill... with a gas stove she prepares her own breakfast but I only use it for re-heating. I'm too old (she laughs)...sometimes the matches don't light and you hear 'shhhhh' (onomatopoeia) from the gas, so I get afraid it will explode. With the plancha you know the fire is on or off" -Quote from participant in an LPG Focus Group (Thompson et al, 2018).*
>
> *" The Upesi [basic ICS] is more common than the solar cooker, because the solar requires young women. But the Upesi, even the elderly women can learn how to use it easily. You find the older lady may not know where to put it. Then you find, your food you put it in the opposite direction, then your food will not cook. That's why the elderly ladies don't like it. The jiko is easy because it's just an extension of the traditional way they're used to" – Quote from a stove promoter (Sesan, 2012).*
>
> *"The young want the more modern tandoor. The old are more habitual [in food preparation and taste] with old chulha," (Wang & Bailis, 2015). [quoting a stove distributor].*

These narratives are supported by findings that a high degree of learning was necessary for some technologies; and by the complexity in design of some of the transition programs. In Himachal Pradesh, India where a program tried to make LPG more accessible to the village women of different castes and income levels by removing barriers to connection, uptake among the target group remained low as a

result of the bureaucratic application process (*Wang & Bailis, 2015*). Yasmin & Grundmann (2019) report on an LPG subsidy reform in El Salvador that although beneficial for the poor was highly unpopular at the beginning among the poor themselves. The authors find visible difference across education levels with satisfaction with the program at the beginning of the reform (although later changed as more information on the reform became available). Among those respondents that were well-informed the satisfaction with the reform was high and negativity bias low, a relationship not observed with any other variable analyzed (such as income, source of fuel for cooking, gender). Barnes et al (2012) report how most users were unaware that the improved stoves being promoted were subsidized; and those who were aware did not understand the subsidy pattern. This lack of awareness is reported to have negatively influenced adoption of the stoves. Similarly, Malakar (2018) reports how information outreach regarding an LPG subsidy and technology use limited and affected its adoption:

> "*In an interview, a couple informed that they were thinking to get a new LPG connection, but they could not afford one (Interview # 1). Upon asking the cost of LPG, they said that they did not exactly know. Apparently, they lacked information on the government subsidy as well" – Malakar, 2018.*

Pollard et al (2018) also documents how the lack of knowledge can deter adoption, based on a study of an LPG program in Peru.

> *The complexity of the enrollment process and confusion about eligibility emerged as important barriers to adoption. Among the 149 households in the community survey who had never participated in FISE, 41 (27.5%) reported not participating in FISE because they do not know how to sign up. Others are not fully informed about the eligibility criteria. For example, 90.4% (199/226) of beneficiary households and 94.0% (140/149) of non-beneficiaries did not know their SISFOH [poverty classification] status, a key component of FISE eligibility criteria. In addition, because electricity companies participate in implementing the FISE program, many participants believe they must have electricity to participate; thus, those without electricity often do not attempt to enroll. Additionally, 14.8% (22/149) of households who were not participating in the program reported having submitted all requirements but never hearing word of whether they qualified; many of these households assumed they were ineligible but were unsure why*

In Rwanda, Seguin et al (2018) report how complexity of fuel purchase protocol for the new technology deterred adoption.

> Citing one respondent:
> *'R: They [Inyenyeri] gave us the purchasing date. For instance, I have to buy the fuel pellets on the 20th, otherwise, they could not allow me to buy before then.*
> *I: What if your fuel pellets are finished on the 17th, wouldn't you be allowed to buy?*
> *R: No, I have to wait until my purchasing date. . . You have to find some other cooking fuels to cook with.'"*
>
> Citing another respondent:
> *'You have to buy pellets on your purchasing day, and if pellets are finished and you need some more, you need to buy per kilo . . .and that was more expensive than buying in bulk. So I real ized it was not going to change and decided to stop using it [Inyenyeri stove]'.*

According to the authors, this reflects a misunderstanding of the fuel purchase protocol that did not actually bar anyone from purchasing fuel when it ran out or penalize them for buying it more frequently.

One exception is Gould & Urpelainen (2018) who found connection fee and monthly cost to be the only deterrent for non-adoption of LPG, whereas lack of information about how to obtain the connection and how to use LPG was less cited.

While most programs provided training to bridge the knowledge gap, several of them did not, or only provided it partially. Furthermore, most of the training was also one-off yet a need for consolidation and reinforcement of training skills and knowledge emerges from most studies. In a Chinese biogas program (Christiaensen & Heltberg, 2013), only 60% of adopters had received technical training in how to make best use of the biogas residues while the rest did not. And of those receiving training, only 64% were aware that biogas residues can also be used to soak the seeds before they are planted, which would have optimized an outcome that was a strong driver for its continued use. Li Jian (2009) found many villagers to lack basic knowledge on operating biodigesters in another Chinese setting, and that they frequently put unsuitable materials in their digesters that shut down their systems. Many never serviced their systems and did not understand the importance of this as a resolution to their problems. In that study, 39% of surveyed households reported that lack of knowledge and skills discouraged them from adopting biogas, while 58% of biogas users reported they urgently needed to learn more about biogas. Barnes et al (2012) report that nearly half of the beneficiaries of an ICS program in India were unaware that the chimneys of their stoves required cleaning, and as a result they never cleaned them. There was variation in knowledge by socio-economic status. According to the authors *"The condition of the improved stoves was dismal among backward classes"* (Barnes et al, 2012). The problem of damaged chimneys was one of the major causes of stove inefficiency and discontinued use; with most of those stoves installed by the program falling into disuse within 6 months.

Wentzel & Pouris (2007) reports of solar cookers that were in disuse because even though people had received training, they had already forgotten how to use them. As part of the training programs, some programs (e.g. in India, Guatemala, Bangladesh) were reported to provide participants with training materials (Alvarez et al, 2004; Thompson et al, 2018; Urpelainen & Yoon, 2017) which imply a presumption of literacy amongst beneficiaries. Urpelainen & Yoon (2017), however, report that only 39% of beneficiaries they interviewees observed that the manuals they received as part of their training was helpful. The authors found that knowledge about the use and maintenance of ICS was low in that community. On a program in rural Mexico, Troncoso et al (2007) report that *"A number of stove users recounted that getting used to this very different technology engaged time and effort".*

Some studies show how knowledge, where provided, can be a driver of adoption Alvarez et al (2004) report of one setting where 83% of those interviewed said they had received training in stove use and maintenance, and most stoves were reported as functioning. The program went on to have more demand than it could meet. A private company's approach that entailed large demonstrations of solar and cooking devices, followed by door to door visits to familiarize communities with technology also reported high adoption (Sovacool & Drupady, 2011). According to one of the agents quoted in the study, those visits were necessary because *"people have been cooking with traditional stoves for thousands of years, and those stoves need big pieces of firewood, many do not think a smaller, more efficient stoves with smaller pieces of wood can actually cook the same."*

The foregoing discussion points to the value of training, but also emphasizes the point that literacy levels would impact on uptake of solutions that require steep learning. It corroborates quantitative findings, but going beyond to explain why some of those characteristics are important for transition. The successful examples suggest that low education, and possibly other SES characteristics that deter transition, can be addressed through well designed programs that take them into account. For example,

it can be through information sharing in format that works for people of all literacy levels (e.g. demonstrations), or taking gradual steps instead of a steep change into new technology. This conclusion is reached based on the evidence base that also seem to suggest that if the change is too small, with no appreciable difference from what already exists (the traditional stove), that in itself can be a barrier to transition. Troncoso et al 2011) reports on a program that gradually increased the features of the stove, with adoption increasing with the pace of improvement. The highest adoption rate was reached at the third stage, and attributed to technology improvement. The program thus balanced between the need for a technology that people can relate to, but also having one that performs way above the baseline to make the change warranted for the users.

3.4.2 Peer influence

Apart from knowledge of the process of acquiring the technology, using it and maintaining it, prior knowledge of the intervention's benefits would be expected to act as an enabler of adoption (where present, and barrier where absent). For instance, Barnes et al (2012) find that in a few well-off villages, users were willing to pay more if they were better informed about the improved stoves. Alvarez et al (2004) reports that awareness creation led to a gradually increased interest in the technology in both rural and urban areas. Other authors however do not clearly demonstrate that awareness on its own impacts adoption. Mudombi et al (2018) observe that all respondents that did not have an ethanol stove had heard about it. Thurber (2014) observe that Smoke- and health-related messages from ICS marketing did not significantly influence the purchase decision, even though they seemed to affect household perceptions about smoke. Gould & Urpelainen (2018) find both users and non-users of LPG to have highly positive views of LPG as a convenient and clean cooking fuel. Barnes et al (2012) report in one of their case studies that household users acknowledged certain benefits provided by the improved stoves, but said they were willing to pay only slightly more than they currently did, citing poverty as the reason.

A departure from the above findings is however on the role of knowledge that comes from peers and social networks who have experienced the same technology. The evidence base shows that this is an important driver of adoption if the knowledge is positive, and barrier if the knowledge is negative. In urban Rwanda, Seguin et al (2018) found peer influence to be both a driver and enabler of adoption. Peer discouragement was a significant factor in non-adopters' decision to forego adoption of the improved cooking system, and was one of the two most frequently-reported barriers to adoption. By contrast, peer encouragement (through positive feedback on stove's performance) was an important facilitator. The study finds peer influence to be an important mediating step in the decision to adopt; through introduction of other new users to the new technology, but also in validation of their decision to adopt the technology.

> *I was told that Inyenyeri cookstoves require constant follow up in order to prevent food from overcooking . . .Some women told me that they returned the Inyenyeri stoves because they damage their cooking pots and overcook food. They advised me not to use the Inyenyeri cook-stoves since they are not good. That is why I do not use them. Female Decision Maker, Non-Adopter (*Seguin et al, 2018*)*

Peer influence as a driver is further supported by studies that assessed the main source of stove information for participants that led them to adopt the solutions. Yasmin & Grundmann (2019) find the main source of information for adopters to have been relatives and friends (46%), substantially higher than other sources (e.g. mass media) that accounted for less than 20% each. Pollard et al (2018), however, report that 74.9% of the participants who had heard of FISE program (discussed earlier)

learned of the program through their community governors/local authorities. Only 9.76% learnt about the program from family members. It is worth noting that this program is reported to have not reached many of the target groups who were not aware of its existence. Patel et al (2016) report how having energy champions within the community is an effective way to promote a new product and gain new users. Out of 41 referrals, 19 came from just two individuals (46%). One program (Ramirez et al, 2018) that utilized only social networks (local leaders, housewives etc) without any investment in formal marketing is reported to have been successful, installing over 40,000 stove units in communities up to 150 km distant from its base of operations. According to the authors whose analysis focused on how stove information is transmitted, most communication occurred between people who were relatively close acquaintances and maintained some degree of trust. Vulturius & Wanjiru (2017) compare experiences of two stove implementors and finds that the stoves promoted using existing social groups achieved much higher levels of adoption than those sold through traditional marketing channels. Troncoso et al (2011) report that the high adoption rates experienced in the third phase of an ICS project phase was partly due to technology improvement, but also because the late adopters had been talking with the health team and with the other women for a whole year during the second stage, which influenced their decision to adopt.

The fact that the role of peers and social networks in driving adoption emerges clearly from the evidence, while that of other sources of information (e.g. media) is inconclusive points to the importance of trust. There could be higher trust placed in the peers, given that they are not stove promoters and do not stand to benefit from the process. They can therefore validate the information obtained from other sources, such as stove promoters. For the peer influence to act as a driver however, and counter the relative advantages of the traditional cooking systems (reported in later sections), the technology ought to have performed according to user expectations, which is a reflection of the interdependency of the drivers and barriers reported in this study. The evidence base is however comprised several studies that report negative user experiences following the transition to MECS, which should be of major concern to the sector developers.

3.4.3 Competition with existing fuels and stoves, and low incentive for change

While technical parameters such as fuel efficiency and improved combustion are what drives most MECS programs, the reasons why users adopt the technologies are varied and certainly not confined to these parameters alone. New solutions to the problem of sustaining transitions therefore have first and foremost to overcome the barrier of these traditional stoves by competing with them on other parameters as well (e.g. versatility and ease of use). This can be quite challenging given the “head start” the technologies being displaced have, their being engrained in local cultures, and even more compounding, their being low cost or free (whether true or perceived) and the target populations poor. Understanding how users perceive MECS relative to traditional alternatives, even without additional information of the influence this have on their ultimate decision making, therefore provides important insights on the barriers and drivers of transition.

Thompson et al (2018) report that households did not prioritize the purchase of LPG stoves over other household items, and many of them had smart phones and stereos that according to the authors, appeared to be more aspirational than acquiring a gas stove. A third of those with gas stoves had received them as gifts from parents, children or their spouse. In that study, wood collection that is often perceived as a driver of adoption was not viewed as drudgery but as enjoyable activity.

> *“-In my case, going out to gather some branches is relaxing because I can spend a few hours outside. What is tiresome is being always at home cleaning and cooking!”* – Thompson et al (2018), quoting participant in Wood and Gas Focus Group

> *"-But going out to get some firewood is not a problem. I like to go out with my neighbor so we can chat (she laughs)"* – Thompson et al (2018), quoting participant in Wood Focus Group

Sesan (2012) finds that the relative food shortage in their study location meant that people did not actually spend so much time in the kitchen (to be able to experience smoke as a problem). They report that households that could least afford to eat well were the ones least exposed to kitchen smoke and could least afford to purchase smoke alleviation interventions. For those households, the issue of immediate priority was not kitchen smoke but food security. This is similar to findings by Barnes et al (2012) in India, where lower-income households in areas of biomass scarcity assigned greater importance to food over improved stoves. Bielecki & Wingenbach (2014) find that stoves in a rural Guatemalan community had several layers of practical importance beyond cooking food. Most prominently, household members valued stoves as heat and light sources, and as a social gathering point for families. Fuel-efficient ICS designs therefore sacrificed important functional, social, and cultural needs. Wentzel & Pouris (2007) note that respondents observed they had stopped using their stoves because "they became too lazy to use the stove [and] bored with it" once the initial attraction had passed. Barnes et al (2012) present case studies from various Indian settings that show that fuelwood savings ranked low among the perceived stove benefits, which is attributed to users' easy access to fuelwood and agricultural residues. Troncoso-et al (2007) finds that despite some users recognizing the burden of carrying non-purchased wood, by and large the no-value perception (of drudgery and time savings) was dominant. In another study (Troncoso et al, 2011) focusing on implementor's perspective, the authors report the following:

> *the main problem during this stage was convincing women in the communities to accept an ICS. Women were reluctant to try the new technology, particularly because they did not perceive the need to change their cooking habits.*

Li Jian (2009) shows how several benefits of biogas technology were not perceived by the households even though they had adopted the technologies. According to the authors, *"Just 10 households thought it was a benefit that sludge offered a potent fertilizer. Only 5 households identified cash savings on electricity, chemical fertilizers, and pesticides as one of the benefits. Only 3 households considered reduction in firewood consumption a benefit of biogas"* – implying other factors besides the promoted benefits motivated adoption. In some Indian villages women adopted the stoves because they believed that the improved stove program would be followed by other government programs (e.g. cemented kitchens or sanitary latrines) from which they could benefit in the future, and are reported to have been disappointed when those programs did not materialize (Barnes et al, 2012). Others adopted the stoves because they thought they were required by law to have them (Barnes et al, 2012).

Thurber et al (2014) report lack of success for one program to be due to competition with other technologies, at both ends of the spectrum:

> *For all the technological sophistication of the Oorja stove, the version we studied ultimately did not achieve its aim of being a cost-effective biomass stove with LPG-like performance. Respondents who had experience with LPG, chulha, and Oorja felt that the Oorja could not quite compete with LPG on convenience, flexibility, prestige, and smoke performance and that it fell short of the traditional chulha on economic criteria, taste, and reliability*.

Thompson et al (2018) report an interplay between the barriers and enablers: while free wood encouraged sustained use of the wood stove, undependable LPG distributors discouraged sustained use of the LPG stove. Jurisoo et al (2019) find that participants could not appreciate the cost of charcoal relative to LPG because charcoal prices fluctuated widely by season, by neighborhood and by vendor.

None of the interviewees could confidently estimate their charcoal expenditure. Instead they emphasized the value of being able to purchase it anywhere (in street corners) and to choose the quantities they purchased each time. Patel et al (2016) recount challenges experienced by an implementor seeking to displace a traditional fuel:

Everything they were trying failed. The main fuel that Pika Poa is competing against is charcoal. In urban and peri urban areas charcoal is readily available and most households can access it within close proximity to their house. Our baseline data shows that 82% of households who took the stove (pellet stove) were using charcoal either as their primary or secondary fuel. Out of these, 69% bought the fuel 1 km away or less from their home. For people to switch to using pellet fuel, making it equally easy to access will be an important factor.

Wentzel & Pouris (2007) report how the solar cookers with their higher prices could not compete with established, well-known and trusted alternative cooking appliances on the market. A kerosene stove which could be bought for a 10th of the price of a solar stove, was available in a variety of outlets withe easily available repair services. Barnes et al (2012) find the importance of fuel savings in ICS adoption to vary by availability of fuelwood. In villages where fuelwood was readily available from the local environment, stove efficiency was a less critical issue than in places where fuelwood collection was labor and time intensive or had to be purchased. Similarly, households had other stove types, such as LPG and biogas, showed little interest in installing ICS. Troncoso et al (2007) found that women appreciated versatility of the traditional stove, a feature that ICS was lacking. According to the users,

“it can be made anywhere, at any time, and since it is on the floor it does not require the user to lift heavy pots to the height of a stove. In addition, wood pieces of any size can be used, and the fire heats the pot directly, thereby achieving a faster heat transfer”.

In that same study, some users reported to use the open fire *just because they are used to it*. Li Jian (2009) suggests that income linkages with LPG usage may be weak in regions with high prevalence of home produced or collected solid fuel consumption.
One program (Thoday et al (2018) offer a unique insight on overcoming the barrier presented by an existing fuel. The program made LPG cheaper relative to kerosene through subsidies, and is one of the very few successful large-scale transition programs we found in the evidence base. Key features of the program are summarized in Box 1. The findings on this program, taken jointly with those of other programs that report substantial challenges of competing with traditional fuels, suggests that interventions may need to occur on both fuels for substantial transition to be achieved. The actual form such interventions should take and the long-term implications is beyond the scope of the current study. At the very least however, programs should fully appreciate the competition that cooking systems being displaced present to the new solutions being introduced.

Box 1: The Mega Conversion Program from kerosene to LPG in Indonesia: Lessons learned and recommendations for future clean cooking energy expansion

As part of the conversion program, free LPG starter packages were distributed to households and micro-businesses consisting of a 3 kg filled cylinder (chosen for easy handling), a one-burner stove, a rubber hose and a regulator. The cost to Pertamina of one conversion package is estimated at around IDR 300,000 (US$ 33 in 2007 or US$ 21 in 2017 ....By 2010 the original target of distributing 42 million starter packages by 2012 was reached .. and the target was increased to 54–58 million units ... By 2015, over 57 million starter packages were distributed Overall, domestic kerosene consumption in Indonesia shrank dramatically, from 10 million kiloliters (kl) in 2006 to 0.8 million kl in 2015 – a 92% reduction in use. In the same period, LPG household consumption rose from 1.1 million tons (Mt) to 6.3 Mt in 2015 .. contributing to 8% of Indonesia's total energy mix ..[this] Corresponds to increase in consumption from 4.7 kg/capita in 2007 to 24.4 kg/capita in 2015 and a concomitant decrease of kerosene from 57.3 kg/capita to 3.1 kg/capita in the same period.

Thoday et al 2018.

3.4.4 Technologies and fuel characteristics

Even where programs had succeeded in getting users to switch, there were several barriers for getting them to stay with the transition. The challenges were unique to technology types, representing their distinct features and characteristics, for instance whether they entailed only a change in technology or technology and fuel changes, design features (fixed or amenable to alterations), practical functions amongst other variables.

While some studies sought direct answers from participants on what led them to adopt and continue with specific technologies and fuels, others inferred these from responses to questions on what is liked most about the new stove and/or what is disliked about the traditional stove. In the latter case there should be some caution in interpreting these factors as drivers of transition without additional information on how they influenced the decisions and the trade-offs made. They may just be an indication of awareness, some of it arising from knowledge acquired during the stove promotion efforts. However the evidence base contains studies reporting clear barriers to transition that are unique to the technology types, or barriers to continuing with the transition. When viewed collectively, this body of evidence indicates an appreciation of benefits of MECS and its disbenefits, which is important for long term adoption (an aspect of sustainability of the change that is extremely difficult to ascertain from short-duration studies) .

Thompson et al (2018) report that common reasons for acquiring the stove were speed of cooking (to facilitative arrival at work on time), cleanliness and ease of use. Improved social status and health reasons were also mentioned although not recurrent. Troncoso et al (2019) report that nearly all the interviewees recognized the advantages of cooking with LPG as well as the health problems associated with firewood use. Mudombi et al (2018) report ease of lighting and use (compared to charcoal stove) as the most commonly cited benefit of the ethanol stove. These findings were corroborated in FGDs with participants. Person et al (2012) cite high fuel consumption as the commonly reported disadvantage of traditional cookstoves, in addition to smoke, inability to control the heat, lack of cleanliness and safety risks. In contrast, Seguin et al (2018) report inability to control heat to be a negative feature of ICS

(pellet stove) for the respondents. On smoke alleviation, Sesan (2012) reports contradicting findings to other studies. According to the authors, when participants in their study were asked about the performance of ICS in smoke alleviation, they reported quality of fuelwood that was being used in ICS and not the cooking device was what determined the smoke levels. The cooks were reported to know the value of dry wood and would buy it (for traditional stoves as well) when they could. In Benka-Coker et al (2018) participants cited convenience and cooking speed as the benefit of ICS, and cost as the reason for not transitioning away from firewood and charcoal Sequin et al (2018) report excessive smoke and damage to cooking pots as a limitation reported of an ICS that had been adopted by the households; which was contrary to what was advertised about the stove. The stove's fast cooking speed (mentioned earlier) was also reported as a problem, that led to the need for constant tending and overcooking of food. For some non-adopters, this feature was the primary reason behind their decision to not adopt the stove. The authors note that such views were contradicted by other adopters who not only stated that the heat was easy to regulate, but also that fast cooking speed is the feature they liked about the stove. Negative perception of ICS is also reported by Otte (2009) on solar cookers that were observed to be slower than firewood, even on sunny days.

In an opinion survey, Shastri et al (2002) find fuel saving to be the most appreciated stove feature. Patel et al (2016) also notes fuel savings as the benefit reported by majority (55%) although was a good proportion of respondents (18%) that said the stoves increased their fuel expenditure. The remainder could not tell whether they were making any fuel savings (similar to findings by Urpelainen & Yoon, 2017). The authors note that there is very high variability in the stove's performance relative to how the fuel is loaded and duration of burning that could explain the variations in user responses:

> *Our in house testing showed that higher levels of fuel efficiency were experienced when using pellets for short, high heat cooking applications such as cooking tea or ugali, whereas for long, low heat applications, such as cooking maize or beans, pellets could be more expensive. It is also requires the user to tailor the way they use the stove to maximize the fuel efficiency for example only filling the stove with as much fuel as is needed and adding small amounts of pellet to lengthening cooking times in a controlled manner. This takes time for users to get right and is a point that many users never reached.*

Muneer (2003) reports that the frequently cited relative advantages of the improved cookstove were reduction of fuel use, cooking time, smoke and use. In Barnes et al (2012) perceived benefits were smoke reduction, faster cooking as a result of being able to use two pots simultaneously and cleaner cooking environment. In Urpelainen & Yoon (2017) users also reported time savings from cooking speed as an important benefit. Although they also reported experiencing less smoke in their kitchen and a perception of better health, this was not prominent. Financial savings from reduced fuel use was also mentioned by a third of the households, but an equivalent proportion were not able to quantify fuel saving at all. High satisfaction levels with the stoves were reported amongst those still using the stoves. Satisfaction with ICS is also reported by Hanna et al (2016). This was in sharp contrast to the study's findings on actual stove performance that showed the stoves achieved none of the alleged benefits. If anything the stove increased time expenditure, as many women had to spend time repairing their stoves. . Agurto Adrianzen (2009) reports high firewood consumption as the main inconvenience of traditional stoves reported by non-adopters.

Compared to other technologies, financial savings in biogas seemed to be more apparent to the users. In Quinn et al (2018)a majority of biogas users report money and time savings as a major benefit of the technology, but also note that on the question of what benefits users appreciate, ease of cooking and

cleanliness were constantly mentioned, but not health benefit. Sovacool & Drupady (2011) report of a participant who was able to create a stove and fuel business from the excess biogas she produced from her farm and earned a regular income from it. In rural China (Christiaensen & Heltberg, 2012), adopters nearly unanimously (98%) said biogas saved them both cooking time and time expenditure in fuel collection. Where users are reported to be unaware of benefits (e.g. Li Jian (2009)) it was benefits related to health and environment but not financial.

The evidence also shows that striking a balance between simplicity and performance is important. Sesan (2012) reports that compared to ICS that was floor-level and similar in form and operation to 3 stone stove, the solar stove was substantially different, with technical precision requirements (specific angle at which the reflective surface of the solar cookit must be tilted to optimise the sun's rays appear) that users found cumbersome and inhibited its adoption (Sesan (2012)). On the other hand Jagger & Das (2018) find the pellet stove which is substantially different from the traditional one to have higher customer satisfaction because customers generally like its "modern" appearance (in addition to performance) and felt they could use it in the living room as well.

Apart from performance features (e.g. fuel saving, smoke reduction) the practicality of the stove is also reported as being of importance to the users; possibly even more than technical performance features. This is evidenced by the extent to which user modifications of the technology to suit their cooking needs and user perceived performance is reported, often to the detriment of objectively assessed efficiency gains. Thus, while the goals of promoters and users were in some cases very similar (e.g. reduced fuel use), how to achieve those goals with a cooking technology was at times viewed very differently, even amongst users themselves.

Barnes et al (2012) report that despite users perceiving benefits of the ICS, they faced multiple practical problems such as chimney leakage, inappropriate pothole size, inconvenient grate design, greater fuel consumption, and the need for frequent chimney cleaning. As a result of these perceived problems, about one-fifth of the users modified their stoves. The authors recount some of these challenges:

> *"---users were reluctant to cut fuelwood to the required size for feeding. Instead, they used large wood pieces, which often damaged the firebox mouth; to correct the problem, they plastered the mouth opening with a clay-dung mixture, which changed its size…the depth of the firebox (was modified) to accommodate a variety of fuels (for example, agricultural waste, leaves, and dried dung). In addition, they often enlarged the tunnel diameter of the two-pot stove to facilitate heat flow to the second pothole. To reduce the frequency of chimney cleaning, they used a chimney pipe with a 10 cm, instead of the required 7.5 cm diameter".*

Similar challenges are reported by Troncoso et al (2007) in a different setting:

> *A wide variety of problems of improved cookstoves were mentioned by users. The small entrance to the chamber involves problems for lighting the fire and for chipping the wood down to small sizes. Some complaints concerned specifically the secondary comales of the improved cookstoves (a comal is a ceramic dish or metal hotplate for cooking tortillas): users would prefer having independent combustion chambers or being able to put heavy pots such as the ones used for nixtamal. Lastly, some people complained that improved cookstoves are not good to heat the room in winter.*

The authors report that approximately 21% of the ICS were damaged to some extent, and in most cases the damage was made by enlarging the fuelwood entrance to fit larger pieces of wood.

Bielecki & Wingenbach (2014) similarly report participants dissatisfaction with small entryway of wood of ICS, which led to modifications of the stove to allow for more wood. This was viewed as necessary to reduce cooking times and increase the amount of food which could be cooked at one time. There was also dissatisfaction with the small internal combustion chamber with many interviewees expressing a desire to enlarge it. **.** Wentzel & Pouris (2007) also find the inadequate stove capacity to be a major reason for non-adoption. Complexity of construction process was also a barrier for this program, which led to variable (and poor) stove quality. The authors observe that

> *the quality of locally produced cookers was low and erratic, producers were unreliable and material difficult to obtain and the manufacturing process was extremely complex—for example, in one cooker, more than five types of material (steel, glass, fibre glass, aluminium and rubber) had to be used.*

Barnes et al (2012) also report challenges of quality control for a program due to lack of standardized stove-construction materials. This led to wide variation in stove prices, depending on where the NGO procured their materials from and the cost. Alvarez et al (2004) in turn find that 33% of the problems reported involved accessories. Similar to other sites, there were also stove modifications made to suit user needs. Alvarez et al (2004) find that three years after the stoves were installed, 50% of the chimneys had to be replaced, but not that this was expected.

In a program reported as very successful, fewer cases of stove malfunction, relative to other studies, were observed by field workers (Wolf et al (2017)). Hyman & Bailis (2018) report the following on yet another program that catered for quality needs: *NBP delivered a technically sound product with timely and effective aftercare services, including a two-year warranty on the dome and a 3-year warranty on the biogas lamps.* Programs that provided quality improvement showed that users appreciated them, even where it entailed extra costs. Troncoso et al (2019) report that people who chose to order one of the two stoves on offer overwhelmingly (82%) chose the chimney stove (over the "efficiency stove") despite it being more expensive. Although Barnes et al (2012) reports several quality challenges associated with the stove programs evalauted, participants are reported to have indicated willingness to contribute toward the cost of a more durable stove. Sovacool & Drupady (2011) report higher preference and adoption of fiberglass biogas units, with users citing the following advantages over the brick system:

> *"fiberglass units … can be constructed quicker and work more efficiently. It takes 15 to 20 days to install a brick biogas system, and is completely impossible during the rainy season. Brick systems also sometimes leak methane from pipes. But fiberglass units can be installed in two to three hours, anytime in the year, and almost never leak."*

Bhat et al (2001) also report increasing popularity of FRP-based floating drum design in spite of its higher first cost as suggestive of the role of reliability and low maintenance in driving adoption of biogas.

The user needs are shown to vary by context, which was not always taken into account by the programs. Barnes et al (2012) find that women in one region (Maharashtra) preferred smaller potholes to accommodate smaller-sized vessels and made modifications to achieve this, while women in another region (Haryana) preferred wider pots and also made modifications to achieve it. Agurto Adrianzen (2009) cites technology transfer without adaptation to local needs to have impacted one program's success.

> *The improved stove technology introduced in the Chalaco District was originally designed for rural communities in the coastal areas of Piura Region, where the main role of a firewood stove is food preparation. In this coastal areas the weather is relatively warm during most part of the year and the type of firewood used is relatively uniform (mainly "algarrobo")…The design did not take into account that the firewood stove also performs as a heating device in high altitude areas where the temperature is much colder during winter months. Also the stove combustion box was designed for the type of firewood that is common to coastal areas and did not take into account the specific varieties and qualities of firewood that are available in the different watersheds of Chalaco District.*

For technologies that also involved fuel change, fuel supply challenges in addition to stove ones are reported. Jagger & Das (2018) report challenges of adoption of a gasifier stove to include lack of regular power supply and electrical faults with the charging system. Even in this case where the stove is manufactured and not alterable, users altered the way of using it by converting from pellets to charcoal to resolve the problems they experienced. This compromised efficiency but also presented a problem for the company's business model that relied on sale of pellets and not the stove.

The unique features of biogas technology meant it could only work for specific target groups that could meet the technical requirements such as water availability, large number of animals as source of feedstock, labor availability etc. These requirements tended to favor wealthy households. Where these factors were not fully taken into consideration the programs were unsuccessful. Other unique barriers reported for biogas include inability to move with it if a family relocates (Sovacool & Drupady, 2011) (a barrier that is also seen with fixed ICS elsewhere) and seasonal effects (Christiaensen & Heltberg, 2013). According to the authors, the biogas generated was sufficient for cooking needs during summer, but not winter due to cold weather effects on digestion speed. The study documents an additional complex set of challenges that faced this particular program, including macro-level factors outside the energy sphere:

> *Although most Apricot adults were skillful pig farmers, 47 percent of surveyed villagers reported they raised two or fewer pigs, which made it not possible for these households to utilize biogas. Furthermore, 36 percent said that they had no plan to raise more pigs in the near future. In the past they raised them and the programs were successful… In the past, pig farming was profitable and formed the core of the Apricot economy…The piglets were cheap, farm residues were plenty, and hog prices were good. Most young men then worked in the village fields, and the older people and women could spend their time taking care of pigs…As China intensified large-scale swine production to feed its growing urban population, hog farmers' profits were quickly made razor thin. Also, the cost of feed was up 20 percent from the previous year. Besides, market options were limited. The threat of disease also discouraged farmers from raising pigs. With the increasing human and animal mobility, more and more porcine diseases emerged in the region, particularly swine fever and hog cholera. When a disease broke out, farmers had neither means nor insurance to protect their pigs* - Christiaensen & Heltberg, 2013.

Cost (discussed in later section) was widely reported as the barrier to continued use of LPG, and for ethanol in two studies. As expected, solar cooking, the only clean fuel transition with no recurrent fuel costs, is reported to have been limited by the weather conditions (Otte, 2009) as earlier mentioned, and cumbersomeness (Wilson et al, 2018).

3.4.5 Cost of MECS relative to lower cost alternatives

This section focuses on studies that directly evaluated cost as a barrier, as opposed to wealth status as an indicator of affordability.

Terrado & Eitel (2005) report the cost of ICS to the most important barrier to its adoption. They note that while fuelwood savings from adoption of the technology could have been substantial, ordinary households could not fully grasp the financial benefits as fuelwood was purchased in small quantities or collected at no cash cost (similar to findings reported in earlier). Seguin et al (2018) also find cost to be a barrier, both for non-adopters as well as those who had adopted the pellet stove and wanted to stay in the transition. This challenge is shared by other populations transitioning to new fuels that entail both the start-up cost and regular fuel purchase costs. In many cases, this cost was evaluated against the cost of traditional cooking fuels, which did not require high startup cost (if any), tended to have relatively stable prices, and could be purchased in small amounts that could be supported by the irregular incomes. Seguin et al (2018) report the following from one interview:

> *I didn't mind using them [Inyenyeri fuel pellets], however, they made it impossible for us to keep using them. . . They have increased pellets prices from 125 Rwandan francs per kilo to 200 per kilo, and at that price you actually spend more than what you would spend on charcoal. Everything else was fine except the dramatic price increase.—Female interviewee*

In Ghana, Asante et al (2018) found that seasonality of the respondents' income impacted on adoption and sustained use of LPG.

> *Mostly the income we get here is seasonal. When crops are in season, it might be easy to refill, however when the farm produce is finished that is when the refilling will stop (FGD, LPG non-beneficiaries).*

Quinn et al (2018) report high upfront cost and limited access to credit to be the main barrier that limited adoption of biogas, based on interviews with respondents. The cost became a barrier after withdrawal of the prior existing subsidy. In Rwanda (Jagger & Das,2018), the most common reasons cited for not participating in the cookstove program were lack of funds to pay the sign-up fee, inability to pay for fuel in one monthly payment, and preference for purchasing fuel in smaller quantities. Wallmo & Jacobson (1997) also report cost to be the primary reason for non-adoption of an ICS in Uganda. Patel et al (2016) narrate an implementors perspective on cost as a barrier.

> *One of the challenges we experienced with signing up users through referrals is the ability to turn a potential customer's interest into a purchasing user. Once we had received a sufficient number of referrals we would arrange for a sign up event at which EcoZoom staff would invite all the referrals to participate. This event involved training on the use of the stove and fuel and how the lease works, after which they can sign up for the product, provide their baseline information and take home training and marketing material. We found that only a small number of the referrals would actually come to the event and sign up. This was mainly due to availability of funds; when a person was referred they had funds available but when we came to do the sign up event a week later they had already spent the money on other needs. To overcome this we tested the idea of having an agent within the community who could sign up new households as and when they became interested and had the funds available to sign up…. This method still did not produce high numbers of signs up…*

The case above reflects several others (see table 9) where users expressed willingness and interest in the stoves, but this did not actualize into purchase, with affordability consistently cited as a barrier.

A survey published by The Ministry of Energy, Republic of Kenya (2019) reports that the main limiting factor for adoption of all stove models evaluated was the cost of the stoves that had to be acquired through upfront cash payments. Barnes et al (2012) in one of their case studies report cost and competing household priorities (in addition to lack of space) as reasons for not adopting ICS. In Wallmo et al (1998), frequently cited reasons by non-adopters of ICS was lack of bricks for building the ICS or money to buy them. Thurber (2014) reports the increased cost of fuel (pellets) triggered a transition away from the ICS.

> *As the company increased fuel prices starting in late 2008 and thereafter, it saw the intensity of Oorja stove usage drop accordingly, to the point where very few households were still using the stove as of the spring of 2011. Survey responses corroborate First Energy's view that increased fuel prices were the single most significant cause of disadoption. As higher fuel prices eroded the value proposition for consumers, dealers also found the stove business to be less attractive, leading to erosion of the distribution network and less convenient fuel availability for household Oorja users.*

Otte (2009) notes that affordability of the solar box cookers was one of the key project challenges. Most of the target population was poor and could not afford a box cooker that cost 70.000 TZS (53 US$).

Several studies reported cost as a major barrier for both initial adoption and continued use of LPG. Terrado & Eitel (2005) report lack of financial resources was the main reason for the continued use of fuelwood, in particular, the lack of resources for acquiring the LPG stove (48%) and/or the gas cylinder (26%). Gould & Urpelainen (2018), in their survey of over 8500 households from six energy-poor Indian states find fuel cost to be one of the critical obstacles to widespread adoption. Both initial cost of the stove and connection as well as regular fuel costs are reported as important barriers to initial adoption and continued use of LPG by the households. Bruce et al (2018) finds that among non-adopters of LPG, the main reported barriers are the initial cost (50.3% rural, 54.6% peri-urban), much more substantial in comparison to other reported barriers such as safety concerns (14.2% rural, 23.6% urban). An interesting point with LPG is that once adopted, the refill cost is then considered a barrier for continued use, a consideration not often taken into account at the beginning. For instance, in the Cameroon, amongst those who had already adopted LPG, 74% thought that the refill cost was expensive or very expensive, a factor not cited by non-adopters. Gould & Urpelainen (2018) who studied a program that subsidized initial costs (free LPG connections to poor households) finds monthly fuel costs to be a major barrier of adoption, reported by 88% of interviewed households. According to the authors, one large cylinder (the unit purchased by 95% respondents) accounted for 10% of the total monthly expenditure of a household.

Perception of high cost can also be a barrier to adoption. Velasco (2008) reports that LPG is recognized in rural communities in Mexico as an expensive and luxurious technology for cooking, limiting its adoption. Consistent with other settings, the cost is weighed against the traditional alternatives; in this case the price being in favor of an ICS.

> *An LPG stove is expensive to maintain, LPG is very expensive, more than wood, even though the price of a Patsari Stove and a LPG stove could be the same we will be always more interested in the Patsari because it consumes wood and works according to our expectations and we can make tortillas on it. (Patsari that was adopted for social cultural reasons).*

Malakar (2018) who did a comparative analysis on LPG adoption versus adoption of televisions found that price was not a barrier (based on their calculations) but the users nonetheless reported that LPG unaffordability was the reason they had not adopted it.

> *The TVs that research participants owned ranged from Indian Rupees4 (INR) 8000 to 9000, including a wireless TV signal receiver that costs around INR 3000. A monthly renewal of a cable subscription cost between INR 160 and 200. Hence, the annual subscription cost was between INR 1920 and INR 2400…. The LPG bottle was INR 1000… which was not added to the total price .. because the GoI subsidised it for BPL families. Refilling a bottle cost INR 650 out of which the GoI would return around INR 180 as an incentive directly to the users' bank account. …. According to the house which stacked fuels, a bottle of LPG lasted up to three to four months. Hence the annual running cost, after deducting the subsidy amount, for LPG stoves was between INR 1880 and INR 1410. It is evident that both the upfront and running costs for a TV are higher than LPG.*

The study finds that lack of information was the real barrier to adoption.

The important role of cost is corroborated by findings of some programs that provided subsidy and other financial incentives that tackle the cost, although not all were successful, partly due to variations in design. Abdulai et al (530) report financial constraints to be one of the reasons (in addition to poor supply and safety) ascribed to discontinued use of LPG by rural households in Ghana. Less than 5 percent of the beneficiary households were reported to use their stoves 9 months after its acquisition through a government program that entailed an initial free distribution of a filled LPG cylinder. In contrast, a program in South Africa (M. Madubansi & Shackleton,....) with similar design features reported a majority of the respondents (72%) to have continued using LPG and regularly refilling their cylinders 7 years after initial rollout. The population in this latter program were beneficiaries of a policy that provides a quantum of free basic energy for households at certain income thresholds, for which over 60% of the population qualified. Another program in Peru (Pollard et al 2018) that entailed free LPG starter kit and refill vouchers is reported to have 88.8% of the beneficiary households regularly refilling their LPG cylinders and to have achieved wide coverage. Key features of this program are summarized in Box 2.

Box 2: The Fondo de Inclusión Social Energético program to promote access to liquefied petroleum gas in Peru

The Fondo de Inclusión Social Energético (FISE), or the Fund for Social Inclusion for Energy in English .. LPG program centers around the monthly provision of a voucher worth 16 soles (approximately 5 USD) to eligible families... The voucher is used to exchange an empty 10 kg LPG cylinder, costing 32 soles (approximately 10 USD) for a full one. The FISE LPG program is targeted toward households living in poverty or extreme poverty. Currently, LPG stoves [costing approx. USD 15) are not subsidized and must be purchased by beneficiaries… To receive vouchers, households with electricity must register with their electricity provider; those without electricity must register with their local MINEM office. Once eligibility is confirmed, vouchers are provided via electronic code on the monthly electricity bill for households with electricity, or via paper vouchers for households without electricity. FISE beneficiary households must use at least one LPG voucher within a four-month period or their beneficiary status is temporarily suspended. Beneficiary status is inactivated after one year of non-use, in which case households must re-enroll.

Source: Pollard et al 2018

Sharma Singh's analysis (2019) showed that an LPG capital subsidy scheme, *Pradhan Mantri Ujjwala Yojana (PMUY)*, provided a trigger for LPG transition among beneficiary households. Thoday et al (2018) reports how the distribution of the free starter packages for LPG and the fact that subsidized LPG was going to be cheaper than kerosene acted as a driver of its adoption, and of a transition away from kerosene. Troncoso et al (2007) compared the outcome of two ICS programs in Mexico and report that the one with free distribution had very high level of adoption (93%, 14 out of 15 respondents), although there were technology design problems that lowevered its life expectancy. In their sample, 35% of the interviewees without ICS argued that they could not afford it. Terrado & Eitel (2005) report that hardly any sales were made at the initially set market price of 35 and 45 US$ for the two ICS models, despite strong expressions of interest to buy the stove. When the prices were subsidized the popularity of the stoves and sales increased. Later when the selling price was raised to 28 US$ and 36 US$ the sales continued, reaching 369 stoves at the time of evaluation. In South Africa there was a successful transition away from solid fuels and paraffin to electricity in the low-income suburbs made possible by electrification of the suburbs (and rising incomes). Over 60% of those households qualified for social support, and did not pay directly for their electricity consumption (Kimemia & Annegarn, 2016).
There are instances where subsidies did not succeed, especially where there were other factors in the domains covered earlier that were reported as major barriers to adoption. The India National Cookstove Program (Barnes et al, 2012) is one example. Efforts by a solar cooker promoter to counter the problem of affordability through instalment payment system did not succeed in achieving transition (Otte, 2009).

3.4.6 Socio-cultural perspectives and gender

Understanding the role of gender is of crucial importance to the widespread adoption and use of cleaner MECS as reported across the studies that present data on the drivers and barriers of men and women adopting cleaner, more modern household cooking solutions. Evidence from the Systematic Map indicates that both men and women hold largely traditional roles behind decision making, purchasing, and use of MECS. While women are the primary users of home cooking systems, men often influence the purchase of new cookstoves or fuel types, but only in some contexts.

Thompson et al (2018) find that men are key decision-makers on household investments including fuel procurement, and yet messages about LPG did not target them. According to the authors, women were given funds to purchase food but did not have the financial independence to make decisions about gas refills. Men were reported to be indifferent about the benefits of LPG, and cited as stating that *"women are accustomed to smoke while cooking", "women prefer to cook with wood", or "smoke is not necessarily a cause of illnesses".* They are however reported to have appreciated the timeliness of food prepared on LPG stoves. In another setting (Acharya & Sadath, 2017) where women could only control cash for food purchase, they are reported to have diverted some of those funds (as well as funds for clothes etc) to acquire an ICS. Troncoso et al (2019) report that 30% of respondents indicated that it is the male head of household who decides which fuel to cook with. Sesan (2012) highlights some gender roles in smoke alleviation behavior that is not necessarily concerned with adoption of cookstoves, but have important implications for such programs.

> *" ...the objectives for wanting to be rid of kitchen smoke are slightly different on both sides: while international organisations advocate smoke eradication for health reasons, West Kochieng households originally took kitchen smoke outside the house mainly to prevent accumulation of soot on the walls – particularly of the living room – because it was important to a man that guests did not perceive his home to be dirty or ill-kept. Therefore, from the perspective of a male*

> *West Kochieng citizen, moving the kitchen outdoors may be a more legitimate solution to the problem of indoor smoke than installing an improved cooking technology in an indoor kitchen area. Indeed, building an outdoor kitchen is a higher-ranking priority for West Kochieng households than acquiring an improved stove or smoke alleviation intervention…Building an outdoor kitchen, apart from traditionally requiring male authorisation, is capital-intensive. This means that a woman usually has to wait till her husband decides that he has enough resources to provide an outdoor kitchen and then gives the go-ahead to build. For many women, the waiting period stretches into years, even decades".*

Person et al (2012) report that women explained during interviews that their husbands did not want them to create a vent necessary for the stove by cutting a hole in their wall, which deterred adoption and proper use of the stove. Similar to findings by Sesan (2012), the barrier was not a direct resistance of men to the technology but other living dimensions that are influenced by gender dynamics, that in turn translate into barriers for MECS transition. The women in this case had purchasing power and bought the technologies, but were not using them properly and not realizing the benefits of smoke alleviation because of gender restrictions.

Acharya & Sadath (2017) finds the ability of women to purchase ICS to vary amongst women based on their access to cash and position of power in the household related. Women reported securing the funds to purchase the cookstove as a negotiation with their husband, co-wife or mother-in-law, with favourable results as exemplified below, and at times unfavorable results.

> *My mother-in-law was the one who negotiated it for me. She told my husband that the cookstove was really good and she would like us to install one in her kitchen and mine so that we would have an easy time for cooking (cookstove purchaser)*

The authors report that while most husbands were viewed as receptive to the woman purchasing ICS, several women they interviewed observed that they had no power to make such a decision.

Catalan-Vazquez et al (2018) find male involvement in stove promotion to be a barrier to adoption. According to respondents, the customs and traditions in the setting made it unwelcome for a man to enter homes while women were alone, which deterred the male stove promoters from performing installation and stove maintenance functions. In this setting, the women could not adopt ICS without the husband's permission. In another setting however in the same study country, women could accept ICS installation on their own, and were even encouraged by the husbands and/or in-laws to enroll in the programs.

Ramirez et al (2013) finds that men played a critical role in the entire dissemination process of ICS. This was attributed to the patriarchal character of the society, whereby men communicated with other men more readily that women did, were more active in disseminating stove information, covered larger distances than women were capable of (greater than 30 km) and were more likely to talk to women about the stoves than vice versa. Barnes et al (2012) documents important roles of gender in stove transitions in India. Regular chimney cleaning which required climbing onto the roof was physically challenging for the women, who were rarely assisted by male family members in performing the task. Lack of such maintenance was an important contributor to stove malfunction and discontinued use. Male household heads' lack of willingness to purchase ICS was also reported as a contributor to non-adoption. Urpelainen & Yoon (2017) found that the reputation of building stoves was not prestigious for men, who viewed the work with mud and clay as "dirty work" and women's work. They were thus not motivated to perform the work (including offering after sales services).

Gender roles in fuel harvesting are also important for adoption. In rural Mexico, Troncoso et al (2007) reports that men are the principal fuelwood harvesters and processors. Of the interviewed women, 70% reported that their husband or another man in the family fulfils this task. In such contexts, the indifference observed by Thompson et al (2018) in Guatemala would be unlikely. Nonetheless, 40% of those without an improved stove stated that the reason for not having a stove built was that the husband had promised to build them one but had failed to keep the promise. In the study, single women were reported to be at a great disadvantage as no one helped them to collect and chip wood, a problem reported by 20% of stove users. Masera et al (2005) report that improving kitchen conditions (e.g. by installing cookstoves) is considered a ''women's'' issue in the setting and of low priority for men who have the economic power within households.

Failing to account for the gender relationships, that can vary considerably by context, can negatively impact program results. A study by Muneer (2003) is a good illustration of this, where contrary to other programs that have been criticized for not involving men, the one they report on targeted men but excluded women. The authors argue that the low adoption witnessed in the program was a consequence of not taking into account gender relations in the setting, where women are decision makers on adoption of ICS. The women's power is however limited to very meager proportion of the household's financial resources, which was below the price set for the ICS (750 Sudanese pounds). They criticize the program for their heuristic assumption that in such patriarchal society the husband is the primary decision-maker regarding all the household's issues.

Keese et al (2017) illustrates how stove performance can also affect gender relations, and be a barrier to adoption. The solar CooKit had low adoption because it was slow; yet preparing and serving their husband and families meals on time was an important woman's role. Women were also expected to be good hostesses, hence needed a stove with a large capacity to prepare meals for not just the family but also guests. Men were also reported to be decision makers on investments in energy in the setting. Social and cultural dimensions that transcend gender were also reported as barriers and enablers.

Sesan (2012) reports that kitchen spaces reflected the social, physical, cultural and economic realities in which the respondents lived. They therefore suggest that any external intervention to improve the space needs to be instructed by the lifestyles that have informed its constitution and evolution over centuries. In Zambia, Jurisoo et al (2019) report that participants in their study stressed the cultural importance of their traditional stove, mentioning that it connected them to their roots and made the food taste the way they were used to. Catalan-Vazque (2018) report how sociocultural dimension of communities can favor or limit adoption of ICS in various ways.

In the indigenous communities, characterized by extended families, uptake of new technology was limited by traditional routine practices, rearrangement of rooms in the house, attachment to the traditional stove, a low- or non-risk perception of woodsmoke. Conversely, in the mestizo community, the uptake of the improved cookstove was favored by routine cooking practices in a nuclear family, a previous use of a raised cookstove and social representations on the health-disease-death effects of woodsmoke vs. the health benefits of cooking with improved stoves.

Sovacool & Drupady (2011) provides a related example from Bangladesh on adoption of electric cooking:

> *In our culture, marital ceremonies center on traditional fuels and energy sources. When a new bride first comes to her new husband's house, for example, it is customary for her to cook boubat (bridal rice) for the entire new family, supplying a meal for all relatives. The ceremony involves firewood and it has strong symbolic meaning. There's no firewood [wood fire] if you have an electric cooker or appliance, for that reason those technologies are slow to proliferate* – Stove promoter.

Bielecki & Wingenbach (2014) report that respondents who exclusively used the three-stone open fire stated that they continued with the practice because it was a cultural custom. Benka-Coker et al (2018) report that traditional stoves were maintained for coffee ceremonies that occur multiple times a day in Ethiopia, and participants wanted to keep the tradition of preparing it on charcoal stoves.
In most of the studies where culture is reported as barrier, the evidence base points to additional factors including practical limitations of the stove, economic factors such as the need to build new kitchens to house the stoves, lack of a motivation to switch, cost of new technology amongst others. It is therefore difficult to isolate culture from these other variables. The following excerpts offer a good illustration of this interconnectedness:

> Bielecki & Wingenbach (2014) - *"The advantage of having [the open fire] is that it keeps us warm. It is a custom to have a low fire on the ground, because we are used to sitting around the fire. The [ICS] is high up so we couldn't gather around it to keep warm .....The open fire, it is a custom to have it. Also, in the time of the elote [corn on the cob] you have to have the open fire to prepare it. Without an open fire we couldn't keep ourselves warm during the winter or grill the elotes..."* (H9).

In Zambia, where participants report a cultural attachment to their traditional stoves (Jurisoo et al 2019), they also state that the cooking techniques required for their everyday dishes such as long-time simmer of beans, grilling maize, and preparing relish and the national staple nshima are quite easily done on the mbaula – suggesting a lack of an incentive to change.

While these socio-cultural dimensions present a clear obstacle to transition, the evidence base shows there are significant proportions of the population that still make the transitions in those settings when other barriers are overcome. Culture should therefore be considered alongside many other barriers to transition. Some cultural factors that inhibit transition include occasional ceremonial events and hosting guests (Sovacool & Drupady, 2011) that were resolved by stacking of cookstoves and fuels. Of great concern would be if cultural attachment precludes MECS for staples that that are energy demanding, but we actually find this not to be the case in the few studies that incorporated such analyses.

In Ethiopia where injera baking accounts for most of the household fuel consumption at 60% (Mekonen et al, 2009: citing Gebreegziabher, 2004 and RTPC, 1998) a significant number of households were reported to have transitioned to preparing injera using electricity. Similarly, in Mexico where tortilla accounts for the highest cooking energy demand, a quarter of respondents (Troncoso et al, 2007) are reported to have transitioned to purchasing industrially produced ones. In India however where chapattis are an integral part of the local staple diet, only 11% of the total households reported preparing it on induction stove (which they used for nearly all other meals) according to Banerjee et al (2015).

There were reported instances however where cultural barriers are dominant, for instance in the choice of feedstock for biodigester, as reported by Sovacool & Drupady (2011):

For biogas units, digesters would work best with pig dung but "Bangladesh is a Muslim country and Muslim households refuse to own or eat pigs." Systems also work optimally with the use of human feces injected alongside cow or animal waste but "people have this idea that human waste is unacceptable, that it's mixing in shit with their food, and could counteract the freshness of their meal."
The authors also report that Bangladeshi women pride themselves in having neat and clean kitchens, would never allow animals to enter their kitchens, and therefore have trouble using gas that emanates from animal waste in these "sacred spaces". In such situations an intervention that does not take those cultural perspectives into account is unlikely to succeed.

3.4.7 After sales support

Performance of the stoves after their initial adoption and their continued use is mediated by after sales support, according to the evidence base. Most studies as earlier discussed report user challenges with the new technologies after adoption that led to discontinuation of their use, reduced use or modifications that affected performance. Of interest to the review and emerging from the evidence base was also how this fact in itself influences adoption, and whether provision of after sales services would counter these negative experiences.

Quinn et al (2018) report that a significant percentage of biodigesters constructed in Phase I of the Africa Biogas Partnership Program (ABPP) program were non-operational at the time of evaluation. Over a quarter (27%) of the installed units had been abandoned by 2016. The rate of abandonment is however reported to be lower in Phase II of the program (compared to Phase I) when the program designers put in measures such as call centers and repair services to address the reported challenges. Thurber (2014) reports that 23% of those who reduced or eliminated usage of ICS cited unresolved stove problems. It was not just the breakdown of the technologies that led to disuse, but also fear of breakdowns occurring without arrangements in place to address them. Bielecki & Wingenbach (2014) cites the following concerns of beneficiaries of a program in rural Guatemala:

> *- "I am using the open fire, because I don't want the [ICS] to break down quickly" (H4).*
>
> *"I am afraid of what would happen if some of the blocks inside break. What would I do or where would I go to get new ones?" (H16).*

In some instances, the concern about breakdown (not the breakdown itself) led to a failure to adopt the MECS, as reported by Li Jian (2009) on biogas program in China.

Vulturius & Wanjiru (2017) who assess stove satisfaction finds that a key reason for the differences in satisfaction and adoption between the two groups was the after-sales support users received from their respective implementers. Wentzel & Pouris (2007) observe that badly assembled stoves, lost and unavailable spare parts hampered acceptance. Barnes et al (2012) in one of their case studies find the availability of after sales support, in the form of stove mason living nearby, to be a driver of transition. That particular program also included a follow-up by three field officers to inspect the stoves after construction, with consequences (loss of government contract) for agencies whose stoves failed the tests. However, in 2001 alone, NGO installations numbered 65,000, far exceeding inspection staffing capacity. In another setting covered by the study, users discarded faulty stoves after a few months due

to lack of after-sales service. Urpelainen & Yoon (2017) reports that lack of local technical expertise and good quality after-sales service were the key weaknesses in the dissemination structure of the program they evaluated. Just 10% of the interviewed households received after-sales services, and 40% of those were dissatisfied with the support received. In more than 10% of those households the ICS did not work properly within a year of installation.

Troncoso et al (2011) is a departure from other studies, with ICS builders in that project reported as visiting every household up to three times after construction and offering technical assistance in stove use and maintenance. Another "success story" is reported of a biogas program in India (Bhat et al,2001) where adopters were offered guarantees and warranties free of cost. Yet another biogas program in Bangladesh (Sovacool & Drupady, 2011) is reported to have offered good after sales service, which motivated people to sign up to the program. The company is reported to have offered a buyback system where clients could return their system at a reduced price, and also offered free maintenance and training to all existing clients on proper maintenance and minor repairs. According to the authors, *"Rather than run things from Dhaka, GS has a network of more than one thousand offices spread throughout the country. GS enrolls communities into renewable energy projects at the household and villager level but also engages district and national policymakers along with inter-national donors and lending firms".* A major contrast to this program is the rural Chinese one (Li Jian, 2009) where according to the author, villagers had to visit County Biogas System Repair Station (CBSRS) in the county seat for technical advice, and had to pay a high fee to attend training, which even those who attended considered not valuable.

Masera et al (2005) stress the importance of after sales services based on their evaluation of a cookstove program in Mexico:

> *Adoption of improved cookstoves implies a learning period that needs to be carefully monitored. In the case of Patsari cookstoves, local women need to adapt themselves to cook standing instead of kneeling, to tend the fire in a different way, to use smaller pieces of wood, to clean the tunnels and chimney, and to cook with a metal comal instead of a ceramic one. All these changes imply an entrance barrier to cookstove adoption; many women take a month to adapt themselves to the new cookstove, a period when cookstove monitoring and user support is essential.*

The challenge in providing after sales services was noted to relate mainly to lack of incentives, emanating from programs failing to invest on this component. According to Barnes et al (2012) interviews with the stove builders in one setting revealed that they were unable to visit all villages for lack of time and funds. Of the 129 user households surveyed, all reported that the builders and masons did not return after installation. In a second setting, stove builders usually failed to check on proper functioning of the installed stoves for lack of incentives to do so, and in ta third study setting, only three field officers were assigned to inspect cookstoves which totaled 65000. Urpelainen & Yoon (2017) report a lack of incentives for the stove builders to provide maintenance, and for engaging in the cookstove business because of low salaries. Only 10% of trained stove builders were retained in the business. Similarly, Barnes et al (2012) report high dropout rates among the youth who were trained in stove building and maintenance because they viewed stove construction as a casual job rather than a profession**.**

4. CONCLUSIONS & RECOMMENDATIONS

This review of the literature is based on 133 articles (comprising 160 studies) that met the inclusion criteria agreed by a wide range of stakeholders and advisory experts, and while small relative to the number of articles screened (13,914) and assessed at full-text (791), this is consistent with the numbers found in other similar systematic reviews (81 by Vigolo et al (2018), 44 by Puzzolo et al (2016), 32 by Lewis and Pattanayak (2012). While most studies are rejected through not meeting inclusion criteria, weaknesses in study designs in primary research account for a disappointingly high number of rejections of studies that undoubtedly contain rich information of central interest to the review question. In terms of the overall availability of relevant studies that meet the criteria for understanding what factors drive the transition to MECS, there is a relative lack of well-designed research that takes account of confounding and contextual factors of the populations targeted for transition programs. Many articles were rejected from the current review because key information on the programs were missing or not reported, and results were discussed with no reference to measured outcomes that could be independently verified. One example of this is the almost total absence of robust, empirical studies of what drives uptake in one of the most successful cookstove programs in Africa – the Kenya Ceramic Jiko - in urban areas, despite many discussion papers in the literature. Future program evaluations could benefit from a more rigorous (perhaps Protocol-driven) approach.

There is great scope to improve study design of transition programs and reporting standards of research articles that emerge from these programs. In common with other reviews in this area, the limited amount of information from sources other than academic journals, including reports from international organizations, non-governmental organizations, and the private sector, means that much valuable work in this area is not finding its way into syntheses of evidence, and this is not only an intellectual loss but limits the value of funded work over many decades. It is beyond the scope of the current review to suggest solutions beyond repeating recommendations for better curation of non-journal evidence.

The evidence base pointed to the importance of socio-demographic factors (particularly age, education, income) and contextual factors on decisions and ability to undertake transitions to modern energy systems and in continuing with them, or reverting to traditional technologies. While these results are not new, and indeed we find that various programs have taken them into account, there were still many programs that did not take into consideration characteristics of the populations they were targeting or did not report them. Programs were transported across contexts without considerations of combined cooking and heating needs of the local populations; highly complex projects were implemented without education and after sales support for users; and high cost solutions requiring up-front cost investments way above the user's incomes (over 10% of monthly wages in some cases) were rolled out without financing options. Consequently, several programs are reported as having been unsuccessful, while some ended up excluding their core target groups. These findings suggest that knowledge on socio-economic factors as barriers is either not common knowledge; and if it is there are underlying barriers from the implementer's perspectives in taking them into account. This review therefore offers useful insights into an old problem. Further studies from an implementor's perspective are also needed to unearth the challengers from implementor's perspective on their challenges in accounting for some of these barriers in their programs. There was some suggestion in the evidence base of donor requirements and financing limiting an implementor's ability to address these challenges (Barnes et al, 2012), a point which requires further probing.

Some of the reported barriers, understandably, lay outside the influence of small-scale, non-governmental transition programs; such as availability of plentiful and low cost biomass and very

low incentives to make a transition, along with poverty barriers. Overcoming such barriers would require interventions at governmental levels. The forms such interventions can take is not clear-cut and possibly raises controversy, and we are therefore hesitant to make recommendations on this aspect. We can nonetheless report some useful insights from programs reported as successful in achieving a transition to MECS. The successful transition program in Indonesia through a government led approach entailed lowering the price of transition fuel to a level below the traditional (secondary) fuel, making it price competitive. Furthermore, the program was clear from the outset that it was not targeting the lowest grade fuel (biomass) and thus was able to tailor the solution to a target group that could afford to pay for some of the transition costs. In Peru where the recurrent cost of LPG was subsidized using a very targeted approach, a large-scale transition is reported to have occurred that was retained over a long period. In contrast a program in Ghana that provided free LPG starter package with no subsequent financial support was not sustained beyond 9 months. Although not covered in this review, there is also anecdotal literature that shows that ban on charcoal has led to increase adoption of LPG. Further studies on this topic would help clarify these claims.

Apart from large-scale measures above, the evidence also provides examples of small and incremental actions that can be taken within programs to improve their outcomes. For example, follow-up by implementers after initial adoption to monitor and record program successes and weaknesses and respond to users' feedback over an extended period of time was important in supporting transitions. This, taken alongside the evidence that peer influence is an important mediating step in adoption supports the recommendation to have this component in-built into programs. Durability of technologies consistently emerged as important, and the need for technologies that respond to user practical cooking needs.

Finally, some areas important for further investigation based on suggestive but limited evidence on their importance because of few studies that addressed them. We found an evidence gap in understanding transitions in urban settings, owing to the relative lack of studies focused on urban and peri-urban settings. Given the growing trend of rapid urbanization, particularly amongst the young, whom the evidence suggests are more likely to adopt modern technologies, this is worthy of future study. We also find reported instances of factors outside the energy sector that impeded transition; thus, it would be expected that there would also be other factors outside the sector that can be harnessed to support the transitions. Although we tried to address this question by including studies from other sectors such as lighting, telecommunications and agriculture? very few of such studies met our inclusion criteria. Additional reviews specifically targeting studies in those sectors are warranted. As observed in the report, nearly all the literature reported continued dependence on traditional cooking fuels for populations that had transitioned to MECS. A better understanding on what drives this practice, and its impact on transitioning process (which can be positive or negative) is necessary.

Limitations of the review

All research reviews have limitations, and, while systematic reviews aim to minimize the limitations caused by bias in selection and assessment of studies, there are limitations which must necessarily affect interpretation of results. The first limitation is of course the scope of the review, as defined by the question and reaching a common understanding of the elements of the question. The systematic method overcomes this to some extent, particularly by the inclusion of involvement of stakeholders in shaping and defining the question and by the production of a method for conducting the review (the Protocol), which is agreed and peer-reviewed rigorously. However, as discussed above, terms like

'large-scale' and 'sustained' and even 'transition' itself are all open to considerable interpretation, and other researchers might reach different conclusions about how these terms should be applied to decide on inclusion or exclusion of studies found by the search strategy. Making excluded articles available for scrutiny and use by other researchers or policy-makers helps mitigate this limitation. The search strategy is also subject to contestation and the addition (or removal) of search terms or knowledge sources would affect the set of studies potentially available for a review. We have been clear that there has had to be a trade-off between breadth of the search strategy and resources (time and cost) available to undertake and finish the review. Again, making the strategy available will allow other researchers to adapt our methods for subsequent reviews. This may be particularly important for increasing the languages of articles that are potentially available for the current topic.

Policy recommendations

The following recommendations should be considered alongside limitations that are inherent with any research design, including systematic reviews, as discussed above. Based on the findings that emerged from the evidence base, we recommend the following measures to address the barriers of transitioning to MECS:

- Have better targeted programs that take into account the socio-economic realities of target groups. As shown in the evidence base, populations who are extremely poor did not prioritize clean cooking; and instead had more pressing needs such as food security. While some programs attempted to overcome this challenge by promoting low cost technologies, several challenges arose from those low-cost solutions that led to their abandonment. Furthermore, some of these technologies were not seen as overly beneficial, as they did not offer any appreciable difference to traditional cooking, with users preferring more durable technologies even if they came at a higher cost. Where poor populations are the target of programs, financial mechanisms that address their affordability constraints should be incorporated.
- Clean cooking interventions should fully take into account the challenge posed by the existing alternatives. This might require intervening on both fuels or offering a way better value proposition for the new technologies. This value proposition is not clear-cut and could be subjective; as we find some programs that are widely reported as having failed to achieve their technical objectives, and yet users reported high satisfaction with the technologies. Awareness creation may also be helpful if additional evidence shows that this is a driver of transition.
- Programs should fully take into account the time demand on women, including in attending long technology training sessions, extra time for fuel processing, stove cleaning as well as marketing and promotion of these solutions. We particularly caution against specifically targeting women as promoters of MECS solutions even though they are reported to be more successful in generating sales than men, without further evidence of how impactful such engagements are to their overall welfare. This is because the evidence base shows a general low overall success of MECS programs, particularly those promoting low cost ICS solutions, and this was reported as one reason inhibiting men's engagement in the promotion efforts. The evidence base further points to the value women attach to their time, which was one of the widely cited benefits of adoption of cooking solutions. Further research is needed that can support or refute this recommendation.
- The role of overcoming the low incentive to switch to MECS through awareness creation on the harmful effects of traditional cooking should not be left to individual cookstove programs but

tackled more broadly by the governments, as a MECS intervention by itself. This would allow for independent and objective messaging and could inspire more trust and thus more likely to elicit a behavior change. Lessons on designing such programs can be taken from NGOs that have been very successful in this type of communication.

Recommendations for further research

- Ensure that evaluation methodologies are incorporated in cookstove program designs, that can allow independent assessment of essential program components and ultimately of program success. This should include projects that are implemented by private sector, many of whom receive some level of financial support from donors.
- Apply more stringent review processes for research on cookstove programs, and ensure stricter adherence to publication guidelines on method design that will ensure robust reporting of studies conducted on the topic.
- Create a repository for grey literature on modern energy cooking systems where researchers and practitioners can deposit key reports and findings on incentives to adoption of cleaner cooking and factors that act as drivers and barriers to transition.
- Increase understanding of transitions to modern energy and improved cookstoves in urban and peri-urban settings, as well as how transition in other settings can be harnessed to support MECS transitions.
- Explore the role stacking' behavior in transitions, which could be either positive in allowing households to have a fall-back option against the inherent challenges associated with transition fuels and technologies; or negative in preventing populations from making a full transition. The current study was not designed to tackle such a question, that would be better addressed with primary data that can define transition in stricter terms and perform separate analyses for those who stack and do not stack.
- Explore the role of subsidies in MECS transitions, including the challenges related to sustaining such measures and any adverse effects of such policy measures.
- Investigate further gender roles in supporting transition to MECS.

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ANNEXES

ANNEX 1 –ADVISORY GROUP & STAKEHOLDER MEETINGS REPORT

Advisory Group members

Jon Cloke, Ed Brown (University of Loughborough), Simon Batchelor (Gamos Ltd), Dan Pope (University of Liverpool, Elisa Puzzolo (Global LPG Partnership & University of Liverpool), Marcos Paya (Dalberg Advisors), Tara Ramanathan (Nexleaf Analytics), Marc Jeuland (Duke University), Samantha Delapena (Berkeley Air Monitoring Group), Lana Zaman (UN ESCAP), Evans Kituyi (East Africa Institute), Cecilia Sundberg (KTH), Phosiso Sola (ICRAF), Natalie Evans (Nexleaf Analytics), Charles Spillane (National University of Ireland, Galway), Guangqing Liu, Mike Toman, Dana Rysankova, Masami Kojima, Yabei Zhang (World Bank), Yuguang Zhou

Report of stakeholder engagement

Energy Sector Management Assistance Program (ESMAP)

Efficient Clean Cooking and Heating (ECCH) Program

Analysis of transition pathways for modern energy cooking services (MECS):

Report of Stakeholder Engagement - Loughborough 30/10/19, Nairobi 08/11/2019

Purpose of this report

The report comprises an overview of the main discussions at the two stakeholder meetings, held as part of the systematic evidence evaluation project, and Minutes of both meetings.

Overview of Stakeholder discussions

There are around 3 billion people who rely on solid fuels, kerosene for their daily cooking and energy needs. Of these 3 billion, 2.2 billion have yet to adopt modern energy which has led to around 4 million premature deaths annually - particularly among women and children. In order to determine the key drivers facilitating, and barriers preventing, transition to modern energy, an assessment of the published and grey literature will be conducted, taking a systematic approach to gathering, mapping and evaluating the published evidence base. Stakeholders were engaged to direct the review and provide scope for its search strategy, inclusion criteria for relevant studies, and extractable data that will help answer the review question, and provide insights into evidence gaps.

Loughborough meeting

The first Stakeholder meeting was held at Loughborough University on 30th October 2019. It comprised mostly academics with expertise in modern energy cooking systems, transitional pathways and theories of change. This meeting discussed the complexities of modern energy uptake within the multi-tier frameworks outlined by ESMAP. After consulting with this group a targeted primary research question was developed to frame the scope of this systematic review.

To frame the question, interdisciplinary dynamics were considered, including: energy pathways, transitions, urbanization, globalization, economics, the environment, ethnologies, geographies and

political economy. The resulting discussion led to the formation of a working title for the systematic review:

“What factors are critical to achieve a large-scale transition towards sustained use of modern energy with particular reference to cooking in LMICs?”

The discussions highlighted the significant differences of opinion, and shades of interpretation within the energy sector, from considerations of the multi-tier framework itself, to the notion that energy transitions are not necessarily linear and the idea of an ‘energy ladder’ was not always helpful.

There was considerable agreement that the review should take account of technology transitions in other sectors that might help inform decision-making for the cooking sector. It was acknowledged that this could potentially open up a very large body of knowledge – essentially any movement from an older to a newer technology from post-industrial times. Assessing whether studies about these transitions would be of relevance to cooking would be difficult to ascertain from Title and Abstract only. This stage is central to the process of screening for inclusion in a manageable fashion that defines the systematic review method – the impossibility of considering all potentially relevant papers at full-text is accepted. Further, the group agreed that studies from all countries should be considered, not simply studies from LMICs, since insights into drivers of change could be taken from one context to another. The review would analyse evidence FOR LMICs, but draw on evidence from everywhere. Again, this will result in a very large set of studies to assess and the review team will have to take account of stakeholder input, but make a practical decision in order to complete the review on time and to budget. Precisely how will be documented in the Protocol.

Helping to narrow the review, was the decision of the group to look at ‘large-scale’ programmes/interventions whose objective was to drive technology transition. A large set of concepts and keywords defining large-scale were generated in the meeting. There were discussions about geographical entities (towns, regions, etc.) vs areas with high population density that may not be defined as an entity. There was acknowledgement that this would be difficult to assess by a screening process, but that the interactive systematic map could include a layer showing population densities. This was an interesting idea that stimulated thinking about other meaningful layers – access to clean energy, access to electricity, etc. that might be included.

In addition to suggesting a large number of search terms and concepts, the group suggested databases and organizations that should be searched.

Nairobi meeting

The second stakeholder meeting was held in Nairobi on the 8th November 2019, following the Clean Cooking Forum 2019, to engage with policy makers, businesses and consumers. The preliminary question developed at Loughborough was scrutinised by this second group with broad agreement that it represented the aim of the project.

Further development of search strategies and terminology to include in database searching was developed to provide the review team with a comprehensive list of search terms and inclusion criteria. The meeting provided a list of over 100 terms to include in the database Boolean search strategy. (Lists of terms are included in the Annexes of the Minutes of the meetings).

Concerns surrounding search terms relating to ‘scale’ were raised with the thought that their inclusion would limit literature return. The discussion raised the point that studies of individual households are themselves almost always part of large-scale interventions or programmes, and that these will be missed if the search strategy is constructed with a scale term being a necessary factor.

Similarly, the discussion on how to define ‘sustainable’ was rich, with concerns raised about whether insisting on its inclusion in the search string would exclude potentially important studies. The response of the review team was to suggest that we would infer sustainability from the length of time measurements were made (outcomes) after the programme (intervention) started. Data in the

systematic map could be filtered with this time criterion (an example was shown of the systematic mapping tool that allows for such filtering (see https://oxlel.github.io/evidencemaps/)

In addition to terminology discussions, the meeting accepted that language coverage could not be fully comprehensive, but that English, French, Spanish and Portuguese language studies would be included, and other languages would be noted as existing but not further analysed. A possibility of including the important Chinese literature was discussed and this will be pursued separately and will be reported in due course.

Initial scoping studies undertaken by the review team using all terms suggested by the two meetings returned well in excess of 300,000 records across 4 bibliographic databases (CABI, Web of Science, SCOPUS and ScienceDirect). Initial random-sample analysis of this dataset indicated a large number of irrelevant literature. The search strategy will have to be refined to remove many of the terms collected from the search string and incorporate them as inclusion criteria or outcomes from the included studies represented in the codified data extraction sheet.

The tests of search terms and development of the final search string will be reported in the Protocol in full.


1st stakeholder meeting


Radisson
MBCS 2nd stakeholder meeting

Report of stakeholder engagement

Minutes of Loughborough meeting

Energy Sector Management Assistance Program (ESMAP)

Efficient Clean Cooking and Heating (ECCH) Program

Analysis of transition pathways for modern energy cooking services (MECS)

First stakeholder consultation on systematic evidence evaluation project on factors driving transitions to Modern Energy Cooking Services, 30th October, 2019, University of Loughborough

Attending

Louise Medland, Jon Leary, Jon Cloke, Nick Rousseau, Richard Sieff (University of Loughborough), Simon Batchelor (Gamos Ltd & University of Loughborough), Dan Pope (University of Liverpool, by Skype), Elisa Puzzolo (Global LPG Partnership & University of Liverpool), Rupert Gammon (De Montfort University), Jacob Todd (University of Sussex), Meron Tesfamichael (UCL), Gillian Petrokofsky, William Harvey (University of Oxford), Leo Petrokofsky (Health Economics Consulting, University of East Anglia), Caroline Adongo Ochieng (Worldbank)

Agenda

Time	Activity	Session Lead
09:30	Welcome & introductions	Louise Medland & Simon Batchelor
10:00	Introduction to MECS systematic review project	Caroline Ochieng
	Introduction to systematic review method and role of Stakeholder engagement	Gillian Petrokofsky
	Overview of related systematic reviews	Elisa Puzzolo & Dan Pope
11.45	Coffee break	
11:45	Protocol development for the project "PICO" framework – with examples Start PICOs for MECS review	Gillian Petrokofsky
12:15	Lunch	
13.00	Group work on developing the search strategy Keywords; key concepts Sources (bibliographic databases & grey literature) Reviewing search strategy	All
14:00	Inclusion criteria: Languages, Date range of articles, Types of publications, Research designs	Gillian Petrokofsky with input from all
14:30	Data coding & data extraction: Overview with examples Key information to code & extract	Gillian Petrokofsky with input from all
15.00	Tea break	
15:30	Theory of change – preliminary thoughts	Ed Brown & Elisa Puzzolo
	Review of decisions, next steps and timelines	Caroline Ochieng

16:00	Meeting ends	

Preparatory materials

Participants had been circulated with details of the project and the aims of the meeting (see Annex 1)

Presentations

Presentations by Ochieng, Petrokofsky, Puzzolo and Pope are available on request.

Variations to the agenda

The items on data coding and developing a theory of change were discussed only briefly owing to time constraints and the additional time all agreed was necessary to discuss the exact scope of the question, where opinions differed substantially amongst participants.

Research Question:

After much discussion, the following framing of the review question was agreed:

What factors are critical to achieve a large-scale transition towards sustained use of modern energy with particular reference to cooking in LMICs?

Explanations and clarifications

'large-scale' to mean national, sub-national, regional, state, district, city, etc. but not individual household

The breadth of the review to include other technologies, not limited to cooking nor transitions to clean energy. It was also to include evidence from transitions (in all sectors) from high-income as well as low and middle-income countries. There was much debate about how potentially large this topic would then become, but it was agreed that useful information about drivers of change (and barriers to change) could be sought in non-cooking or energy sectors. The analysis of such information would be focussed on relevance to modern energy for cooking.

PICO framework

While recognising that this is only a framework, albeit one widely used in systematic reviews, variants are often more appropriate for broad-topic evaluations, such as the current review.

The PICO framework is typically as follows:

Population: Which population(s) are we interested in? How best can it be described? Are there subgroups that need to be considered?

Intervention (sometimes 'Exposure'): Which intervention(s), approach, programme should be examined? Which exposures are the populations experiencing?

Comparators: Are there alternative(s) to the intervention being examined? If so, what are these (for example, other interventions, and other meaningful controls)?

Outcomes: Which outcomes should be considered to assess how well the intervention is working (including outcomes on both benefits and harms)?

For our current review, the workshop considered that a possible PICO framing was:

Population – terms describing the groups we should consider:

(i) Geographical determinants, such as rural, sub-urban, urban, national, regional, sub-national, city, district, state, city, peri urban, community, neighbourhood, but also consider population density as a determinant of a group affected by the transition intervention

(ii) Programme/policy determinants such as energy program*, national program*, regional program*, subnational program*, sub-national program*, subregional program*, sub-regional program*, NGO programme*

(iii) Users of different fuel types – transitions to Tiers 4 and 5, etc.

Interventions - Technology adoption, transition, uptake, rollout, dissemination, mechanization, mechanization, delivery, conversion, scale up, acceptance, innovation, diffusion, mainstreaming, adoption, adaptation, delivery, behaviour change, Energy Transition, energy turn around, Household energy transition, Household Energy, Public energy mobility, decarbonization)

Outcomes- Sustained use, numbers of uptake, widespread, energy per capita, power per capita, CO2 equivalent, particulates, Carbon monoxide, carbon dioxide, Nitrogen Oxide, environmental impact, emissions within homes, health, time savings, QOL metrics, (income, and/or expenditure), productivity, safety, gender equity, education, drudgery, deforestation, climate metrics. Drivers and/or barriers must be discussed. **Other factors** –

Pillars of influence: Framework of factors e.g. social, economic, and environmental

Identified Evidence sources:

https://www.africalics.org/ African universities https://lilacs.bvsalud.org/en/

https://www.carbontrust.com/tea/news/2019/03/tea-learning-partnership/

https://cdkn.org/organisations/panos/?loclang=en_gb

https://cdkn.org/organisations/ids-nepal/?loclang=en_gb https://www.tata.com https://www.teriin.org/

http://kippra.or.ke/

Development Banks – AsDB, AfDB https://www.3ieimpact.org http://www.hedon.info/HomePage SEI

https://www.pauwes.dz UCT

https://www.ait.ac.th

Next steps

The systematic review team will present findings from this consultation to the Nairobi consultation and use the combined inputs to draft a Protocol for the systematic map. Search terms tabulated against PICO elements will be included in the 2nd Report for clarity. The workshop attendees were informed that normally systematic reviews and systematic maps take up to 18 months to complete. The timetable for the current work is very much shorter than that and we will be seeking guidance as we progress on ways to reduce time spent on our literature discovery, in particular. We will invite all stakeholders to submit relevant studies for the team to assess against inclusion criteria.

Most attendees said that they would be willing to be contacted further, so we will circulate the draft Protocol to all who confirm their willingness to serve on the Advisory Group in late November.

Annex 1 – Preparatory materials. Invitation to participants

Dear Colleagues,

We are pleased to invite you to the first stakeholder consultation for our new systematic evidence evaluation project which forms part of our work on 'Modern Energy Cooking Services (MECS)' https://www.mecs.org.uk/, implemented by World Bank Energy Sector Management Assistance Program (ESMAP) and University of Loughborough.

Our aim is to assess the evidence base (both formally published peer-reviewed literature and grey literature) that will help us in an analysis of transition pathways for modern energy cooking services (MECS).

We intend to follow an interdisciplinary mixed-method project design that will comprise of the following:

Systematic mapping to provide information on the amount and quality of evidence available to address the review objectives. Systematic mapping also provides a filtered and manageable set of research from a large and chaotic literature and presents papers of direct relevance that can then be the source for detailed analyses.

Quantitative and qualitative analyses to answer the central research question on what drives and impedes transition to MECS.

For literature that cannot be subject to a systematic analysis, a narrative analysis will be used to provide insight into what has happened/is happening and why.

Expert informant interviews to fill in gaps for questions, geographies and historical contexts that do not yield a sufficient number of publications.

We will work closely with stakeholders to ensure that we frame the question correctly, find and assess the literature comprehensively, and understand how best to interpret the drivers of change and barriers to change that emerge from the literature and the evidence assembled.

We would like to gather together experts in the clean cooking field in Loughborough University on 30th October 2019 to introduce the project, and harness your expertise to help us produce a Protocol for the systematic evaluation element of the project. We do not expect any knowledge of systematic evaluation techniques - we will introduce these in the meeting, but we are keen to draw on expertise to establish in particular:

A robust search strategy that will help us identify, locate and select relevant studies.

Develop a strategy for seeking grey literature from other stakeholders and organisations which hold relevant studies that are not easily accessible to us;

Start to develop a theory of change that might be helpful in guiding our initial work.

We will send a more detailed agenda in advance of the meeting, but meanwhile, you may be interested in (1) taking a look at recent systematic maps and (2) browse the detailed editorial guidelines that we will follow closely as we write a Protocol that will form the method blueprint for our review, and that will ultimately guide our final report.

1. Recent Evidence maps as an example: see https://nam03.safelinks.protection.outlook.com/?url=https%3A%2F%2Foxlel.github.io%2Fevidence maps%2F&data=02%7C01%7Ccochieng2%40worldbank.org%7C940cebfc02ef4a33755d08d74b6b dad4%7C31a2fec0266b4c67b56e2796d8f59c36%7C0%7C0%7C637060798911328878&sdata=WV F76BhywNDsdw7G3EJ8WG%2BXktgQ1kxW8gFcAm0iMZA%3D&reserved=0 and follow link to,

for example, Woodfuel use in Sub-Saharan Africa (full report published at https://nam03.safelinks.protection.outlook.com/?url=https%3A%2F%2Fenvironmentalevidencejournal.biomedcentral.com%2Farticles%2F10.1186%2Fs13750-017-0082-2&data=02%7C01%7Ccochieng2%40worldbank.org%7C940cebfc02ef4a33755d08d74b6bdad4%7C31a2fec0266b4c67b56e2796d8f59c36%7C0%7C0%7C637060798911328878&sdata=518y096K565xXR7irGPZnAoQyWloR%2Bvr8cPBdLEzyj0%3D&reserved=0

2. Guidelines for evidence evaluations:

See https://nam03.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.environmentalevidence.org%2Finformation-for-authors&data=02%7C01%7Ccochieng2%40worldbank.org%7C940cebfc02ef4a33755d08d74b6bdad4%7C31a2fec0266b4c67b56e2796d8f59c36%7C0%7C0%7C637060798911328878&sdata=CN1SKPTIzws31kmVuTeljGkrbeEIO91Eyv2cZ9qx1zQ%3D&reserved=0

Section 2.6 Involving stakeholders, and

Section 3 -Planning a CEE Evidence Synthesis

In addition to presenting the aims of the project, we will spend time taking you through the steps of a systematic review and solicit your input to developing a robust strategy to carry out the review.

Please let us know if you will be available to attend the event for planning purposes. Additional information on travel logistics will be shared once we receive your confirmation.

We are looking forward to seeing you in Loughborough.

Report of stakeholder engagement Minutes of Nairobi workshop

Energy Sector Management Assistance Program (ESMAP)

Efficient Clean Cooking and Heating (ECCH) Program

Analysis of transition pathways for modern energy cooking services (MECS) Minutes of 2nd stakeholder consultation on systematic evidence evaluation project on factors driving transitions to Modern Energy Cooking Services, 8 November, 2019, Hotel Radisson Blu, Nairobi

Attending

Marcos Paya (Dalberg Advisors), Beryl Onjala (IredAfrica), Tyra Oduttu (African Clean Energy), Tara Ramanathan (Lexleaf Analytics), Dana Charron (Berkeley Air Monitoring Group), Lana Zaman (UN ESCAP), Megan Bomba (Nexleaf Analytics), Evans Kituyi (East Africa Institute), Ruth Mendum (Penn State University), Mary Njenga (ICRAF), Cecilia Sundberg (KTH), Phosiso Sola (ICRAF), Alisha Pinto (World Bank), Nivel Scott (Gamos.org), Natalie Evans (Nexleaf Analytics), Elsie Onsongo (Centre for Frugal Innovation), Yabei Zhang (World Bank), Gillian Petrokofsky, William Harvey (University of Oxford), Leo Petrokofsky (Health Economics Consulting, University of East Anglia), Caroline Adongo Ochieng (World Bank)

Agenda

time	activity	lead
09:00	Coffee & informal introductions	
9:30	Introduction to meeting & MECS research programme	Caroline Ochieng

	Introduction to systematic review method	Gillian Petrokofsky
	Stakeholder engagement and outputs from 1st consultation in Loughborough	Caroline Ochieng
	Panel discussion: Reflections on related systematic review work and how the current review fits with the overall MECS and ESMAP programs	Sola Phosiso, Lana Basneen Zaman, Yabei Zhang), moderated by Caroline Ochieng
10:30	Coffee	
11:00	Protocol development for the project	Gillian Petrokofsky
	• "PICO" framework for the review, building on 1st stakeholder consultation • Developing the search strategy	
12:45	Group work on developing the search strategy	Input from all (Group work)
	• Keywords, key concepts • Sources (bibliographic databases & grey literature)	
13:15	Reviewing search strategy	Input from all
14:15	Inclusion criteria	
	🎬 Languages, date range of articles to include, types of publications, research designs to include	Gillian Petrokofsky + All
14:15	Data coding & data extraction • Overview with examples • Key information to code & extract	Gillian Petrokofsky + All
15:00	Review of decisions, next steps, timelines	Caroline Ochieng
15:30	Meeting ends	

Preparatory materials

Participants had been circulated with the same details of the project and aims of the meeting as those in the 1st stakeholder consultation, with minor alterations to the email to provide location details for Nairobi's meeting.(see Minutes of Loughborough meeting)

Presentations

Presentations by Ochieng and Petrokofsky were, with minor modification, the same as those for the 1st stakeholder consultation (see Minutes of Loughborough meeting).

Panel Discussion

The challenges, particularly with respect to time taken to process a systematic review were discussed, with PS and LZ both stressing how the current project is very short on time. Their reviews took over 1 year and closer to 18 months is considered a normal time. The review team acknowledge this limitation and informed the meeting that they will use machine-learning for screening the large number of studies expected to be found by the comprehensive searches suggested by stakeholders. The ESMAP and MECS projects already have a very large number of highly-relevant studies which will be helpful in reducing

time spent searching. The work currently being finalized by Dalberg will also feed into the current review in an efficient way, and document-sharing with LZ's work can also benefit both work streams.

Building on 1st stakeholder meeting

Review question: What factors are critical to achieve a large-scale transition towards sustained use of modern energy with particular reference to cooking in LMICs?

This was discussed during breakout sessions, but not generally-agreed amendment was agreed and people were happy that this was broad enough to capture an interesting question. Debates focussed mainly on how to define 'sustainable' and 'large-scale', with useful key concepts and key terms suggested to augment the list produced in Loughborough.

The combined list of terms, loosely arranged under PICO elements is reproduced in Annex 1. Useful sources of information and relevant netoworks are listed in Annex 2. Additional potentially useful concepts and words were collected by the review team in the preceding Clean Cooking Conference and are attached in Annex 3 (these are not coded or arranged in any particular order in the present report). These lists will form the basis of a search strategy to be developed in the draft Protocol.

Languages covered

There was much discussion about what languages could be covered. The team are already able to source studies in English, French, Spanish, and Italian, and can call on some help for Arabic and German, but is not able to cover Chinese, Russian, Japanese, and Korean adequately. A possible way of covering the important Chinese literature was discussed. These issues will be set out clearly in the Protocol, with recommendations for additional work, where the current very tight timetable may not allow for a full range of languages. A comprehensive suggestion/recommendation matrix will be prepared to set out clearly what can be included in the current review and what will be suggested for follow-up work.

Annex 1 Combined search terms from both stakeholder workshops

Search Terms

Population	Intervention/Counterfactual	Outcomes
Rural	Technology Adoption	Sustained Use
Sub-Urban	Transition	Number* of Uptake
Urban	Uptake	Widespread
National	Rollout	Energy Per Capita
Regional	Dissemination	Power Per Capita
Sub-Regional	Mechanization	CO2 Equivalent
City	Delivery	Particulates
District	Conversion	Carbon Dioxide Equivalent
State	Scal* Up	Carbon Monoxide
Peri-Urban	Accept*	Carbon Dioxide
Community	Innovat*	Nitrogen Oxide
Neighbourhood	Diffusion	

National Program*	Energy Turnaround	Environmental Impact
Regional Program*	Household Energy Transition	Emissions Within Homes
Subnational Program*	Household Energy	Health
Subregional Program*	Public Mobility	Time Savings
NGO Program*	Mobility	Quality of Life Metrics
Wood-Primary markets	Decarbonization	Income
High-Level Action Group	Whole-Systems approach	Expenditure
Purchasing	Industrial Production	Productivity
Buy	Semi-Industrial Production	Safety
Companies	Pay-As-You-Go Gas	Gender Equity
Enterprises	Consumption	Education
Private Sector	Modern Energy	Drudgery
Entrepreneur		
Energy Markets	DC	Deforestation Climate
	AC	
Sanitation sector		End-User Perception
Mobile Phones/Smartphone sector	Subsidies	Supply-Chain Costs
	Sensors	Electrification
	Measurements	Job Creation
	Infrastructure	Gender Imbalance
	Monitor	
	Cooking Systems	
	Financing	

Asset Finance Microfinance
Results Based Financing
Marketing
After Sales Service
Branding
Business Model
Capacity Building
Impact Investing
Venture Capital
Business Environment
Experiment
Policy
Legislation
Tariff reform

Behaviour Change
Society Perception
Risk Perception
Downstream Fuels
Network Coverage
Sustained Public Funding
Vertical Integration
Welfare
Wellbeing
Cost Saving
Employment
Work
Burden (Women)
Convenience
Hygiene
Social Inclusion
Social Capital
Social Status
Aspiration
Modern Lifestyle
Fuel stacking
Energy bundling

Annex 2 Identified Evidence sources – supplementing those suggested in Loughborough

Practical Action
Nexleaf analytics
Berkeley air monitoring
Duke University
FAO
OECD
USAID
Check local NGO websites
GIZ - energising development
SSRN

SNV
University of Michigan - southern africa
Swedish embassy
International energy agency
Sustainable energy for all (UN)
HIVOS
Energia
Dalberg
Clean Cooking Alliance
Gates Foundation
Susana.org - sanitation
Faraday Institute - batteries
UNHCR
Rocky Mountain Institute
WFP
CGIAR
Solar cookers international
GLPGP
Gogla
NBER - national bureau of economic research
Rockefeller foundation
UN Stats IRENA
-
UN Women
UNDP
GSMA development utilities
Shell foundation BP?
Deloitte
MCC - millennium challenge corporation
McKinsey
Private sector - publically funded ceew - India based think tank TERI - The energy resources institute
BCAS - Bangladesh Centre for advanced studies
Initiative for sustainable energy policy
Measure evaluation
ESD - energy for sustainable development - Univ. Cape Town

Usable Information Networks

- Sustainable energy transitions initiative
- Environment for development initiative
- Global energy partnership
- UN climate and clean air coalition
- ICRW
- Safe network
- African academy of sciences
- European academy of sciences
- American academy of sciences
- Sustainable transitions research network
- IIASA (Austria)

Annex 3 – Useful concepts and terms used at the Clean Cooking Conference immediately before the stakeholder workshop

These will help inform the review team when searching for relevant studies. They are included here as an aide memoire.

Words from Opening Plenary:

KEY NOTE – (SDG7, whole-systems approach, sustain* change/development, multiple geographies)

KATRIN – (end-user perception, market-based, industrial/semi-industrial production, supply-chain costs, electrification, job creation, EMPLOYMENT SECTOR)

Dutch and Norwegian Ambassadors - emphasized ***gender imbalance***

Media perception of clean energy

Baseline data

Systematic approach - embracing all sectors.

Entire value chain

Pay as you go gas consumption - some studies. Cheaper alternatives will always win with consumers.

(hidden cost of deforestation) natural resources costing

Affordable appliances - not just cookstoves

Distribution

Agenda 2063

Cooking value chain

Opinions on most important interventions medium-term -

Dr Njoroge: product creation that attracts investors - then in turn providing resources - using evidence to map way forward

Ms Maina: social change - adoption of technology dependent on social views and mobilisation - political will

Dr Kandeh: data collection and analytics - convincing leaders and *media* to associate clean energy targets with the (already popular) electrification targets - smart subsidies

Parallel session- 1Mt Kenya3 notes

(Bangladesh speaker Adnan Amin - communicator)

Tradition vs modern cooking innovation

House design - kitchen hidden space (architecture - could be useful word/sector)

social influence - mobilization, etc.

Overcoming personal/social barriers - behaviour change campaigns Social ecological model

Stop old useage; start new one (behaviour change)

Society perception of adoptee being rich (clean cooking equipment perceived as luxury item)

Stoves that charge phones - appeal to men (gender impact) - but in practice, not successful because of perceptions of the kitchen as dirty women area

Design issues of cooking equipment (e.g. round-bottomed cooking bowl doesn't fit new clean stove.

Adoption of product must be fitted to useage.

Barriers: up-front cost; awareness of new product (benefits mostly clearly understood once explained)

Impact on health doesn't sell stoves - must be economic, and useable

Words from the finance session

- Cooking investment
- Risk perception
- Downstream fuels
- Network coverage
- Sustained public funding
- Incentives - Tariffs, concessions

Words from MECS session

- Consumer behaviour (cooking diaries)
- High-level action group
- solid /non-solid solutions
- Catalyse - catalytic donor funding
- Wood-primary markets
- Modern energy
- At-scale investees
- Unit (Frog) cost
- Battery-assisted DC, Direct AC (from Myannmar case study) - DC, AC
- Off-peak tariffs, extended lifeline tariffs
- Change norms

Words from supply chain

- Cash-to-cash cycle
- Vertical integration - can cause collapse when scaling ● Taxes and tariffs - regulatory environment https://www.esmap.org/node/55526

Words from KOSAP project (1:30 Wednesday)
Enterprises (larger-scale regions/communities descriptor)
Facilities (ditto)
Ex-ante incentives (generating market awareness, enable inventory)
Ex-post incentives (based on actual sales)
Bundling (energy sources, e.g. biomass, electricity, kerosene)

ANNEX 3- DETAILED METHOD - PEER-REVIEWED PROTOCOL

Methods
Details of the methodological approach published in the Protocol, which was reviewed by members of the Advisory Group, are described here, unless reported in the main report. The published Protocol is available in Supplementary material.

Searches

Bibliographic databases
Clarivate Analytics Web of Science™ Core Collection http://apps.webofknowledge.com/.
Elsevier's SCOPUS http://www.elsevier.com/online-tools/scopus.
CAB Abstracts - CAB Abstracts: (http://www.ovid.com/site/catalog/databases/31.jsp)
Grey literature sources
Google
Google scholar
Websites of organizations and networks listed in Annex 2

Search string

A number of search strings for closely-related systematic reviews were examined as a starting point. Puzzolo et al (2013) used keywords grouped into stove and fuel type and uptake:
((cook* AND (fuel* OR technol*) OR (stove OR cookstove OR cook-stove OR woodstove OR wood-stove OR LPG OR "LP Gas" OR "Liquid petroleum gas" OR "Liquefied petroleum gas" OR Biogas OR Biodigester OR Bio-digester OR Ethanol OR Solar OR "Clean fuel" OR "Modern fuel") AND (Accept* OR Adopt* OR Deliver* OR Dissemin* OR Implement* OR Scale OR "Scal* up" OR "Roll* out" OR "Tak* up" OR Uptake).

While this search was successful for a focus on cleaner and more efficient household energy technologies, it did not encapsulate the broader aims of the current review. Time was spent at both stakeholder meetings examining possible keywords and concepts to incorporate into a robust search string.
Tests of these search strings were carried out to test the feasibility of including all keywords suggested at the meetings to achieve a balance of accuracy and precision. Tests of strings of terms are reported in full in Annex 3, together with the number of articles retrieved. Good practice in systematic reviewing tests possible search strings against a set of documents known to be of direct relevance to the review question. The set of documents used to test comprehensiveness of the search is in Annex 1.

A further important consideration in creating a search string was to take account of the practical considerations of time and resources for the review. To assess what would be practical in a review with the time and resources available, use was made of the systematic review tool PredicTER[4]
Haddaway & Westgate 2019). The tool uses algorithms derived from real experiences of different systematic review teams working in environmental science (and related fields) to estimate time taken for different stages of a review based on the number of articles retrieved from searches, and a number of other factorss. PredicTER estimated that within the time allocated for the project, no more than 11000 records retrieved from searches could be processed by the team. The first search run using keywords suggested in the first workshop yielded 159,881 in one database alone (Scopus) – see Annex 3.

A revised version capturing the main concepts from both meetings, yielded 65,000 records in Scopus.

(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) AND (fuel OR ethanol OR "LPG" OR "LP gas" OR "liquid petroleum gas" OR "liquefied petroleum gas" OR "liquefied petroleum gas")) OR electrification OR "clean 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 neighborhood OR village OR scale).

The tool predicted that it would take on average 456 days for review completion, and is therefore not practical within the time constraints of the project.

Drawing on Lewis & Pattanyak (2013), who introduced a filter based on analysis method (regression and statistics):
keywords were grouped into fuel and choice and scale AND analytical method -

[4] https://predicter.org/

(“cookstove,” “biomass,” “fuelwood,” “fuel wood,” “firewood,” “biogas,” “electricity,” “solar power,” “photovoltaic,” “renewable,” “charcoal,” “energy,” “energy ladder”) AND (“choice,” “choos*,” “switch*,” “adoption,” “dissemination,” “uptake”) AND (“household,” “residential,” “domestic”) AND (“regression,” “statistics”)
and departing from Puzzolo’s general format which did not add such a filter to her search strategy, the review team explored adding an appropriate filter ‘barriers and drivers’ to the search string.

This, achieved a result that fell within reasonable boundaries of what numbers of articles could be practically processed during the very short duration of the project (by comparison with most systematic reviews and systematic maps, which can routinely take over 12 months to complete).

The following search string also took account of feedback received from Advisory Group members in earlier drafts of the Protocol. The majority of test papers were retrieved using the search string. It was recognized by the team that particular effort would need to be spent on hand-searching (or ‘snowballing’) references in related systematic reviews and literature reviews, and from reports received after requests for grey literature.

(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 neighborhood OR village OR scale))

It should be noted that suggested replacement of the original term ‘clean cooking by ‘cooking’, to take account of advice that there was a danger of missing studies on ‘cleaner cooking’ added 7 additional articles, addition of the term ‘village’ added 3 articles, and addition of a set of fuel terms (biogas OR biodigester OR bio-digester OR solar) added no additional articles. However, addition of the term ‘project’ added 446 articles and the term ‘constraint’ added 1792 articles. This represents a large additional screening burden, but will make the search more complete.

The string was adapted to each of the major bibliographic databases, and a simplified version used for Science Direct, Google and Google Scholar searches and for organizational websites, which do not support long, complex Boolean logic

Article screening

Screening strategy
Bibliographic information of articles retrieved from the searches will be downloaded to EndNote reference management tool and duplicates removed. The set of articles will be uploaded into Colandr, an open-source tool created to incorporate computer assistance for screening and metadata extraction.

The machine-learning capability of the screening tool reduces time spent on screening considerably. Literature retrieved will be screened sequentially for relevance at the (1) title, (2) abstract and (3) full text. After title and abstract screening stages, reviewers will download the accepted articles for full text screening. Reasons for not including articles at full-text will be reported (based on PICO framework – e.g. article rejected because Population was wrong, or article rejected because no Outcomes were reported. At this stage of the process, studies are not included or excluded on the basis of quality of research design or analytical robustness; these are assessed during data extraction (see below)

Practical consideration and limitations of the review process

Given the short duration of the review project (5 months), and the necessity of balancing the time constraint with both comprehensiveness and rigour of the review, the following table indicates where variances from best practice for systematic review will likely occur.

Bibliographic databases	Three major databases will be searched – see strategy. Other possible bibliographic databases which will not be included are AGRIS, AGRICOLA, Science Direct.
Organizations & grey literature	The long list of organizational websites considered useful could be extended. A suggestion was made at the stakeholder meeting to write to all African universities asking for post-graduate theses on the topic of interest. This may not be possible to accomplish in the time. The review team sent a short information flyer explaining the project and asking for grey literature by mail merge to as many addresses as the team could readily assemble. There will be insufficient time to follow-up individually with organizations.
Languages covered	The bulk of the studies assessed will be in English. Priority will, by necessity, be given to processing the English-language articles. The team can cover some French, Spanish, Portuguese and Italian. The team may be able to cover some Arabic. Chinese coverage may be able to be covered in a parallel effort. The team will attempt to document how much material in other languages is potentially available to inform subsequent reviews about the size of a follow-up review to embrace these languages.
Date of studies	Non-electronic articles will be processed in reverse chronological order. It is recognized that there was much work on clean cooking in the 1980s, but that much of this may not be available electronically. The team will document the existence of such material even if it is not processed. This will enable subsequent reviewers to focus on this body of knowledge.
Critical appraisal of studies	Systematic maps do not routinely require the same level of critical appraisal as systematic reviews, since meta-analysis is not performed. There is insufficient time to apply a rigorous critical appraisal of studies in the current project. However, data extraction and coding for all studies in the report will include details of the study design that can be used as a filter to show methodological weaknesses (e.g. missing data, un-documented sample selection, etc.). Subjecting all included studies to independent statistical/analytical assessment is outside the remit of the current study and will not be applied.

Review period	Review periods for the Protocol and subsequent outputs will be shorter than one month. While not ideal, requesting rapid turn-round for feedback will be help ensure the review is completed on time

Data coding and data extraction

The coding and extraction template devised for the current preview recognized seven domains: Fuel and technology characteristics; Household and setting characteristics; Knowledge and perceptions; Financial, tax and subsidy mechanisms; Regulation, legislation and standards; Market development; and Programmatic and policy mechanisms. The coding sheet devised for the present work comprises the following 79 extraction elements organised into 17 categories:

	Unique ID
Article metadata	Reason for exclude (PIOQ)
	Brief details of reason if Q (and in some cases I)
	Synthesis Paper? (Y/N)
	Supplementary Material Required? (Y/N)
	Reference Type
	Year
	Author
	Title
	Journal Title
	ISBN/ISSN
	DOI
	URL
	Abstract
	Volume
	Issue
	Pages
	Keywords from databases
	Notes
Aim	Study Aim
	Is the Study about Cooking Sector?
Population details	Country
	Region
	Latitude
	Longitude
	Rural/Urban/Peri-Urban
	Unit Studied
	Population affected by Intervention (N)
	Units Sampled (n)
Intervention/programme details	Primary Intervention Aim - Social (supporting data present)

	Primary Intervention Aim - Economic (supporting data present)
	Primary Intervention Aim - Environmental (supporting data present)
	Funding Source
	Implementer
	Dates of Intervention/Program
	Program
	Program focus
	Baseline Technology (Transition From)
	If Other Please State
	Target Technology (Transition To)
	If Other Please State
Study design details	Study Design
	Data Collection Approach
	Data Collection Details (Text from paper)
	Study Date
	Study Duration (Years)
	Years Since Intervention (Sustainability Measure)
	Measure of Uptake/Sustained Use (% of N)
Basic critical appraisal	Missing Data? (Y/N)
	If Yes, Is There Accountability?
	Is Secondary Data Used? (Y/N)
Independently Measured Outcomes (For data on perceptions see Drivers/Barriers section)	Social (Human Health and Wellbeing, Safety, Education, Gender Equity, Time Savings, Drudgery, Hygiene, Convenience, Aspiration, Leisure, Other, etc.)
	If Other Please State
	Economic (Income Generation, Employment, Cost Saving, Inflation, Sustained Funding, Supply Chain, Fuel Use, Time Saving, Other etc.)
	If Other Please State
	Environmental (Environmental Pollution, Climate, Emissions within Homes, Deforestation, Water Quality, Other, etc.)
	If Other Please State
	Success Measure (Text from Report)
Characteristics of Setting - Enabling Factors e.g. household characteristics, farm, uplands, lowlands. Compounding factors	Drivers
	Barriers
Knowledge and Perception, Information	Drivers
	Barriers

Technology Characteristics (Fuel) - impacts based on measured data - e.g. time, safety, health	Drivers
	Barriers
Financial, Tax and Subsidy Aspects - Did financial incentives (or lack thereof) lead to programme success/failure	Drivers
	Barriers
Regulation, Legislation and Standards	Drivers
	Barriers
Market Development (e.g. Distribution, advertising campaign)	Drivers
	Barriers
Programmatic and Policy Mechanisms (e.g. Government leafleting, demonstrations, setting up networks, government promotion)	Drivers
	Barriers
Poverty	Drivers
	Barriers
Gender	Drivers
	Barriers
Other	Drivers
	Barriers
General Notes about the study	

The template was adapted iteratively as articles were tested. It should be noted that some articles yield more than one study. In such cases, studies were given unique ID numbers and coded as though they were separate articles, while retaining article metadata information.

Working collaboratively

A shared workspace was created in Google Drive and daily back-ups were made of all sheets and documents stored on the drive. Access to relevant folders on the Drive were made available on request to project leaders. An Advisory group provided feedback on early version of this Protocol. Responses to the feedback were documented and were made available to group members.

ANNEX 2.1- KEYWORDS & CONCEPTS – BROADLY GROUPED UNDER POPULATION, INTERVENTION AND OUTCOME CONCEPTS

Population terms & concepts	Intervention/Counterfactual	Outcomes
Rural	Technology Adoption	Sustained Use
Sub-Urban	Transition	Number* of Uptake
Urban	Uptake	Widespread
National (individual LMIC countries, listed)	Rollout	Energy Per Capita
Regional	Dissemination	Power Per Capita
Sub-Regional	Mechanisation	CO2 Equivalent
City	Delivery	Particulates
District	Conversion	Carbon Dioxide Equivalent
State	Scal* Up	Carbon Monoxide
Peri-Urban	Accept*	Carbon Dioxide
Community	Innovat*	Nitrogen Oxide
Neighbourhood	Diffusion	Black carbon
Village	Transition	Short lived climate pollutants
	Energy ladder	Access
National Program*	Energy Turnaround	Energy access
Regional Program*	Household Energy Transition	Pneumonia
Subnational Program*	Public Mobility	Respiratory infections
Subregional Program*	Mobility	Blood pressure
NGO Program*		Stacking
Project*	Household Energy	Environmental Impact
	Biomass	Emissions Within Homes
Government	Firewood	Health
High-Level Action Group	Charcoal	Time Savings
Off-grid solar access	Coal	Quality of Life Metrics
Wood-Primary markets	Solid fuels	
Companies	Wood fuels	Income
Enterprises	Traditional stove	Expenditure
Private Sector	Three stone stove	Productivity
Entrepreneur*	Open fire	Safety
Energy Markets	Modern Energy	Gender Equity
	Wood stove	Education
wood users	Decarbonization	Drudgery
biomass fuel users	Whole-Systems approach	Hardship

fuel wood users	Industrial Production	Time use
firewood users	Semi-Industrial Production	Time savings
charcoal users	Pay-As-You-Go Gas (with and without the gas)	Ventilation
	Consumption	Indoor air quality
	Manufactured stoves	Household air pollution
purchasing		air pollution
buy	LPG	polluti*
	gas	Smoke
	ethanol	Soot
	advanced stove	Smog
	TLUD	Burns
	biogas	
	gasifier	Deforestation
	pellets	Climate
	briquettes	
	kerosene	
	Kenya ceramic jiko	End-User Perception
	electricity	Supply-Chain Costs
	lighting	
	gel	Job Creation
	solar	Gender Imbalance
	Electrification	
		Behaviour Change
	Sanitation	Society Perception
	WASH	Risk Perception
	Mobile phones	Downstream Fuels
	Smartphones	Network Coverage
	Network	Sustained Public Funding
	Information technology, IT	Vertical Integration
	Subsidies	Welfare
	Sensors	Wellbeing
		Cost Saving
	Infrastructure	Employment
	Monitor	Work
	Cooking Systems	Burden (Women)
	Financing	Convenience
	Asset Finance	Hygiene
	Microfinance	Social Inclusion
	Results Based Financing	Social Capital
	Marketing	Social Status
	After Sales Service	Aspiration

	Branding	Modern Lifestyle
	Business Model	
	Capacity Building	
	Impact Investing	
	Venture Capital	
	Business Environment	
	Experiment	
	Co-benefits	
	Incentives	
	Willingness to pay, WTP	
	Revealed preference	
	Policy	
	Legislation	

ANNEX 2.2 TRIALS OF KEYWORD COMBINATIONS SUGGESTED AT STAKEHOLDER MEETINGS (REVERSE CHRONOLOGICAL ORDER)

9/1/2019

Creating set of additional records when including word 'constraint' intp barriers/drivers concept.

Scopus – 1792 records to review

((TITLE-ABS-KEY (barrier OR driver OR constraint)) AND (TITLE-ABS-KEY (initiative OR intervention OR technology OR microgrid OR "energy conversion" OR "energy program" OR "modern energy" OR "energy transition" OR "clean cooking" OR ((cook* OR stove) AND fuel OR ethanol OR "LPG" OR "LP gas" OR "liquid petroleum gas" OR "liquefied petroleum gas" OR "liquefied petroleum gas")) OR electrification OR "clean energy" OR sanitation OR toilet OR "clean water" OR "mobile phone" OR smartphone OR telecom*) AND (TITLE-ABS-KEY ("pathways to change" OR transition OR uptake OR adopt OR rollout OR scale-up)) AND (TITLE-ABS-KEY (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 neighborhood OR village OR scale))) AND NOT ((TITLE-ABS-KEY (barrier OR driver)) AND (TITLE-ABS-KEY (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) AND fuel OR biogas OR gasifier AND orpellets OR briquettes OR kerosene OR jiko OR ethanol OR "LPG" OR "LP gas" OR "liquid petroleum gas" OR "liquefied petroleum gas" OR "liquefied petroleum gas")) OR electrification OR "clean energy" OR sanitation OR toilet OR "clean water" OR "mobile phone" OR smartphone OR telecom*) AND (TITLE-ABS-KEY ("pathways to change" OR transition OR uptake OR adopt OR rollout OR scale-up)) AND (TITLE-ABS-KEY (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 neighborhood OR village OR scale))) 12/12/2019

Re-run following feedback from AG - returned 5422

(TITLE-ABS-KEY (barrier OR driver)) AND (TITLE-ABS-KEY (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) AND fuel OR ethanol OR "LPG" OR "LP gas" OR "liquid petroleum gas" OR "liquefied petroleum gas" OR "liquefied petroleum gas")) OR electrification OR "clean energy" OR sanitation OR toilet OR "clean water" OR "mobile phone" OR smartphone OR telecom*) AND (TITLE-ABS-KEY ("pathways to change" OR transition OR uptake OR adopt OR rollout OR scale-up)) AND (TITLE-ABS-KEY (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 neighborhood OR village OR scale))

WoS - returned 6,414

((TS=(barrier OR driver)) AND (TS= (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) AND (fuel OR ethanol OR "LPG" OR "LP gas" OR "liquid petroleum gas" OR "liquefied petroleum gas" OR "liquefied petroleum gas")) OR electrification OR "clean energy" OR sanitation OR toilet OR "clean water" OR "mobile phonete" OR smartphone OR telecom*)) AND (TS=("pathways to change" OR transition OR uptake OR adopt OR rollout OR scale-up)) AND (TS= (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 neighborhood OR village OR scale)))

22/11/2019
ran search again to yield 9744.
Putting the concept of 'scale' back in with our urban, regional, etc. terms (plus the term 'scale') halves the search result -to 4891. I then added in sanitation, which increased it slightly to 4914. Adding mobile phone or smartphone again slightly increased to 4946. This is encouraging as a lot of the sanitation and phone literature was already being picked up, but we added another 100. I then added in 'toilet OR "clean water" OR telecom*), which nudged it up a little to 5012. Putting in 'water' instead of "clean water" pushed it right up again, so this is not going to be added - it is far too general and will give us a lot of noise.
So, the final search could be this one:

(TITLE-ABS-KEY (barrier OR driver)) AND (TITLE-ABS-KEY (initiative OR intervention OR technology OR microgrid OR "energy conversion" OR "energy program" OR "modern energy" OR "energy transition" OR "clean cooking" OR electrification OR "clean energy" OR sanitation OR toilet OR "clean water" OR "mobile phone" OR smartphone OR telecom*)) AND (TITLE-ABS-KEY ("pathways to change" OR transition OR uptake OR adopt OR rollout OR scale-up)) AND (TITLE-ABS-KEY (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 neighborhood OR village OR scale))

WOS = 6315
((TS=(barrier OR driver)) AND (TS= (initiative OR intervention OR technology OR microgrid OR "energy conversion" OR "energy program" OR "modern energy" OR "energy transition" OR "clean cooking" OR electrification OR "clean energy" OR sanitation OR toilet OR "clean water" OR "mobile phonete" OR smartphone OR telecom*)) AND (TS=("pathways to change" OR transition OR uptake OR adopt OR rollout OR scale-up)) AND (TS= (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 neighborhood OR village OR scale)))

Date 18/11/2019
CABI = 184 ((barrier or driver).ab,bt,cc,hw,id,ot,ti. AND (initiative or intervention or technology or microgrid or "energy conversion" or "energy program" or "modern energy" or "energy transition" or "clean cooking" or electrification or "clean energy").ab,bt,cc,hw,id,ot,ti.) AND ("pathways to change" or transition or uptake or adopt or rollout or scale-up).ab,bt,cc,hw,id,ot,ti.))

Date 15/11/2019
Realising that 15,000 records is simply too large, I went back to focus on the *transition* aspect of any sector (but again focus on energy) and the barriers or drivers. I think with snowballing we can justify this.

Scopus - returns 9729

(TITLE-ABS-KEY (barrier OR driver)) AND (TITLE-ABS-KEY (initiative OR intervention OR technology OR microgrid OR "energy conversion" OR "energy program" OR "modern energy" OR "energy transition" OR "clean cooking" OR electrification OR "clean energy")) AND (TITLE-ABS-KEY ("pathways to change" OR transition OR uptake OR adopt OR rollout OR scale-up))

Date 15/11/2019
WoS = 11802
(TS = (barrier OR driver)) AND (TS = (initiative OR intervention OR technology OR microgrid OR "energy conversion" OR "energy program" OR "modern energy" OR "energy transition" OR "clean cooking" OR electrification OR "clean energy")) AND (TS = ("pathways to change" OR transition OR uptake OR adopt OR rollout OR scale-up))

Date: 14/11/2019
SCOPUS - AMENDED SEARCH FOLLOWING DISCUSSION THAT THE STUDY SHOULD NOT BE LIMITED TO COOKING.
Returns - 15,465 records.
It is now looking for transitions in any sector (technology added) but some words from 'transition' column removed as they were returning pure chemistry/physics papers.
(((TITLE-ABS-KEY (adoption OR transition OR uptake OR rollout OR dissemination OR "Scale Up" OR "scaling up" OR "scales up" OR accept* OR innovat* OR turnaround OR transition)) AND (TITLE-ABS-KEY (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 neighborhood OR village))) AND (TITLE-ABS-KEY (sustained OR sustainable))) AND (TITLE-ABS-KEY (energy OR cooking OR fuel OR heating OR lighting OR technology OR infrastructure))

2. Further refining that by hard-wiring programme/project/ policy gives 8422.

(TITLE-ABS-KEY (programme OR program OR initiative OR intervention OR project OR policy)) AND ((((TITLE-ABS-KEY (adoption OR transition OR uptake OR rollout OR dissemination OR "Scale Up" OR "scaling up" OR "scales up" OR accept* OR innovat* OR turnaround OR transition)) AND (TITLE-ABS-KEY (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 neighborhood OR village))) AND (TITLE-ABS-KEY (sustained OR sustainable))) AND (TITLE-ABS-KEY (energy OR cooking OR fuel OR heating OR lighting OR technology OR infrastructure)))

3. Then after discussion with Marcos (who sent an interesting paper) I add the word 'access' to the transition words. That gave an additional 1844 papers and the following amended search:

(TITLE-ABS-KEY (programme OR program OR initiative OR intervention OR project OR policy)) AND ((((TITLE-ABS-KEY (access OR adoption OR transition OR uptake OR rollout OR dissemination OR "Scale Up" OR "scaling up" OR "scales up" OR accept* OR innovat* OR

turnaround OR transition)) AND (TITLE-ABS-KEY (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 neighborhood OR village))) AND (TITLE-ABS-KEY (sustained OR sustainable))) AND (TITLE-ABS-KEY (energy OR cooking OR fuel OR heating OR lighting OR technology OR infrastructure)))

Then a further refinement to increase sustainable/long-term words, based on the paper Marcos sent over that was still not being picked up. Returned 14,557

(TITLE-ABS-KEY (programme OR program OR initiative OR intervention OR project OR policy)) AND ((((TITLE-ABS-KEY (access OR adoption OR transition OR uptake OR rollout OR dissemination OR "Scale Up" OR "scaling up" OR "scales up" OR accept* OR innovat* OR turnaround OR transition OR pathway)) AND (TITLE-ABS-KEY (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 neighborhood OR village))) AND (TITLE-ABS-KEY (sustained OR longterm OR achieve OR sustainable))) AND (TITLE-ABS-KEY (energy OR cooking OR fuel OR heating OR lighting OR technology OR infrastructure)))

Date 12/11/2019 - 16:30)
Strict search imposing the notion of sustained/sustainable on the general search...in Scopus = 9753
(TITLE-ABS-KEY (sustained OR sustainable)) AND (((((TITLE-ABS-KEY (adoption OR transition OR uptake OR rollout OR dissemination OR conversion OR "Scale Up" OR "scaling up" OR "scales up" OR accept* OR innovat* OR diffusion OR turnaround OR transition)) AND (TITLE-ABS-KEY (energy OR cooking OR fuel OR heating))) AND (TITLE-ABS-KEY (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))) AND (TITLE-ABS-KEY (energy OR cooking OR fuel OR heating)))) AND (TITLE-ABS-KEY (energy OR cooking OR fuel OR heating)))

Amended search Scopus 12/11/2019 17:00 –
10,261 records - exported to ris and uploaded into Drive.
(TITLE-ABS-KEY (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 neighborhood OR village)) AND (((TITLE-ABS-KEY (adoption OR transition OR uptake OR rollout OR dissemination OR mechanisation OR delivery OR conversion OR "Scale Up" OR "scaling up" OR "scales up" OR accept* OR innovat* OR diffusion OR turnaround)) AND (TITLE-ABS-KEY (sustained OR sustainable))) AND (TITLE-ABS-KEY (energy OR cooking OR fuel OR heating)))

WoS

#10,408 - TS=("Energy Transition" OR "energy turn around" OR "Household energy transition" OR "Household Energy"OR "Public energy mobility" OR "energy programm*" OR "national program*" OR "regional program*" OR "subnational program*" OR "sub-national program*" OR "subregional program*" OR "sub-regional program*")

Date 12/11/2019 - 13:00

Rural OR “Sub-Urban” OR Urban OR National OR Regional OR “Sub-Regional” OR City OR District OR State OR “Peri-Urban” OR Community OR Neighbourhood OR (National OR Regional OR Subnational OR Subregional OR NGO) AND (Program*)) OR “Wood-Primary markets” OR “High-Level Action Group” OR Purchasing OR Buy OR Companies OR Enterprises OR “Private Sector” OR Entrepreneur OR “Energy Markets”
AND
“Technology Adoption” OR Transition OR Uptake OR Rollout OR Dissemination OR Mechanisation OR Delivery OR Conversion OR “Scale Up” OR “Scaling up” OR Accept OR Innovat OR Diffusion OR “Energy Turnaround” OR “Household Energy Transition” OR “Household Energy” OR “Public Mobility” OR Mobility OR Decarbonization OR “Whole-Systems approach” OR “Industrial Production” OR “Semi-Industrial Production” OR “Pay-As-You-Go Gas Consumption” OR “Modern Energy” OR Sanitation OR “Mobile phones” OR Smartphones OR Subsidies OR Sensors OR Measurements OR Infrastructure OR Monitor OR “Cooking Systems” OR Financing OR “Asset Finance” OR Microfinance OR “Results Based Financing” OR Marketing OR “After Sales Service” OR Branding OR “Business Model” OR “Capacity Building” OR “Impact Investing” OR “Venture Capital” OR “Business Environment” OR Experiment OR Policy OR Legislation
AND
“Sustained Use” OR Number* of Uptake OR Widespread OR “Energy Per Capita” OR “Power Per Capita” OR “CO2 Equivalent” OR Particulates OR “Carbon Dioxide Equivalent” OR “Carbon Monoxide” OR “Carbon Dioxide” OR “Nitrogen Oxide” OR “Environmental Impact” OR “Emissions Within Homes” OR Health OR “Time Savings” OR “Quality of Life Metrics” OR Income OR Expenditure OR Productivity OR Safety OR “Gender Equity” OR Education OR Drudgery OR Deforestation OR Climate OR “End-User Perception” OR “Supply-Chain Costs” OR Electrification OR “Job Creation” OR “Gender Imbalance” OR “Behavior Change” OR “Behaviour Change” OR “Society Perception” OR “Risk Perception” OR “Downstream Fuels” OR “Network Coverage” OR “Sustained Public Funding” OR “Vertical Integration” OR Welfare OR Wellbeing OR “Cost Saving” OR Employment OR Work OR Burden OR Convenience OR Hygiene OR “Social Inclusion” OR “Social Capital” OR “Social Status” OR Aspiration OR “Modern Lifestyle”

159,881 records in Scopus
((TITLE-ABS-KEY ("Sustained Use" OR number* AND of AND uptake OR widespread OR "Energy Per Capita" OR "Power Per Capita" OR "CO2 Equivalent" OR particulates OR "Carbon Dioxide Equivalent" OR "Carbon Monoxide" OR "Carbon Dioxide" OR "Nitrogen Oxide" OR "Environmental Impact" OR "Emissions Within Homes" OR health OR "Time Savings" OR "Quality of Life Metrics" OR income OR expenditure OR productivity OR safety OR "Gender Equity" OR education OR drudgery OR deforestation OR climate OR "End-User Perception" OR "Supply-Chain Costs" OR electrification OR "Job Creation" OR "Gender Imbalance" OR "Behavior Change" OR "Behaviour Change" OR "Society Perception" OR "Risk Perception" OR "Downstream Fuels" OR "Network Coverage" OR "Sustained Public Funding" OR "Vertical Integration" OR welfare OR wellbeing OR "Cost Saving" OR employment OR work OR burden OR convenience OR hygiene OR "Social Inclusion" OR "Social Capital" OR "Social Status" OR aspiration OR "Modern Lifestyle"))) AND ((TITLE-ABS-KEY ("Wood-Primary markets" OR "High-Level Action Group" OR purchasing OR buy OR companies OR enterprises OR "Private Sector" OR entrepreneur OR "Energy Markets")) OR ((TITLE-ABS-KEY (rural OR "Sub-Urban" OR urban OR national OR regional OR "Sub-Regional" OR city OR district OR state OR "Peri-Urban" OR community OR neighbourhood)) OR ((TITLE-ABS-KEY (program*))

AND (TITLE-ABS-KEY (national OR regional OR subnational OR subregional OR ngo))))) AND ((TITLE-ABS-KEY ("Technology Adoption" OR transition)) OR (TITLE-ABS-KEY (uptake OR rollout OR dissemination OR mechanisation OR delivery OR conversion)) OR (TITLE-ABS-KEY ("Scale Up" OR "Scaling up")) OR (TITLE-ABS-KEY (accept OR innovat OR diffusion OR "Energy Turnaround" OR "Household Energy Transition")) OR (TITLE-ABS-KEY ("Household Energy" OR "Public Mobility")) OR (TITLE-ABS-KEY (mobility OR decarbonization OR "Whole-Systems approach" OR "Industrial Production")) OR (TITLE-ABS-KEY ("Semi-Industrial Production" OR "Pay-As-You-Go Gas Consumption" OR "Modern Energy")) OR (TITLE-ABS-KEY (sanitation OR "Mobile phones" OR smartphones OR subsidies OR sensors OR measurements OR infrastructure OR monitor)) OR (TITLE-ABS-KEY ("Cooking Systems" OR financing OR "Asset Finance" OR microfinance OR "Results Based Financing")) OR (TITLE-ABS-KEY (marketing OR "After Sales Service" OR branding OR "Business Model" OR "Capacity Building" OR "Impact Investing" OR "Venture Capital" OR "Business Environment" OR experiment OR policy OR legislation)))

Limit by (Barrier* or driver*):

20,230 documents in Scopus
(((TITLE-ABS-KEY ("Sustained Use" OR number* AND of AND uptake OR widespread OR "Energy Per Capita" OR "Power Per Capita" OR "CO2 Equivalent" OR particulates OR "Carbon Dioxide Equivalent" OR "Carbon Monoxide" OR "Carbon Dioxide" OR "Nitrogen Oxide" OR "Environmental Impact" OR "Emissions Within Homes" OR health OR "Time Savings" OR "Quality of Life Metrics" OR income OR expenditure OR productivity OR safety OR "Gender Equity" OR education OR drudgery OR deforestation OR climate OR "End-User Perception" OR "Supply-Chain Costs" OR electrification OR "Job Creation" OR "Gender Imbalance" OR "Behavior Change" OR "Behaviour Change" OR "Society Perception" OR "Risk Perception" OR "Downstream Fuels" OR "Network Coverage" OR "Sustained Public Funding" OR "Vertical Integration" OR welfare OR wellbeing OR "Cost Saving" OR employment OR work OR burden OR convenience OR hygiene OR "Social Inclusion" OR "Social Capital" OR "Social Status" OR aspiration OR "Modern Lifestyle"))) AND ((TITLE-ABS-KEY ("Wood-Primary markets" OR "High-Level Action Group" OR purchasing OR buy OR companies OR enterprises OR "Private Sector" OR entrepreneur OR "Energy Markets")) OR ((TITLE-ABS-KEY (rural OR "Sub-Urban" OR urban OR national OR regional OR "Sub-Regional" OR city OR district OR state OR "Peri-Urban" OR community OR neighbourhood)) OR ((TITLE-ABS-KEY (program*)) AND (TITLE-ABS-KEY (national OR regional OR subnational OR subregional OR ngo))))) AND ((TITLE-ABS-KEY ("Technology Adoption" OR transition)) OR (TITLE-ABS-KEY (uptake OR rollout OR dissemination OR mechanisation OR delivery OR conversion)) OR (TITLE-ABS-KEY ("Scale Up" OR "Scaling up")) OR (TITLE-ABS-KEY (accept OR innovat OR diffusion OR "Energy Turnaround" OR "Household Energy Transition")) OR (TITLE-ABS-KEY ("Household Energy" OR "Public Mobility")) OR (TITLE-ABS-KEY (mobility OR decarbonization OR "Whole-Systems approach" OR "Industrial Production")) OR (TITLE-ABS-KEY ("Semi-Industrial Production" OR "Pay-As-You-Go Gas Consumption" OR "Modern Energy")) OR (TITLE-ABS-KEY (sanitation OR "Mobile phones" OR smartphones OR subsidies OR sensors OR measurements OR infrastructure OR monitor)) OR (TITLE-ABS-KEY ("Cooking Systems" OR financing OR "Asset Finance" OR microfinance OR "Results Based Financing")) OR (TITLE-ABS-KEY (marketing OR "After Sales Service" OR branding OR "Business Model" OR "Capacity Building" OR "Impact Investing" OR "Venture Capital" OR "Business Environment" OR experiment OR policy OR legislation)))) AND ((driver*) OR (barrier*))

Original test of search string used by Puzzolo et al (2013), which looked at a narrower question than the current proposal, but is of high relevance to developing the search strategy: Clean fuels for resource-poor settings: A systematic review of barriers and enablers to adoption and sustained use

ANNEX 2.3 – EVIDENCE SOURCES SUGGESTED BY STAKEHOLDERS

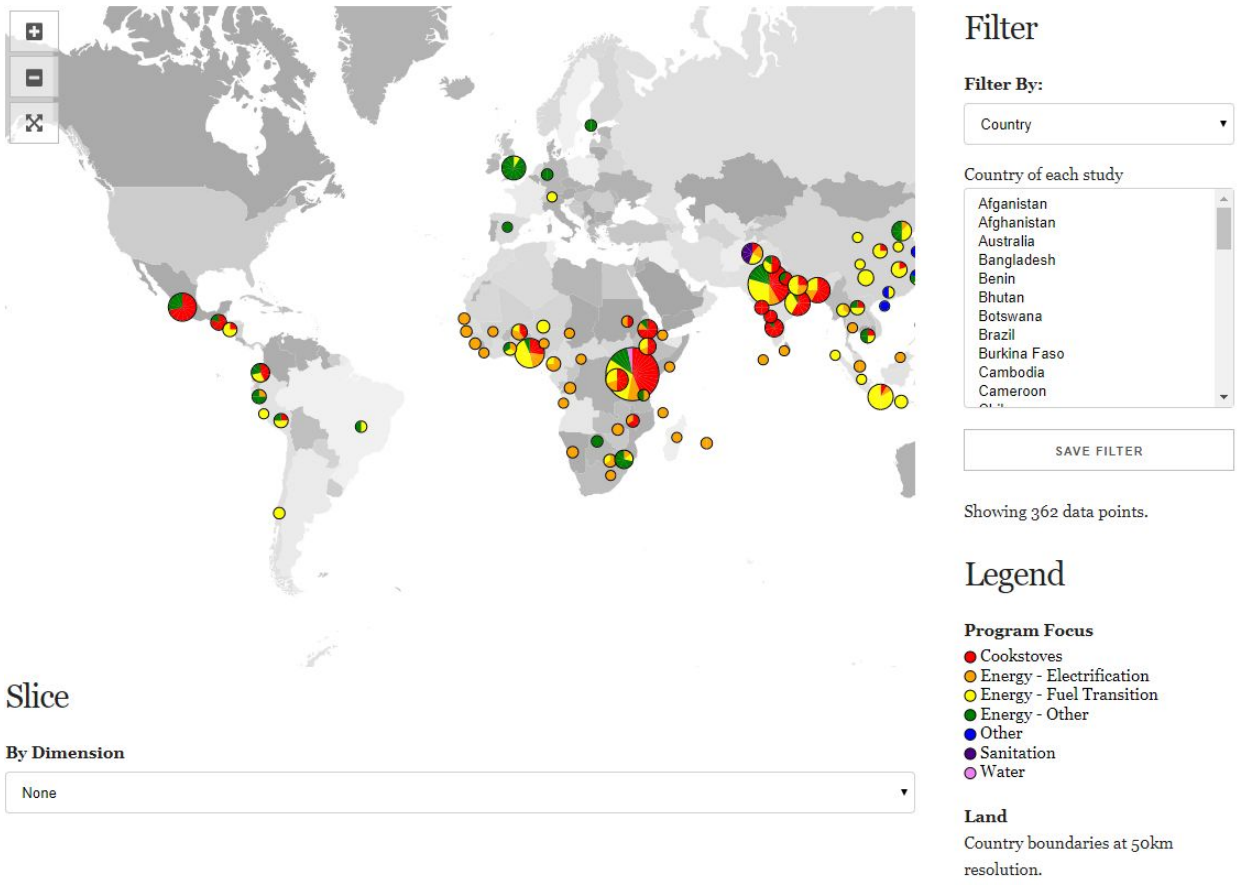
African universities
BCAS - Bangladesh Centre for advanced studies
Berkeley air monitoring
BP
ceew - India based think tank
CGIAR
Check local NGO websites
Clean Cooking Alliance
Dalberg
Deloitte
Development Banks – AsDB, AfDB
Duke University
Energia
ESD - energy for sustainable development - Univ. Cape Town
FAO
Faraday Institute - batteries
Gates Foundation
GIZ - energising development
GLPGP
Gogla
GSMA development utilities
HIVOS
http://kippra.or.ke/
http://www.hedon.info/HomePage
https://cdkn.org/organisations/ids-nepal/?loclang=en_gb
https://cdkn.org/organisations/panos/?loclang=en_gb
https://lilacs.bvsalud.org/en/
https://www.3ieimpact.org
https://www.africalics.org/
https://www.ait.ac.th
https://www.carbontrust.com/tea/news/2019/03/tea-learning-partnership/
https://www.pauwes.dz
https://www.tata.com
https://www.teriin.org/
Initiative for sustainable energy policy
International energy agency
IRENA
MCC - millennium challenge corporation
McKinsey
IIASA (Austria)
Measure evaluation
NBER - national bureau of economic research
Nexleaf analytics
OECD
Practical Action
Private sector - publically funded
Rockefeller foundation
Rocky Mountain Institute
SEI
Shell foundation
SNV
Solar cookers international
SSRN
Susana.org - sanitation
Sustainable energy for all (UN)
Swedish embassy
TERI - The energy resources institute
UCT
UN Stats
UN Women
UNDP
UNHCR
University of Michigan - southern africa
USAID
WFP
Information Networks

- Sustainable energy transitions initiative
- Environment for development initiative
- Global energy partnership
- UN climate and clean air coalition
- ICRW
- Safe network
- African academy of sciences
- European academy of sciences
- American academy of sciences
- Sustainable transitions research network

ANNEX 4 USER GUIDE TO THE SYSTEMATIC MAPPING TOOL

The systematic mapping tool is operational at [https://energydata.info/apps]. Its functionality is described on the mapping tool page. Below is a brief explanation of the tool.

The mapping tool is a visual representation of the Data Sheets in the evidence map. Studies are georeferenced with and displayed as points on a global map. This screen shot shows all mapped points in the evidence base.



Legend
Cookstoves (Red); Energy - Electrification (Orange); Energy - Fuel Transition (Yellow); Energy - Other (Green); Other (Blue); Sanitation (Indigo); Water (Violet)

Filter
Using the filter function users can select one or more of the following categories to sort the data displayed on the systematic mapping tool: Country; Program Focus; Setting of Study; Missing Data; Missing Data Accountability; Secondary Data (these are proxies for quality); and Drivers/Barriers data. Multiple filters can be selected (for example, selecting China, India and Ghana). Filters can also be combined using a Save Filter option, if users want to view results with multiple active filters, for example, looking at only studies from China, India or Ghana with information on cookstoves in a rural setting (see below)

Slice

The slice option is another way to filter results, and enables the data in the systematic mapping tool to be sectioned by: Year of Publication; Study Sample Size; Study Start Data; Study Duration; and Start Date of Intervention/Program. Slices, like filters, can also be saved for multi-filtered views of results, and can be combined with other filters.

Viewing Data Sheets

To view a coding sheet, users select a result by double clicking its point on the map. This will display the associated data sheet below the map. All data sheets have full bibliographic details and a link to the full-text of the article from which the study was taken, if available. The systematic mapping tool also contains partial data sheets of studies which did not contain information on Drivers or Barriers, but which had sufficient information to be of value to potential users of the map. An example of part of a data sheet is shown below.

ID	106
Reference Type	Journal Article
Year	2014
Author	Sehjpal, R.; Ramji, A.; Soni, A.; Kumar, A.
Title	Going beyond incomes: Dimensions of cooking energy transitions in rural India
Journal Title	Energy
ISBN/ISSN	0360-5442
DOI	https://doi.org/10.1016/j.energy.2014.01.071
URL	http://www.sciencedirect.com/science/article/pii/S0360544214000930; https://www.sciencedirect.com/science/article/abs/pii/S0360544214000930?via%3Dihub
Abstract	Most studies on household energy choices have considered income and education as suitable proxies for socio-cultural contexts, primarily because the available data on household energy is from census surveys which are mainly household consumption surveys, not focused energy surveys. Acknowledging the existing data constraints, a more focussed household energy survey was designed for rural India with the aim of better understanding determinants of current energy use patterns, energy choices, to measure the impacts of these factors, and importantly, arrive at key policy insights. This paper revisits the definition of access to include for reliability and quality going beyond conventional understanding. It also relooks at the role of gender in household energy choices. Having established that apart from income, socio-cultural factors may have a greater role in determining household energy choices, the model results indicate electricity access would have a positive impact on cooking energy choices only after meeting a minimum threshold requirement. As women move towards more formal employment, the odds of choosing cleaner fuels increase significantly. Thus, while macro-policies may provide important guidelines and the necessary framework, implementation strategies need to be designed at the local level through a participatory approach making energy an integral part of the development paradigm.
Volume	68
Issue	
Pages	470-477
Keywords	Energy access; Logit model; Household choices
Country	India
LatDD	23.26623
LonDD	77.412062
Rural/Urban/Peri-Urban	Urban Peri-Urban and Rural

ANNEX 4 – ORGANIZATION CONTACTED FOR GREY LITERATURE

Name	Email
BCAS - Bangladesh Centre for advanced studies	monowarul.islam@bcas.net

Berkeley air monitoring	info@berkeleyair.com
BP	careline@bp.com
CEEW - India based think tank	info@ceew.in
CGIAR	contact@cgiar.org
Clean Cooking Alliance	info@cleancookingalliance.org
Dalberg	Via personal contact
Deloitte	Via website
African Development Bank	J.TOKINDANG@AFDB.ORG
Asian Development Bank	Via website
Duke University	dukenews@duke.edu
Energia	homeenquiries@energia.ie
Univ. Cape Town	libraries@uct.ac.za
FAO	FAO-HQ@fao.org
Faraday Institute - batteries	opportunities@faraday.ac.uk
Gates Foundation	info@gatesfoundation.org
GIZ - energising development	endev@giz.de
GLPGP	secretariat@ccacoalition.org
Gogla	info@gogla.org
GSMA development utilities	utilities_grants@gsma.com
HIVOS	info@hivos.org
Climate and Development Knowledge Network	cdkn@southsouthnorth.org
International Initiative for Impact Evaluation	info@3ieimpact.org
African Network for Economics of Learning, Innovation, and Competence Building Systems	secretariat@africalics.org
Asian Institute of Technology	solutions@ait.ac.th
Transforming Energy Access	TEA@carbontrust.com
Pan African University	info@pauwes.dz

ANNEX 5 - SUPPLEMENTARY MATERIAL

The following files can be accessed at: https://drive.google.com/drive/folders/1Ri0S-1_aPXMua-2ASe5yRjVN7rYgG6u5?usp=sharing

File of included articles
File of articles excluded at Full-text