Factors influencing the large-scale uptake by households of cleaner and more efficient household energy technologies

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Executive summary

Background

Nearly three billion people worldwide rely on biomass fuels (2.4 billion) and coal (0.4 billion) burnt inefficiently on open fires or simple stoves. These traditional household energy practices have dramatic consequences for health, the environment and socio-economic development. Ensuring access to clean and efficient household energy is therefore a major and urgent challenge faced by low- and middle-income countries. While marked by some successful programmes at both large and small scales, this is generally acknowledged to be a challenging area for policy and implementation. This mixed-method systematic review aims to contribute to this endeavour by identifying those factors which can help ensure more successful delivery of policies and programmes that promote improved solid fuel stoves (ICS) and/or clean fuels.

The main objective of this systematic review was to describe and assess the importance of different enabling and/or limiting factors that have been found to influence the large-scale uptake by households of cleaner and more efficient household energy technologies. These comprise five intervention areas: ICS and four clean fuels, i.e. liquefied petroleum gas (LPG), biogas, solar cookers and alcohol fuels.

More specifically, the systematic review: (i) provides a framework consisting of seven domains of factors influencing large-scale uptake, distinguishing between short-term adoption and longer-term sustained use; (ii) gives a summary of existing knowledge relating to each of these domains, including interpretation of data with respect to equity; (iii) outlines a proposal for a tool to facilitate implementation of these findings in programme planning, and (iv) sets an agenda for essential primary research to better understand how policies and programmes to promote cleaner and more efficient household energy technologies must be designed in order to be successful.

Methods

This systematic review, registered with the Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI-Centre) at the University of London, employed a comprehensive search strategy comprising searches in 27 multi-disciplinary bibliographic databases, 14 specialist websites, the grey literature and consultation with experts, covering the period 1980 to 2012. Three types of evidence - qualitative studies, quantitative studies and policy and case studies - were eligible, provided that they related to a direct experience with one of the five types of intervention, and that they reported empirical information on factors influencing adoption or sustained use.

Study selection, data extraction, quality appraisal and a two-stage synthesis procedure followed standardised methodologies and employed a degree of independent verification by two or more authors. Thematic and tabular/narrative syntheses were used for qualitative and other studies respectively, with findings categorised according to seven a priori defined domains relevant to household energy uptake and equity (see Figure ES.1). Domains (D1-D7 on the figure) include: (1) Fuel and technology characteristics, (2)
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Household and setting characteristics, (3) Knowledge and perceptions, (4) Financial, tax and subsidy aspects, (5) Market development, (6) Regulation, legislation and standards, and (7) Programmatic and policy mechanisms, with Domains 2 and 3 primarily operating at household and community level and Domains 4-7 operating primarily at programme and societal level. Additional considerations were how the findings related to equity with respect to gender, socio-economic status (SES) and geography (urban/rural location), and the extent to which evidence informed about adoption and sustained use at scale.

**Figure ES.1:** Framework domains (D1-D7) influencing uptake

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**Findings**

**Extent and quality of evidence**

Based on nearly 14,000 records identified, this review selected 101 eligible studies across Asia, Africa and Latin America, with 57 studies relating to ICS, and 44 to clean fuels (17 on biogas, 12 on LPG, nine on solar cookers, six on alcohol fuels). Studies included peer-reviewed publications, reports, book chapters, dissertations and conference proceedings, categorised as qualitative studies (19 studies), quantitative studies (22 studies) and policy and case studies (60 studies).

Quality appraisal of individual studies following established criteria found 17 out of 19 qualitative studies, 17 out of 22 quantitative studies and 47 out of 60 policy and case studies scoring moderate or strong quality respectively. It was concluded that this is a moderately strong and consistent set of evidence, and that the identified findings are sufficiently robust to use as a basis for policy planning and evaluation. Although no studies on newer ICS technologies (e.g. advanced combustion biomass stoves which hold promise
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of delivering much lower levels of emissions) were identified within the timeframe of this review, it seems reasonable that the findings would also apply to these technologies and the means through which these are promoted.

**Overview of findings**

For all five types of intervention, a series of factors were identified across all the pre-specified domains. Rather than presenting these factors as discrete enablers and barriers, the systematic review suggests that these can most usefully be seen as operating on a spectrum, so that when present or satisfactory they are enabling, and vice versa.

In terms of relative importance, while factors such as meeting household needs, fuel savings, higher income levels, effective financing and facilitative government action seem critical and necessary for success, none is sufficient in its own right to guarantee adoption and sustained use, and all those relevant to a given setting need to be assessed. Accordingly, these are described as ‘necessary but not sufficient’. The nature of the available evidence does not support a more formal prioritisation of factors, and the relevance of most will vary according to context (setting, fuel and technology); indeed some are very specific to fuel type, especially for biogas and solar cookers.

Consistency across different types of evidence, countries and settings supports the robustness of the findings and the general relevance of individual factors. Findings from this review draw on experience from some large-scale programmes including the Indian and Chinese national improved stove programmes, the national mega-conversion from kerosene to LPG in Indonesia and the Brazilian LPG experience, but mainly stem from much smaller-scale projects and programmes.

**Factors influencing the adoption and use of improved solid fuel stoves**

A total of 31 factors spread across all the seven pre-defined domains were identified for ICS (see Figure ES.2) and are further discussed in section 4.2 of this report. Sensitivity analysis excluding weak studies led to little substantive change in the levels of evidence supporting each domain. Based on these findings, the assessment of all factors as relevant to the setting would seem to be important for ensuring the best prospects for success in adoption and sustained use of ICS.

As noted for the overall findings, the nature of the available evidence for ICS does not support formal prioritisation of these factors or domains; all of the factors can be influential, most are inter-related, and many are context-specific. Nevertheless, some appear to be critical to the extent that if these are not met, adoption and sustained use are unlikely. Examples of some of these (note this is not an exhaustive list) include: (i) meeting users’ needs, particularly for cooking main dishes and being able to use large enough pots; (ii) providing valued savings on fuel; (iii) offering products of a quality that meets user expectations and ensures durability; (iv) having success with early adopters, in particular opinion formers; (v) guaranteeing support (e.g. loans) for businesses producing and promoting ICS; (vi) ensuring support to users in initial use, and for maintenance, repair and replacement; (vii) developing an efficient and reliable network of suppliers/retailers; and (viii) providing financial assistance for equitable access and/or for more expensive ICS.
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Subsidies remain a complex area of policy, and can work for and against adoption and sustained use, depending on how these are applied and managed. Subsidies are likely to be important for equity of access, especially with respect to better-performing and more expensive ICS, but must be managed carefully to avoid adverse effects on markets and on the perceived value of the technology.

Several factors were supported by only a few studies, but this does not imply that they are unimportant for adoption and continuity of use over time. For example, the lack of evidence on standards, testing and certification (Domain 6) is mainly a reflection of the fact that these instruments have not been widely available and implemented, and a concomitant lack of attention in research studies.

Figure ES.2: Factors influencing the uptake of ICS across seven domains (D1-D7), by study type and number of studies

Factors influencing the adoption and use of clean fuels

Several factors are common to all four types of clean fuel intervention. The cost associated with using clean fuels is one of the more important factors determining adoption, the extent to which these fuels are used (that is, the proportion of cooking done with clean as compared to traditional fuels) and sustained use.

Costs include three major components: (i) the initial outlay for the technology, (ii) the ongoing purchase of fuel, and (iii) the maintenance of the technology/system; these vary significantly between fuel types. Ongoing fuel purchase does not apply to fuels such as biogas or solar cookers, but maintenance does and this aspect is very important in
promoting effective use over time. Other aspects relevant to individual clean fuels are further described below.

**Liquefied petroleum gas**

A total of 26 factors across the seven pre-specified domains were identified for LPG (see Figure ES.3 and section 5.1). Following exclusion of weak studies through sensitivity analysis, evidence was available for 23 out of the 26 factors, with some representation across all seven domains, although this was very limited for Domains 3, 6 and 7.

LPG is an aspirational fuel for many (if not most) households currently using solid or other liquid fuels (e.g. kerosene), but both the start-up costs and ongoing fuel costs are relatively high. Exclusive use for cooking is limited to higher-income and mainly urban households; where used by lower-income and rural populations, this is almost always in combination with traditional (solid) fuels and stoves appropriate to needs and financial circumstances. Issues of safety (and associated regulation), production vs importation, oil price volatility, subsidy, demand and distribution/availability are critical determinants of the use of LPG and require a strong policy and programme management response.

**Figure ES.3:** Factors influencing the uptake of LPG across seven domains (D1-D7), by study type and number of studies
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Biogas

A total of 33 factors spread across all seven pre-defined domains were identified for biogas (see Figure ES.4 and section 5.2). Sensitivity analysis made very little difference to the evidence available for each of these factors.

Production and use of this fuel are constrained by a set of necessary conditions, including adequate numbers of livestock and suitable farming practices, water supply, climate (the technology does not function in low temperatures without costly enhancements) and labour to manage the digester. As a consequence, biogas is most suitable for rural households, although urban users are by no means excluded.

Biogas systems are expensive to install (costs range from approximately US$180 to $500 depending on type, etc.), and substantial financial support, mostly in the form of subsidies to users, has been the norm for all programmes reviewed. Maintenance and repair services are also needed if the biogas plant is to function well over many years. When functioning well and appropriately maintained, the fuel is popular in everyday use. It saves on wood collection and/or purchase, provides fertiliser slurry, can be used for lighting and can be linked to a latrine which both improves sanitation and provides additional feed.

Figure ES.4: Factors influencing the uptake of biogas across seven domains (D1-D7), by study type and number of studies
Solar cookers

A total of 23 factors across six of the pre-defined domains were identified for solar cookers (see Figure ES.5 and section 5.3). Most of the evidence pertains to the first three domains, and no study reported on Domain 6. Following sensitivity analysis, 21 factors were retained with at least some supporting evidence, although the factors ‘institutional arrangements’ and ‘monitoring and quality control’ were lost.

Solar cooking can be very effective but has restricted potential, as experience shows that even among users familiar with solar cookers it generally only meets around 25-33 percent of cooking needs. It relies on high levels of sunshine and appropriate placement. Users need training to plan ahead for their cooking requirements, in particular because the cooker can be used only during the middle of the day.

It may, however, have more potential than realised as an option complementing other fuels and technologies, not least as it can save on fuel collection and costs, including expensive clean fuels. However, to date production and marketing of low-cost, high-quality solar cookers has been constrained by what would appear to be a piecemeal and poorly co-ordinated strategy.

Figure ES.5: Factors influencing the uptake of solar cookers across seven domains (D1-D7), by study type and number of studies
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Alcohol fuels

A total of 22 factors across the seven domains were identified for alcohol fuels (see Figure ES.6), with the majority of identified studies (five out of six) concerned with ethanol rather than methanol (section 5.4). All of the available reports were case studies. Also, as most studies were small-scale feasibility studies, special attention was given to users’ perceptions of stove design, the advantages and disadvantages of stove use during tests and willingness to pay for the fuel. Following sensitivity analysis, the number of factors with supporting evidence was reduced to 17, with loss of information in Domains 4, 5 and 7.

Ethanol is a relatively new household fuel for which there is less evidence than for the other fuels reviewed here. As a consequence, firm conclusions cannot currently be drawn on the situations and circumstances where it is most likely to succeed. Nevertheless, as a renewable, safe, clean and relatively cheap fuel (compared to LPG, although ethanol costs do vary according to production and taxation arrangements) it may have considerable potential for urban settings and possibly also for rural areas.

Although it can be produced from a wide range of feedstock, land competition with agricultural production and excise (pricing) issues arising from the need to separate its use as a fuel from the legal and illegal alcoholic beverage markets present challenges, and should be priorities for strong and consistent policy.

Figure ES.6: Factors influencing the uptake of alcohol fuels across seven domains (D1-D7), by study type and number of studies
**Equity considerations**

Inequalities in relation to poverty, urban-rural location and gender are still prevalent and programmes will need to adopt strategies to overcome these.

Evidence suggests that an explicit focus on equity as part of a programme’s objective can facilitate the targeting of disadvantaged households in terms of geographic setting (e.g. rural, more remote settings) and SES. While mechanisms to reach families on lower incomes have been employed by some programmes/initiatives, exclusively market-based dissemination programmes usually fail to penetrate beyond a certain level of poverty. Poor people tend to use the limited resources they have on what they regard as more pressing household priorities and hence generate little or no demand for improved stoves and/or clean technologies. However, a gender-sensitive approach may increase success through a better understanding of women’s and men’s needs and their appropriate involvement in technology development and implementation. Also, use of gender-sensitive promotional campaigns (targeting both women and men) may increase willingness to pay, as it is usually men who exercise the greater control over household expenditure, and control decisions with regards to installing/buying a new technology.

**Common and distinct factors across interventions**

The majority of factors are common to all or most of the five interventions reviewed, although there are also some important differences, which usually reflect specific requirements for one or more of the clean fuels (in particular for biogas and solar cookers, where unique factors apply). Lack of evidence for some of the listed factors however - especially among the clean fuels - does not necessarily mean a factor is unimportant. This could partially reflect limited research into some of these aspects. Therefore the summary table (Table ES.1) provided here should be considered as a synthesis based on the knowledge gained so far from the available studies, and not necessarily as a definitive account of all factors important to adoption and use of each of the fuels and technologies reviewed (see Chapter 6).

For example, among the common factors identified, initial stove cost and ongoing fuel costs play a crucial role in influencing uptake, as well as the characteristics of the fuel and cooking technology itself. Design and construction includes a set of very important aspects such as the use of well-designed technology with quality materials and careful construction in order to meet users’ needs and ultimately to significantly reduce emissions and improve safety.

Time saving can be an important enabler and improved stoves and fuels can save time in two main ways, first in reduced fuel collection time and second through more efficient cooking. With respect to time saving, the issue of opportunity cost also emerges as a common theme across both ICS and clean fuels: where time saving is valued (e.g. where fuel is paid for and labour is more limited or it is possible to engage in paid employment), this acts as an enabler, but where not or less valued (e.g. in rural areas with more abundant labour, especially where education levels are low) this enabling function seems less apparent. Programme planning should include assessment of how time and fuel savings are valued, and should be followed up by engagement with prospective users to see whether and how appreciation of the opportunity costs of inefficient fuel collection and cooking can be increased. By contrast, households that purchase rather than collect
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Wood or other commercial fuels are more likely to adopt an improved stove with demonstrably better fuel efficiency, as monetary savings are directly experienced and more highly valued by those already paying for their fuel.

**Table ES.1:** Common and distinct factors influencing uptake of ICS and clean fuels

<table>
<thead>
<tr>
<th>Domain</th>
<th>Factors influencing uptake</th>
<th>ICS</th>
<th>Clean fuels</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>LPG</td>
</tr>
<tr>
<td>Fuel and technology characteristics</td>
<td>Fuel savings</td>
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<td>✓</td>
</tr>
<tr>
<td></td>
<td>Impacts on time</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>General design requirements</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Durability/specific design requirements</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Fuel requirements</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Operational issues</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Safety issues</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Household and setting characteristics</td>
<td>Socio-economic status</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Education</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td></td>
<td>Demographics</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>House ownership and structure</td>
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<td>✓</td>
</tr>
<tr>
<td></td>
<td>Land and animal ownership</td>
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<td>-</td>
</tr>
<tr>
<td></td>
<td>Multiple fuel and stove use</td>
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<td>✓</td>
</tr>
<tr>
<td></td>
<td>Geography and climate</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Knowledge and perceptions</td>
<td>Smoke, health and safety</td>
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<td>✓</td>
</tr>
<tr>
<td></td>
<td>Cleanliness and home improvement</td>
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<tr>
<td></td>
<td>Total perceived benefit</td>
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<td>✓</td>
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<tr>
<td></td>
<td>Social influence</td>
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<td>-</td>
</tr>
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<td></td>
<td>Tradition and culture</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Environmental and agricultural benefits</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Financial, tax and subsidy aspects</td>
<td>Stove costs and subsidies</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td></td>
<td>Fuel costs and subsidies</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Payment modalities</td>
<td>✓</td>
<td>✓</td>
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<td></td>
<td>Programme subsidies</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Market development</td>
<td>Demand creation</td>
<td>✓</td>
<td>✓</td>
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<td></td>
<td>Supply chains</td>
<td>✓</td>
<td>✓</td>
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<td></td>
<td>Business and sales approach</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Regulation, legislation and standards</td>
<td>Regulation, certification and standardisation</td>
<td>✓</td>
<td>✓</td>
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<td></td>
<td>Enforcement mechanisms</td>
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<td>✓</td>
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<tr>
<td>Programmatic and policy mechanisms</td>
<td>Construction and installation</td>
<td>✓</td>
<td>-</td>
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<tr>
<td></td>
<td>Institutional arrangements</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td></td>
<td>Community involvement</td>
<td>✓</td>
<td>-</td>
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<td></td>
<td>Creation of competition</td>
<td>✓</td>
<td>-</td>
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<td></td>
<td>User training</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td></td>
<td>Post-acquisition support</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td></td>
<td>Monitoring and quality control</td>
<td>✓</td>
<td>✓</td>
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</table>
Conclusions and recommendations for research and practice

The breadth of factors identified across domains may appear to present a challenge for focused and efficient policy-making, so the question of which are most important is critical.

This review has reported on the enabling and limiting roles of a wide range of factors under seven domains, and found that, although some are critical for success, none guarantees this and therefore it is important to consider all those factors that are relevant to a given setting, technology or fuel.

Consequently, it is recommended that a policy planning tool incorporating the findings of the review work be developed and tested. Given that specific policy and programmatic actions are dependent on the choice of intervention and setting, the tool needs to incorporate an element of flexibility in order to allow adaptation. A proposal for the content of this tool is described in Table ES.2, covering seven key components; this would be applicable to both programme planning and in the evaluation of programmes that have already been implemented.

Interactions are noted as important, and may operate at the level of individual factors (within and between domains), but also between sets of domains. Thus, it is important to recognise that some factors primarily act at the household or community level (e.g. Household and setting characteristics; Knowledge and perceptions) whereas other factors primarily act at the regional, national and international level (e.g. Financial, tax and subsidy aspects; Regulation, legislation and standards). Since all domains impact in a significant way on whether programmes reach their intended populations and whether they achieve sustained adoption and use, this suggests that the connection between local and national levels is important, if programmes are to be successful at scale and over extended periods of time. Given the structure and function proposed for the policy planning tool, such interactions can be highlighted, although the most useful method and format for doing so will need to be refined through development and testing.

In addition to the development and testing of a policy tool, two general recommendations for research and practice emerge. First, future and ongoing intervention programmes or initiatives should - in addition to ensuring the technology/fuel meets needs and expectations - establish the effectiveness of the stoves and fuels, in particular in relation to reducing emissions and exposure to household air pollution, but also in relation to fuel efficiency and safety, prior to embarking on large-scale dissemination. Second, such programmes should be accompanied by robust monitoring and evaluation efforts and, in selected cases, by research studies designed specifically to strengthen the understanding of which factors are most important for securing adoption and sustained use, including maintenance and replacement. Such research studies will need to draw on a combination of quantitative and qualitative scientific approaches.
### Table ES.2: Key components of the proposed policy planning tool

<table>
<thead>
<tr>
<th>Section</th>
<th>Component</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Programme information</td>
<td>A preliminary section to record key information on the setting, fuel and technology (single or multiple), delivery mechanisms, etc., being assessed.</td>
</tr>
<tr>
<td>II</td>
<td>Framework covering all factors in the seven domains, and key aspects for equity</td>
<td>The tool would be structured to allow assessment of all domains and factors. This can be prepared within a suitable software program with each domain represented by a separate section, and structured to facilitate assessment of factors, summarising findings, and highlighting interactions between domains, as described in sections III–VI below.</td>
</tr>
<tr>
<td>III</td>
<td>Method for assessing the relevance of each factor</td>
<td>This component would assist in determining the relevance of each factor to the setting, technology and fuel under consideration (section I above). Based on the information in section I, certain factors may be given more or less emphasis. In addition, guidance would be provided for making further assessment of relevance in the setting.</td>
</tr>
<tr>
<td>IV</td>
<td>Data collection to assess each factor</td>
<td>Survey instruments and examples of other sources of information would be provided to assist in assessing the status of each (relevant) factor. It is expected the survey forms would mainly be in outline form to allow adaptation to local circumstances, although more complete sections would be provided where appropriate.</td>
</tr>
<tr>
<td>V</td>
<td>A scheme for assessing how each factor is operating</td>
<td>Based on the information collected on each factor in section IV, a scheme will be provided to assess whether each factor is acting as a barrier or enabler and (if possible) the extent. A scoring system will be developed to simplify this and allow comparison, while preserving important information on direction and strength of effect.</td>
</tr>
<tr>
<td>VI</td>
<td>Guidance for compiling results for individual factors by domain, and highlighting inter-relationships</td>
<td>A facility will be built into the tool to compile and display the results for each factor, and to summarise these by domain. In addition, important interactions can be highlighted, some of which can be ‘built-in’ within the tool to draw attention to common or expected interactions, but also with a component that is user-defined.</td>
</tr>
<tr>
<td>VII</td>
<td>Guidance on application of results</td>
<td>The final component will provide guidance to users on reviewing the results by factor, by domain, and overall for the purpose of programme planning and evaluation. This guidance will be developed and improved during testing and initial piloting of the tool with programme partners.</td>
</tr>
</tbody>
</table>
References

8.1 Reference list of included studies on improved solid fuel stoves


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References


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8.2 Reference list of included studies on LPG


References


8.3 Reference list of included studies on biogas


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8.4 Reference list of included studies on solar cookers


References


8.5 Reference list of included studies on ethanol

Couto R (2007) Tapping the potential of proalcool for the household energy sector. Results of Project Gaia’s 100 CleanCook Stove pilot study, Minas Gerais State, Brazil. Shell Foundation Project 21316.


Factors influencing the large-scale uptake by households of cleaner and more efficient household energy technologies
