Systematic review

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

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Abbreviations and acronyms

AFD	Agence Française de Développement (Cambodia)
AFPRO-CHF	Action for Food Production – Canadian Hunger Foundation (India)
AGECC	Advisory Group on Energy and Climate Change
ARTI	Appropriate Rural Technology Institute (India)
BCRED	Basin County Rural Energy Development Office (China)
BCSIR	Bangladesh Council of Scientific and Industrial Research
BSP	Biogas Support Program (Nepal)
BMZ	Federal Ministry for Economic Cooperation and Development (Germany)
CBFCD	Commercialization of Biomass Fuel and Cooking Devices (India)
CCT	Controlled cooking test
CDC	Centers for Disease Control and Prevention (USA)
CIEco	Centro de Investigaciones en Ecosistemas (Mexico)
CILSS	Comité permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel/ Permanent Interstates Committee for Drought Control in the Sahel
CIRCODU	Centre for Integrated Research and Community Development (Uganda)
CONAFOR	Comisión Nacional Forestal (Mexico)
DFID	Department for International Development (United Kingdom)
DME	Department of Minerals and Energy (South Africa)
EAC	East African Community
ECOWAS	Economic Community of West African States
EHP	Eco-Household Project (China)
ENCOVI	Encuesta Nacional de Condiciones de Vida (Guatemala)
ENERGIA	International Network on Gender and Sustainable Energy
ESMAP	Energy Sector Management Assistance Program (World Bank)
FAO	Food and Agriculture Organization of the United Nations
FASEN	Foyers Ameliores au Senegal
FGD	Focus group discussion
GIRA	Grupo Interdisciplinario de Tecnología Rural Apropiada (Mexico)
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (formerly GTZ), Germany
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (now GIZ)
HAP	Household air pollution from solid fuel
HEDON	Household Energy Development Organisation Network
IAP	Indoor air pollution

ICS	Improved solid fuel stove
IDCOL	Infrastructure Development Company Ltd (Bangladesh
INE	Instituto Nacional de Ecología (Mexico)
ISO	International Standarization Association
KENGO	Kenya Energy Non-Governmental Organization
KIDP	Kalam Integrated Development Project (Pakistan)
KII	Key informants interview
KREDP	Kenya Renewable Energy Development Programme
KVIC	Khadi and Village Industries Commission (India)
LPG	Liquefied petroleum gas
MIRHAS-PERU	Movimiento para la Realización del Hábitat Social (Peru)
NICHE	Nyando Integrated Child Health and Education Project (Kenya)
NFCP	National Fuelwood Conservation Programme (Sri Lanka)
NPBD	National Project on Biogas Development (India)
NPIC	National Programme on Improved Chulha (India)
PEMF	Proyecto de Estufa Mejorada del FIS/Improved Stove Project of the Social Investment Fund
PKK	Pemberdayaan Kesejahteraan Keluarga (Indonesia)
PM	Particulate matter
PO	Participant observation
PPKT	Pusat Penelitian Kelapa Terpadu/Center for Integrated Coconut Research (Indonesia)
SED	Sustainable Energy for Development (Bangladesh)
SES	Socio-economic status
SE4All	Sustainable Energy for All Initiative
SHE	Solar Home Energy Inc.
SHS	Solar home systems
SME	Small or medium-sized enterprise
SNV	Netherlands Development Organisation
SSI	Semi-structured interview
SWAP	Safe Water and AIDS Project (Kenya)
UNAM	Universidad Nacional Autónoma de México
UNDP	United Nations Development Programme
UNGACC	United Nations Foundation Global Alliance for Clean Cookstoves
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
VERC	Village Education Resource Center (Bangladesh)
WHO	World Health Organization

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.

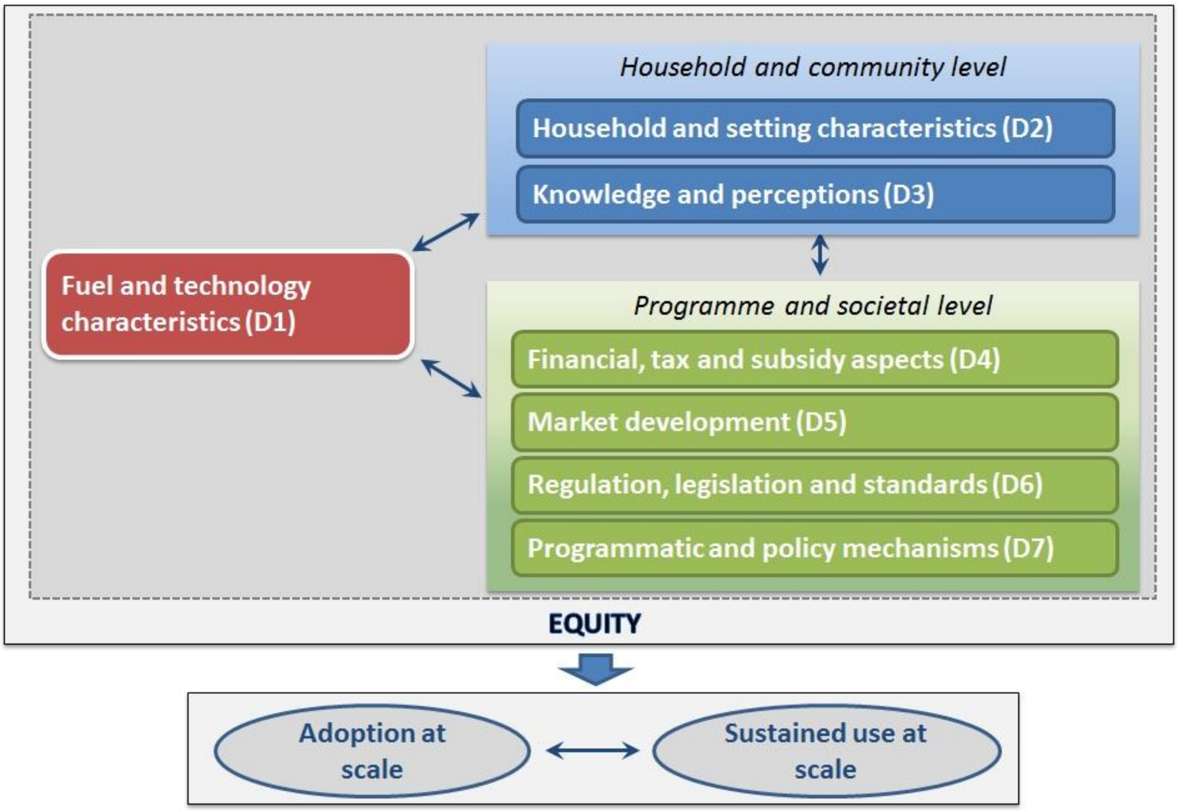
More specifically, the systematic review: (i) provides a framework consisting of seven domains of factors influencing large-scale uptake, distinguishing between short-term adoption and longer-term sustained use; (ii) gives a summary of existing knowledge relating to each of these domains, including interpretation 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) 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



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 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

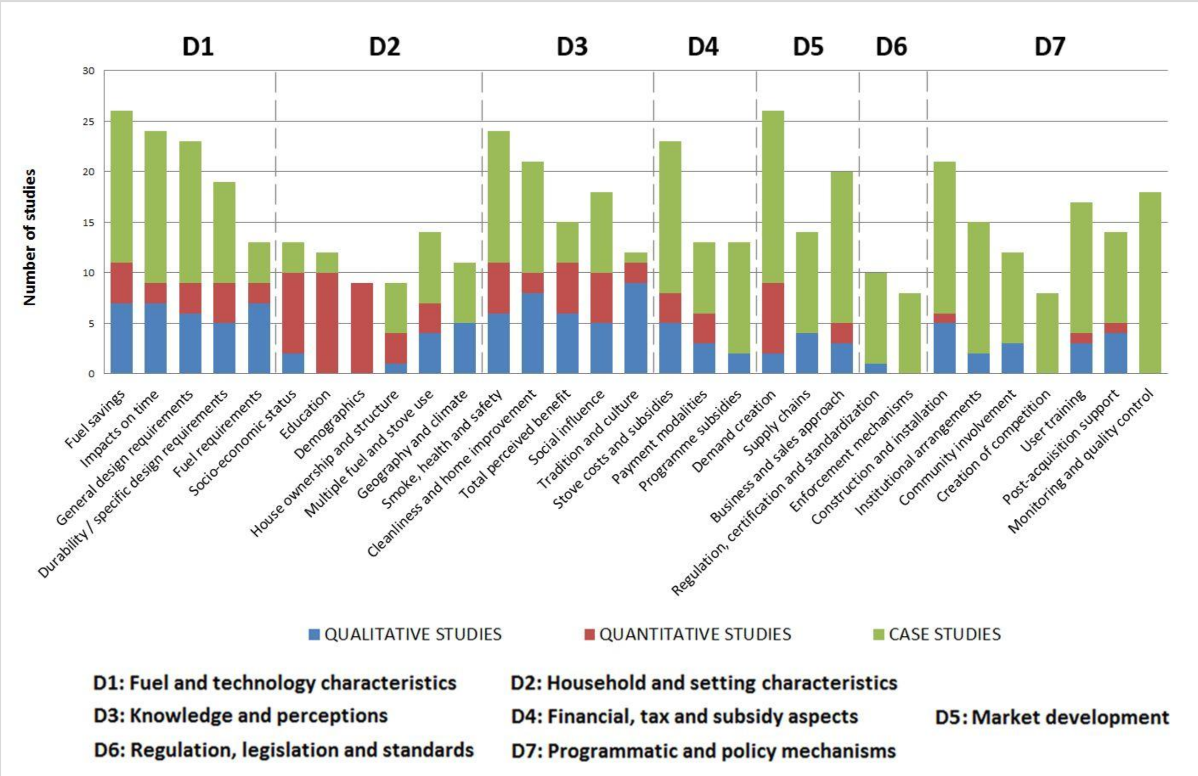
A total of 31 factors spread across all the seven pre-defined domains were identified for ICS (see Figure ES.2) and are further discussed in section 4.2 of this report. Sensitivity analysis excluding weak studies led to little substantive change in the levels of evidence supporting each domain. Based 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.

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.

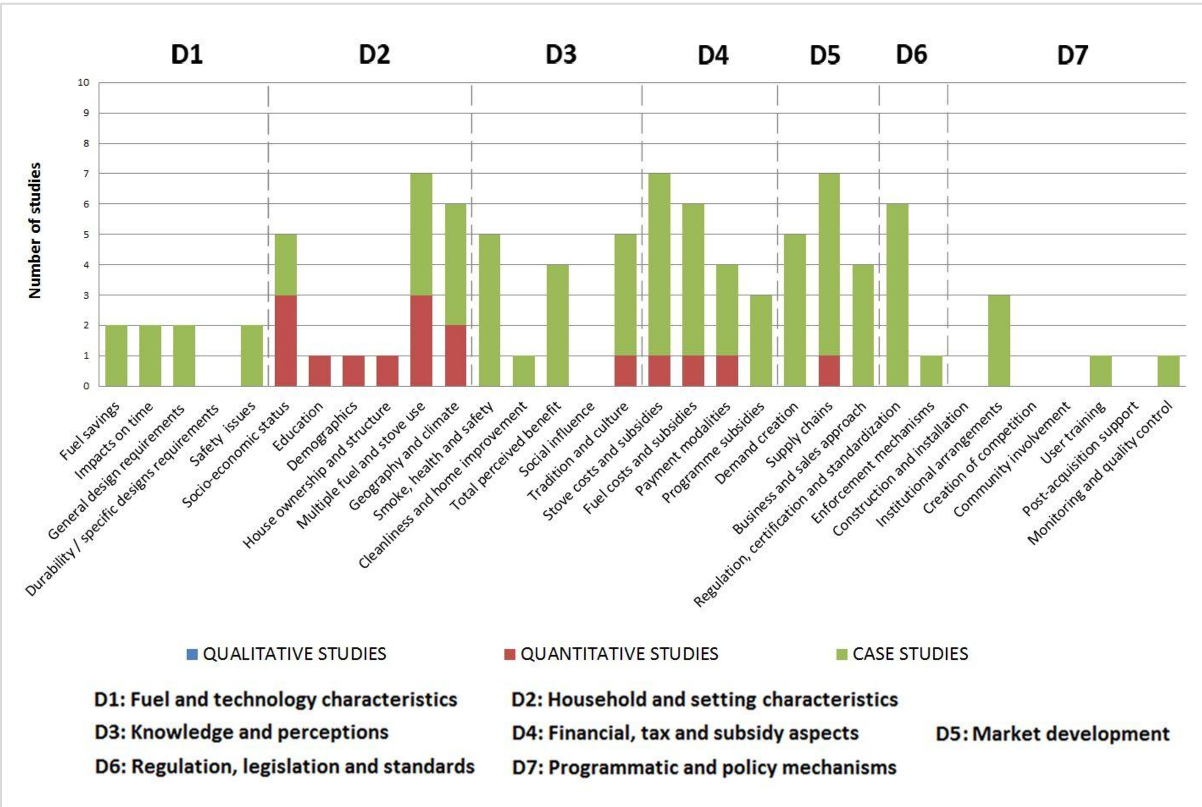
Costs include three major components: (i) the initial outlay for the technology, (ii) the ongoing purchase of fuel, and (iii) the maintenance of the technology/system; these vary significantly between fuel types. Ongoing fuel purchase does not apply to fuels such as biogas or solar cookers, but maintenance 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



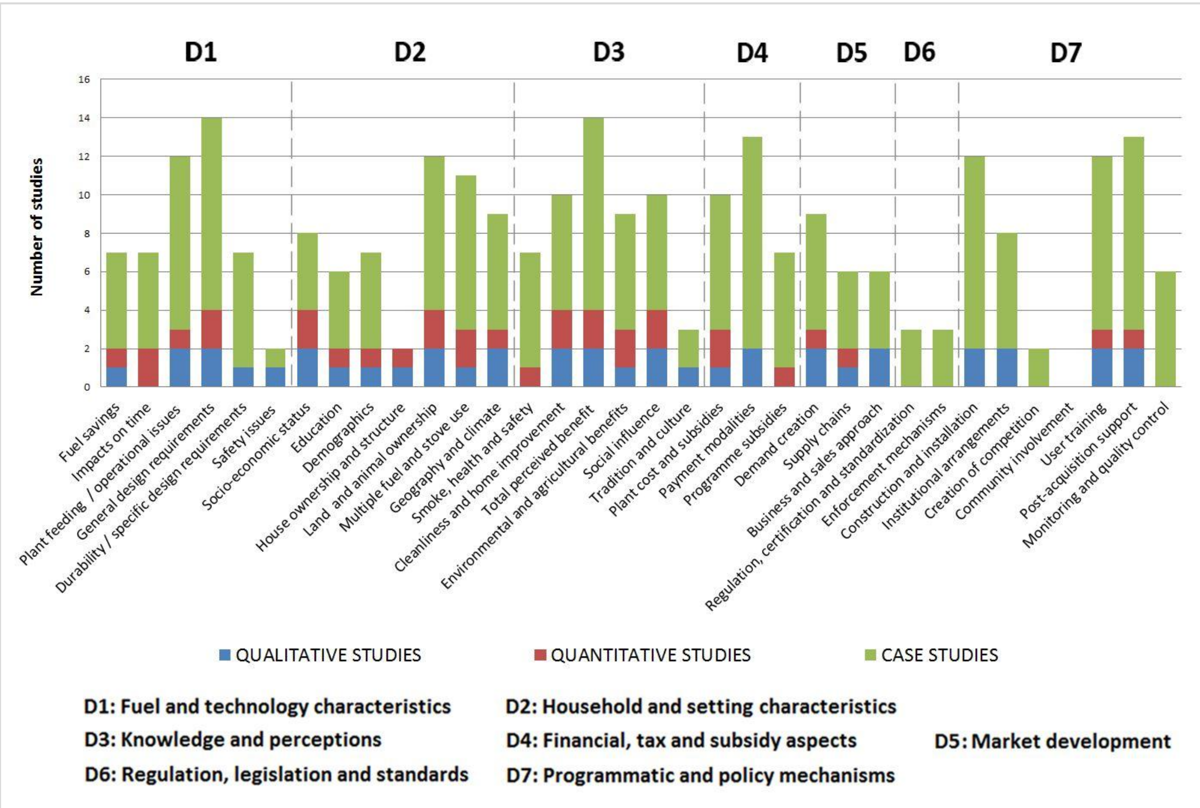
Biogas

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



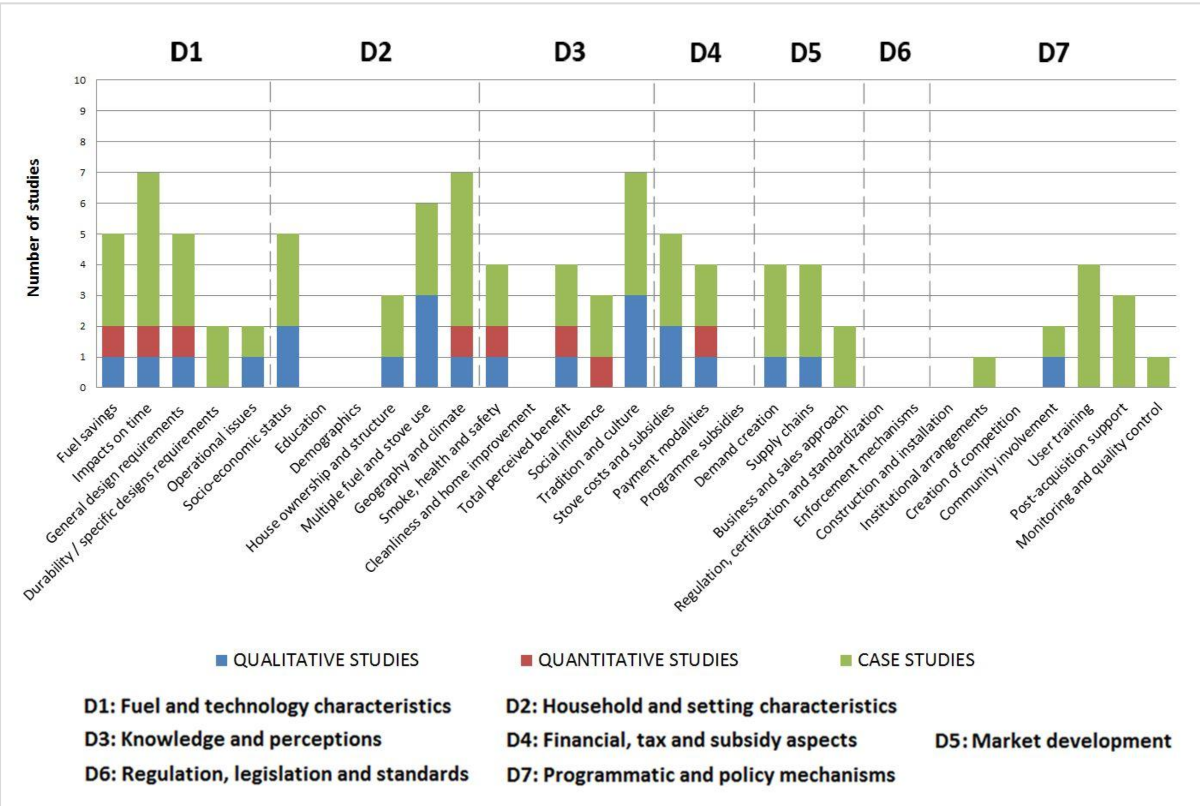
Solar cookers

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



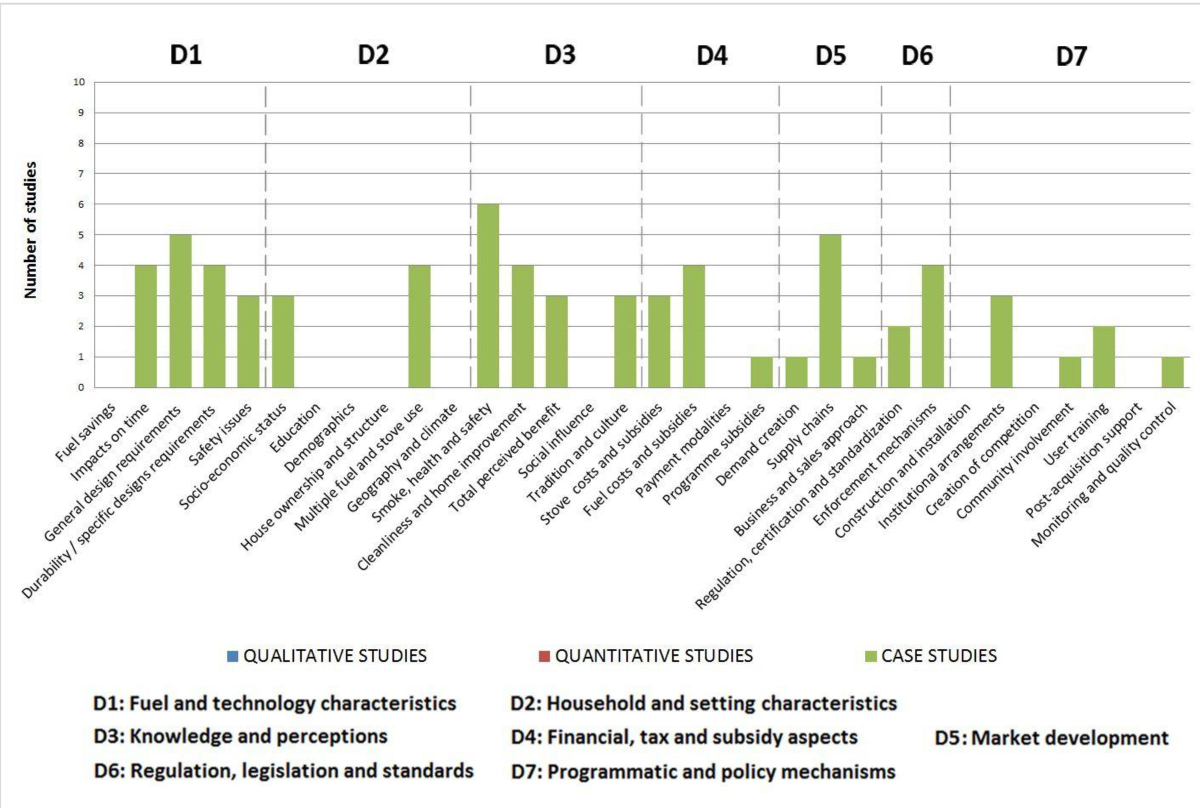
Alcohol fuels

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 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

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

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

Section	Component	Explanation
I	*Programme information*	A preliminary section to record key information on the setting, fuel and technology (single or multiple), delivery mechanisms, etc., being assessed.
II	*Framework covering all factors in the seven domains, and key aspects for equity*	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.
III	*Method for assessing the relevance of each factor*	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.
IV	*Data collection to assess each factor*	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.
V	*A scheme for assessing how each factor is operating*	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.
VI	*Guidance for compiling results for individual factors by domain, and highlighting inter-relationships*	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.
VII	*Guidance on application of results*	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.

1. Background

1.1 Aims and rationale for current review

Ensuring access to clean and efficient household energy is arguably one of the major challenges facing developing countries today. Around three billion people rely on solid fuels and traditional, inefficient stove technologies to meet their basic energy needs, including cooking, heating and boiling water (1). Unless rapid and effective action is taken, this number will increase over the coming decades (2), especially in view of population increase (notably in Africa), the global financial crisis and volatile energy prices (3).

Traditional household energy practices have dramatic consequences for health, the environment and socio-economic development. Household air pollution from solid fuels (HAP)[1] is an important risk factor for pneumonia, chronic respiratory diseases and several other health outcomes, resulting in more than 3.5 million annual deaths, as reported by the Global Burden of Disease Project 2010 (4).

The inefficient burning of solid fuels also represents an unsustainable use of natural resources, aggravating deforestation in areas where wood is scarce. In addition, it contributes to climate change, since much of the fuel energy is lost as so-called products of incomplete combustion, including the potent climate warming pollutants methane and black carbon (5, 6). Finally, much time is spent on fuel collection and cooking and/or a disproportionate amount of income is spent on securing lower-quality fuels which undermines opportunities for education and development. Lack of access to modern energy services therefore contributes to trapping poor households in a cycle of ill health and poverty.

Several regional and global initiatives, including the Economic Community of West African States (ECOWAS) (7), the East African Community (EAC) (8), the United Nations Commission on Sustainable Development (9), the United Nations Foundation Global Alliance for Clean Cookstoves (UNGACC; www.cleancookstoves.org/), and the United Nations Secretary-General's Advisory Group on Energy and Climate Change (AGECC) (10) and the subsequent Sustainable Energy for All (SE4All) programme (11), have emphasised the need to address the household energy crisis and to achieve universal access to modern energy.

In view of this growing recognition and the substantial untapped financial resources in development aid, private sector investment and official/voluntary carbon offset schemes, the large-scale promotion of modern household energy technologies seems more realistic today than ever before.

In working towards this goal, one critical consideration is the effectiveness of interventions in achieving desired benefits for health, the environment and socio-

[1] Since the comparative risk assessment of burden of disease study, which was conducted in 2000, it has become clear that the risk factor'indoor air pollution (IAP) from household use of solid fuel' is not adequate to describe fully the issues associated with this factor (e.g. that much of the health-relevant air pollution exposure from fuel use occurs in the near-household environment, not just indoors). Thus this risk factor has recently been reframed as 'household air pollution from solid fuels' (HAP) (4).

economic development. An ongoing systematic review of the impacts of household energy interventions on HAP and health outcomes being carried out for the new World Health Organization (WHO) indoor air-quality guidelines for household fuel combustion (WHO effectiveness review) (12), is addressing one major question regarding effectiveness. An equally important consideration is how we can achieve the 'quantum leap' (13) required for the sustainable adoption of modern household energy practices by hundreds of millions of households.

Synthesis of insights into the 'how' to deliver interventions, the subject of the present review, is becoming more urgent as a result of the recognition that a range of research questions addressing issues beyond effectiveness have an important role to play in informing policy and practice (14). Both systematic reviews – the WHO effectiveness review and the present systematic review – are complementary and of central importance to policy formulation.

1.2 Definitions and conceptual issues

1.2.1 Fuels and technologies investigated

Solid fuel use includes biomass fuels (e.g. wood, dung, crop residues, charcoal) and coal. 'Clean' fuel use includes various liquid (e.g. liquefied petroleum gas [LPG], ethanol, plant oils) and gaseous fuels (e.g. producer gas, biogas) as well as electricity. Kerosene and paraffin occupy a separate category as they are relatively efficient liquid/solid fuels but should not be actively promoted as cleaner fuel options given the mounting evidence on associated health hazards, including increased risks for tuberculosis, burns, poisonings and other unintentional injuries (15).

Solid fuels are used for cooking, heating, boiling water and other tasks, including home-based income-generation. Cooking takes place in households worldwide and is the only household energy task for which comparative information on solid fuel use is available for most developing and middle-income countries, whereas heating is highly climate- and season-specific and data on use in countries are far less complete. This systematic review therefore focuses on cooking as the most important global use of solid fuels but it should be kept in mind that, depending on the setting, interventions may need to meet other household energy needs, too.

1.2.1.1 LPG and improved solid fuel stoves interventions

In the short to medium term, solid fuels are likely to remain an important source of energy for many poor households in developing countries, and improved solid fuelstoves will therefore be a critical means of achieving greater fuel efficiency and improved health. Among middle-income households in developing countries and in most middle-income countries, gas, and in particular LPG, has already replaced other traditional solid fuels for all or selected cooking tasks, and increasingly represents a likely alternative fuel for poorer households. In selected settings, biogas, alcohol stoves or other alternative fuels can provide an efficient and clean source of household energy but seem less likely to be scaled up in a large number of countries on different continents.

1.2.2.2 Biogas

Biogas is a form of renewable energy generated by anaerobic digestion of organic materials such as animal wastes (especially from cattle and pigs) and, to a lesser extent, agricultural residues. Biogas is mainly composed of methane, and burns very cleanly. In addition, linking biogas digesters to latrines offers the potential of additional health benefits by contributing to the prevention of diarrhoea and parasitic diseases (16).

Biogas is certainly not a universal fuel, as its potential is largely restricted to households owning a sufficient number of cattle or other livestock and being located within a certain temperature and altitude range. Moreover, the construction and installation of biogas plants is relatively expensive, which is why the technology is most frequently found among middle-income households, mainly in rural areas, and even then has usually been heaviliy support by subsidy. Nevertheless, the diffusion of household biogas plants to meet a family's cooking, lighting and heating needs has been widely promoted in a number of countries, especially in India (17) and China (18).

1.2.3.3 Solar cookers

The idea of cooking using solar energy is not new. Solar cooking has been used in many different settings worldwide over the past 200 years (19). The sun is a major source of energy (20) and it offers a viable alternative as a clean cooking fuel. However, one of the drawbacks is that solar radiation is subject to seasonal and climatic variation and for this reason solar cookers can only realistically be marketed in countries that have high levels of insolation. Another critical drawback is that solar cooking is time-consuming (preparing a standard meal can take several hours) and can only take place during times of day with sufficient irradiance. Therefore, even under optimal climatic conditions, solar cookers can only meet between one-quarter and one-third of a household's cooking needs (19, 21). A great public interest in solar cookers emerged in the 1960s, a time when most of the basic design variants were tested and disseminated (19). Since then, various campaigns have followed, with China beginning distribution of subsidised cookers in 1981 (22), and India having had over 500,000 solar cookers distributed (23).

1.2.3.4 Alcohol fuels

Promotion of alcohol-based fuels for domestic cooking is a relatively recent phenomenon. The primary driver of this fuel technology at a regional community level has been through Project Gaia[2], a no-profit organisation which has supported the production and diffusion of alcohol fuels (ethanol and methanol) and stoves in a number of countries worldwide. Ethanol is a high-viscosity liquid that can be produced at a local level from a variety of feedstock which includes sugar-containing (e.g. sugar cane), starch-containing (e.g. maize) and cellulose-containing (crop residues) materials (24). The low cost and abundant availability of raw material for the production of ethanol make it a competitive fuel among other clean fuels used for cooking, especially in rural areas where it can be directly produced in micro-distilleries (24, 25). Methanol can be produced from natural gas but also from the inedible portion of biomass crops (i.e. lignin and cellulose) (26).

Ethanol is produced in several countries, but its price is usually high, in part due to the demand created by its use as a transport fuel. Land competition with agricultural production may present a challenge in some settings, as well as taxation related to the use of alcohol for beverages.

[2] See www.projectgaia.com

1.2.2 Applying lessons learnt to effective interventions

While this systematic review is not concerned with assessing the effectiveness of improved solid fuel stove (ICS) technologies and cleaner fuels, the lessons learnt regarding household uptake should be applied to effective rather than potentially ineffective interventions (see section 3.4).

Critically, effectiveness encompasses a set of features including:

- Good acceptability and capacity for use for all (or at least most) cooking tasks;
- Reduced emissions and concentrations of, as well as exposure to, air pollutants;
- Improved fuel efficiency (resulting in monetary or time savings for households and the option of accessing carbon finance);
- Improved safety of children, cooks and other household members.

1.2.3 Explicit consideration of equity

Poorer households tend to be those most dependent on inefficient and polluting household energy practices and, as a result, suffer disproportionately from related health and social impacts. Furthermore, these households have the most limited financial means for switching to more expensive technology and fuels, including the move from collected to purchased fuels in many cases. Equity is therefore critical in efforts to scale up interventions at global level (i.e. making sure that the most affected countries are reached) and national level (i.e. making sure that the most disadvantaged households in poor urban and rural settings are reached). Equity is therefore explicitly considered in the objectives of this systematic review.

1.2.4 Learning for scaling up

To date, experience at scale is limited and this review therefore considers factors enabling or limiting household uptake in projects/programmes/initiatives undertaken at any scale in an effort to inform large-scale uptake. In doing this, however, careful consideration is given to the relevance of such findings to larger-scale uptake.

Achieving large-scale changes in household energy practices, technologies and fuels requires actions across multiple public, private and non-governmental organisation (NGO) sectors. The enabling and limiting factors identified by the review, and the domains in which these operate, reflect the wide range of actions and areas of policy controlled or influenced by all of these stakeholder groups.

1.3 Policy and practice background

Practical solutions to the health and other problems resulting from reliance on polluting and inefficient household energy exist and include (i) switching to cleaner liquid and gaseous fuels, such as LPG, ethanol and biogas; (ii) using ICS; and (iii) a variety of measures to reduce exposure to HAP (e.g. smoke hoods, modifications to kitchen location and design, moving children away from the exposure source). Even though many questions remain with respect to their effectiveness, several interventions have been shown to reduce concentrations of pollutants, increase fuel efficiency, free women's and children's time, and be good value for money (27).

Interventions should be designed to be (i) more efficient, resulting in fuel and monetary or time savings, (ii) cleaner, leading to reduced pollution levels and better health, and (iii) safer, reducing the risk of burns, scalds and poisoning. In view of current global practices and considerations of acceptability and feasibility (e.g. biogas may only be a suitable intervention for households holding a minimum number of cattle and adequate supplies of water), ICS and LPG are likely to be the most relevant interventions for large-scale implementation in the near to medium term, as they are at least potentially available in all countries around the world.

Apart from the large national solid fuel cookstove programmes in China and India most scale-up programmes to date have been small to medium scale, many of which have been led or facilitated by international and national NGOs, business ventures at varying scales, and national development agencies. Independent of scale, some programmes have demonstrated success in various ways. For example, as a consequence of the Chinese National Improved Stove Program most improved biomass stoves now available for sale in the country have flues and other technical features that classify them as improved (28). Enabling factors contributing to the Chinese success story include quality control through the central production of critical stove components and an emphasis on commercialisation (29). Other efforts have not had a lasting impact; for example, 10 years after the start of India's National Programme on Improved Chulha (NPIC), improved stoves (i.e. chulas) accounted for less than seven percent of all stoves in use (30). This limited large-scale impact can in part be explained by insufficient interaction with end-users and high subsidies.

Similarly, national-level analyses of demand- and supply-side factors in relation to solid fuels in various African countries (31), LPG in Brazil (32) and India (33), and kerosene in Nicaragua (34), as well as subnational-level case studies of New Delhi (35) and South African townships (36) have provided useful insights into why (or why not) a policy or programme has been successful. Finally, rapid large-scale uptake by households is possible, as is illustrated by the Indonesian experience, where a national policy change, motivated by government policy to reduce the large financial burden of kerosene subsidies, led more than 40 million kerosene-using homes to switch to LPG over the course of approximately five years (37, 38).

While these various studies individually provide insights related to the specific programmes, to date there has been no comprehensive review and synthesis of all of the available evidence.

1.4 Research background

Historically there has been a notable lack of research on factors that enable or hinder the implementation of household energy interventions. This may be due in part to the lack of funding available for implementation research resulting from the division between those who implement interventions (i.e. governmental or non-governmental organisations in developing countries who often lack the capacity to conduct quantitative or qualitative evaluation) and those who conduct research (i.e. researchers who are often more interested in or more likely to receive funding for rigorous research designs focused on health and technical issues that may not inform better understanding of the success or failure of implementation).

Broadly speaking, this systematic review sought to include the following types of primary studies:

- Observational and intervention-based studies using a variety of epidemiological designs with accompanying descriptions of factors affecting household uptake;
- In-depth qualitative research related to specific household energy interventions and conducted as either a stand-alone study or part of an intervention study (e.g. focus groups and key informants interviews [KIIs]);
- Evaluations of household energy projects, programmes or policies (e.g. Chinese National Improved Stove Program, including impact on consumer choice of fuel prices, etc).

Two systematic reviews are of direct relevance to this current review. The first is an ongoing WHO effectiveness review systematically evaluating the impacts of household energy interventions on indoor air pollution (IAP) concentrations and exposures and (where available) health outcomes. The second is a recently published systematic review by Lewis and Pattanayak (2012) (39), which also attempts to study adoption of improved stoves and fuels. Based on 11 regression analyses in eight studies and the basic meta-analytical technique of vote-counting, the review found 18 variable groups across the three categories: price, socio-economic status (SES) and demographics associated with adoption. As the authors do not offer any explanation of the likely mechanisms that underlie these associations, it is difficult to draw conclusions with respect to the development of programmes and policies.

1.5 Authors, funders and other users of the review

This systematic review was conducted by a team of researchers based at the University of Liverpool (Dr Elisa Puzzolo, Dr Debbi Stanistreet, Dr Daniel Pope and Dr Nigel Bruce) and the University of Munich (Dr Eva Rehfuess); see Appendix 1.1 for further details. The review was funded by the UK Department for International Development (DFID).

In view of the global momentum that access to clean cooking energy is currently experiencing this review is most timely. It is critical that global efforts (in particular the ambitious 10-year goal set by UNGACC that '100 million homes adopt clean and efficient stoves and fuels by 2020' and also the two key goals of the AGECC summary report and evolving SE4All initiative 'ensuring universal energy access and reducing global energy intensity' (10) proceed in an evidence-based way and this systematic review can potentially make a major contribution to informing what works and what does not in this respect.

1.6 Aim and objectives of this review

The aim of this systematic review was to describe and assess the importance of different enabling or limiting factors that influence the large-scale uptake by households of cleaner and more efficient household energy technologies. More specifically, the systematic review has the following three objectives:

i. To develop a framework for different categories of factors influencing large-scale uptake.

ii. To provide a summary of existing knowledge relating to each of these categories, including interpretation of data through an equity lens (in relation to poverty, gender and urban/rural location).
iii. To develop proposals for implementing the findings and set an agenda for further priority research.

1.7 Guidance for readers: structure of the report

This report is based on a mixed-method systematic review and is structured into seven chapters, together with a chapter of references:

- **Chapter 1** describes the household energy context in relation to cooking practices in the developing world and explains the rationale and the objectives of the systematic review.
- **Chapter 2** presents the methodology adopted for the systematic review, the evidence synthesis and the quality assessment of included studies.
- **Chapter 3** summarises attributes of studies selected for the systematic review (including both ICS and clean fuels). Included studies were grouped into three broad categories depending on the type of information provided: qualitative studies, quantitative studies and case/policy studies. A detailed description of the included studies (by study type and fuel type) is also provided within the results in Chapters 4 and 5. Section 3.5 is of particular relevance and needs to be considered carefully in the context of interpreting the findings from this review, as it highlights core aspects of factors influencing uptake.
- **Chapters 4 and 5** present the synthesis of evidence from this review, which is based on seven specified domains of particular relevance to uptake: (1) Fuel and technology characteristics; (2i) 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. Findings also include considerations in relation to equity. **Chapter 4** specifically relates to findings from studies on ICS. **Chapter 5** relates to findings from studies on switching to clean fuels, including LPG, biogas, solar cookers and alcohol fuels.
- **Chapter 6** presents a discussion of the findings supported by further interpretation, and a summary of the limitations and strength of evidence.
- **Chapter 7** provides the final recommendations and overall implications for policy and practice in relation to the scaling up of cleaner and more efficient household energy. This chapter presents also the draft of a policy tool which needs to be further developed and piloted in order to effectively support implementers.

The report is also extensively supported by detailed appendices. These include summary and synthesis tables which are integral to the reporting process and have enabled firm conclusions to be derived from a heterogeneous evidence base. Cross-references to these appendices are provided within the main body of the report.

2. Methods used in the review

2.1 Users involvement

Different groups of users were approached at different stages of the review process. Selected individuals served as peer-reviewers of the protocol and draft report.

Broadly, we can distinguish three main groups of users (see Appendix 2.1 for details):

- Those making decisions regarding household energy and health interventions, in particular international organisations and partnerships and current or potential donors;
- Those actively engaged with the implementation of household energy projects/programmes at international or national level;
- Those conducting research on household energy interventions including university researchers and government-related or non-governmental organisations.

A broader purposive sample of stakeholders was involved to make sure that our approach to the review and the interpretation of the results were appropriate.

Our primary means of approaching users during the design of the review was via email. Sixteen experts, representative of the different groups of users just described, were emailed with the following questions: (i) Do you consider the approach to the research question appropriate? (ii) Are you aware of any specific aspects not currently taken into account in the review? (iii) Can you recommend relevant scientific literature or 'grey' literature on enabling/limiting factors?

Experts gave very positive feedback about the protocol, confirmed the relevance of including clean fuels (especially ethanol) in our search strategy and suggested a number of reports present in the grey literature which were relevant to the review.

2.2 Identifying and describing studies

2.2.1 Defining relevant studies: inclusion and exclusion criteria

Studies were included or excluded from our review according to the following criteria (reported also in Appendix 2.2).

2.2.1.1 Types of studies

In view of the heterogeneous evidence base available and the value of information provided by different types of study, it was decided to take an inclusive approach with respect to study design and methodology. We therefore considered: (i) in-depth qualitative research studies, often conducted at a very local level (e.g. focus groups, KIIs), (ii) quantitative studies that follow standard epidemiological principles, and (iii) case/policy studies that usually draw on more than one source of information.

For qualitative studies, any studies that used a qualitative approach to data collection (e.g. semi-structured interviews [SSIs] or focus group discussions [FGDs] with users or key informants) but did not pursue a qualitative approach to data analysis were excluded from this category and re-classified for inclusion as case/policy studies.

For case/policy studies, we applied the following additional inclusion/exclusion criteria:

- At least one of the main sources of information about reasons for success/failure must be empirical in nature, i.e. based on some documented way of data collection and analysis, rather than subjective story-telling only;
- For empirical data, to ensure reasonable validity and representativeness of findings, at least some information is provided on sampling, data collection, and data analysis;
- The study must provide in-depth insights, for example with analysis and/or discussion of the implications of factors identified for success/failure, rather than simply describing factors.

2.2.1.2 Study setting

Lack of access to cleaner cooking energy is primarily a problem of developing and middle-income countries. We therefore included all projects/programmes/initiatives of relevant cooking fuel and technology options conducted in both urban and rural developing or middle-income settings, defined according to the World Bank income regions reported in Appendix, Tables A2.1a-c.

2.2.1.3 Types of interventions

We included projects/programmes/initiatives targeting the household setting (rather than public or commercial settings).

Cooking fuel and technology options were assessed as follows:

- ICS (using solid fuels or kerosene for cooking prior to intervention);
- Cleaner fuels replacing solid fuels or kerosene, including: LPG and gas, biogas, ethanol (and methanol) and solar cookers.

Studies were required to relate to a direct experience with these interventions and/or projects/programmes/initiatives rather than non-empirical considerations prior to their development and implementation. The same inclusion/exclusion criteria were applied to all interventions considered.

2.2.1.4 Types of enabling and limiting factors

As a means of structuring the review and identifying entry-points for intervening on relevant factors, this review developed a comprehensive framework for likely enabling and limiting factors. The framework includes factors under the following broad domains (further discussed in section 2.3): (i) Fuel and technology characteristics; (ii) Household and setting characteristics; (iii) Knowledge and perceptions; (iv) Financial, tax and subsidy aspects; (v) Market development; (vi) Regulation, legislation and standards; and (vii) Programmatic and policy mechanisms.

2.2.1.5 Excluded studies

Studies were excluded according to the following criteria:

- Studies not based on empirical evidence or based on indirect evidence (e.g. opinions of stakeholders);
- Studies that lacked specificity (i.e. studies related to general energy sector reform rather than specific information on adoption and use of named improved stoves or clean fuels in homes);

- Studies that focused on technology effectiveness rather than household uptake and/or scaling up;
- Studies undertaken in humanitarian settings such as refugee camps (as this is a very distinct setting and insights gained would not be transferable to the general population).

2.2.2 Search strategy

2.2.2.1 Databases, timeframe and languages

Studies conducted between 1980 (when the first intervention programmes to promote fuel efficiency and save trees were initiated) and 2011/12 were included, if they were available in English, Spanish, Portuguese, French, German or Italian.

A wide range of multi-disciplinary bibliographic databases, websites and search engines were used, reported in Appendix 2.3. The main search on ICS and LPG was conducted in July 2011 and the supplementary search on clean fuels was conducted in June 2012. Both searches were complemented by reviewing the grey literature and carrying out handsearches of key references. Specifically, this included studies provided by key stakeholders as well as relevant reports/additional material identified through internet search engines such as Google and Google Scholar, and searches of bibliographies from studies included in the review. Dissertations (at Master's and PhD level) were also searched using five specific databases (e.g. ProQuest Dissertations and Theses Database). Relevant studies on ICS and LPG which were identified or suggested after the main search period (July 2011) were also included in the review process.

2.2.2.2 Search terms

Search terms reported in Table 2.1 consist of the most common cooking technology intervention options and cooking fuel (i.e. LPG), combined with a range of terms related to the framework domains defined in section 2.3.1. Search terms reported on the first column of Table 2.2 consist of the most relevant clean fuels (in terms of diffusion) and their spelling variations (e.g. biogas) which were used for the supplementary search for this review.

The various intervention search terms were combined with the uptake search terms using the Boolean operator 'AND'. These general search terms were adapted to the needs of specific databases (e.g. pluralisation, wild cards, etc.). In particular, in those databases where forward truncation is not permitted, the following combination was used for the term **stove*: *stove* OR *cookstove* OR *cook-stove* OR *woodstove* OR *wood-stove*.

Table 2.1: Search terms used in the main search strategy for ICS and LPG

Intervention AND	**Uptake**
*stove/*stoves cook* AND technol* cook* AND fuel* LPG "LP gas" "liquid petroleum gas" "liquefied petroleum gas" "liquified petroleum gas" chulha/chulhas chulla/chullas chullah/chullahs chulas	adopt* accept* deliver* dissemin* implement* scale "scal* up" "roll* out" "tak* up" uptake

All variants of 'chulha' (a local name for a South Asian stove type) were included rather than using a wild card. Where possible, database searches were conducted on the 'Title, Keyword and Abstracts'. When this option was not available (in the case of smaller databases), a wider search field was adopted (see Appendix 2.4 for additional information on the search strategy).

Table 2.2: Search terms used for the supplementary search on clean fuels[3]

Intervention AND	**Uptake**
Biogas Bio-gas Biodigester Bio-digester Ethanol Solar "clean fuel" "modern fuel"	adopt* accept* deliver* dissemin* implement* scale "scal* up" "roll* out" "tak* up" uptake

2.2.3 Screening studies: applying inclusion and exclusion criteria

Initial selection of studies was based on titles and abstracts, and conducted by one author (EP), with 10 percent independent random checks of included and excluded abstracts (DP

[3] In main bibliographic databases such as SCOPUS, terms included in the intervention column were initially combined (using 'AND') with the following specific string of terms relevant to this review (i.e. *cook* OR *cooking* OR *cooker* OR *stove* OR *cookstove* OR *domestic* OR *household*). This initial search output was subsequently combined with the uptake column using 'AND'. See Appendix 2.4 for additional details.

and DS). All selected studies were then independently screened for relevance by two or more authors (EP, ER, DP, DS, NB), with all decisions for inclusion/exclusion being documented using the EPPI-Reviewer software. Any discrepancies in study inclusion and quality appraisal were resolved through discussion within author teams. Further details on the selection process are provided in the flow charts in Figure 3.1.

2.2.3.1 Data extraction

The studies included in this review drew on a wide range of research and analytic approaches, including qualitative research, quantitative studies (e.g. surveys, economic modelling and scenario analysis), and policy and case studies. Data were extracted by one researcher onto data extraction forms designed for each type of study category (see Appendices 2.5 and 2.6) and assessed for quality (see section 2.2.5); 50 percent of data extraction forms were double-checked by a second author.

Extracted data were subsequently summarised across all included studies in summary tables by the researcher who had undertaken the data extraction; these summary tables also included a brief description of critical methodological issues, and are presented in Appendices 3.1–3.5.

2.2.4 Assessing quality of studies

Teams of two authors independently appraised the quality of studies meeting the inclusion criteria using established criteria for each study type (see Appendices 2.7-2.9). Any discrepancies in quality appraisal were recorded and resolved through discussion within author teams, where necessary involving a third author. For each study type, ratings on individual criteria were used to derive an overall three-level score (i.e. strong, moderate and weak). This score was not used as a criterion for post hoc exclusion. Instead, it was used as a basis for conducting sensitivity analyses, where weaker studies were excluded.

However, it is important to note that the quality appraisal processes for qualitative, quantitative and case/policy studies are not equivalent, so direct comparisons between final scores should be made only among studies within the same study design group. In particular:

- Qualitative studies were assessed using established criteria adapted from Harden et al. (2009) (40) (see Appendix 2.7). The 11 criteria used (for an overall score of 11) covered three major quality issues: (i) the quality of the reporting (including study objectives, rationale, context, methods of data collection, data analysis and interpretation); (ii) strategies used to establish the reliability of data collection and analysis (i.e. to assess the validity of findings); and (iii) approaches to assess the extent to which findings reflect participant perspectives and experiences. In terms of final scores, studies were classified based on the following cut-offs: strong (9-11), moderate (5-8) or weak (1-4).
- Quantitative studies were assessed for methodological quality using a Liverpool University Quality Assessment Tool (LQAT) (see Appendix 2.8), developed for and tested in a number of systematic reviews (41, 42). The tool has been independently appraised against other quality assessment instruments (43). It focuses on five main methodological domains: (i) sampling (generalisability); (ii) exposure/intervention (description of baseline and intervention with emphasis on distribution of intervention); (iii) outcome (relevant to scaling up); (iv) analysis (clarity and absence

of confounding); and (v) impact (overall assessment of quality and relevance of findings to the review). For each category of methodological quality 3 points were allocated for a “strong” classification and 1 for “weak” generating a total score ranging from 5 to 15. Overall scores were based on the following cut-offs: strong (13-15), moderate (8-12) or weak (5-7).

- Quality of case/policy studies (initially selected for full-data extraction after applying more stringent inclusion/exclusion criteria as described in section 2.2.1) was examined by adapting published criteria by Atkins and Sampson (2002) (44) for case studies (see Appendix 2.9). We also paid particular attention to distinguishing between empirical analysis and subjective author interpretation. Fourteen criteria were selected, which covered the following main quality issues: (i) the quality of reporting and presenting the evidence; (ii) strategies used to address bias; and (iii) appropriateness of methods/analysis to answering the research question. In terms of the final score, studies were classified as follows: strong (11-14), moderate (6-10) or weak (1-5).

2.3 Synthesis methods

2.3.1 Overall approach

The synthesis of the different studies was organised under the seven pre-specified domain headings (see Box 2.1), identified from recent reviews on household energy adoption (45, 46). Attention was also paid to equity, focusing on poverty, gender issues and urban vs

Box 2.1 - Domain headings used for synthesis of study findings

1. Fuel and technology characteristics.
2. Household and setting characteristics.
3. Knowledge and perceptions.
4. Financial, tax and subsidy mechanisms.
5. Regulation, legislation and standards
6. Market development.
7. Programmatic and policy mechanisms.

rural location.

Because a number of distinct issues arise in the adoption and use of ICS that differ from those related to clean fuels, syntheses were carried out separately for each type of intervention, generating five sets of findings reported in Chapters 4 (ICS) and 5 (clean fuels) respectively. In particulatr, the syntheses for each of the included clean fuel interventions (LPG, biogas, solar cookers and alcohol fuels) are presented in separate sections of Chapter 5.

2.3.2 Detailed approach

2.3.2.1 Phase I

The synthesis process consisted of two phases. In the initial phase, study findings on what enabled or limited adoption were initially extracted and recorded separately according to type of study design (i.e. qualitative, quantitative and case/policy studies) by one or two authors working together.

The approach to synthesis of **qualitative studies** was based on thematic synthesis (47). The approach has been applied in other systematic reviews looking at factors which impact on implementation of interventions. While the seven framework domains represented a useful way of organising the findings of the review, initially domains were not 'assumed' during synthesis in order to provide an opportunity for themes to emerge from the data. Recording of the process of the development of themes was explicit to ensure methods were both transparent and rigorous. The thematic synthesis followed the following steps:

i. Data were initially coded line by line by two authors (ED, DS).
ii. Codes were then combined generating a set of descriptive themes for each included study.
iii. Themes across studies were then compared and subsequently synthesised under the seven framework domains.

Quantitative and case/policy studies were initially synthesised by compiling key findings under a tabular format. In order to retain fidelity to the nature of the data and findings, these were recorded separately under headings of 'barriers' and 'enablers' respectively according to how these were reported in each study. This process generated 'synthesis tables' which retained this information (see Appendices 4.1–4.5).

2.3.2.2 Phase II

In the second phase, findings across different study designs, countries and settings were combined into a set of relatively distinct 'factors', which were identified for each of the seven domains. Preserving a distinction between barriers and enablers in the final stage of synthesis was not considered meaningful as it emerged from the data that each factor can operate along a spectrum, enabling if the characteristic was present or satisfactory in some respect, and acting as a barrier if absent or unsatisfactory. This concept and the nature of factors are further discussed in section 3.5.

2.4 Deriving conclusions and implications

We ultimately attempted to draw conclusions across all study designs (qualitative, quantitative and case/policy studies) by (i) conducting a detailed narrative synthesis of findings at the level of each identified factors within domains, and (ii) carefully reviewing the strength of findings with respect to support provided by consistency across study types and number of studies.

In deriving conclusions, we paid special attention to the potential combined effects of different domains and possible interactions between them. We also considered to what extent these various factors enhanced or diminished equitable access to cleaner cooking with respect to poorer households, rural vs urban communities and women.

2.4.1 Quality assurance of methods

The entire review process, including the electronic search, inclusion and exclusion criteria, and extraction forms, was piloted and discussed among team members before instruments were finalised.

We initially used an over-inclusive approach in terms of including studies on title and abstract and subsequently on full data extraction. Study rejection at this later stage was agreed by two or more authors and studies excluded at this stage were re-categorised as ‘critical background reading’ and summarised in specific extraction forms to avoid losing important information; some of these forms were checked during the writing of the final narrative synthesis across the three study designs.

Synthesis tables and narratives were prepared by pairs of authors: qualitative: EP, DS; quantitative: NB, DP; and policy and case studies: EP, ER).

Lastly, comments received from official peer-reviewers, as well as experts consulted during a WHO Guideline Development Group Meeting (April 2012), were incorporated into the revised protocol as well as considered during the synthesis process.

3. Studies included in the review

3.1 Studies included from searching to screening

We systematically searched for interventions relating to ICS and cleaner fuels in 27 multi-disciplinary electronic databases (including specialist systematic review libraries) and 14 websites of the main organisations involved in the household energy sector. We contacted 17 individuals who acted as key informants, asking them to comment on our draft protocol and to forward any relevant evidence. We incorporated suggestions provided by peer-reviewers to improve our search strategy and handsearched the references of all included studies, which allowed us to identify additional relevant literature not initially captured by our main search strategy.

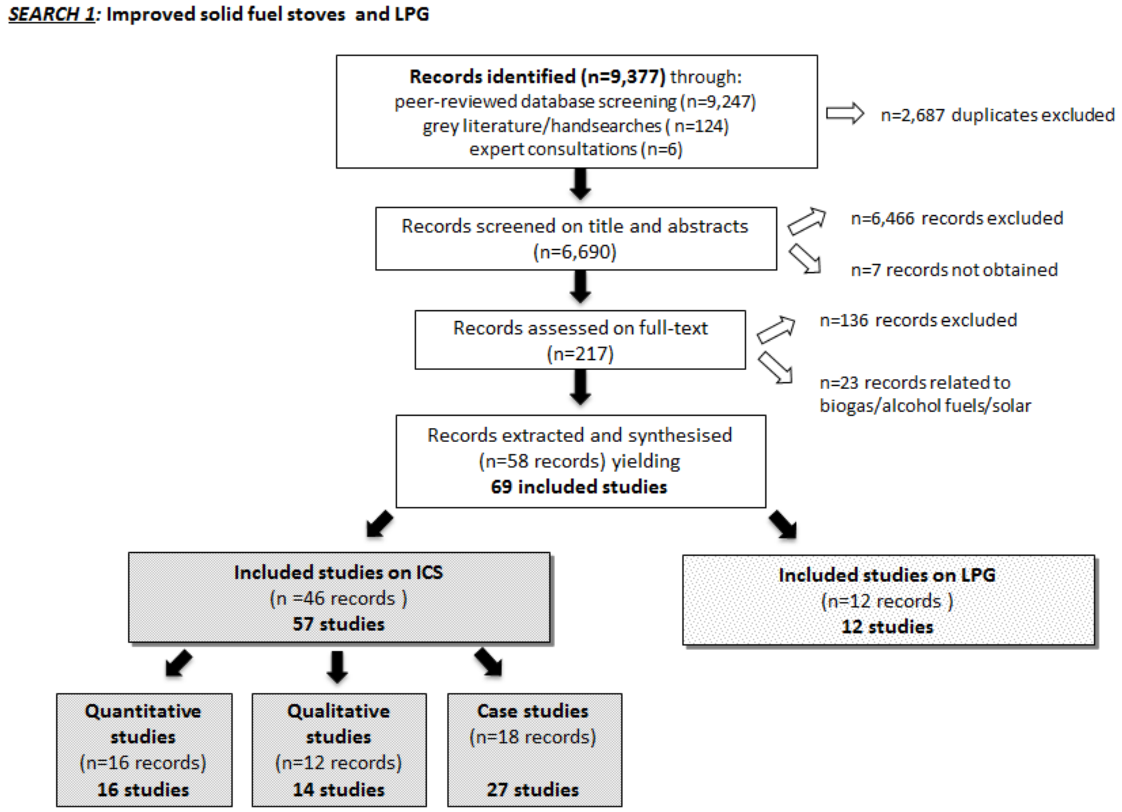
As reported in Figure 3.1, the bibliographic search on ICS and LPG (based on the search terms reported in Table 2.1) initially provided over 9,300 records. A total of 217 documents was screened on full-text, with 69 eligible studies being included in the review and extracted on full-text (57 on ICS and 12 on LPG).

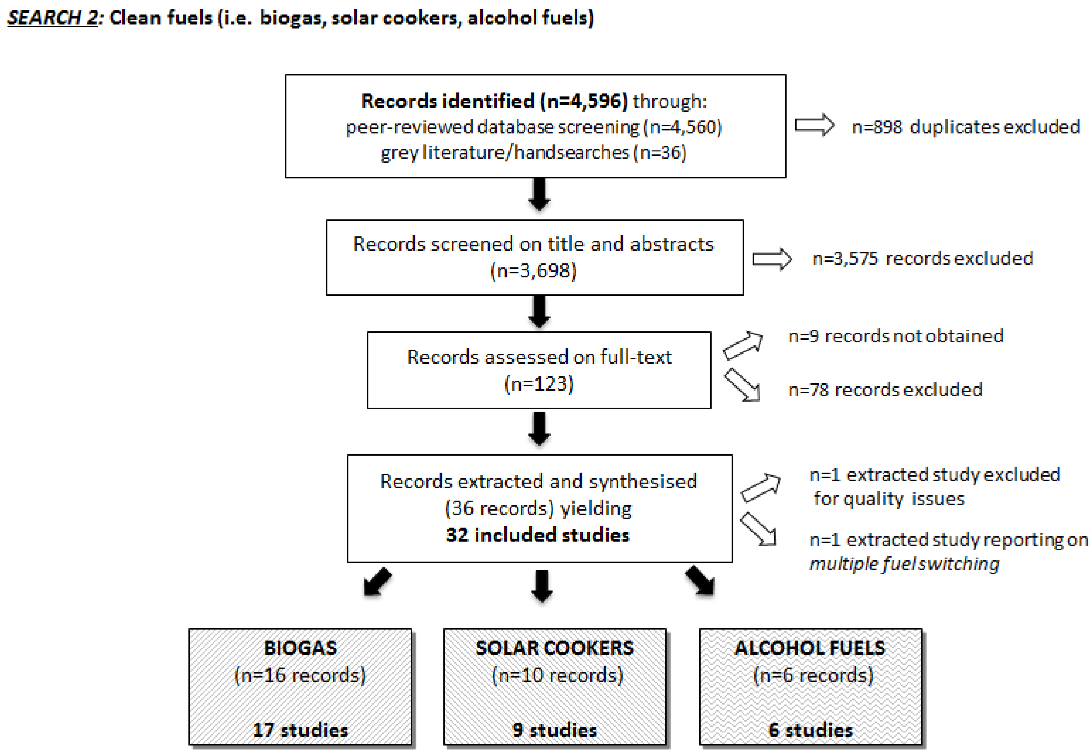
We then conducted a second search focused on additional clean fuels including biogas, alcohol fuels and solar cookers (using the search terms reported in Table 2.2), which identified over 4,500 records (see Figure 3.1). Of these, 123 documents were screened on full-text, and a total of 32 studies were included in the systematic review (17 on biogas, nine on solar cookers and six on alcohol fuels).

When studies reported evidence related to use of multiple stoves or fuels (i.e. ICS and biogas and/or solar cookers) or to different projects/programmes presented as part of an overall report/book, these were treated as distinct studies and counted separately. Similarly, when studies used mixed-method approaches and extensively reported findings from the two components, these were treated as distinct studies and counted independently.

Finally, in order to facilitate the presentation of findings from this review, studies on LPG were included with the other clean fuel categories, and results are presented in Chapter 5.

Figure 3.1: Flow charts of factors influencing the uptake of clean clean household energy



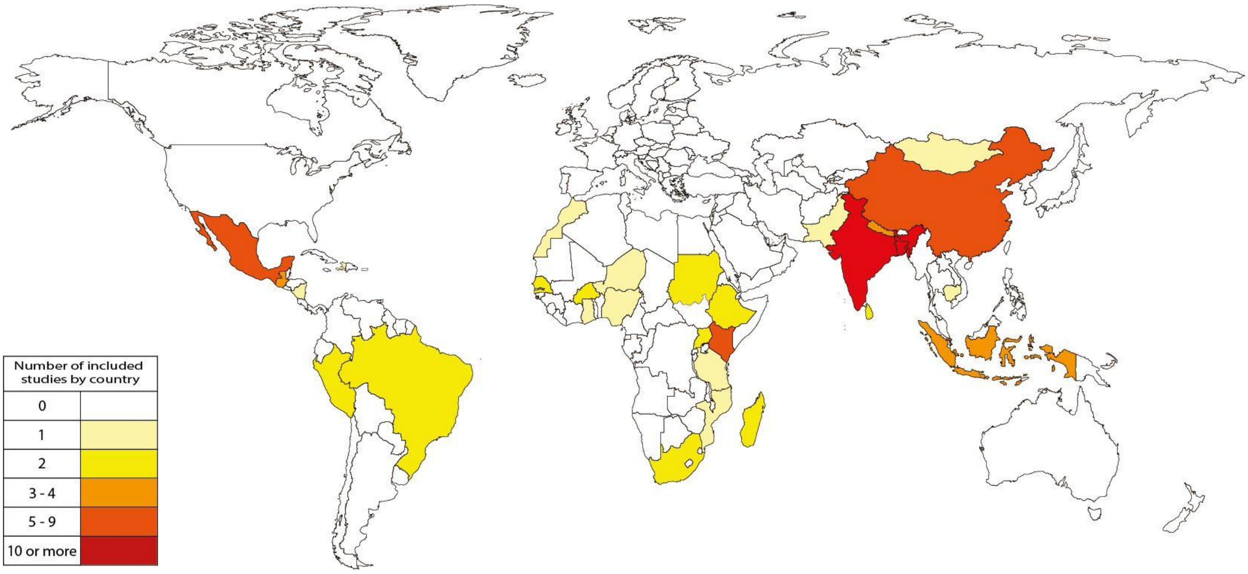


3.2 Characteristics of included studies

3.2.1 Geographical location

Studies included in the review were identified across five WHO regions as illustrated in Figure 3.2.

Figure 3.2: Countries with one or more studies included in review



Fuel and technology category	**WHO region[4]**				
	Africa	**Americas**	**Eastern Mediterranean**	**South-East Asia**	**Western Pacific**
ICS	Burkina Faso Ethiopia Ghana Kenya Niger Senegal Uganda	Guatemala Mexico Peru	Pakistan Sudan	Bangladesh India Indonesia Nepal Sri Lanka	Cambodia China Indonesia
LPG	Mozambique	Brazil Haiti Nicaragua	Morocco Sudan	India	Indonesia
Biogas	-	-	-	Bangladesh India Nepal Sri Lanka	China
Solar cookers	Burkina Faso Kenya Senegal South Africa Tanzania	Mexico	-	India	-
Alcohol fuels	Ethiopia Madagascar Nigeria	Brazil	-	-	Indonesia

[4] See www.who.int/about/regions/en/index.html

3.2.2 Description of studies

Studies were categorised as follows:

- **Qualitative studies**: using qualitative methods (e.g. semi-structured or in-depth interviews, FGD, participant observation (PO), etc.);
- **Quantitative studies**: using quantitative methods (e.g. randomised controlled trials, before-and-after studies, cross-sectional surveys, etc.);
- **Policy and case studies**: often based on multiple sources of information, with at least one source being empirical in nature and providing in-depth insights on factors influencing success/failure of a project/programme or technology.

Details of included studies classified according to type of intervention and study type are reported in chronological order in Table 3.1.

3.3 Quality of individual studies

This section describes included studies on ICS and clean fuels according to the three study types described above.

3.3.1 Included qualitative studies and quality assessment

A total of 19 qualitative studies were included, 14 of which related to ICS exclusively or in combination with clean fuels (which were treated and counted as separate studies). The remaining studies addressed either biogas or solar cookers exclusively. No qualitative studies investigating a switch to LPG or alcohol fuels were identified.

Studies ranged from 1989 to 2012 and included ethnographies (a detailed and in-depth description of everyday life and practice), FGD, as well as SSIs or in-depth interviews (with users, stove builders, stove promoters or key informants/stakeholders).

Studies were appraised using established criteria adapted from Harden et al. 2009 (40) (see section 2.2.4 and Appendix 2.7). Quality appraisal of individual studies resulted in six studies, 11 studies and two studies classified as strong, moderate and weak respectively (see Appendices 3.1, 3.3 and 3.4). Variable quality reflected a lack in some studies of detailed description of methods used (in particular in relation to data analysis and interpretation) and limited descriptions of how themes were derived or data presented to support findings. This caused difficulties in assessing whether the author(s)' interpretation was appropriate.

Table 3.1: Overview of all included studies by study type and intervention

Intervention	Qualitative studies	Quantitative Studies	Policy and case studies
ICS	Pandey (1989) Jagoe et al. (2006a)* Jagoe et al. (2007a)* Anderson (2007) Gordon et al. (2007) Simon (2007) Troncoso et al. (2007) Velasco (2008) Christoff (2010) Chowdhury et al. (2011) Troncoso et al. (2011) Sovacool and Drupady (2011)** Person et al. (2012) Sesan (2012)**	Mwangi (1992) Pandey andYadama (1992) George and Yadla (1995) Wallmo and Jacobson (1997) Muneer and Mohamed (2003) Jagoe et al. (2006b)* Jagoe et al. (2007b)* Agurto-Adrianzen (2009) Bensch and Peters (2011) Damte and Koch (2011) Inayatullah (2011) Miller and Mobarak (2011) Pushpa (2011) Pine et al. (2011) Levine and Cotterman (2012) Silk et al. (2012)	Amarasekera (1989) Mounkaila (1989) Namuye (1989) Sawadogo (1989) Sudjarwo et al. (1989) Shastri et al. (2002) Sinton et al. (2004) World Bank (2004a,b,c)[$] Masera et al. (2005) GERES (2009) Kürschner et al. (2009) USAID/Winrock (2008) USAID/Winrock (2009) World Bank (2010a,b,c)[$] Osei (2010) Simon (2010) Shrimali et al. (2011) Barnes et al. (2012a,b,c,d,e,f)[$]
LPG	*None identified*	Heltberg (2005) Edwards and Langpap (2005) Rogers (2009)	Viswanathan and Kumar (2003) Lucon et al. (2004) USAID (2005) Terrado and Eitel (2005) Pandey and Morris (2006) Bates (2009) USAID (2010) Elgarah (2011) Budya and Arofat (2011)
Biogas	Jian (2009) Sovacool and Drupady (2011)**	Mwirigi et al. (2009) Christiaensen and Heltberg (2012)	Daxiong et al. (1990) Dutta et al. (1997) BSP and CEDA (1998) Bhat et al. (2001) Planning Commission (2002) de Alwis (2002) Bajgain and Shakya (2005) Ghimire (2005) Kumargoud et al. (2006) World Bank (2010d,e)[$] Qi and Li (2010) iDE (2011)
Solar cookers	Velasco (2008)** Otte (2009) Sesan (2012)**	Levine and Beltramo (2011)	Biermann et al. (1999)/Sejake (1998)[#] Ahmad (2001) Baptista et al. (2003) Wentzel and Pouris (2007) Toonen (2009)
Alcohol fuels	*None identified*	*None identified*	Murren (2006) Couto (2007) Obueh (2008) Practical Action Consulting (2010) Practical Action Consulting (2011) Imam (2011)

*Mixed-method studies where quantitative and qualitative components were included and treated separately.
**Studies that included evidence on both ICS and clean fuels, for which each component was included and treated separately.
[$]Multiple case studies extracted from the same report/book. [#]Two studies which were extracted and treated as just one study.

3.3.2 Included quantitative studies and quality assessment

The search identified a total of 22 quantitative studies, of which 16 related to ICS, and six to fuel switching. With regard to the latter, three studies on LPG, two on biogas and one on solar cookers were included.

Studies covered the period 1992 to 2012 and varied considerably in design and methodology. Some of the included studies reported a single quantitative component of data collection such as one or a set of community-based surveys. A few studies were economic analyses based on either national survey data or local surveys. One study used scenario modelling based on a large national survey. Three studies were randomised trials. Details of the context of these studies, the methods used and the participants sampled, are available in the summary tables presented in Appendices 3.1–3.4.

Quantitative studies were assessed for methodological quality using a Liverpool University Quality Assessment Tool (LQAT) (see section 2.2.4 and Appendix 2.8). The quality assessment of individual studies classified eight, nine and five studies as strong, moderate and weak respectively. Sampling was classified as 'strong' in 11 studies (50 percent) that had included stratified random sampling with large sample sizes to be representative of the study population. The description of baseline intervention stove/fuel and outcome (definition of adoption or use) were classified as strong in five studies (22 percent) and two studies respectively (9 percent). The analysis was classified as strong in 10 studies (45 percent) (which provided adjusted estimates of predictors of enablers/barriers using regression analysis).

3.3.3 Included policy and case studies and quality assessment

There were a total of 60 policy and case studies, of which 27 related to ICS and 33 to fuel switching. Studies covered the period 1989 to 2012 and several were published in peer-reviewed journals, with the majority being reports, book chapters or in conference proceedings.

These studies were very different in nature. Case studies were characterised by presenting a range of information about a specific project or programme, which variously included survey information, reported experience with and observation of implementation, and data from other sources such as government or industry. The distinction between case studies and policy analysis was not always clear, but the latter typically sought to make more generalisable assessments from similar combinations of data sources. Details of the studies on ICS and clean fuels are described in the summary tables in Appendices 3.1–3.5.

Case/policy studies were examined by published criteria for case studies adapted by Atkins and Sampson (2002) (44) (see section 2.2.4 and Appendix 2.9). This resulted in 11, 33 and 16 studies classified as strong, moderate and weak respectively. More than half were considered medium or low quality for the following reasons: (i) inadequate reporting and description of methods used (e.g. sampling and representativeness of data sources), (ii) poor data analysis (i.e. most used a largely descriptive approach to analysis), and (iii) sometimes the reports were written by the implementing agency. However, most of the studies were based on mixed-method approaches, with use of large sample sizes and representation of a range of stakeholders in addition to users, and they often provided relevant information across all seven domains.

3.4 Effectiveness of the interventions studied

Improvements to household energy technology and fuels can bring many benefits, including reductions in pollution emissions and exposure, greater fuel efficiency with associated cost and time savings, improved safety, and a set of social and related benefits that follow from having a cleaner and less polluted home environment. Although assessing the effectiveness of interventions was not among the objectives of this systematic review, very little information on effectiveness was provided or even referred to in the included studies. From a health perspective, it is the impact on emissions and exposure that is of most concern, along with safety through the prevention of burns, scalds and poisoning (e.g. from kerosene use).

A key question, therefore, in drawing conclusions from this review is whether the findings on factors influencing adoption and use of interventions of uncertain effectiveness will be relevant to the adoption of the much more effective stoves and clean fuels which governments and programmes will promote in the future in order to meet air-quality guideline limits. For clean fuels, the issue is more the degree to which households (and their neighbours) can make a complete transition from solid fuels. The extent that it is possible to answer this question from the review is considered further in Chapter 6.

3.5 Factors on a spectrum from enabling to limiting adoption

In section 2.3, it was explained that the initial stage of data extraction included recording separately whether a factor was found to be an enabler or a barrier. For example, some studies identified a factor such as poverty as a barrier to adoption, while other studies reported that higher income was enabling.

As the analysis progressed, it emerged that, rather than there being some discrete characteristics that were enablers and others that were barriers, the data were more consistent with findings representing data points on a spectrum of effect for each factor. These factors would generally enable adoption and use if present or satisfactory in some respect, and act as barriers if absent or unsatisfactory. This concept is illustrated by the examples given in Table 3.2.

Thus, while it may appear attractive to seek a list of enablers (which should be incorporated into policy) and barriers (which should be avoided or explicitly overcome), it would seem more useful to identify a set of factors capable of acting for or against adoption and sustained use, the status of which can be assessed for any given project or programme. These factors are presented within the seven domains for ICS in Chapter 4 and for clean fuels in Chapter 5.

Table 3.2: Examples of factors influencing uptake on a spectrum from enabling to limiting

Factor	How factor operates as an enabler or barrier
Household income level	Higher household income favours adoption, while lower (and low absolute) income acts as a barrier (although this may be modified by financing options).
Perceived and/or measured fuel savings	Fuel saving is highly appreciated and therefore enabling (especially in areas where it is paid for), while households report disappointment with stoves that do not save fuel.
Post-acquisition support	The provision of after-sales or post-acquisition support makes repairs and maintenance easier, and is appreciated by users. The lack of this service means that stoves requiring maintenance or repair may fall into disuse.
Number of animals for biogas users	More cattle can help a larger family generate enough gas for its use and possibly also to sell some locally. A minimum number of cattle or other animals (e.g. pigs) is required, usually at least 2, and where these cannot be kept, this (along with other key requirements including water supply) is a barrier to production.

3.6 Relative importance of factors

One critical issue, especially for those responsible for policy and planning, is whether it is possible to identify some factors which are more important than others, or indeed whether there is a shortlist of essential factors. Furthermore, prioritisation requires both a suitable method and an evidence base that supports such assessment, and it is not clear that either of these is currently available. As will be shown, this review finds that all factors can matter, but some are undoubtedly critical for successful adoption and/or use. For example, a stove that does not meet the majority of needs for a family's cooking will not be adopted and used for this purpose. However, meeting those needs does not guarantee adoption or sustained use, if – for example – the stove is not reasonably durable, creates safety concerns, or cannot easily be replaced or repaired when worn out. Thus, meeting users' needs can be thought of as one of a number of **necessary but not sufficient** factors.

Factors which are considered especially important in this way are identified and discussed in the 'Summary of findings' in sections 4.4 and 5.5, although it must be emphasised that the nature of the evidence available and the critical influence of context does not easily allow a clear separation of essential factors from other influential factors. A key message is that all factors need to be considered, almost all are interdependent and the relative importance of many is context-specific.

3.7 Differentiation of factors impacting on initial adoption and sustained use

Factors affecting short-term adoption and use may differ from those affecting longer-term sustained use. For the purposes of this review, drawing on and further developing concepts advanced in the literature (48, 49), adoption is defined to include both acquisition (stoves are purchased or installed without any reference to their use) and initial adoption (use is assessed less than one year from acquisition). Sustained use comprises both medium-term (assessed one or two years from acquisition) and long-term sustained use (reflecting longer time periods). Factors linked to one or both of these ‘phases’ of use are identified in the results.

4. Improved solid fuel stoves

4.1 Evidence on adoption and use of ICS

This section presents the findings from the 57 included studies on ICS (14 qualitative, 16 quantitative and 27 case studies). Studies were conducted in Asia, Africa and Latin America; 31 studies in rural settings, 11 in urban areas, and 15 in both settings. The countries most represented were India and Bangladesh, followed by Mexico and Kenya. Biomass was the principal fuel used, but two studies assessed coal. A total of 36 studies were concerned with adoption, 13 with sustained use and eight with elements of both adoption and sustained use. Improved stove technologies included a variety of stove models, with one or more potholes and also including some with a chimney or smoke hoods. The majority of studies were concerned with locally produced stoves. No studies were found on adoption of more recently developed advanced combustion stoves (e.g. forced draft or semi-gasifier stoves). More detailed information on study characteristics and the ICS technology involved is presented in Table 4.8 at the end of this chapter.

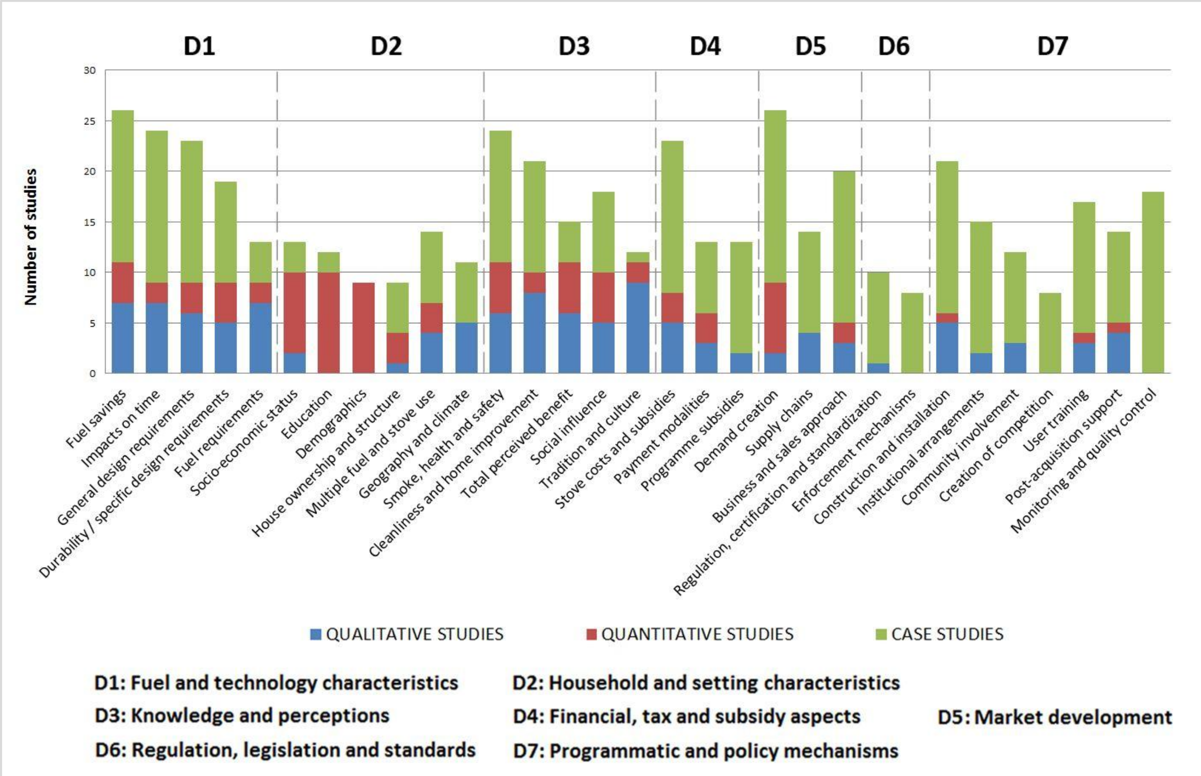
4.2 Factors influencing adoption of ICS by domain

A total of 31 factors influencing uptake of ICS were identified across the seven framework domains, summarised by contributing study designs (i.e. qualitative, quantitative and case studies) in Figure 4.1. A narrative describing the findings within each domain is given below.

Some of the identified factors were drawn from a more extensive evidence base (i.e. larger numbers of studies across different study design) than others (Figure 4.1), potentially suggesting that these factors were more important than those supported by less information. Scarcity of evidence, however, does not necessarily mean that a given factor should be given less consideration. Often, limited findings in support of a given factor are a consequence of the particular issues that researchers have elected to investigate and how suitable a certain study design is addressing these. For example, Domain 6 (Regulation, legislation and standards) is supported by only a few case studies; however there is no doubt that standards and regulation are needed for meeting efficiency requirements, reducing health and safety hazards and increasing user satisfaction. The lack of evidence is therefore more a reflection of historical lack of policy attention in this field. Indeed, much effort is currently being put into developing stove standards with the International Standarization Association (ISO) along with regional testing centres (50).

Quantitative evidence is available across most domains, but most frequent for ’Household and setting characteristics’ (Domain 2), and particularly limited for Domains 6 and 7. The qualitative findings largely relate to ‘Fuel and technology characteristics’ and ‘Knowledge and perceptions’ of users (Domains 1 and 3 respectively). Case studies generally offer a broader perspective and are represented in all domains, although relatively few provide evidence on household characteristics and settings.

Figure 4.1: Factors influencing uptake of ICS across seven domains (D1–D7), by study type and number of studies



In terms of individual study quality, 19 out of 57 studies were appraised as strong, 29 as moderate and 9 as weak. As noted in section 3.2, the quality score for individual studies should not be considered equivalent across the three study methodology groups as it is design-specific. The potential impact of study quality was examined through sensitivity analysis which examined how domains and factors were affected following exclusion of the weak studies. The results of this analysis did not result in any substantive impact on the level of evidence available for the 31 factors, and the remaining studies provided evidence on all of the factors identified in Figure 4.1.

4.2.1 Domain 1: Fuel and technology characteristics

Fuel saving: Fuel and time savings were widely cited and assessed mainly through self-reports from users and in some cases direct measurement. Fuel saving was an incentive highly valued by users (51–67) as it impacted on household expenditure (where fuel is purchased) and the amount of time women spent collecting fuel (and in some studies associated injuries and threats) where fuel is gathered (59, 60, 68–73). Conversely, increases in fuel use/consumption with no associated savings in fuel expenditure discouraged use (53–55, 57, 74), especially when stoves required additional time for fuel processing and/or stove or chimney cleaning (75–78).

Impacts on time: Stoves which reduced cooking time due to better heat transfer efficiency and/or parallel cooking on multiple potholes were highly valued by women (52–54, 56–60, 64, 66–68, 71, 77–81, 84). Time savings from faster cooking and/or reduced collection time have been reported to be used for other household work (59, 60, 81) or income generation (59), but the attached value varied between settings (69, 76). Poor performance and longer cooking times were reported as a barrier (54, 55, 57, 75, 76, 82).

Table 4.1: Domain 1. Fuel and technology characteristics: ICS

Factor	Examples	Country and setting*	Type and quality of evidence**
Fuel savings	• Perceived or measured savings • Impacts on fuel collection and/or purchase	Bangladesh (60, 65, 70, 74), Burkina Faso (63), Cambodia (59), Guatemala (51), India (53–58, 64, 68, 69, 72, 75), Kenya (62, 71), Mongolia (73), Mexico (76), Nepal (66), Niger (61), Sri Lanka (52), Uganda (67)	QL=7 *(4=S; 2=M; 1=W)* QN=4 *(1=S; 1=M; 2=W)* CS=15 *(8=S; 5=M; 2=W)*
Impacts on time	• Cooking time • Fuel collection time	Bangladesh (60, 77), Burkina Faso (63), Cambodia (59), Guatemala (51, 83), India (53-58, 64, 68, 69), Indonesia (82), Kenya (62), Mexico (76, 78, 80), Nepal (66, 84), Sri Lanka (52), Uganda (67)	QL=7 *(2=S; 5=M)* QN=2 *(2=W)* CS=15 *(8=S; 5=M; 2=W)*
General design requirements	• Design to meet users' needs • Use of traditional utensils and pots	Bangladesh (85), Cambodia (59), China (28), Guatemala (51, 83, 86), India (53–58, 68, 69, 75, 79, 87), Indonesia (82), Mexico (48, 76, 78, 88), Nepal (66), Uganda (67)	QL=6 *(2=S;4=M)* QN=3 *(1=M; 2=W)* CS=14 *(8=S; 6=M)*
Durability and other specific design requirements	• Stove cracking • Chimney/stove cleaning • Stove entrance design • Need for warmth	Bangladesh (60), Burkina Faso (63), Guatemala (51), India (58, 68, 79, 81, 87), Indonesia (82), Kenya (62), Mexico (76, 78, 89), Nepal (66), Niger (61), Sri Lanka (52), Uganda (67, 90)	QL=4 *(2=S; 2=M)* QN=4 *(2=M; 2=W)* CS=10 *(1=S; 7=M; 2=W)*
Fuel requirements	• Fuel processing • Use of traditional fuels	Bangladesh (70, 77), India (58, 68, 87), Indonesia (82), Mexico (76, 78, 88), Nepal (66, 84), Uganda (67), Guatemala (83)	QL=7 *(2=S; 4=M; 1=W)* QN=2 *(2=W)* CS=4 *(4=M)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *All factors are supported by findings in rural as well as urban settings. **Quality of evidence not comparable across different study design.

General design requirements: A number of design features were found to be of fundamental importance in relation to adoption and sustained use with multiple studies reporting that culturally and/or locally inappropriate stove designs hampered use, often leading to stove modifications by users (51, 53, 55–58, 68, 76, 78, 81) or reversion to traditional stoves (51, 53–58, 68, 76, 78, 81, 87). It is therefore clear that households will not adopt of their own volition, or continue using, stoves which do not meet their needs (28, 55, 59, 82, 85, 86, 88), especially for cooking most of their daily meals at least as quickly as the traditional stove, achieving favoured taste, and using available fuels and familiar pots (51, 66, 67, 82, 86). These factors are thus very important for appropriate stove design (28, 55, 85, 88) and successful adoption (48, 92).

Durability and specific design requirements: Positive features of stoves reported to facilitate adoption included convenience, safety, durability, and the ability to provide warmth and portability in cold and rainy settings respectively (51, 52, 59–63, 66, 67, 81, 90). Aesthetic features (as further discussed under Domain 3) were also valued (62, 67, 76, 78, 80, 89). The involvement of women in the design of stoves was found to be important in a variety of settings (51, 54, 57, 88, 89), and failure to do so has led to several examples of women subsequently modifying the stove (53, 55–58, 91), for example enlarging the entrance to the combustion chamber to allow use of larger pieces of wood (76, 78), and removal of grates (68, 81) which had been included to improve combustion.

Fuel requirements: Stoves which were more restrictive in terms of type of fuel (66, 67, 70, 82, 84, 87), reliance on dry fuel (68, 76) and size of fuel (68, 76, 78, 88, 92) could add work for users (e.g. cutting wood into smaller/straighter pieces) (58) and studies reported this could act as a barrier to sustained stove use (58, 68, 76–78, 83, 84, 88).

4.2.2 Domain 2: Household and setting characteristics

The household and settings domain includes SES, education, demographics, home ownership and geography, factors which are often highly inter-related and linked in a variety of ways to most of the other domains affecting adoption and sustained use of improved cooking technologies.

Socio-economic status: Having a higher SES was widely reported across different study designs as a key enabler to uptake of ICS (63, 82, 93–98). This was measured differently across studies in terms of income, household expenditure, land ownership or household assets. Initial adoption, especially when stoves were sold on the open market and purchased at full price by users, was more frequent among better-off families with greater financial liquidity.

Education: Education is closely related to SES, and was found to be associated with increased uptake in a number of studies (48, 52, 65, 82, 93, 99–101), but not all (96, 102, 103).

Demographics: No clear conclusions can be drawn in terms of demographics, although there was evidence that larger families were less likely to adopt (48, 90, 96, 99, 102). This is probably related to the number of adults working in the household as well as the number of women and children available for fuel gathering (48, 95, 102, 103), resulting in low opportunity costs being attributed to time spent in traditional fuel collection and cooking(56, 59, 60).

House ownership and structure: Additional factors such as home ownership and having a permanent house and enough space inside/around the house for positioning a permanent stove were reported to increase willingness to adopt (48, 55, 56, 67, 89, 93, 98, 104).

Multiple fuel and stove use: The majority of studies reported existing fuel use and/or stove 'stacking' – the continued use of the old fuel and stove as the new one is adopted. This appeared to facilitate uptake of an additional cooking technology (and/or fuel) (48) as there was already familiarity with using more than one type of stove/fuel (59, 72, 76, 80, 82, 94), but clearly also acted as a barrier to exclusive use of the improved stove (52, 55, 59, 75, 82, 89). A variety of combinations was described, but most frequently households employed a mix of traditional stoves (52, 56, 59, 72, 82) and LPG (with the latter used to a lesser extent mainly due to the costs of refilling the bottle) (76, 80, 88, 94). Households that purchased rather than collected solid fuels were more likely to adopt an improved stove (94), as monetary savings were valued more than time savings where wood is collected (76, 78). This issue of opportunity cost (56, 99) and valuation of time was reported to be very important and is a recurrent theme across several other domains.

Geography and climate: Not surprisingly, geographical settings were reported to greatly impact on initial uptake and sustained use of improved stoves, as cold and rainy conditions require stoves to be able to meet heating and drying needs (54, 73, 76, 86) and (where outdoor cooking is practiced) to be portable so as to be able to cook indoors or under shelter during the rainy season (54, 61, 71). Also, urban households appeared to be more willing to adopt – a finding that appeared to be at least partly independent of SES (59, 60, 94). Households located in disaster-prone areas (77) or affected by drought and famine (71) were reported to be less likely to adopt.

Table 4.2: Domain 2. Household and setting characteristics: ICS

Factor	Examples	Country and setting*	Type and quality of evidence**
Socio-economic status	• Income • Assets • Expenditure	Burkina Faso (63), Ethiopia (93), India (94, 102), Indonesia (82), Kenya (71, 95, 98, 103), Pakistan (99), Peru (96), Senegal (97), Sudan (101)	QL=2 *(1=S; 1=M)* QN=8 *(3=S; 4=M; 1=W)* CS=3 *(1=S; 2=M)*
Education	• Years of schooling for men and women	Bangladesh (65), Ethiopia (93), India (100, 102), Indonesia (82), Kenya (103), Mexico (48), Pakistan (99), Peru (96), Sri Lanka (52), Senegal (97), Sudan (101)	QN=10 *(3=S; 6=M; 1=W)* CS=2 *(1=M; 1=W)*
Demographics	• Age • Sex • Head of household • Household size	Ethiopia (93), India (102), Kenya (95, 103), Mexico (48), Pakistan (99), Peru (96), Sudan (101), Uganda (90)	QN=9 *(2=S; 6=M; 1=W)*
House ownership and structure	• Availability of permanent home • Space for kitchen	Ethiopia (93), Kenya (98), India (54–56), Mexico (48, 89), Peru (104), Uganda (67)	QL=1 *(1=M)* QN=3 *(2=M; 1=W)* CS=5 *(3=S; 2=M)*
Multiple fuel and stove use	• Existing fuel and stove stacking	Cambodia (59), India (55, 56, 72, 75, 94), Indonesia (82), Mexico (48, 76, 80, 89), Pakistan (99), Sri Lanka (52)	QL=4 *(1=S; 3=M)* QN=3 *(3=M)* CS=7 *(3=S; 3=M; 1=W)*
Geography and climate	• Urban/rural • Cold and rainy settings • Disaster prone settings	Bangladesh (60, 77), Cambodia (59), Guatemala (86), India (54, 68, 94), Kenya (71), Mexico (76), Mongolia (73), Niger (61)	QL=5 *(3=S; 2=M)* CS=6 *(3=S; 3=M)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *All factors are supported by findings in rural as well as urban settings. **Quality of evidence not comparable across different study design.

4.2.3 Domain 3: Knowledge and perceptions

This domain relates to the knowledge and perceptions of users, mostly women, with respect to the impact of a new technology on cooking habits, health and home cleanliness.

Smoke, health and safety: When new stoves were perceived to reduce emissions (51, 53–56, 58, 64, 82), women typically reported (for themselves and for their children) fewer negative health effects (48, 53–58, 68, 73, 76–81), although these tended to be related to more acute symptoms, rather than more chronic and longer-term health effects. Where the stove was perceived to be safer, women also reported fewer burns and injuries (59, 62, 67, 72, 76, 78, 81).

In most studies, it was not clear whether an expectation of health benefits could be considered an enabler of uptake (67, 68, 73); however, less smoke and fewer symptoms certainly formed part of the users' satisfaction with the new technology. Moreover, these benefits were often a subject of conversation with neighbours and friends and were therefore likely to influence adoption patterns in the community (98). In a study exploring gender dynamics in household decision-making, economic benefits from improved stove uptake such as fuel savings and associated costs were more valued by men, who tended not to acknowledge the importance of health benefits in the same way that the women did (65).

Table 4.3: Domain 3. Knowledge and perceptions: ICS

Factor	Examples	Country and setting*	Type and quality of evidence**
Smoke, health and safety	• Smoke exposure • Health effects • Burn Injuries	Bangladesh (65, 77), Cambodia (59), Guatemala (86), India (53-58, 64, 68, 79), Indonesia (82), Kenya (62, 98), Mexico (48, 78, 80, 89), Mongolia (73), Nepal (66), Niger (61), Uganda (67)	QL=6 *(3=S; 3=M)* QN=5 *(1=S; 2=M; 2=W)* CS=13 *(8=S; 4=M; 1=W)*
Cleanliness and home improvement	• Cleaner home • Family benefits	Guatemala (83, 86), India (53–58, 69, 79), Kenya (62, 71, 98), Mexico (76, 78, 80, 89), Mongolia (73), Nepal (84), Niger (61), Uganda (67)	QL=8 *(2=S; 6=M)* QN=2 *(1=M; 1=W)* CS=11 *(6=S; 4=M; 1=W)*
Total perceived benefit	• Willingness to pay • Overall perceived advantages	Bangladesh (85), India (55, 57, 68, 79, 81, 102), Kenya (71, 98), Mexico (76), Nepal (66, 84), Niger (61), Sudan (101)	QL=6 *(2=S; 4=M)* QN=5 *(1=S; 1=M; 3=W)* CS=4 *(2=S; 2=M)*
Social influence	• Influence of social networks and opinion leaders	Bangladesh (65), India (53-55), Indonesia (82), Kenya (62, 71), Mexico (48, 76, 78, 80, 89), Nepal (66, 84), Niger (61), Peru (104); Uganda (67)	QL=5 *(2=S; 3=M)* QN=5 *(2=S; 1=M; 2=W)* CS=8 *(2=S; 5=M; 1=W)*
Tradition and culture	• Suitability for preparing local dishes • Food taste	Bangladesh (77), India (56, 68, 69, 81), Kenya (71), Mexico (76, 78, 88), Nepal (66, 84), Uganda (67)	QL=9 *(3=S; 6=M)* QN=2 *(2=W)* CS=1 *(1=S)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *All factors are supported by findings in rural as well as urban settings. **Quality of evidence not comparable across different study designs.

Cleanliness and home improvement: A cleaner home/kitchen (51, 53–58, 67, 69, 73, 76, 78, 79, 86, 89) and cleaner cooking vessels (53–58) due to smoke reduction (62) were appreciated by users of improved stoves (71, 98). Conversely, some technologies require more cleaning, in particular of the chimney, which could be a barrier to sustained use (54, 73, 78, 83, 84). Additional benefits, such as warmth provided by the stove, the family being able to eat together in the kitchen (86, 89) or children being able to study/play indoors as a result of less smoke (57, 58) were also valued.

Total perceived benefit: Where the overall advantages of improved stoves were thought to outweigh those associated with traditional practices, households perceived the investment in ICS purchase to be good value for money (66, 81, 101, 102). However, improved stoves were not always found to meet users' expectations (57, 61, 68, 84). This and competing household priorities (55), in particular the need to secure food prior to investing in the purchase of an improved stove, (98) could impact negatively on willingness to pay for a new stove.

Social influence: Beyond individual household knowledge and perceptions, social factors and community interactions were reported to influence adoption (48, 67, 78, 96). The decision whether or not to purchase was significantly influenced by both positive and negative experiences of neighbours or relatives who had adopted the stove (55, 61, 62, 71, 78, 82, 84). The influence of opinion leaders within a community was likewise important in this regard (48, 65). The aesthetic appeal and subsequent social status gain associated with the new technology were also reported to be among motivating factors for both adoption and sustained use, (62, 76, 78, 80), including for example where users in some settings (e.g. in Latin America) were reported to be planning improvements to their houses as a consequence of acquiring a built-in ICS (76, 89, 104).

Tradition and culture: The suitability for preparing traditional dishes with the normal taste (using the pots that users own and are familiar with) was reported to be an enabling factor for adoption and sustained use of a new cooking technology (69, 78). Several studies reported that users found it possible to cook only some of their usual meals on the improved stoves, with the rest being prepared on the traditional stove, for practical reasons such as use of larger pots (71, 76, 78, 84), or to achieve the preferred smoky taste of the prepared food (56, 66–69, 77, 78). The lack of any perceived need for a new stove and change in cooking habits was also quite frequently reported as being associated with a lower likelihood of adoption (68, 76, 77, 88).

4.2.4 Domain 4: Financial, tax and subsidy aspects

Stove costs and stove subsidies: In the case of market-based approaches in which the full costs of stoves had to be paid by users, the key barrier to purchasing or re-purchasing tended to be cost (55, 61, 62, 65, 67, 68, 71, 73, 82, 90, 98). Flexible stove pricing policies were reported to encourage adoption of a wider variety of stoves according to customers' ability to pay (58, 91, 105). Economies of scale through bulk orders of stoves (53, 54, 87) or fixed costs for raw materials also favoured adoption (74, 86).

Many government-led and NGO-led approaches have employed stove subsidies; in the majority of cases these were reported to facilitate adoption (51, 53, 58, 72, 83, 106, 107) but not necessarily sustained use of the ICS (54, 56, 57). For example, two studies conducted in India reported that subsidies were perceived to devalue the improved stove, with evidence that households receiving the greatest subsidies had the poorest maintenance record (53, 54). On the other hand, evidence suggested that without subsidies the poorest families tended to be excluded from access to improved stoves (51, 108).

Payments modalities: Payments in instalments (60, 90, 105, 109) and consumer finance through microcredit (85, 105), community-lending schemes (71) or loan schemes (104) were reported to facilitate adoption of ICS (65, 69, 79, 81, 94) but long-term success varied across settings. However these financing arrangements for individual households were not without problems including difficulties related to high interest charges (105), excessively short payback periods for microcredit (105), lack of credit for the poorest (51) and users' inability to complete their payments for the stove (85, 90).

Programme subsidies: Direct or indirect financial support by the government for improved stove programmes was reported to have facilitated ICS uptake in China (28). In other programmes, adequate upfront capital for entrepreneurs to develop their stove businesses and carry out staff training was reported as potentially critical (28, 60, 74, 85, 94, 110), and programmes that did not receive or provide financial support for longer-term stove maintenance, user support and awareness-raising were found to be less successful (56, 57, 60, 91). Dependence on external financial support (national or international) should, however, be carefully evaluated with a view to implications for programme sustainability (51, 83, 86, 88, 98).

Table 4.4: Domain 4. Financial, tax and subsidy aspects: ICS

Factor	Examples	Country and setting*	Type and quality of evidence**
Stove costs and subsidies	• Initial stove cost • Stove subsidies • Competing household priorities • Maintenance costs	Bangladesh (65, 74, 105), Guatemala (51, 83, 86), India (53–58, 68, 72, 87), Indonesia (82), Kenya (62, 71, 98), Mongolia (73), Niger (61), Uganda (67, 90)	QL=5 *(4=S; 1=M)* QN=3 *(1=S; 1=M; 1=W)* CS=15 *(6=S; 7=M; 2=W)*
Payment modalities	• Availability of loans, microcredit, instalments	Bangladesh (65, 85, 105), Ghana (110), Guatemala (51), India (69, 79, 81, 94), Kenya (98), Mexico (89), Peru (104), Uganda (90)	QL=3 *(3=M)* QN=3 *(1=S; 2=M)* CS=7 *(1=S; 6=M)*
Programme subsidies	• Government support • Financial incentives	Bangladesh (60, 85, 91), China (28), Ghana (110), Guatemala (51, 83, 86), India (56, 57, 94), Kenya (98), Mexico (88)	QL=2 *(2=M)* CS=11 *(4=S; 6=M; 1=W)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *All factors are supported by findings in rural as well as urban settings. **Quality of evidence not comparable across different study design.

4.2.5 Domain 5: Market development

Demand creation: The last decade has seen an increased trend towards market-based dissemination of improved stoves and as a consequence demand creation is becoming a higher priority resulting in more attention being paid to designing and promoting stoves with attributes that are more attractive to potential customers. A wide range of marketing strategies has been used across countries to generate demand (51, 61, 63, 64, 85, 87, 89, 91, 94). Stove promoters making contact with individual users and live demonstrations of the new technology were cited among the most successful strategies (51, 62, 67, 71, 72, 74, 82, 85, 86, 89–91, 94, 95, 104, 105). On the other hand, coercion, false promises or misinformation were reported to lead to rapid rejection of new cooking technologies even if initial purchase/adoption occurred (54, 57, 60, 70, 82).

'Word-of-mouth' was also reported to be a powerful influence within communities (48, 71, 78, 84, 103), acting for or against adoption depending on the perceptions and experiences communicated (see Domain 3, social influence). A number of studies recommended that more should be done to specifically target men (in addition to women) during stove promotion, as they tended to be the main household decision-makers (65, 71, 101). One study indicated that this could be achieved through promotion of additional products or attributes which directly attract the interest of men (65).

Supply chains: Functional and efficient supply chains for stoves or stove components were reported as essential for meeting demand and keeping costs as low as possible (51, 52, 61, 68, 72, 77, 91, 94), with the extent and condition of road infrastructure impacting on price and market diffusion (51, 71, 85). Another important aspect of supply was related to ensuring availability of replacement parts and services (51, 57, 82, 86, 110), which are essential for market sustainability. Short-term projects, which usually focus on rapid initial stove uptake, have frequently omitted this aspect of planning and implementation.

Table 4.5: Domain 5. Market development: ICS

Factor	Examples	Country and setting*	Type and quality of evidence**
Demand creation	• Strategies used to increase demand and awareness raising • Avoidance of coercion	Bangladesh (60, 65, 74, 85, 91, 105), Burkina Faso (63), Ethiopia (93), Guatemala (51, 83, 86), India (54, 64, 72, 87, 94), Indonesia (82), Kenya (62, 71, 95, 103), Mexico (89), Niger (61), Peru (104), Sudan (101), Uganda (67, 90)	QL=2 *(2=S)* QN=7 *(3=S; 3=M; 1=W)* CS=17 *(3=S; 13=M; 1=W)*
Supply chains	• Supply infrastructure • Availability of raw materials, stove parts and complete stoves • Road infrastructure	Bangladesh (77, 85, 91), Ghana (110), Guatemala (51, 86), India (57, 68, 72, 94), Indonesia (82), Kenya (71), Niger (61), Sri Lanka (52)	QL=4 *(3=S; 1=M)* CS=10 *(2=S; 7=M; 1=W)*
Business and sales approach	• Stove production • Stove marketing and dissemination • After-sales service	Bangladesh (60, 77, 85), Cambodia (59), Ghana (110), Guatemala (51, 86), India (54–57, 64, 72, 87, 94), Indonesia (82), Kenya (71, 103), Mexico (89), Uganda (90)	QL=3 *(2=S; 1=M)* QN=2 *(2=M)* CS=15 *(8=S; 6=M; 1=W)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong*; M*=moderate*; W*=weak. *All factors are supported by findings in rural as well as urban settings. **Quality of evidence not comparable across different study design.

Business and sales approach: A number of studies explored the perspectives of stove builders, stove entrepreneurs (53–60, 72, 77, 88, 94) and sales approaches (71, 72, 90). The stove market is characterised by numerous challenges for generating and maintaining adequate income (56, 64), including the development of an effective business plan, ensuring sufficient upfront capital (56, 60) and coping with relatively low demand (54, 55, 57, 72). Business development and demand creation therefore need to go hand-in-hand (59, 64). Approaches that have been used to help ensure sustained income among both small- and larger-scale producers included: (i) combining sales through a government programme with sales on the open market (53), (ii) cross-subsidising sales to households through business with commercial/institutional customers (e.g. restaurants) (94), (iii) specialising in the production of stove parts (51, 86, 89, 110), (iv) identifying appropriate distribution channels via indirect (through sales outlets) (85) or direct sales (from manufacturers) (82), (v) exploring opportunities for marketing multiple products (103), and (vi) ensuring an independent second source of income (85).

4.2.6 Domain 6: Regulation, legislation and standards

Relatively few studies reported on the role of regulation and certification of ICS, but those that did concluded that standards and their enforcement were fundamental for achieving successful large-scale use, by increasing the likelihood of efficient functioning of ICS in everyday use and over time.

Regulation, certification and standardisation: Certification of stoves or stove components by a standards agency or a network of producers was reported as a means of ensuring adherence to design specifications for fuel efficiency and emissions (28, 59, 71, 94). The use of prefabricated moulds (55) or stove labels to guarantee construction standards (59, 94) were successfully used in a few settings. Indeed, in some reviewed programmes/projects, poorer-quality stoves or stove parts or chimneys were purchased from uncertified manufacturers (51, 57, 62, 86), leading to stove modification and limited ICS use over time (53, 58). Lack of regulation was also reported to be problematic where there was no state control of the financial speculation on raw materials (61).

Enforcement mechanisms: In order to be effective, certification must be enforced through mechanisms such as the procurement of materials from designated suppliers, the exclusive use of accredited manufacturers and penalties to revoke accreditation in case of non-compliance with standards (28, 54, 59, 64, 87). Dissemination of stoves and stove parts purchased from non-approved vendors and dealers was documented in a number of studies, resulting in users often having problems with the stoves and experiencing considerable variation in procurement rates (53, 56, 58).

Table 4.6: Domain 6. Regulation, legislation and standards: ICS

Factor	Examples	Country and setting*	Type and quality of evidence**
Regulation, certification and standardisation	• Fuel and raw material pricing • Stove certification	Cambodia (59), China (28), Guatemala (51), Kenya (62, 71), India (55, 57, 58, 94), Niger (61)	QL=1 *(1=S)* CS=9 *(7=S; 2=M)*
Enforcement mechanisms	• Whether or not effective mechanisms adopted • Penalties for non-compliance	Cambodia (59), China (28), India (53, 54, 56, 58, 64, 87)	CS=8 *(8=S)*

QL=qualitative studies; CS=case studies; *S*=strong; *W*=weak. *All factors are supported by findings in rural as well as urban settings. **Quality of evidence not comparable across different study design.

4.2.7 Domain 7: Programmatic and policy mechanisms

Construction and installation: Successful programmes involved careful planning and implementation at all stages from choice of raw materials for stove construction to post-acquisition support (51, 59, 100). Stove builders should be adequately trained (28, 52-57, 59, 60, 76), as professionalism is needed for achieving good-quality stoves and for an effective start-up of the stove businesses. Lack of proper construction or installation of stoves and chimneys was widely reported as a barrier to sustained use (28, 53–57, 59, 60, 70, 83, 86, 104, 105).

Table 4.7: Domain 7. Programmatic and policy mechanisms: ICS			
Factor	**Type of evidence**[1]	**Country and settings***	**Type and quality of evidence****
Construction and installation	• Quality of stove construction and installation	Bangladesh (60, 70, 105), Cambodia (59), China (28), Guatemala (51, 83, 86), India (53-58, 81, 100), Mexico (76, 78), Nepal (84), Peru (104), Sri Lanka (52)	QL=5 *(1=S; 3=M; 1=W)* QN=1 *(1=W)* CS=15 *(8=S; 6=M; 1=W)*
Institutional arrangements	• Stakeholder co-ordination • Government role	Bangladesh (77, 91), China (28), Guatemala (83, 86), India (53-58, 87, 94), Kenya (98), Sri Lanka (52)	QL=2 *(2=M)* CS=13 *(8=S; 4=M; 1=W)*
Community involvement	• Women's engagement	Bangladesh (85, 105), Guatemala (51), India (53-56, 58, 72), Kenya (98), Mexico (88, 89)	QL=3 *(1=S; 2=M)* CS=9 *(5=S; 4=M)*
Creation of competition	• Mechanisms to promote uptake • Rewards schemes	Cambodia (59), China (28), India (53-56, 58, 72), Peru (104)	CS=8 *(7=S; 1=M)*
User training	• Training in stove use and maintenance	Bangladesh (60, 77, 91, 105), Guatemala (51, 86), India (53-56, 58, 64, 100), Indonesia (82), Mexico (76, 78, 89)	QL=3 *(1=S; 2=M)* QN=1 *(1=M)* CS=13 *(6=S; 7=M)*
Post-acquisition support	• Availability and quality of support	Bangladesh (60, 77, 91, 105), India (53-55, 57, 58, 64, 72, 100), Mexico (78, 88)	QL=4 *(2=S; 2=M)* QN=1 *(1=M)* CS=9 *(6=S; 3=M)*
Monitoring and quality control	• Monitoring of implementation • Users feedback	Bangladesh (60, 74, 85, 91), Cambodia (59), Guatemala (51, 83, 86), India (53-58, 94), Indonesia (82), Mexico (89), Niger (61)	CS=18 *(8=S; 10=M)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *All factors are supported by findings in rural as well as urban settings. **Quality of evidence not comparable across different study design.

Institutional arrangements: Lack of co-ordination and regular interaction among key stakeholders and programme actors at local, regional and national levels was widely reported as a barrier for successful adoption and use because of poor planning, management and lack of effective monitoring (52–55, 58, 86, 91). Synergies through integration with other stove programmes in the same geographical area (83, 86) and with rural development programmes (involved in energy, housing or other related areas of policy) were reported to exist but were rarely used to maximise uptake (28, 56, 94). Careful programme management (55, 58, 77) with good feedback systems were recommended to respond to and correct problems at an early stage (77, 91).

Independent of the ideological approach pursued in promoting improved technologies (i.e. the respective roles of the state vs the market), the government role should include policy co-ordination, support for research and development, education and awareness-raising as well as financial planning and investment to make improved stoves programmes successful (87, 91, 94). By contrast, short-term and target-driven programmes (frequently related to strict funding schemes) were generally found not to achieve sustainability (57, 58, 77, 88, 98).

Community involvement: Involving the community throughout the process from the identification of an appropriate stove design to stove distribution was found to create a greater sense of ownership (51, 55, 56, 72, 88). Fostering women's engagement was particularly important (51, 54, 57, 85, 98, 109) (see also 'durability and specific design requirements' under Domain 1).

Creation of competition: Some programmes have successfully employed competition and reward schemes – between households, implementing companies or networks, villages or counties – to encourage uptake and sustained use of stoves (28, 53–56, 58, 59, 72, 104), and also to identify promising stove designs for local adoption (28).

User training: Insufficient user training on stove (and chimney) use, cleaning and maintenance negatively affect functionality and sustained use, leading to frustration and rejection of the improved technology (53–58, 76, 78, 82, 105). Hands-on training of users (64, 76, 91, 100, 109) was reported to be more effective than the provision of an instruction manual (60).

Post-acquisition support: A lack of, or inadequate, follow-up or after-sales services for improved stoves and chimneys was reported to result in stove malfunctioning and users experiencing difficulties with the stove (28, 53, 55, 58, 60, 72, 77, 78, 91, 105). The absence of a pre-arranged agreement to pay for after-sales service, and the lack of warranties, can result in users subsequently being reluctant to pay for repairs (58, 91, 105). Conversely, mandatory or upon-request after-sales/post-construction visits for minor repairs and stove maintenance were reported to promote sustainability (54, 64, 88, 91, 100).

Monitoring and quality control: Many of the included studies reported a lack of appropriate monitoring and quality control mechanisms in relation to stove production, installation and post-installation support (51, 53, 55–58, 60, 77, 85, 86, 89). Ensuring the allocation of adequate financial resources for monitoring the different stages of a dissemination campaign (54, 55, 57, 59) – including immediate verification of stove installation (57, 74, 91), follow-up checks (51, 57, 59, 91) and post-installation surveys (57, 59), – is important for successful adoption and use of ICS (61, 82).

4.3 Equity considerations on ICS uptake

Equity is critical in efforts to scale up improved stove interventions because it is generally those with the lowest incomes, those living in rural and more remote areas, and women who experience the greatest health risks, yet these groups are also the least able to access or afford improved stoves. The evidence from this review suggests that an explicit focus on equity as part of a programme's objective can facilitate the targeting of disadvantaged households.

With regard to poverty, some programmes have adopted mechanisms to reach families on lower incomes, including (i) a tiered approach offering different stove models and prices for higher- vs lower-income households (54, 105), (ii) subsidies (53, 56, 60, 72), (iii) payments in instalments (60, 105), and (iv) access to credit (110). The risk of exclusion of more disadvantaged families with market-based dissemination programmes (87) was reported in several settings (62, 69, 72, 77, 94), especially in rural areas (28, 59, 76, 94). This is because very disadvantaged groups with limited education (52, 59) tend to favour spending limited resources on what are seen as more pressing household priorities (including food and clothes) (71, 98) and hence generate little or no demand for improved stoves (59, 83).

In terms of rural/urban location, perceptions about the opportunity costs of fuel collection (76, 78) and fuel availability (56) both appear to play a part in determining uptake. Poor rural communities – who usually collect firewood and pay for little or nothing for their fuel – can be a difficult group to target. Two factors may contribute to this: first, they have little direct financial incentive for saving fuel; second, the availability of labour (and especially that of poorly educated women) results in a low perception of the opportunity costs of time spent collecting fuel and using inefficient stoves. As a consequence, commercial businesses tend to target more urban and other higher population density and income areas (53, 62), where the business is more feasible and profitable (77), as users often pay for fuelwood or other solid fuels and are more willing to pay for an improved stove (52).

A gendered approach is critical for adoption and sustained use of improved stoves, and the key message is that while better understanding of women's needs and involvement in technology development and implementation are vitally important (51, 62, 74, 85, 91), so too is greater involvement of men (65, 70, 76, 98). This is because men usually exercise more control over the household budget, and have more decision-making authority when it comes to changing the structure of the kitchen, or installing/buying an improved cookstove (70, 76, 98). However, although women's decision-making power is often limited (68, 76), there are examples where women were able to pay for the ICS using their savings which had been intended for purchasing clothes or additional food (71). Studies also reported that women could significantly influence their husbands in favour of ICS adoption through negotiations with other family members (e.g. mothers-in-law, co-wives) (71, 76, 98, 101). Further, the role of women in some projects was defined much more broadly than simply being the beneficiaries of improved stoves. There are examples of women being properly trained in stove manufacture, stove installation or as retail entrepreneurs (62, 74, 85). One way of specifically encouraging women to take on these roles is micro-loans for opening stove businesses to be offered only to women (74, 85).

While we are also aware of programmes that have supported acquisition of ICS in low-income communities through conditional cash transfer schemes, for example the Juntos programmes in Peru (111), no studies evaluating the impacts of these on equitable adoption were available for this review.

4.4 Summary of findings in relation to ICS

This review has included a total of 57 qualitative, quantitative and case studies, from a wide variety of settings. These studies have provided evidence of the influence on adoption and sustained use of ICS of some 31 factors, spread across all seven domains. All domains were well populated, with the possible exception of Domain 6 (Regulation, legislation and standards). Sensitivity analysis excluding weak studies led to little substantive change in the levels of evidence support across the domains. No evidence was found on the adoption and use of advanced combustion stoves (i.e. models using forced draught and gasification), reflecting the fact that these have only recently been introduced and so far lack evaluation of factors influencing their adoption and sustained use.

The nature of the available evidence does not support formal prioritisation of these factors or domains; all of the factors can be influential, most are inter-related, and many context-specific. Nevertheless, some appear to be critical to the extent that if these are not met, adoption and sustained use are unlikely. Accordingly, these are described as 'necessary but not sufficient'. Examples of some of these (note this is not an exhaustive list) include:

- Meeting users' needs, particularly for cooking main dishes and being able to use large enough pots;
- Providing valued savings on fuel;
- Offering products of a quality that meet user expectations and ensure durability;
- Having success with early adopters, in particular opinion formers;
- Guaranteeing support (e.g. loans) for businesses producing and promoting ICS;
- Ensuring support to users in initial use, and for maintenance, repair and replacement;
- Developing an efficient and reliable network of suppliers/retailers;
- Providing financial assistance for equitable access and/or for more expensive ICS.

Furthermore, some of the factors that are poorly supported by the available studies are still likely to be of importance. For example, the lack of evidence on standards, testing and certification is mainly a reflection of the lack of these instruments being available and implemented in practice, and a concomitant lack of attention in research studies.

Subsidy remains 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 to higher performing and more expensive ICS, but must be managed carefully to avoid adverse effects on markets and the perceived value of the technology. Conditional cash transfer schemes and other forms of 'smart' targeted subsidy – for which evidence was not available for this review – may well be important instruments and should be given attention in future research.

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. There is no standard approach for identifying setting-specific 'necessary and sufficient' factors.

Table 4.8: Characteristics of included studies on ICS, by study category

Author (year) ***(reference no.)***	**Country/ setting**	**Study design and sampling**	**Data collection**	**Data analysis***	**Quality appraisal#**	**Improved stove technology**			**Adoption (A) vs sustained use (S)**
						Stove type	**Potholes**	**Stove ventilation**	
				QUALITATIVE STUDIES (QL)					
Anderson (2007) *(68)*	India (rural)	Ethnographic case study: FGDs, 3 SSIs, 2 KIIs, PO	Interviews and FGDs with women users and non-users	Editing analysis	Strong	Bhagyalaxmi stoves (cement)	2	×	S
Chowdhury et al. (2011) *(70)*	Bangladesh (rural)	70 SSIs, 1 FGD, PO	Face-to-face survey and FGD with women users and non-users	Method not stated; descriptive narrative and tables	Weak	Mud stoves	2	✓	A/S
Christoff (2010) *(78)*	Mexico (rural)	4 FGDs	FGDs with women users	Thematic analysis	Strong	Patsari stoves Onil stoves	Multiple 1	✓ ✓	A
Gordon et al. (2007) *(73)*	Mongolia (urban)	3 FGDs, 6 SSIs	Mixed-gender FGDs with users and non-users	Editing analysis	Strong	Coal stoves	Not specified	✓	A
Jagoe et al. (2006a) *Qualitative findings (69)*	India (rural)	FGDs at baseline and follow-up	Separate FGDs with men and women users	Framework analysis	Moderate	Anandi stoves Sukhad stoves	1 2	✓ ✓	A
Jagoe et al. (2007a) *Qualitative findings (81)*	India (rural)	FGDs at baseline and follow-up	FGDs with women users and non-users	Framework analysis	Moderate	Bhagyalaxmi stoves Laxmi stoves	2 2	× ✓	A
Pandey (1989) *(84)*	Nepal (rural)	25 SSIs, PO	Interviews with women users and non-users	Method not stated; descriptive narrative	Moderate	Bikase stoves	2	×	A/S
Person et al. (2012) *(71)*	Kenya (rural)	40 SSIs	Interviews with women purchasers and stove promoters	Thematic analysis	Strong	Upesi Jiko charcoal stoves	1	×	A
Sesan (2012). *Findings on ICS (98)*	Kenya (urban**)	15 SSIs, 9 KIIs, PO	Interviews with women users	Method not stated; descriptive narrative	Moderate	Mainly Upesi Jiko charcoal stoves with/without eaves space	1	×/✓	A
Simon (2007) *(72)*	India (rural)	55 SSIs, 11 KIIs, PO	Interviews with women users, stove builders and stakeholders	Method not stated; descriptive narrative	Strong	Bhagylaxmi and Laxmi stoves and other models	1, 2	×/✓	A/S

Author (year) ***(reference no.)***	**Country/ setting**	**Study design and sampling**	**Data collection**	**Data analysis***	**Quality appraisal#**	**Improved stove technology**			**Adoption (A) vs sustained use (S)**
						Stove type	**Potholes**	**Stove ventilation**	
Sovacool and Drupady (2011) *Findings on ICS (77)*	Bangladesh (rural/urban)	Case study based on 48 SSIs/KIIs	Interviews with users and stakeholders	Narrative analysis	Moderate	Clay stoves	1-3	✓	A/S
Troncoso et al. (2007) *(76)*	Mexico (rural)	67 SSIs, 18 KIIs	Interviews with women users and non-users	Method not stated; descriptive narrative and tables	Moderate	Patsari stoves	Multiple	✓	A
Troncoso et al. (2011) *(88)*	Mexico (rural)	24 KIIs	Interviews with stakeholders, including stove builders	Method not stated; descriptive narrative	Moderate	Patsari stoves	Multiple	✓	A
Velasco (2008) *Findings on ICS (80)*	Mexico (rural)	24 SSIs, PO	Interviews with women users	Method not stated; descriptive narrative	Moderate	Patsari stoves	Multiple	✓	A
				QUANTITATIVE STUDIES (QN)					
Agurto-Adrianzen (2009) *(96)*	Peru (rural)	Cross-sectional survey (n=816); stove monitoring survey (n=82% of beneficiaries)	Interviews with heads of household (users/non-users)	Multivariable approach adjusting for confounders	Strong	Mud brick and metal frame/plate stove	Multiple	✓	A
Bensch and Peters (2011) *(97)*	Senegal (urban)	Cross-sectional survey (n=624) and KII	Interviews with users/non-users	Analytical approach without adjustment	Moderate	Portable Jambar charcoal stoves	Not specified	×	A
Damte and Koch (2011) *(93)*	Ethiopia (urban)	Cross-sectional survey (n=1577)	Interviews with users/non-users	Multivariable approach adjusting for confounders	Strong	Mirt Injera stoves Portable Lakech charcoal stoves	1 Not specified	× Not specified	S
George and Yadla (1995) (100)	India (rural)	Cross-sectional survey (n=390)	Interviews with main cooks	Descriptive comparison and analytical approach without adjustment	Weak	Mamta stoves	2	✓	A
Inayatullah (2011) *(99)*	Pakistan (rural)	Cross-sectional survey (n=100)	Interviews with male respondents	Multivariable logistic regression	Moderate	Biomass metal stoves	1	×	A
Jagoe et al. (2006b)*Quantitative findings (75)*	India (rural)	Before-and-after study (12 months) without control group (n=150)	Structured questionnaires at baseline, follow-up at 3 and 12 months	Analytical approach without adjustment	Weak	Anandi stoves Sukhad stoves	1 2	✓ ✓	A

Author (year) *(reference no.)*	**Country/ setting**	**Study design and sampling**	**Data collection**	**Data analysis***	**Quality appraisal#**	**Improved stove technology**			**Adoption (A) vs sustained use (S)**
						Stove type	**Potholes**	**Stove ventilation**	
Jagoe et al. (2007b) *Quantitative findings (79)*	India (rural)	Before-and-after study (12 months) with interventions and controls (n=156 + n=98)	Structured questionnaires at baseline, follow-up at 6 and 12 months	Multivariable approach adjusting for confounders	Moderate	Bhagyalaxmi stoves Laxmi stoves	2 2	× ✓	A
Levine and Cotterman (2012) *(90)*	Uganda (urban)	Randomised trial of multiple sale offers (n=1690)	Interviews with households during marketing visits	Multivariable approach adjusting for confounders	Moderate	Ugastove charcoal stoves	1	×	A
Miller and Mobarak (2011) *(65)*	Bangladesh (rural)	Randomised controlled trial (n=3079)	Interviews during marketing visits	Multivariable approach adjusting for confounders	Strong	Mud stoves Clay stoves	1 2	× ✓	A
Muneer and Mohamed (2003) *(101)*	Sudan (rural/urban)	Cross-sectional survey (n=300)	Interviews with wife and husband in household	Multivariable approach adjusting for confounders	Strong	Firewood/charcoal stoves	Not specified	Not specified	A
Mwangi (1992) *(95)*	Kenya (rural)	Cross-sectional survey (n=306)	Interviews with heads of household	Multivariable approach adjusting for confounders	Moderate	Kenya Ceramic Jiko charcoal stoves Portable Kuni Mbili stoves	1 1	× ×	A
Pandey and Yadama (1992) *(66)*	Nepal (rural)	Cross-sectional survey (n=100)	Interviews with women users	Analytical approach without adjustment	Weak	Bikase stoves	2	×	A
Pine et al. (2011) *(48)*	Mexico (rural)	Longitudinal study with baseline and monthly follow-up surveys (n=233)	Interviews with users over 10 months	Univariate multinomial logistic regression	Moderate	Patsari stoves	3	✓	A
Pushpa (2011) *(102)*	India (rural)	Cross-sectional survey (n=492)	Interviews with users/non-users	Analytical approach without adjustment	Weak	Several stove models	Not specified	✓	A
Silk et al. (2012) *(103)*	Kenya (rural)	Cross-sectional surveys (n=1,250) and follow-up (n=293)	Interviews with women; follow-up with purchasers	Analytical approach without adjustment	Moderate	Upesi Jiko biomass and charcoal stoves	1	×	A
Wallmo and Jacobson (1998) *(67)*	Uganda (rural)	Cross-sectional survey (n=165)	Interviews with users/non-users	Descriptive comparison and analytical approach without adjustment	Weak	Lorena stoves	3	✓	A

Author (year) *(reference no.)*	Country/ setting	Study design and sampling	Data collection	Data analysis*	Quality appraisal[#]	Improved stove technology			Adoption (A) vs sustained use (S)
						Stove type	Potholes	Stove ventilation	
CASE/POLICY STUDIES (CS)									
Amarasekera 1989 *(52)*	Sri Lanka (rural/urban)	Surveys (n=not stated)	Not described	Descriptive narrative	Weak	Several mud stove models	1, 2	×	A
Barnes et al. (2012a). *Case study I (53)*	India, western Maharashtra (rural/urban)	Mixed-method approach: household survey (n=73) and FGDs, SSIs, KIIs	Interviews and FGDs with users and non-users, stove builders and other stakeholders	Descriptive narrative and statistics	Strong	Laxmi, Grihalaxmi, Parvati and Bhagyalaxmi stoves Portable Priagni stoves	1, 2 1	✓/× ×	S
Barnes et al. (2012b). *Case study II (54)*	India, Haryana (rural/urban)	Mixed-method approach: household survey (n=94) and FGDs, SSIs, KIIs	Interviews and FGDs with users and non-users, stove builders and other stakeholders	Descriptive narrative and statistics	Strong	Mud and cement stoves	1, 2	✓	S
Barnes et al. (2012c). *Case study III (55)*	India, Karnataka (rural/urban)	Mixed-method approach: household survey (n=190) and FGDs, SSIs, KIIs	Interviews and FGDs with users and non-users, stove builders and other stakeholders	Descriptive narrative and statistics	Strong	Astra Ole and Sarale Ole stoves (mud) Portable Priagni, Swosthee and Chara Ole stoves	1, 2 Not specified	✓/× ×	S
Barnes et al. (2012d). *Case study IV (56)*	India, Gujarat (rural/urban)	Mixed-method approach: household survey (n=79) and FGDs, SSIs, KIIs	Interviews and FGDs with users and non-users, stove builders and other stakeholders	Descriptive narrative and statistics	Strong	Mamta, Supriya, Priya, Kiran, Sneha, Grihalaxmi and Kamdhenu stoves	1, 2	✓/×	S
Barnes et al. (2012e). *Case study V (57)*	India, Andhra Pradesh (rural/urban)	Mixed-method approach: household survey (n=134) and FGDs, SSIs, KIIs	Interviews and FGDs with users and non-users, stove builders and other stakeholders	Descriptive narrative and statistics	Strong	Sukhad, Gayathri and Gramalakshmi stoves Portable stoves	2 Not specified	✓/× ×	S
Barnes et al. (2012f). *Case study VI (58)*	India, West Bengal (rural/urban)	Mixed-method approach:household survey (n=100) and FGDs, SSIs, KIIs	Interviews and FGDs with users and non-users, stove builders and other stakeholders	Descriptive narrative and statistics	Strong	Mud/cement biomass and coal stoves; Portable stoves	1–3 Not specified	✓/× ×	S
GERES (2009) *(59)*	Cambodia (urban)	Mixed-method approach: cross-sectional survey (n=1,600) and SSIs (n=51)	Interviews with users and stove builders	Descriptive narrative and statistics	Strong	New Lao charcoal stoves	1	×	A/S

Author (year) *(reference no.)*	**Country/ setting**	**Study design and sampling**	**Data collection**	**Data analysis***	**Quality appraisal#**	**Improved stove technology**			**Adoption (A) vs sustained use (S)**
						Stove type	**Potholes**	**Stove ventilation**	
Kürschner et al. (2009) *(60)*	Bangladesh (rural/urban)	Mixed-method approach: surveys, interviews, FGD (n=450 overall)	Interviews with users, non-users and stove builders	Descriptive narrative	Moderate	Mud/clay stoves	1, 2	✓	A/S
Masera et al. (2005) *(89)*	Mexico (rural)	Cross-sectional survey (n=42)	Interviews with users	Descriptive narrative	Moderate	Patsari stoves	Multiple	✓	A
Mounkaila (1989) *(61)*	Niger (urban)	Survey and KIIs (n=unknown)	Not described	Descriptive narrative and statistics	Moderate	Mai Sauki metal stoves	1	×	A
Namuye (1989) *(62)*	Kenya (urban)	Survey (n=unknown)	Interviews with users, stove producers and stove promoters	Descriptive narrative	Weak	Kenya Ceramic Jiko charcoal stoves	1	×	A
Osei (2010) *(110)*	Ghana (rural/urban)	Business model case study (3 KIIs)	Not described	Descriptive narrative	Weak	Toyola charcoal stoves	1	×	A
Sawadogo (1989) *(63)*	Burkina Faso (urban)	Mixed-method approach: survey, interviews and PO	Not described	Descriptive narrative and statistics	Moderate	Ouaga stoves; Mixte wood or charcoal stoves	1	×	A
Shastri et al. (2002) *(64)*	India (rural)	Cross-sectional surveys (n=155 in 1994 and n=132 in 2001)	Interviews with housewives	Descriptive narrative and statistics	Strong	Astra stoves	2, 3	✓	S
Shrimali et al. (2011) *(94)*	India (rural/urban)	12 KIIs	Interviews with company representatives	Descriptive narrative and statistics	Strong	Several stove models	Not specified	Not specified	S
Simon (2010) *(87)*	India (rural)	55 SSIs, surveys, 11 KII, PO	Interviews with women users, stove builders and NGO employees	Descriptive narrative	Moderate	Laxmi, Bhagyalaxmi stoves and other models	1, 2	✓/×	A/S
Sinton et al. (2004) *(28)*	China (rural/urban)	Mixed-method approach: household survey (n=3,476) and stakeholders survey (n=108)	Open-ended interviews with structured questionnaire	Descriptive narrative and statistics	Strong	Biomass and coal stoves	Multiple	✓	S
Sudjarwo et al. (1989) *(82)*	Indonesia (rural)	Surveys of users and non-users (n=1,000) and PO	Interviews with households, stove producers and stove traders	Descriptive narrative and statistics	Moderate	SAE pottery stoves	2	×	A/S

Author (year) *(reference no.)*	Country/ setting	Study design and sampling	Data collection	Data analysis*	Quality appraisal#	Improved stove technology			Adoption (A) vs sustained use (S)
						Stove type	Potholes	Stove ventilation	
USAID/Winrock (2008) *(104)*	Peru (rural)	Mixed-method approach: survey (n=169) and FGDs (n=unknown)	Not described	Descriptive narrative and statistics	Moderate	Inkawasina rocket stoves	2	✓	S
USAID/Winrock (2009) *(85)*	Bangladesh (urban)	Survey (n=625)	Interviews with main cooks	Descriptive narrative	Moderate	Portable and fixed BCSIR stoves Grihalaxmi stoves	1, 2 1	✓ ×	A
World Bank (2004a). *Case study I (51)*	Guatemala (rural)	24 SSIs, 2 FGDs	Interviews and discussions with users	Descriptive narrative and statistics	Moderate	Tezulutlan plancha stoves	3	✓	A
World Bank (2004b). *Case study II (86)*	Guatemala (rural)	31 SSIs and 2 FGDs	Interviews and discussions with users	Descriptive narrative and statistics	Moderate	Plancha stoves	1–4	✓	A
World Bank (2004c). *Case study III (83)*	Guatemala (rural)	32 SSIs and 2 FGDs	Interviews and discussions with users	Descriptive narrative and statistics	Moderate	Plancha stoves	3	✓	A
World Bank (2010a). *Case study I (91)*	Bangladesh (rural/urban)	Literature review supported by surveys with users (n=142)§ and FGDs and KIIs	Survey with women users (n=70)#, interviews with technicians and other stakeholders (n=41)§	Descriptive narrative	Moderate	Portable or semi-submerged mud stoves Fixed mud stoves	1 1, 2	× ✓	S
World Bank (2010b). *Case study II (105)*	Bangladesh (rural/urban)	Literature review supported by surveys with users (n=142)§ and FGDs and KIIs	Survey with women users (n=70)§, interviews with technicians and other stakeholders (n=41)§	Descriptive narrative	Moderate	Mud or mud/brick stoves	1, 3	✓	S
World Bank (2010c). *Case study III (74)*	Bangladesh (urban)	Literature review supported by surveys with users (n=142)§ and FGDs and KIIs	Survey with women users (n=70)#, interviews with technicians and other stakeholders (n=41)§	Descriptive narrative	Moderate	Portable and fixed BCSIR stoves Grihalaxmi stoves	1, 2 1	✓ ×	A

✓=Yes, ×=No.

BCSIR=Bangladesh Council of Scientific and Industrial Research; FDG=focus group discussion; KII=key informants interview; PO=participant observation; SSI=semi-structured interview.

*Data analysis for quantitative studies: (i) *descriptive comparison*=summary of attributes of adopters; (ii) *analytical approach*=comparison of adopters with non-adopters univariately; (iii) *multivariable approach*=summary of factors associated with adoption after adjustment for potential confounders/covariates.

#Quality appraisal of studies was conducted using separate quality assessment tools for each type of evidence resulting in an overall score of strong, moderate or weak. Please note that quality appraisal across evidence types is not directly comparable.

§These figures are cumulative for all the World Bank 2010 (a–e) case studies; a breakdown for each case study is not available

5. Evidence on adoption and use of clean fuels

This section presents findings from the 44 studies investigating fuel switching from biomass (firewood, charcoal and other biomass fuels), coal and kerosene to cleaner fuels, namely LPG, biogas, solar cookers and alcohol fuels. Although there are some general characteristics influencing uptake which are common to all clean fuels (see sections 5.5.2 and 6.2), there are sufficient distinct features regarding their production, supply, adoption and use to warrant separate reporting of the findings for each of these fuels in sections 5.1 to 5.4. For each of the clean fuels, results are reported under the seven domains plus equity.

To facilitate the comparison across different fuels, graphical representations illustrating factors affecting uptake are presented at the beginning of each subsection, similar to the approach used for ICS (Chapter 4). The graphics display a full list of factors, some of which were found to be common across ICS and clean fuels, while others were found to be fuel-specific. This approach aims to facilitate the visual identification of those factors for which limited or no evidence is reported in relation to the different fuel categories.

Absence of evidence for some of the listed factors – in particular relating to LPG, solar cooking and alcohol fuels – should, however, be treated with caution as the overall number of included studies for clean fuels is rather limited. Indeed, the gaps in the evidence need to be recognised but should not be interpreted to mean that these factors or domains are of less or no importance. Among the reasons for the limited evidence are the topics chosen for investigation by those conducting research and the limited availability of certain study approaches, in particular qualitative studies, in the field of clean fuels.

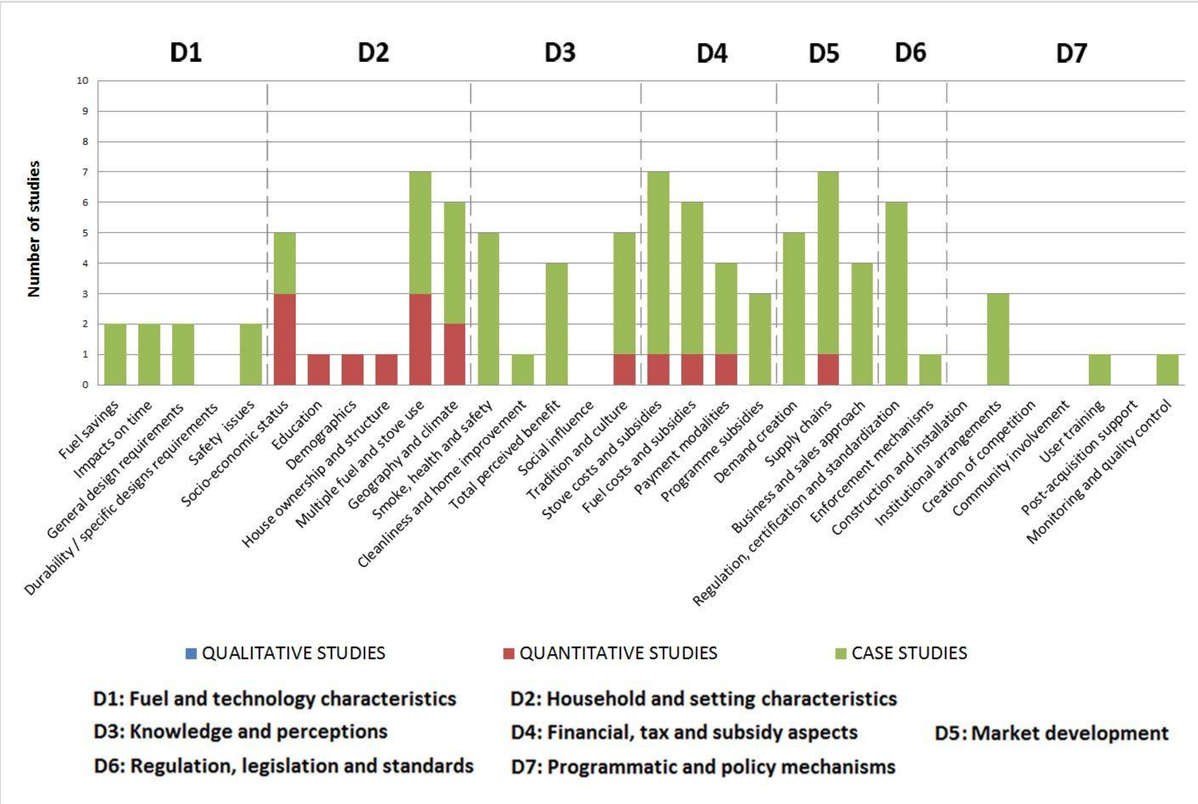
5.1 Liquefied petroleum gas

A total of 12 studies were found reporting on the adoption and use of LPG and gas stoves. Studies were classified as quantitative (n=3) and case/policy studies (n=9); no qualitative studies were identified. There was a mix of small-scale studies and larger studies of subnational or national scope, with studies conducted in South Asia (n=3), Africa (n=3), Western Pacific (n=1) and Latin America/Caribbean (n=5). Nine of the studies assessed factors influencing adoption of LPG (initial switch up to one year); two studies assessed sustained use over time (as part of national campaigns) and one study assessed elements of both adoption and sustained use. In terms of methodological quality, studies were found to be variable, with two, five and five studies scoring as strong, moderate and weak respectively.

The majority of studies focused on switching from biomass to LPG, while one reported on the large-scale Indonesian conversion from kerosene to LPG for cooking, which had (at the time of reporting) involved more than 40 million households (37). Another study described the impact of market liberalisation of LPG in Brazil (32). The case/policy studies focused mainly on the long-term assessment of national policy affecting level of subsidies and LPG usage patterns (84, 113). More detailed information on study characteristics is presented in Table 5.8 at the end of this section.

As illustrated in Figure 5.1, 26 factors were identified as influencing the uptake of LPG across all framework domains. Evidence from quantitative studies is limited to Domains 2 and 4, whereas evidence from case/policy studies is spread across all domains (albeit very thinly for Domains 1 and 7). Evidence for most of the factors under Domains 4 and 5 is drawn from a more extensive evidence base, whereas Domains 1, 3 and 7 are supported by limited evidence. The gaps in the evidence need to be recognised but should not be interpreted to mean that these domains are less important for LPG uptake. For example, if we consider the factor 'durability and specific design characteristics' under Domain 1, where no evidence is reported, this is likely to reflect the lack of studies focusing on this aspect through exploring users' perspectives, rather than this factor being unimportant in adoption and sustained use of LPG.

Figure 5.1: Factors influencing the uptake of LPG across seven domains (D1–D7), by study type and number of studies



Following exclusion of the five weak studies through sensitivity analysis, evidence was available for 23 out of the 26 factors, with some representation across all the seven domains, although this was very limited for Domains 3, 6 and 7. The factors lost (as these had been reported only within weak studies) included 'programme subsidies' under Domain 4 and 'user training' and 'monitoring and evaluation' under Domain 7, further emphasising the need to strengthen research on adoption and use of LPG as a clean fuel.

5.1.1 Domain 1: Fuel and technology characteristics

Fuel savings: Although LPG is generally considered to be an expensive fuel, when costs for biomass fuels are relatively high LPG uptake can be favoured (114). In Indonesia, users reported monthly savings associated with LPG use instead of kerosene use, which was considered an important enabler for successful fuel switching (37).

Impacts on time: Users appreciate faster cooking with LPG stoves (37). The expectation that cooking with LPG is quicker than wood was also documented and was reported as a reason for switching among firewood users (114).

General design requirements: A large majority of the recipients of LPG conversion packages given in Indonesia reported overall satisfaction with the LPG stoves and 3 kg LPG refills (37). Stoves and bottles were received in good condition and stoves were reported to be easy to use and maintain, and were largely preferred over kerosene stoves (37). A suggestion made in a market survey conducted in Haiti was for LPG stoves to be designed to accommodate larger pots (115), in order to facilitate cooking in households with a larger family size, especially in rural areas (115).

Safety issues: Very few studies report on this aspect, but it merits special attention, as safety concerns are frequently reported. Safety issues arise primarily from leaks and bottle failures caused by inadequate manufacture and safety checks on bottles and valves, which can result in explosions (37, 116). This issue is discussed further under Domain 3.

Table 5.1: Domain 1. Fuel and technology characteristics: LPG

Factor	Examples	Country and setting*	Type and quality of evidence**
Impacts on time	• Cooking time	Indonesia (37), Nicaragua (114)	CS=2 *(2=M)*
Fuel savings	• Impacts on fuel purchase	Indonesia (37), Nicaragua (114)	CS=2 *(2=M)*
General design requirements	• Design to meet users' needs	Indonesia (37), Haiti (115)	CS=2 *(1=M, 1=W)*
Safety issues	• Risk of explosions • Quality of equipment	Indonesia (37), Sudan (116)	CS=2 *(1=M, 1=W)*

CS=policy and case studies; *M*=moderate; *W*=weak. *All factors are supported by findings in rural as well as urban settings. **Quality of evidence not comparable across different study design.

5.1.2 Domain 2: Household and setting characteristics

Socio-economic status: Measures of income and/or household expenditure are important features of LPG uptake (113, 117–119) and one study reported that achieving a complete switch requires reaching a certain threshold of income or household expenditure (120). Having an electricity connection seems to promote fuel switching (119), probably in part due to higher SES, but electricity access may also be enabling in other ways. The studies reporting this, however, did not provide data or insights to help with further explanation of the finding.

House ownership and structure: The number of rooms in the house was reported to be positively associated with LPG switching in urban areas, and this was thought to be probably due to the association with wealth (119).

Education: In an analysis of nationally representative survey data from Guatemala, a higher level of education was associated with adoption (119). This same study provided insights into a number of other social, economic and cultural factors: for example, indigenous ethnicity was a barrier to uptake (119), and this was presumed to be due to cultural preferences (e.g. food preparation) in addition to associated socio-economic factors.

Demographics: In terms of household size, uptake was found to be greater in households with fewer members in one national study from Guatemala (119). In that study, a higher proportion of females in the home (availability of female labour) (119) and of those with a lower level of education (availability of labour with low economic value) (119) acted as barriers to adoption; these findings were interpreted as being the result of the low perceived opportunity cost of the additional time spent using traditional (solid) fuels and stoves.

Table 5.2: Domain 2. Household and setting characteristics: LPG

Factor	Examples	Country and setting*	Type and quality of evidence**
Socio-economic status	• Income • Household expenditure • Assets	Guatemala (118, 119), India (113, 117), Mozambique (120)	QN=3 *(2=S, 1=M)* CS=2 *(2=W)*
House ownership and structure	• Number of rooms (may be a marker of wealth)	Guatemala (119)	QN=1 *(1=S)*
Education	• Years of schooling for men and women	Guatemala (119)	QN=1 *(1=S)*
Demographics	• Household size • Ethnicity	Guatemala (119)	QN=1 *(1=S)*
Multiple fuel and stove use	• Availability of traditional fuels • Time since fuel introduction	Brazil (32), Guatemala (118, 119), India (117), Indonesia (37) Morocco (121), Nicaragua (114)	QN=3 *(2=S, 1=M)* CS=4 *(3=M, 1=W)*
Geography and settings	• Urban/rural • Road infrastructure	Guatemala (118, 119), India (92, 113), Mozambique (120), Nicaragua (114)	QN=2 *(2=S)* CS=4 *(1=M, 3=W)*

QN=quantitative studies; CS=policy and case studies; *S*=strong*; M*=moderate; *W*=weak. *All factors are supported by findings in rural as well as urban settings. **Quality of evidence not comparable across different study design.

Multiple fuel and stove use: Where data on multiple fuel use in developing countries were available, LPG was almost always accompanied by use of more traditional fuels, generally biomass (32, 92, 117, 118, 120). Although existing widespread use of LPG was enabling (including use by the commercial sector as this enhances demand in and supply to a given location) (32, 121), the perception of lower fuel costs associated with traditional practices acted as a barrier to change. For example, living on a farm (i.e. greater availability of biomass) (119) or being able to buy small amounts of wood on a daily basis (which avoids large periodic outlays required for gas refills) (114) were found to discourage LPG adoption.

Geography and settings: Adoption and use was greater in urban settings (92, 114, 119, 120) due to higher income and fuel availability and because time savings tend to be more highly valued by urban dwellers (119). This finding was supported by an additional study conducted in Sri Lanka and not formally included in the review, as it considered transition to multiple clean fuels including LPG, biogas and electricity (122). According to this study, women in the labour market valued time savings much more than women who did not engage in paid work, and this served as an incentive to switch from traditional to modern fuel. Rural areas also face relatively higher prices of LPG (due to supply issues as further discussed under Domain 5) (120) and less access to credit (118), which act as barriers to uptake.

5.1.3 Domain 3: Knowledge and perceptions

Table 5.3: Domain 3. Knowledge and perceptions: LPG

Factor	**Examples**	**Country and setting***	**Type and quality of evidence****
Smoke, health and safety	• Health considerations • Safety concerns	Haiti (115), Indonesia (37), Mozambique (120), Nicaragua (114), Sudan (116)	CS=5 *(2=M, 3=W)*
Cleanliness and home improvement	• Cleaner kitchen	Indonesia (37)	CS=1 *(1=M)*
Total perceived benefit	• Overall perceived advantages • Opportunity costs of traditional fuels and practices	Indonesia (37), Morocco (121), Mozambique (120), Sudan (116)	CS=4 *(1=M;3=W)*
Tradition and culture	• Suitability for preparing local dishes • Food taste • Cooking for large gathering	Brazil (32), Guatemala (119), Haiti (115), Mozambique (120), Nicaragua (114)	QN=1 *(1=S)* CS=4 *(2=M, 2=W)*

QN=quantitative studies; CS=policy and case studies; *S*=strong*; M*=moderate*; W*=weak. *All factors are supported by findings in rural as well as urban settings. **Quality of evidence not comparable across different study design.

Smoke, health and safety: Negative perceptions and fear of LPG explosions, due to leaks and poor quality equipment (37, 114) or lack of knowledge on the safe use LPG (116), were reported as barriers to LPG adoption (37, 114–116, 120). Some users considered it a toxic fuel (120). Safety fears could also adversely affect traders' willingness to stock LPG (120), which in turn impacts on fuel availability (as further discussed in Domain 5). No direct health benefits associated with LPG use and reduced emissions were reported in the identified studies, but perceptions that wood was a dirtier fuel and could negatively impact on health were expressed (114).

Cleanliness and home improvement: Having a cleaner kitchen was listed by users among the LPG benefits (37).

Total perceived benefits: Prior knowledge of LPG use was usually accompanied by a greater level of awareness of its benefits and increasing willingness to adopt (116, 120, 121). Users considered the LPG equipment (i.e. LPG stove and LPG refill bottles) easy to use (37).

Tradition and culture: Cultural aspects such as cooking habits and food taste, as found in relation to uptake of ICS, are also important in relation to uptake of LPG (114, 115, 119, 120). Preference for food tasting of smoke and the habit of cooking outside can reduce the likelihood of LPG adoption and use, especially in rural areas (119, 120). On the other hand, the widespread and growing use of LPG in many developing countries suggests that such preferences only operate as a barrier in some circumstances, and can change over time and with increasing familiarity with LPG (32).

5.1.4 Domain 4: Financial, tax and subsidy aspects

Stove costs and stove subsidies: The initial purchase price of the LPG stove and gas bottles were among the most frequently reported factors limiting uptake (92, 114, 116, 118, 121). Direct subsidies on stoves and bottles were used to promote adoption (37, 113, 118). For example, such subsidies supported the large-scale conversion of kerosene to LPG in Indonesia, where LPG stoves and bottles were initially provided for free, with users responsible for paying for subsequent refills; the LPG price, however, remained subject to a general subsidy (37).

Fuel costs and subsidies: The price of the LPG fuel itself (as opposed to the initial costs of stove, regulator and gas bottle) is an important issue in relation to resistance to fuel switching (118), especially for poorer and rural households (92, 113, 120). For these, low-price availability of traditional fuels and poor road infrastructure (which increases fuel price due to transportation costs) negatively influenced uptake (116, 120). Fuel subsidy may therefore be an issue of critical importance (32, 113). Fuel subsidies are argued to have been one of the main reasons for widespread uptake of LPG in Brazil prior to market liberalisation, and withdrawal of these subsidies led to poorer families reducing the amount of cooking and/or reverting to solid fuel (32). This, in turn, led to the introduction of a targeted benefit for low-income families in what appears to have been an effective means of promoting and maintaining LPG use among the poorer segments of society. In India, LPG subsidies have been available for over 20 years and different LPG consumption patterns have been observed across Indian states, with the northern region and some of the more prosperous states reporting higher number of LPG connections and LPG use (92, 113). Misuses of such general fuel subsidies were also reported (e.g. LPG subsidies used for fuelling air conditioning devices or vehicles, rather than for cooking purposes) (32, 92).

Table 5.4: Domain 4. Financial, tax and subsidy aspects: LPG

Factor	Examples	Country and setting*	Type and quality of evidence**
Stove costs and subsidies	• Initial stove and bottle costs • Availability of initial subsidies	Guatemala (118), India (92, 113), Indonesia (37), Morocco (121), Mozambique (120), Nicaragua (114),	QN=1 *(1=S)* CS=6 *(3=M, 3=W)*
Fuel costs and subsidies	• Price of fuel and refilling costs • Fuel subsidies	Brazil (32), India (92, 113), Mozambique (120), Guatemala (118), Sudan (116)	QN=1 *(1=S)* CS=5 *(2=M, 3=W)*
Payment modalities	• Availability of loans, credit and instalments	Guatemala (118), Indonesia (37), Mozambique (120), Sudan (116)	QN=1 *(1=S)* CS=3 *(1=M, 2=W)*
Programme subsidies	• Government support • Financial incentives	Haiti (115), Morocco (121), Sudan (116)	CS=3 *(3=W)*

QN=quantitative studies; CS=policy and case studies; *S*=strong*; M*=moderate*; W*=weak. *All factors are supported by findings in rural as well as urban settings. **Quality of evidence not comparable across different study design.

Payments modalities: Methods of payment for LPG stoves and bottles include loans, credit and payments in instalments (116, 118, 120). Since users struggle with the recurrent high cost of LPG refills, the use of smaller 3 kg bottles to reduce these costs was found to be beneficial (37).

Programme subsidies: Aspects such as the provision of financing facilities for retailers (115), financial incentives to rural entrepreneurs to set up an LPG business (121) and programmes/initiatives covering the costs of user training on safe LPG use (116) were all reported as positive factors in setting up sustainable LPG markets.

5.1.5 Domain 5: Market development

Demand creation: In Indonesia, demand for LPG was fostered by widespread media promotion (37). Targeting potential customers in local dialects (121) and safe cooking events were used in other countries, such as Sudan, as part of participatory projects with low-income communities (116). Consumer profiling for effective marketing was also recommended (115, 120).

Supply chains: Distribution and supply play a key role in LPG uptake. Supply is strongly influenced by oil prices, and the extent to which a country is a producer or importer of oil. In addition, policies on national/regional supply and distribution planning for LPG and LPG appliances were found to be important (32, 37, 115, 116, 119). In Indonesia, for example, calculations were made on the amount of LPG required, based on the respective energy content of kerosene and LPG, to ensure that supply of the latter would meet household energy needs, and local distributors of kerosene were encouraged to change to supplying LPG (37). Conversely, limited LPG availability and distributional problems were reported to limit the continuous use of LPG (114, 120).

Table 5.5: Domain 5. Market development: LPG

Factor	Examples	Country and setting*	Type and quality of evidence**
Demand creation	• Strategies used to increase demand	Indonesia (37), Haiti (115), Morocco (121), Mozambique (120), Sudan (116)	CS=5 *(1=M, 4=W)*
Supply chains	• Supply infrastructure • Road infrastructure • Fuel availability, importation and stock	Brazil (32), Haiti (115), Indonesia (37), Mozambique (120), Nicaragua (114), Sudan (116)	QN=1 *(1=S)* CS=6 *(3=M, 3=W)*
Business and sales approach	• Factors favouring market expansion	Indonesia (37), Morocco (121), Mozambique (120), Sudan (116)	CS=4 *(1=M, 3=W)*

QN=quantitative studies; CS=policy and case studies; *S*=strong*; M*=moderate*; W*=weak. *All factors are supported by findings in rural as well as urban settings. **Quality of evidence not comparable across different study design.

Business and sales approaches: Approaches to favour market growth and to reduce LPG costs include market expansion (for example extending demand through LPG use in schools and businesses) (32), bulk transportation (120), and credit mechanisms to increase commercial use (120, 121). This can particularly help price stability in rural areas (121). In Indonesia, extensive opportunities for the private sector to invest in building private bottle refilling stations across much of the country favoured the acceleration of the programme (37).

5.1.6 Domain 6: Regulation, legislation and standards

Table 5.6: Domain 6. Regulation, legislation and standards: LPG

Factor	Examples	Country and setting*	Type and quality of evidence**
Regulation, certification and standardisation	• Price volatility • Importation costs • Design standards and certification	Brazil (32), Haiti (115), India (92), Indonesia (37) Mozambique (120), Nicaragua (114)	CS=6 *(2=M, 4=W)*
Enforcement mechanisms	• Whether or not effective mechanisms are adopted • Penalties for non-compliance	Indonesia (37)	CS=1 *(1=M)*

CS=policy and case studies; *M*=moderate; *W*=weak. *Enforcement mechanisms supported only by findings related rural settings (37). **Quality of evidence not comparable across different study design.

Regulation legislation and standardisation: Policy and legislation are fundamental to controlling LPG price volatility (92), including importation issues (115) and regional price variations (120). Price volatility (114) and lack of control over large regional price differentials (120) adversely affect adoption and sustained use of this fuel. As noted above for Domain 4, legislation to allow low-income households to continue buying LPG emerged as necessary in Brazil subsequent to market liberalisation (32). In Indonesia, the establishment of the legal basis and parliamentary approval for the conversion programme were important in obtaining budgetary support (37).

Enforcement mechanisms: Enforcement of standards is required to ensure LPG safety (37); lack of oversight mechanisms and insufficiently regulated expansion of the LPG market contribute to the release into the market of unsafe products, which may further reinforce general fears concerning the use of LPG (37).

5.1.7 Domain 7: Programmatic and policy mechanisms

Institutional arrangements: Strong institutional arrangements to prepare for large-scale implementation and the presence of an implementing agency with overall responsibility were argued to be an essential component for the success of the LPG conversion programme in Indonesia (37). Government support at the highest level was also found to be important in this programme. In particular, having one ministry to co-ordinate other ministries and stakeholders facilitated programme implementation (37). In general, various institutional arrangements are needed to address key issues of price volatility (92) and ensuring adequate LPG imports (115).

User training: Small-scale initiatives to support user training for safe use of LPG are valuable and were found to positively affect demand (116). Provision of user training is an aspect which should not be overlooked as a means of reducing fear of explosions (116).

Monitoring and quality control: There is little documentation on the role monitoring and evaluation can and should play in large-scale conversion initiatives, with only one study describing the importance of this in a small-scale intervention (116).

Table 5.7: Domain 7. Programmatic and policy mechanisms: LPG

Factor	Examples	Country and setting*	Type and quality of evidence**
Institutional arrangements	• Stakeholder co-ordination • Government role	Haiti (115), India (92), Indonesia (37)	CS=3 *(1=M, 2=W)*
User training	• Training in safe LPG use	Sudan (116)	CS=1 *(1=W)*
Monitoring and quality control	• Monitoring of implementation • User feedback	Sudan (116)	CS=1 *(1=W)*

CS=policy and case studies; *M*=moderate; *W*=weak. *Factors supported by findings related to either urban (116), rural (37) or both settings (114). **Quality of evidence not comparable across different study design.

5.1.8 Equity considerations in relation to LPG uptake

Only a few studies addressed issues of poverty and urban/rural location, with no studies specifically looking into gender issues.

The aspect that most clearly emerges in relation to LPG adoption and use is the problem of disadvantaged families being unable to afford the cost of a new LPG stove and bottle, and the cost of refilling bottles. Both were found to be prohibitive among poorer communities when no form of subsidy or financial support was applied (116, 120, 121). However, the extent to which subsidies for the initial costs (stove and bottle) and the ongoing fuel costs can overcome inequalities in access was debated (92). Two Indian studies reported that subsidies were primarily directed at the middle-income groups (92, 113) who were likely to be able to buy and use LPG independent of subsidies (92), lending support to the concept of graded subsidies such as those used in Brazil (32). Microfinance schemes, however, can be successful in supporting disadvantaged families in acquiring LPG equipment (116, 120, 121), but refilling costs may continue to be a barrier.

LPG adoption and sustained use in rural areas encounters similar problems. The high price of LPG in rural areas, which may be as much as three times higher than in urban areas (120), is related to the higher cost of distribution (113) and exacerbated by poor road infrastructure (116, 120, 121). Such high costs discourage LPG use in rural areas, with less access to credit for the initial purchase of the LPG stove and bottle being additional limiting factors (118).

Table 5.8: Characteristics of included studies on LPG, by study category

Author (year) *(reference no.)*	**Country/ Setting**	**Study design and sampling**	**Data collection**	**Data analysis***	**Quality appraisal#**	**Adoption (A) vs sustained use (S)**	**Baseline fuel**	**Technology package**
QUANTITATIVE STUDIES (QN)								
Edwards and Langpap (2005) *(118)*	Guatemala (rural/urban)	ENCOVI survey (n=3,424 rural + n=3,852 urban)	Household interviews	Multivariable approach adjusting for confounders	Strong	A	Firewood	LPG stove and gas bottle
Heltberg (2005) *(119)*	Guatemala (rural/urban)	ENCOVI survey (n=3,424 rural + n=3,852 urban)	Household interviews	Multivariable approach adjusting for confounders	Strong	A	Firewood	Not specified
Rogers (2009) *(117)*	India (rural)	Cross-sectional survey (124 users + 124 non-users)	Face-to-face interviews with heads of household	Analytical and multivariable approaches adjusting for confounders	Moderate	A/S	Firewood, crop residues	Not specified
CASE/POLICY STUDIES (CS)								
Bates (2009) *(116)*	Sudan (urban)	Community-based project (n=1,100) with a participatory approach.	Not described	Descriptive narrative	Weak	A	Firewood, charcoal	LPG stove, gas bottle, connectors and hotplates
Budya and Arofat (2011) *(37)*	Indonesia rural/urban)	Baseline survey (n=500), user surveys (n=550 and n=288)	Several approaches, including market surveys	Descriptive narrative and statistics	Moderate	A	Kerosene	LPG stoves, 3 kg bottle, hose pipe and regulator
Elgarah (2011) *(121)*	Morocco (rural/urban)	Interviews with KI (n=3)	Phone interviews	Descriptive narrative	Weak	A	Not specified	LPG stove and gas bottle
Lucon et al. (2004) *(32)*	Brazil (rural/urban)	Ecological study covering 1970-2002	National statistics	Descriptive narrative and statistics	Moderate	S	Firewood	LPG stoves, 13 kg bottles
Pandey and Morris (2006) *(92)*	India (rural/urban)	Ecological study on LPG subsidisation	National statistics	Descriptive narrative and statistics	Weak	S	Not specified	Not specified

Author (year) *(reference no.)*	**Country/ Setting**	**Study design and sampling**	**Data collection**	**Data analysis***	**Quality appraisal#**	**Adoption (A) vs sustained use (S)**	**Baseline fuel**	**Technology package**
Terrado and Eitel (2005) *(114)*	Nicaragua (rural/urban)	Cross-sectional surveys with HHs (n=unknown) and business (n=93)	Interview-based questionnaires	Descriptive narrative and statistics	Moderate	A	Firewood	Not specified
USAID (2005) *(120)*	Mozambique (urban)	FGDs (overall n=40) and market surveys (n=400)	Interviews with customers, fuel traders and food vendors	Descriptive narrative	Weak	A	Mainly charcoal	One/two burners LPG stoves and 5.5 kg bottles
USAID (2010) *(115)*	Haiti (rural)	Surveys and FGDs (n=unknown)	Interviews with food-vendors and customers	Descriptive narrative	Weak	A	Mainly charcoal	Not specified
Viswanathan and Kumar (2005) *(113)*	India (rural/urban)	Cross-sectional survey for three survey periods (n=unknown)	Sample collected by the National Sample Survey Organisation	Descriptive narrative and statistics	Moderate	A	Firewood, dung	Not specified

ENCOVI=Encuesta Nacional de Condiciones de Vida; FDG=focus group discussion; HH=household; KII=key informants interview; PO=participant observation; SSI=semi-structured interview.

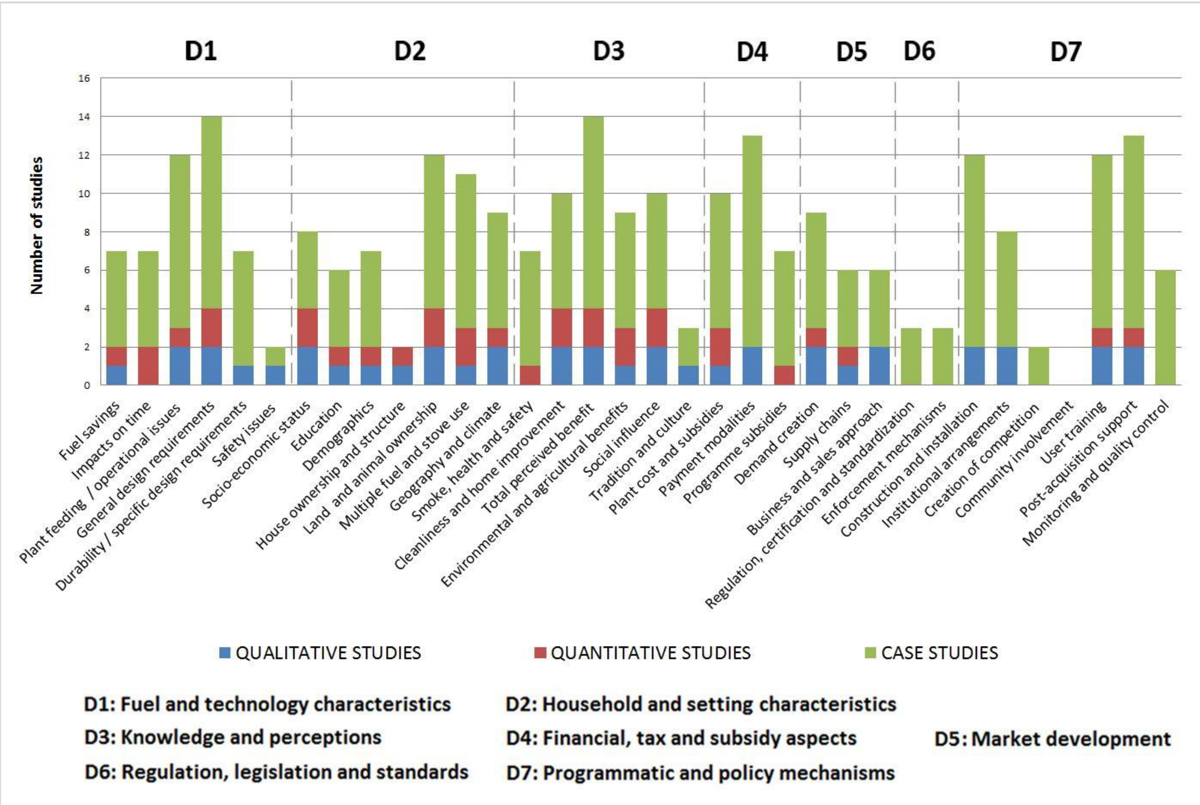
*Quality appraisal of studies was conducted using three separate quality assessment tools resulting in an overall score of strong, moderate or weak. It is, however, important to note that quality appraisal across study designs is not directly comparable.

5.2 Biogas

A total of 17 studies were identified on the adoption and sustained use of household biogas systems (two qualitative, two quantitative and 13 case studies). Studies ranged from 1990 to 2012 and were conducted in Bangladesh (n=5, China (n=4), India (n=4), Kenya (n=1), Nepal (n=2) and Sri Lanka (n=1). Two of the studies assessed factors influencing adoption of biogas (defined as up to one year since installation of biogas plant); 11 studies explored the status of biogas plants (i.e. to check functionality) and their sustained use; and four studies assessed elements of both adoption and sustained use. In terms of methodological quality, this can be considered robust, with two, 12 and three studies scoring strong, moderate and weak respectively (see Tables 5.9–5.15). Detailed information on study characteristics, type of biogas plant and capacity are reported in Table 5.16, presented at the end of this section.

A total of 33 factors influencing uptake of biogas were identified across all framework domains, summarised with contributing study designs (i.e. qualitative, quantitative and case studies) in Figure 5.2.

Figure 5.2: Factors influencing the uptake of biogas across seven domains (D1–D7), by study type and number of studies



Some of the factors are clearly biogas-specific and include: (i) land and animal ownership, (ii) plant feeding and operational issues, and (iii) environmental and agricultural benefits. All domains are supported by evidence from all three study designs, except for Domain 6, which is supported by case studies only. Sensitivity analysis excluding the three weak studies made very little difference to the evidence available for each of these factors.

5.2.1 Domain 1: Fuel and technology characteristics

Plant feeding and operational issues: Biogas places labour demands on users, as regular maintenance and daily management of the plant are essential and labour-intensive.

For effective biogas production, adequate amounts of feed and water are required (123, 124). Cattle dung is the main feed, but while use of human waste, straw and poultry droppings increase available feed (125–128), these are not always available. Underfeeding due to (i) lack of available manure (17, 18, 123, 126, 127, 129), (ii) the use of unsuitable feeding materials which can block the digester (123, 129, 130), (iii) lack of knowledge about the correct water–dung ratio (77, 123, 124, 127, 131), (iv) labour shortage (17, 123, 129) and (v) inadequate management (124, 129, 131) were all reported in multiple studies. These aspects can reduce energy output and/or cause malfunctioning of the digester and need to be better addressed through user training (see Domain 7).

Fuel savings: A range of savings are attributed to biogas and are likely to enable adoption and use, with no corresponding barriers identified in the studies. Studies reported cost savings due to greater energy efficiency (131, 132) and less money spent on purchased fuels such as firewood (124, 125, 127, 133) and kerosene (77, 125).

Table 5.9: Domain 1. Fuel and technology characteristics: biogas

Factor	Examples	Country and setting*	Type and quality of evidence**
Plant feeding and operational issues	• Availability of feeding material • Correct feeding mix • Plant cleaning	Bangladesh (77, 126, 127), China (18, 129, 130), India (17, 124, 131), Nepal (125), Sri Lanka (123)	QL=2 *(1=S; 1=M)* QN=1 *(1=S)* CS=9 *(7=M; 2=W)*
Fuel savings	• Impacts on fuel collection/purchase	Bangladesh (77, 127, 128), China (132), India (17, 131), Nepal (125)	QL=1 *(1=M)* QN=1 *(1=M)* CS=5 *(4=M; 1=W)*
Impacts on time	• Cooking time • Fuel collection time	Bangladesh (127, 128), China (18), Kenya (133), India (17, 131), Nepal (125)	QN=2 *(1=S; 1=M)* CS=5 *(4=M; 1=W)*
General design requirements	• Selection of plant types and sizes • Functionality and gas production	Bangladesh (77, 126–128), China (18, 129, 132), India (17, 124, 131, 134), Kenya (133), Nepal (125), Sri Lanka (123)	QL=2 *(1=S; 1=M)* QN=2 *(1=S; 1=M)* CS=10 *(9=M; 1=W)*
Durability and specific design requirements	• Plant functionality and maintenance • Gas stoves and appliances	Bangladesh (127), China (129, 132), India (124, 131, 134), Nepal (125)	QL=1 *(1=S)* CS=6 *(3=M; 3=W)*
Safety issues	• Plant and pipes inspections	Bangladesh (127), China (129)	QL=1 *(1=M)* CS=1 *(1=M)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *All factors are supported by findings in rural settings. **Quality of evidence not comparable across different study design.

Impacts on time: Using biogas saves cooking time as a result of faster cooking due to greater energy efficiency (131, 132) and the use of multi-pot stoves (17, 77, 127, 131, 133) which is highly valued by users. Time savings from reduced or no wood collection was also reported to be a positive consequence of biogas use (18, 125, 127).

General design requirements: There are multiple types of digesters (e.g. floating and fixed dome) and considerable variations in the type and standards of materials and construction methods (17, 77, 124, 133, 134). Functionality depends on plant type and plant size (17, 77, 134) and is affected by animal holding and daily operation (18, 123, 125, 126, 129, 131, 132) (see Domain 2). Specific features of the design and construction need to be taken into account in assessing whether these act as enablers or barriers for adoption and use in any given setting. In Bangladesh, for example, greater rates of adoption and sustained use were reported when service providers (127) or trained engineers (135) correctly advised households on the type and size of biogas system suitable to their specific circumstances.

Durability and specific design requirements: Durability relating to design and construction has been found to be variable (124, 134), but high-quality biogas units can operate for several decades if properly maintained (134). Poor design and quality (e.g. leaks, absence of moisture traps in pipes) are commonly reported and impact on sustained use (123, 127, 131). Having a plant with the capacity to produce sufficient gas output to meet household needs favours use over time (134). Specific design enhancements are needed in cold settings (129) and add to cost (125, 132); without these, low temperatures slow down and ultimately stop digestion (See Domain 2).

Safety issues: Regular inspection of the digester and pipes is important to ensure functionality (technical reliability) and safety of the digester (127, 129). While the studies did not specify the key areas of safety concern, these are expected to relate to gas leakages.

5.2.2 Domain 2: Household and setting characteristics

Socio-economic status: Biogas is more frequently adopted, maintained and used over time among higher socio-economic groups as measured by income (17, 18, 77, 127, 129, 133), caste (136), type of profession (128, 136) and broader measures of household wealth, such as access to electricity or ownership of a toilet (136), as well as in settings where there is a high market value for cattle (133).

Education: Higher education and/or literacy level facilitates adoption (127-129, 134, 136), primarily through greater awareness of benefits but also through greater awareness of credit options (136).

Demographics: Larger households are more likely to adopt, mainly because more labour is available to look after the biogas plant (127, 128, 136). Reduction in family size over time (17), including through rural to urban migration by the younger generation in the face of economic stresses, was reported as an important factor in several studies (especially China), which affects the functionality of existing digesters and limits interest in future installations (18, 123, 129, 130).

House ownership and structure: Having tenure of the home (77) and title deeds (133) can favour uptake, as once constructed, biogas plants cannot be moved. Consequently, adopting biogas requires an investment in long-term infrastructure.

Land and livestock availability: Having sufficient land and space close to the house to construct the biogas system is crucial for adoption (17, 127, 133, 136) and management of the bio-slurry (128); indeed lack of space was reported as one of the main reasons for not building a plant (18, 128, 129). Having enough livestock to produce sufficient gas to cover family needs is also crucial (17, 18, 123, 124, 127-130, 133, 134, 136), and greater functionality of plants was found among those working with animal husbandry (17). A larger number of cattle (i.e. at least four) and the practice of zero grazing (keeping and feeding cattle in pens) is enabling, as this facilitates collection of dung and feeding the digester (133). The availability of dung in general, including collection from neighbours (126, 127), also favours uptake of biogas plants. In China, pig dung and straw stalks are used as primary feeding material (18, 129, 130, 132).

Table 5.10: Domain 2. Household and setting characteristics: biogas

Factor	Examples	Country and setting*	Type and quality of evidence**
Socio-economic status	• Income • Occupation • Assets	Bangladesh (77, 127, 128), China (18, 129), India (17), Kenya (133), Nepal (136)	QL=2 *(1=S; 1=M)* QN=2 *(1=S; 1=M)* CS=4 *(4=M)*
Education	• Years of schooling for men and women	Bangladesh (127, 128), China (18, 129), India (134), Nepal (136)	QL=1 *(1=S)* QN=1 *(1=S)* CS=4 *(4=M)*
Demographics	• Age • Sex • Household size • Labour availability	Bangladesh (127, 128), China (18, 129, 130), Nepal (136), Sri Lanka (123)	QL=1 *(1=S)* QN=1 *(1=S)* CS=5 *(3=M; 2=W)*
House ownership and structure	• Permanent home	Bangladesh (77), Kenya (133)	QL=1 *(1=M)* QN=1 *(1=M)*
Land and animal ownership	• Land owned and operated • Space availability to build a digester • Livestock availability	Bangladesh (127, 128), China (18, 129, 130, 132), Kenya (133), India (17, 124, 134), Sri Lanka (123), Nepal (136)	QL=2 *(1=S; 1=M)* QN=2 *(1=S; 1=M)* CS=8 *(7=M; 1=W)*
Multiple fuel and stove use	• Availability and opportunity cost of other fuels	Bangladesh (127, 128), China (18, 129, 130), India (17, 124, 134), Kenya (133), Sri Lanka (123)	QL=1 *(1=S)* QN=2 *(1=S; 1=M)* CS=8 *(6=M; 2=W)*
Geography and climate	• Cold settings and altitude • Disaster prone settings	Bangladesh (77, 126, 127), China (18, 129, 132), India (17, 124), Nepal (125)	QL=2 *(1=S; 1=M)* QN=1 *(1=S)* CS=6 *(4=M; 2=W)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *All factors are supported by findings in rural settings. **Quality of evidence not comparable across different study design.

Multiple fuel and stove use: Limitations in access to other fuels (128), including shortage of fuelwood (124) and shortage or high costs of LPG (123, 134) are all factors that can favour the adoption and the use of biogas (123, 124, 127). Conversely, easily available wood and coal, and access to other inexpensive fuels and cooking technologies, are reported to be barriers (17, 18, 129). Some households that have already invested in other ‘modern’ energy sources were reluctant to invest further in biogas (133).

Geography and climate: Biogas production is reduced at low temperatures and/or higher altitude (17, 18, 125, 127, 132) and ceases below 10°C (132). In these settings production is not reliable across seasons without costly adaptations including insulation and a warm-water feed (132). The rainy season is a favourable time for production of good-quality bio-slurry to be used as fertiliser (128). Seasonal drought and other factors may lead to selling animals hence reducing or stopping gas production (124, 129). Similarly, flooding disrupts digester function unless digesters are sited or built to withstand it (77, 126).

5.2.3 Domain 3: Knowledge and perceptions

Smoke, health and safety: Acknowledgement of health benefits including fewer episodes of eye and respiratory diseases from not using traditional solid fuel stoves (125, 127, 128, 131), and less backache from reduced firewood collection (133) were widely described, in particular among women (17). Some concerns about infectious diseases spreading through handling of manure (123) and increased breeding of insects after plant installation (123, 125) were also reported.

Cleanliness and home improvement: Perceived benefits from improved sanitation (in particular through the inclusion of latrines during the installation) (18, 125, 129), reduced smoke (133), a cleaner home environment (17, 128) and cleaner cooking vessels (17, 127) were reported. Biogas is also used for lighting purposes in some settings, but the evidence does not allow any conclusions to be drawn as to whether or not this is considered an incentive for biogas uptake (125, 131, 133).

Total perceived benefits: Other perceived benefits from biogas use included improved quality of life (127, 129), convenience for cooking (128, 129, 133) and the possibility of meeting all cooking needs (17, 134). Additional economic benefits associated with biogas include cost savings made from purchasing less fuel (77, 128) and from the production of bio-slurry; the latter is a substitute for chemical fertiliser (18, 127), but can also be used as an insecticide (18) or fish feed (128). Moreover, if sold to other households, it can provide a source of income generation (17, 18, 77, 127, 131, 135), as can excess biogas (128).

Satisfaction with the system is mainly related to the status of functioning (128, 129). Poor system functionality (129), insufficient gas production (especially in certain climatic conditions) (17, 18, 123, 124, 126, 131, 132), and inadequate knowledge about biogas benefits, significantly impact on continued use of biogas for cooking (17, 129, 133). Biogas production requires labour-intensive daily operations and some users suggested that the perceived monetary value of overall benefits are lower than they felt had been 'advertised' (123, 129). This perception was, however, strongly related to lack of awareness about the potential economic benefits from bio-slurry use (123, 124, 129).

Environmental and agricultural aspects: Forest conservation and other environmental benefits from the use of biogas (77) were acknowledged by some users (127, 133, 134), including increase in crop yield due to seeds being soaked in bio-slurry before planting (18, 131, 134). Two studies reported a potential concern that slurry not converted into fertiliser could pollute close-by water sources, although these studies did not provide data on how these influenced behaviour (77, 128).

Social influence: The influence of social networks in the decision to adopt can reinforce the positive experience of users (enabling wider adoption) (18, 125, 128) or act as a barrier where there have been negative experiences (123). The perception of enhanced social status (131, 133) and a greater number of years over which the technology has been available in a given community (18) favour adoption. However, social and cultural taboos with the use of human waste can reduce connection to latrines which would otherwise increase the amount of available feed and consequent gas production (77, 123, 125, 127, 131, 136). Also, the smell of dung and animals in close proximity of the dwelling can be a matter of concern for some users (123, 129).

Tradition and culture: Familiarity with cooking on traditional stoves (124), food taste (17, 124) and a family preference to sit around an open fire during the winter (129) were all reported to play a part in discouraging uptake.

Table 5.11: Domain 3. Knowledge and perceptions: biogas

Factor	Examples	Country and setting*	Type and quality of evidence**
Smoke, health and safety	• Smoke exposure • Health effects • Burn injuries	Bangladesh (127, 128), Kenya (133), India (17, 131), Nepal (125), Sri Lanka (123)	QN=1 *(1=M)* CS=6 *(5=M; 1=W)*
Cleanliness and home improvement	• Cleaner home • Family benefits	Bangladesh (77, 127, 128), China (18, 129), India (17, 131), Kenya (133), Nepal (125)	QL=2 *(1=S; 1=M)* QN=2 *(1=S; 1=M)* CS=6 *(4=M; 2=W)*
Total perceived benefit	• Overall perceived advantages/disadvantages • Economic benefits • Multiple use of bio-slurry	Bangladesh (77, 126–128), China (18, 129, 130), India (17, 124, 131, 134), Kenya (133), Nepal (125), Sri Lanka (123)	QL=2 *(1=S; 1=M)* QN=2 *(1=S; 1=M)* CS=10 *(9=M; 1=W)*
Environmental and agricultural benefits	• Forest conservation • Use of bio-slurry	Bangladesh (77, 127, 128), China (18), India (124, 131, 134), Kenya (133), Sri Lanka (123)	QL=1 *(1=M)* QN=2 *(1=S; 1=M)* CS=6 *(6=M)*
Social influence	• Influence of social networks • Social taboos	Bangladesh (77, 127, 128), China (18, 129), India (131), Kenya (133), Nepal (125, 136), Sri Lanka (123)	QL=2 *(1=S; 1=M)* QN=2 *(1=S; 1=M)* CS=6 *(5=M; 1=W)*
Tradition and culture	• Food taste • Family habits	China (129), India (17, 124)	QL=1 *(1=S; 1=M)* CS=2 *(2=M)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *All factors are supported by findings in rural settings. **Quality of evidence not comparable across different study design.

5.2.4 Domain 4: Financial, tax and subsidy aspects

Biogas plant cost and subsidies: Initial plant installation is very expensive (US$180–500 among the included studies) (17, 18, 123, 126, 131). Therefore almost all biogas programmes offered some form of subsidy ranging from 25 percent to 80 percent of initial costs, which constituted an important motivating factor for installation (17, 125, 127, 129, 133, 134). Subsidy could be constant or vary according to plant type and size (17, 125, 133, 134). The subsidy amount covered only part of the total installation costs, and the building of a latrine or an animal house associated with the digester was usually an extra cost to be incurred by users themselves (129, 131).

Payment modalities: Multiple forms of credit were available to complete installation costs (123–125, 127, 128, 134) but provision of grants or loans was not always appropriately managed; for example, some users experienced pressure from creditors to repay loans in less time than the agreed monthly instalments (128). In addition, some households stopped paying monthly instalments due to a lack of adequate after-sales support (126). Bureaucracy and delays in receiving subsidies (131) as well as difficulty in obtaining loans for securing livestock (126, 135) were also reported as barriers. Attempts to manipulate personal data in order to become eligible for subsidies and other types of assistance were reported (77). Lack of personal investment by the household in the biogas system was associated with less commitment to continue its use and high rates of non-functionality in some settings (17, 123).

Programme subsidies: In addition to subsidies on plant construction and installation, some governments/programmes offered additional subsidies for toilet attachment (17) and construction of an improved kitchen (18) by households.

Programme subsidies were also made available towards the development of the biogas market with financing of trained staff and post-acquisition support (17, 125). However, additional financial support for purchasing of livestock, user training in use and maintenance of the biogas plant or awareness campaigns on bio-slurry benefits and correct use were not usually provided (17, 126, 129, 135).

Table 5.12: Domain 4. Financial, tax and subsidy aspects: biogas

Factor	Examples	Country and setting*	Type and quality of evidence**
Plant cost and subsidies	• Initial cost • Availability of subsidies	Bangladesh (126, 127), China (18, 129), India (17, 131, 134), Kenya (133), Nepal (125), Sri Lanka (123)	QL=1 *(1=S)* QN=2 *(1=S; 1=M)* CS=7 *(6=M; 1=W)*
Payment modalities	• Availability of loans, microcredit, instalments	Bangladesh (77, 126–128, 135), China (129, 130), India (17, 124, 131, 134), Nepal (125), Sri Lanka (123)	QL=2 *(1=S; 1=M)* CS=11 *(9=M; 2=W)*
Programme subsidies	• Government support • Additional financial incentives	Bangladesh (126–128), China (18, 129), India (17, 134), Nepal (125),	QL=1 *(1=S)* QN=1 *(1=S)* CS=6 *(5=M; 1=W)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *All factors are supported by findings in rural settings. **Quality of evidence not comparable across different study design.

5.2.5 Domain 5: Market development

Demand creation: The importance of demand creation is well recognised, and programmes employed a range of marketing strategies, such as local companies employing local masons/rural energy technicians (17, 77, 125, 127), local government representatives (135) or local NGOs and village-level motivators (124, 126, 127, 133). Companies investing more in personal contact and demonstration activities showed better achievements (136); seeing functional plants of neighbours and relatives also increased willingness to adopt (127, 129, 135, 136).

Supply chains: In terms of supply, existing road infrastructure favoured plant construction (18, 127), while lack of roads and construction in rugged terrain increased installation costs (125, 129). The lack of availability of construction materials, equipment and labour were also found to be important factors impacting on plant construction and completion (17, 128).

Table 5.13: Domain 5. Market development: biogas

Factor	Examples	Country and setting*	Type and quality of evidence**
Demand creation	• Strategies used to increase demand • Awareness-raising	Bangladesh (77, 127, 135), China (129), Kenya (133), India (17, 124), Nepal (125, 136)	QL=2 *(1=S; 1=M)* QN=1 *(1=M)* CS=6 *(5=M; 1=W)*
Supply chains	• Road infrastructure	Bangladesh (127, 128), China (18, 129), India (17), Nepal (125)	QL=1 *(1=S)* QN=1 *(1=S)* CS=4 *(3=M; 1=W)*
Business and sales approach	• Marketing dissemination and client satisfaction • After-sales business	Bangladesh (77, 127, 135), China (129), India (134), Nepal (125)	QL=2 *(1=S; 1=M)* CS=4 *(4=M)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong*; M*=moderate*; W*=weak. *All factors are supported by findings in rural settings, and peri-urban settings are also represented (136).**Quality of evidence not comparable across different study design.

Business and sales approaches: Income generated through biogas plant construction can be sufficient for ensuring livelihoods (134), although repair work has been reported to be less profitable in remote areas (129). Promotion of small-sized digesters able to operate with a limited number of animals (usually two) (125) and avoidance of creating false expectations among clients (77) were reported to increase biogas uptake (127, 135). Shops which offer the possibility of purchasing livestock were also valued by users, as reported in studies from Bangladesh (77, 126).

5.2.6 Domain 6: Regulation, legislation and standards

Regulation, certification and standardisation: Standards for design, materials and construction of biogas systems are crucial for proper system functioning and this aspect was acknowledged in a number of programmes (125, 130, 135). Incentives for high-quality construction and maintenance (including certification, signed agreements and linkage to a subsidy mechanism) (125) and the obligation to provide after-sales services were considered to favour adoption and sustained use.

Enforcement mechanisms: Enforcement through inspection visits (127, 135), verification of quality standards and penalties for non-compliance with standards (125) are important for longer-term plant functionality. Indeed, lack of verification of technical standards set by the service provider can negatively impact on the quality of construction materials and construction methods (127).

Table 5.14: Domain 6. Regulation, legislation and standards: biogas			
Factor	**Examples**	**Country and setting***	**Type and quality of evidence****
Regulation, certification and standardisation	• Design standards and certification	Bangladesh (135), China (130), Nepal (125)	CS=3 *(1=M; 2=W)*
Enforcement mechanisms	• Inspection visits • Whether or not effective mechanisms adopted • Penalties for non-compliance	Bangladesh (127, 135), Nepal (125)	CS=3 *(2=M; 1=W)*

CS=case studies; *M*=moderate; *W*=weak. *All factors are supported by findings in rural settings, and peri-urban settings are also represented (136).**Quality of evidence not comparable across different study design.

5.2.7 Domain 7: Programmatic and policy mechanisms

Construction and installation: The success of biogas adoption and use is increased through construction and installation by skilled masons or service centres, use of good-quality appliances and the appropriate placement of plants, e.g. on higher ground to avoid flooding where this is a risk (125, 127, 130). Construction is expensive, so poor-quality construction by inadequately trained builders, and use of poor-quality materials, which were reported to be used in a range of different settings (17, 77, 124, 126–129, 131), adversely affected adoption and use because of negative experiences and poor plant functioning. Also, there are a number of specific design and construction issues that may need attention, for example the underground placement of pipes which can make detection of leaks difficult (123, 135).

Creation of competition: Competition among builders favours good-quality construction and regular follow-up of plants (125, 134), resulting in an increase in client satisfaction with subsequent promotion of the technology within the community. Entrepreneurs able to assist prospective users in obtaining financial support (i.e. subsidies) were favoured (134).

Institutional arrangements: Success appeared to be more frequent when built on well-functioning dissemination networks (involving multiple agencies, local government and collaboration with the private sector) (77, 125, 128, 134), and on national targets (such as overall numbers of installed plants) (17, 125, 129). However, failure to achieve national targets was not infrequent and was reported to be mainly due to poor co-ordination between agencies involved (17), lack of interaction with other rural development programmes (17) and insufficient programme staff (17, 123).

User training: User training in the operation and maintenance of biogas systems was reported as a crucial factor in ensuring system functionality (17, 77, 125, 129). In several settings, lack of proper training was a recognised barrier to proper functioning of biogas systems, impacting on daily production of biogas to meet cooking needs and the adequacy of system maintenance (123, 126, 127, 129, 132, 136). Training in relation to correct use and benefits from bio-slurry production was also generally insufficient (18, 125, 128).

Table 5.15: Domain 7. Programmatic and policy mechanisms: biogas

Factor	Examples	Country and setting*	Type and quality of evidence**
Construction and installation	• Quality of plant construction and installation • Mason training	Bangladesh (77, 126–128, 135), China (129, 130), India (17, 124, 131), Nepal (125), Sri Lanka (123)	QL=2 *(1=S; 1=M)* CS=10 *(1=S; 7=M; 2=W)*
Creation of competition	• Competition for client satisfaction	India (134), Nepal (125)	CS=2 *(1=M; 1=W)*
Institutional arrangements	• Stakeholder co-ordination • Government role	Bangladesh (77, 126, 128), China (129), India (17, 134), Nepal (125), Sri Lanka (123)	QL=2 *(1=S; 1=M)* CS=6 *(5=M; 1=W)*
User training	• Training in safe system operation and maintenance • Use of correct feeding mix	Bangladesh (77, 126–128), China (18, 129, 132), India (17, 124), Nepal (125, 136), Sri Lanka (123)	QL=2 *(1=S; 1=M)* QN=1 *(1=S)* CS=9 *(8=M; 1=W)*
Post-acquisition support	• Availability of after-sales service • Quality of repair service	Bangladesh (77, 126–128), China (18, 129, 132), India (17, 124, 134), Nepal (125, 136), Sri Lanka (123)	QL=2 *(1=S; 1=M)* QN=1 *(1=S)* CS=10 *(8=M; 3=W)*
Monitoring and quality control	• Monitoring of implementation • Plant inspections	Bangladesh (126, 135), India (17, 124), Nepal (125, 136)	CS=6 *(5=M; 1=W)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong*; M*=moderate*; W*=weak. *All factors are supported by findings in rural settings, and peri-urban settings are also represented (136).**Quality of evidence not comparable across different study design.

Post-acquisition support: After-sales service is another aspect associated with maintenance and long-term functionality of biogas systems (124, 125, 134). In some countries, programmes offered a combination of free repair services during warranty periods with subsequent services against payment, which ensured performance (17, 77, 125, 134). Lack of a warranty period or some form of insurance for plant installation (126, 129), high repair costs (17, 18, 129), long distances from repair stations (129, 136) or service unavailability (17, 123) usually led to lack of maintenance and a digester with insufficient gas production.

Monitoring and quality control: Quality control procedures are critical in ensuring the functionality and continued use of biogas systems (125, 135). As described under Domain 6, household inspection visits were found to be a key element of successful monitoring schemes (125, 126, 135), sometimes embedded in a multi-level monitoring system, such as for the National Domestic Biogas and Manure Programme in Bangladesh, which combined overall programme monitoring by the steering committee and day-to-day monitoring by the partner organisations (135). Users may be empowered by involvement in quality control, for example, by paying building charges directly to masons upon satisfactory completion of construction and installation (124), or by only paying monthly instalments to microfinance agencies if the plant is operating properly (126). Poor or no follow-up services provided by installers have a negative impact on quality (123). Also, while some programmes formulated obligations to inspect plants and issue certificates for subsidy release, these obligations were often not met due to shortage of staff and excessively low fixed inspection fees (17).

5.2.8 Equity considerations in relation to biogas uptake

Biogas is a clean fuel primarily acquired and used by upper- and middle-income (mainly rural) households in possession of sufficient livestock and land. In view of this and based on the studies reviewed, uptake currently seems unlikely to be scaled up for poorer households with smallholdings (i.e. small-scale farms usually supporting a single family with a mixture of cash crops and subsistence farming) (18, 77, 129).

In general, loan and subsidy mechanisms are widespread, and the provision of higher subsidies for the construction of smaller-sized digesters among small- and medium-scale farmers was one possible means to overcome inequalities in access to the technology (17, 125). However, in addition to the initial high costs for construction of the biogas system, poor families may also require financial support to purchase and maintain livestock, and to maintain and repair the biogas system in appropriate ways (17, 129). Results show remote settings to be particularly disadvantaged in terms of obtaining technical post-acquisition support (123, 129, 136) as the repair business is not considered profitable in these areas and users may need to travel long distances to reach a repair station (129).

Table 5.16: Characteristics of included studies on biogas, by study category

Author (year) *(reference no.)*	Country/ Setting	Study design and sampling	Data collection	Data analysis*	Quality appraisal[#]	Adoption (A) vs sustained use (S)	Prevalent biogas digester type	Capacity	Prevalent feeding material
				QUALITATIVE STUDIES (QL)					
Jian (2009) *(129)*	China (rural)	Ethnography. Survey (n=247), SSI (n=38), FGD (n=12) and PO	Case histories with 3 plant users. SSI with users. Self-completed questionnaires and FGD with non-users (male and female)	Method not specified	Strong	A/S	Fixed dome	2 to 8 m^3	Human/pig dung and straw/stalks
Sovacool and Drupady (2011) *(77)*	Bangladesh (rural/urban)	Case study based on interviews (n=not specified)	Interviews with users and stakeholders	Narrative synthesis	Moderate	A/S	Brick and fibreglass biogas units	2 to 3 m^3	Cattle and poultry dung
				QUANTITATIVE STUDIES (QN)					
Christiaensen and Heltberg (2012) *(18)*	China (rural)	Cross-sectional baseline survey (n=2,700)	HHs selected from project and control villages, including users and non-users.	Multivariable approach adjusting for confounders	Strong	A	Not specified	10 to 12m^3	Pig dung
Mwirigi et al. (2009) *(133)*	Kenya (rural)	Cross-sectional survey (n=100 users + n=100 non-users)	Face-to-face interviews with users and non-users	Analytical approach without adjustment	Moderate	A/S	Fixed dome; Floating drum and flexible bag	4 and 16 m^3 8 to 10 m^3	Cattle dung
				CASE/POLICY STUDIES (CS)					
Bajgain and Shakya (2005) *(125)*	Nepal (rural)	Case study: survey (n=600) and interviews	Poorly reported. Interviews with users	Descriptive narrative	Weak	S	Small fixed dome	Mainly 6 m^3	Cattle dung
Bhat et al. (2001) *(134)*	India (rural)	Case study: survey (n=187), biogas measurements and interviews (n=10)	Survey with users. Interviews with biogas entrepreneurs and implementing agencies	Descriptive narrative and statistics	Moderate	S	Floating drum and fixed dome	3 to 8 m^3	Cattle dung
BSP and CEDA (1998) *(136)*	Nepal (rural/urban*)	Mixed-method approach. HH survey (n=866) and 9 FGDs (n=8 each)	Interviews with HH heads. FGDs with local people	Descriptive narrative and statistics	Moderate	S	Not specified	4 to 10 m^3	Cattle dung
Daxiong et al. (1990)	China	Case study: 2 cross-sectional surveys (n=58 and n=242)	Survey with users and biogas plant inspections	Descriptive narrative and statistics	Weak	S	Not specified	6 to 10 m^3	Animal and human dung; straw

Author (year) *(reference no.)*	**Country/ Setting**	**Study design and sampling**	**Data collection**	**Data analysis***	**Quality appraisal[#]**	**Adoption (A) vs sustained use (S)**	**Prevalent biogas digester type**	**Capacity**	**Prevalent feeding material**
de Alwis (2002) *(123)*	Sri Lanka (rural/urban)	Review study based on two cross-sectional surveys (n=303 in 1986 and n=369 in 1996)	Not described	Descriptive narrative and statistics	Moderate	S	Fixed dome (Chinese type)	6 m^3	Cattle dung
Dutta et al. (1997) *(124)*	India (rural)	Case study based on inspected plants (n=482)	Poorly reported. Interviews with users and NGO staff	Descriptive narrative	Moderate	S	Fixed dome designs	2 to 6 m^3	Cattle dung
World Bank (2010d) *(126)*	Bangladesh (rural)	Literature review supported by surveys with users (n=142)[§] and FGDs and KIIs	Survey with women users (n=70)[#], interviews with technicians and other stakeholders (n=41)[§]	Descriptive narrative	Moderate	S	Fixed dome (2 types)	6 sizes	Cattle dung
World Bank (2010e) *(135)*	Bangladesh (rural)	Literature review supported by surveys with users (n=142)[#] and FGDs and KIIs	Survey with women users (n=70), interviews with technicians and other stakeholders (n=41)[#]	Descriptive narrative	Moderate	S	Fixed and floating models	5 sizes	Cattle and poultry dung
Ghimire (2005) *(127)*	Bangladesh (rural)	HH survey (n=72)	Face-to-face interviews with users, including family and key community members	Descriptive narrative and statistics	Moderate	S	Fixed dome (3 types)	2 to 6 m^3	Cattle dung
iDE (2011) *(128)*	Bangladesh (rural)	Mixed-method approach. Cross-sectional survey (n=300), FGDs	Structured questionnaire with users. FGDs with users and non-users. Interviews with stakeholders.	Descriptive narrative and statistics	Moderate	S	Not reported	1.6 to 4.8 m^3	Cattle and poultry dung
Kumargoud et al. (2006) *(131)*	India (rural)	Cross-sectional survey (n=200)	Face-to-face interviews with users	Descriptive narrative	Moderate	S	Deenabandhu and KVIC models	Not reported	Cattle dung
Planning Commission (2002) *(17)*	India (rural)	Cross-sectional survey (n=620 users + n=744 non-users)	Not described	Descriptive narrative	Moderate	A/S	Mostly Deen Bandhu and KVIC models	2 to 8 m^3	Cattle dung
Qi and Li (2010) *(132)*	China (rural)	Cross-sectional survey (n=400)	Interviews with users and non-users	Descriptive narrative	Weak	A	N/A	Not reported	Not reported

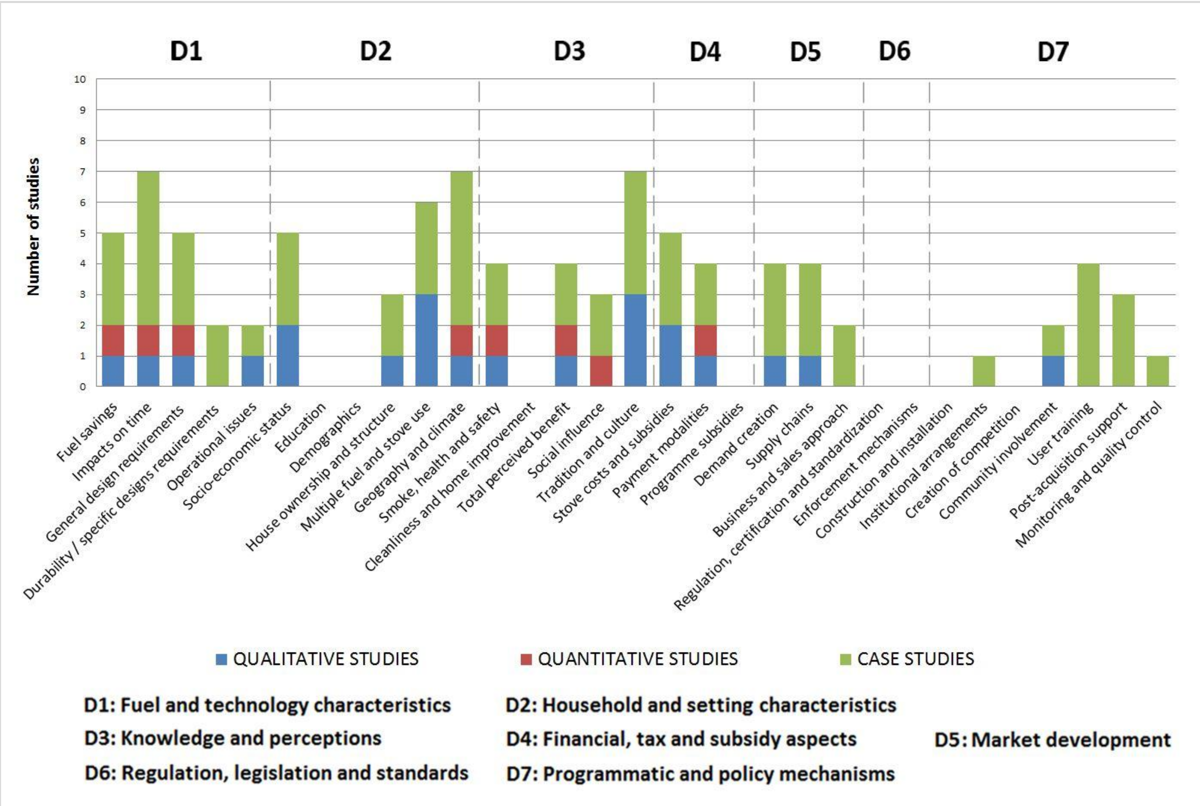
FDG=focus group discussion; SSI=semi-structured interview; KII=key informants interview; KVIC=Khadi and Village Industries Commission; PO=participant observation, HH=household.
*Quality appraisal of studies was conducted using three separate quality assessment tools resulting in an overall score of strong, moderate or weak. It is, however, important to note that quality appraisal across study designs is not directly comparable. [§]These figures are cumulative for all the World Bank 2010 (a–e) case studies; a breakdown for each case study is not available.

5.3 Solar cookers

A total of nine studies were identified on adoption and use of solar cookers (three qualitative, one quantitative and five case studies). Studies ranged from 1998 to 2012 and were conducted in South Africa (n=2), Kenya (n=2), Senegal (n=1), Burkina Faso (n=1), Tanzania (n=1), India (n=1) and Mexico (n=1). Six studies assessed adoption of cookers, and three described aspects related to sustained use of cookers or a mix of adoption and sustained use over time. Cookers included mainly panel cookers ('Hotpot' and 'CooKit'), as well as parabolic and box cookers. In terms of quality, two studies were scored as strong, five as moderate, and two as weak (see Tables 5.17–5.22). Detailed information on study characteristics, type of solar cooker and quality appraisal are reported in Table 5.23 at the end of this section.

Twenty-three factors were identified as influencing the uptake of solar stoves as illustrated in Figure 5.3.

Figure 5.3: Factors influencing the uptake of solar cookers across seven domains (D1–D7), by study type and number of studies



Most of the evidence pertains to the first three domains, and no study reported on Domain 6. The only quantitative study contributed evidence to four domains; qualitative studies supported factors across the first five domains, and case studies supported all domains apart from Domain 6. Traditional and cultural aspects, followed by impact on time and opportunity cost issues, along with geographical and climatic considerations, are among the principal factors guiding household choice about adoption and use of solar cookers.

As further discussed below, the fact that solar cookers cannot meet all cooking tasks, in particular not those required early in the morning or later in the afternoon/evening, greatly impacts on who adopts solar cookers and on how these cookers are used. Following sensitivity analysis excluding the two weak studies, 21 out of 23 factors were retained with at least some supporting evidence, although the factors ‘institutional arrangements’ and ‘monitoring and quality control’ were lost.

5.3.1 Domain 1: Fuel and technology characteristics

Fuel savings: Solar cooker users were found to benefit from cost savings due to reduced need to purchase fuels, provided the stove was frequently used (19, 21, 137, 138). However, when the cookers were used infrequently (i.e. 10 percent of days over a six-month time period in one study) there may have been no significant difference in fuel used and time spent gathering (108).

Impacts on time: Solar cooking requires forward planning to be time-efficient. Time savings arose from less time spent collecting wood (19, 21, 138, 139) and less need for regular attention to be paid to the food (19, 137–140). Loss of time occurred mainly due to slower cooking (137, 139–141).

Table 5.17: Domain 1. Fuel and technology characteristics: solar cookers

Factor	Examples	Country and settings*	Type and quality of evidence**
Fuel savings	• Impacts on fuel collection • Fuel cost savings	Burkina Faso (139), South Africa[#] (19, 21, 138), Tanzania (137)	QL=1 *(1=S)* QN=1 *(1=S)* CS=3 *(2=M; 1=W)*
Impacts on time	• Fuel collection time • Cooking time • Requirement for forward planning of cooking	Burkina Faso (139), India (141), Kenya (140), Senegal (108), South Africa (19, 21, 138)[#], Tanzania (137)	QL=1 *(1=S)* QN=1 *(1=S)* CS=5 *(4=M; 1=W)*
General design requirements	• Cooking capacity • Portability and weight	Burkina Faso (139), India (141), Senegal (108), South Africa (19), Tanzania (137)	QL=1 *(1=S)* QN=1 *(1=S)* CS=3 *(3=M)*
Durability and other specific design requirements	• Thermal performance • Adequacy of heating power	India (141), South Africa (21)	CS=2 *(2=M)*
Operational issues	• Technical requirements for cooking	Burkina Faso (139), Kenya (98)	QL=1 *(1=M)* CS=1 *(1=M)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong*; M*=moderate*; W*=weak. *Factors are supported by findings in urban (139, 141), rural (137, 140) or mixed settings. **Quality of evidence not comparable across different study design. [#]Two studies describe the same project conducted in South Africa and are counted as one study (21, 138).

General design requirements: In terms of design requirements, a common issue reported was that most solar cookers did not have sufficient capacity to cook for large households (e.g. more than 5–6 family members) (19, 108, 139); one study suggested that using two solar cookers could offer a solution to this problem (139). Another design issue was that most cookers were heavy and bulky and therefore difficult for women to handle and move; this issue was particularly important in urban settings where space for cooking with or storing the solar cooker was a concern (137, 141).

Durability and specific design requirements: In terms of thermal performance, variability across cookers was reported (21) and the lack of control for regulating heat negatively impacted uptake (141).

Operational issues: New users of solar cookers were not familiar with the technology, and needed to master the basic technical requirements for cooking, in particular correct orientation of the reflective surface and how often to change this orientation. Lack of these skills led to difficulties in initial use of the technology (98, 139).

5.3.2 Domain 2: Household and setting characteristics

Socio-economic status: Households with higher incomes were more likely to adopt solar cookers, as high-quality cookers were usually costly (19), and lower-income families were unable to afford them (98, 137, 140, 141).

Table 5.18: Domain 2. Household and setting characteristics: solar cookers

Factor	Examples	Country and settings*	Type and quality of evidence**
Socio-economic status	• Income	India (141), Kenya (98, 140), South Africa (19), Tanzania (137)	QL=2 *(1=S; 1=M)* CS=3 *(2=M; 1=W)*
House ownership and structure	• Yard/roof availability • Space for storage	India (141), South Africa (19), Tanzania (137)	QL=1 *(1=S)* CS=2 *(2=M)*
Multiple fuel and stove use	• Availability of and familiarity with traditional stoves and fuels	Kenya (98, 140), Mexico (80), South Africa (19, 21, 138)[#], Tanzania (137)	QL=3 *(1=S; 1=M; 1=W)* CS=3 *(2=M; 1=W)*
Geography and climate	• Solar radiation • Seasonality	Burkina Faso (139), India (141), Kenya (140), Senegal (108), South Africa (19, 21, 138), Tanzania (137)	QL=1 *(1=S)* QN=1 *(1=S)* CS=5 *(3=M; 2=W)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *Factors are supported by findings in urban (139, 141), rural (80, 137, 140) or mixed settings. **Quality of evidence not comparable across different study design. [#]Two studies describe the same project conducted in South Africa and are counted as one study (21, 138).

House ownership and structure: Use of a solar cooker requires a sunny area by definition, and in practice this needs to be a protected area located close to the home, ideally within the yard. Lack of a convenient, well-insolated area such as this discouraged adoption (19, 137). In some settings where no yard is available, a roof can be used (particularly in urban settings), but daily cooker transfer to the roof and back to the house was reported to be a major source of inconvenience (141). In one study conducted in an urban area, adoption was more likely among those living in detached houses or on top floors of buildings, as the cooker could more easily be moved between places of cooking and storage (141).

Multiple fuel and stove use: The prevailing fuel use and availability affected solar cooker adoption, as accessibility of alternative cheaper fuels (140) and use of more familiar stoves (98) was a disincentive to switch to solar cooking. Conversely, scarcity of gathered fuelwood, situations where women face personal risks in fuel collection (19, 80) or high prices of commercial fuels (e.g. kerosene or LPG) among more affluent households habitually using these (19, 21, 137, 138) favoured adoption.

Geography and climate: Climatic conditions and seasonality play critical roles in daily use, as solar cookers require reliably high levels of solar irradiance (21, 138, 141); their use is usually not possible or practical when conditions are cloudy, windy or very dusty (19, 108, 137, 139). Also, cookers cannot be used at all during the early morning or late afternoon/evening (21, 138, 140) which impacts on continuity of stove use, and highlights the need for forward planning of cooking activity, including fitting this in with other commitments (see Domain 3).

5.3.3 Domain 3: Knowledge and perceptions

Smoke, health and safety: From a health perspective, female users found a number of advantages in using solar cookers, including better health conditions (137), less backache with no need to stand for long periods (141) and less risk of burn-related injuries (138). However, results from a recent randomised controlled trial conducted in Senegal identified no statistical difference on self-reported health data between users in intervention groups using solar cookers and non-users. This, and the lack of exposure reduction to carbon monoxide (CO) among the intervention group, can be explained as a result of intervention households using open fires and/or other traditional stoves as well as solar cookers to meet cooking needs (108).

Table 5.19: Domain 3. Knowledge and perceptions: solar cookers

Factor	Examples	Country and settings*	Type and quality of evidence**
Smoke, health and safety	• Smoke exposure • Health effects • Burn injuries	India (141), Senegal (108), South Africa (138), Tanzania (137)	QL=1 *(1=S)* QN=1 *(1=S)* CS=2 *(2=M)*
Total perceived benefit	• Suitability for slow cooking • Unable to rely on solar cooking for all needs	Kenya (140), Mexico (80), Senegal (108), South Africa (21, 138)[#]	QL=1 *(1=W)* QN=1 *(1=S)* CS=2 *(1=M; 1=W)*
Social influence	• Influence of social networks • Ease with which cooker can be loaned	Kenya (140), Senegal (108), South Africa (138)	QN=1 *(1=S)* CS=2 *(1=M;1=W)*
Tradition and culture	• Suitability for preparing local dishes • Food taste	Burkina Faso (139), India (141), Kenya (98, 140), Mexico (80), South Africa (138), Tanzania (137)	QL=3 *(1=S; 1=M; 1=W)* CS=4 *(3=M; 1=W)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *Factors are supported by findings in urban (139, 141), rural (80, 108, 137, 140) or mixed settings. **Quality of evidence not comparable across different study design. [#]Two studies describe the same project conducted in South Africa and are counted as one study (21, 138).

Total perceived benefit: Solar cookers are particularly suitable for preparing dishes which require slow cooking (80, 138, 140), but cannot be used for preparing all meals. This means that users are generally unable to rely on solar cookers alone (80). Although some users reported satisfaction with technology (108, 138), others were found not to appreciate the benefit of using a cooker when they were already able to meet all their cooking needs with just one device (140).

Social influence: The use of solar cookers can offer other benefits, including in relation to social networks (138). In one study, for example, it was found that the cooker could easily be lent to relatives and neighbours, and this was a positive attribute (138). However, the inability to prepare large quantities of food or the need for special food size requirements (such as meat being chopped into smaller pieces) was seen as a sign of inhospitality in some settings, and hence discouraged use of the device (108, 140).

Tradition and culture: In relation to food preferences, results were mixed; some users reported satisfaction in terms of taste, colour and texture of the food (137–139, 141) whereas others did not (80, 139–141). The use of solar cookers also requires behavioural change, including alteration to daily routine, planning ahead and adaptation to technology requirements, which can discourage use (139–141). Adapting to these changes was reported to be more difficult for older women (98).

5.3.4 Domain 4: Financial, tax and subsidy aspects

Stove cost and subsidies: High-quality solar cookers were generally considered to be expensive, especially when imported (137, 139). Although cost depends on cooker design, stove cost was reported as a major barrier to adoption in several studies (98, 137, 139, 140). Availability of subsidies for initial purchase and cooker replacement favoured adoption and use over time (141), but even with large subsidies in place, solar cookers may still be beyond the reach of medium- and low-income households as reported in other studies (108, 137, 140).

Payment modalities: Access to credit schemes (e.g. microcredit through local co-operation) (140) or payment in instalments (21, 108, 137) facilitated stove purchase, as did the promotion of locally manufactured cookers which were more affordable than imported stoves (137).

Table 5.20: Domain 4. Financial, tax and subsidy aspects: solar cookers

Factor	Examples	Country and settings*	Type and quality of evidence**
Stove cost and subsidies	• Initial cost • Availability of subsidies	Burkina Faso (139), India (141), Kenya (98, 140), Tanzania (137)	QL=2 *(1=S; 1=M)* CS=3 *(2=M; 1=W)*
Payment modalities	• Availability of loans, microcredit • Payment by instalments	Kenya (140), South Africa (21, 138)[#], Senegal (108), Tanzania (137)	QL=1 *(1=S)* QN=1 *(1=S)* CS=2 *(1=M)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *Factors are supported by findings in rural (90, 137, 140), urban (141) or mixed settings **Quality of evidence not comparable across different study design. [#]Two studies describe the same pilot project conducted in South Africa and are counted as one study (21, 138).

5.3.5 Domain 5: Market development

Demand creation: Strategies to promote solar cookers included media advertisements (137, 141) and cooking demonstrations (137). Word-of-mouth within small communities was also found to be effective (137). Special attention to design features was recommended, as poor appearance and packaging discourage users from purchasing products which are perceived as low quality (19).

Supply chains: Local production of cookers contributes to sustainability (137, 141), while lack of supply of parts is a barrier (140). Importation costs, taxes and shipping costs for the cookers were reported as additional barriers to adoption (19, 140).

Business and sales approaches: Some donor and NGO programmes have had restricted population or geographical reach and consequently may fail to build up a broader, selfsustaining market (19). Low demand for cookers indirectly impacts on prices but also on availability and stocking of cookers by shops and other commercial outlets, as doing so is perceived as a high risk investment (140).

Table 5.21: Domain 5. Market development: solar cookers

Factor	Examples	Country and settings*	Type and quality of evidence**
Demand creation	• Workshops and other strategies used to increase demand	India (141), Kenya (140), South Africa (19), Tanzania (137)	QL=1 *(1=S)* CS=3 *(2=M; 1=W)*
Supply chains	• Import prices and tariffs vs local production • Supply of stove parts • Distribution infrastructure	India (141), Kenya (140), South Africa (19), Tanzania (137)	QL=1 *(1=S)* CS=3 *(2=M; 1=W)*
Business and sales approach	• Stove marketing	Kenya (140), South Africa (19)	CS=2 *(2=M)*

QL=qualitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *Factors are supported by findings in rural (137, 140), urban (141) or mixed settings (19). **Quality of evidence not comparable across different study design.

5.3.6 Domain 6: Regulation, legislation and standards

No evidence has been identified under this domain.

5.3.7 Domain 7: Programmatic and policy mechanisms

Institutional arrangements: A consortium of organisations working together to promote market development, focusing on areas such as reducing production costs and developing financial incentives for production, distribution and training, was reported to have facilitated uptake use in one study (140). However, lack of government support was considered a reason for limited dissemination in the same study (140).

Community involvement: Inclusion of users in the development of projects to promote solar cookers was recommended in two studies as a means to increase popularity and usability of cookers (137, 141).

User training: Adequate training to adjust to the practicalities of solar cooking was reported to be very important for successful adoption and longer-term use of solar cookers (19, 139–141), although training could be costly, especially if this involved individual or small-group demonstrations and support (140).

Post-acquisition support: After-sales service in person or by telephone was reported to be promoted in one study, but it is not clear whether this favoured sustained use of the cookers (141). In small-sized community projects selected individuals have been appointed as mentors to offer technical support to their peers (21). It was argued that follow-up which offers more than just technical assistance is needed to encourage users to continue use of the cookers (140).

Monitoring and quality control: As for several other interventions, systematic monitoring has been stated to be a crucial element for effective promotion of solar cookers in one study (140), but was an issue that has been neglected by most studies.

Table 5.22: Domain 7. Programmatic and policy mechanisms: solar cookers

Factor	Examples	Country and settings*	Type and quality of evidence**
Institutional arrangements	• Government role in promotion and support • Stakeholder co-ordination for market development	Kenya (140)	CS=1 *(1=W)*
Community involvement	• Users involvement	India (141), Tanzania (137)	QL=1 *(1=S)* CS=1 *(1=M)*
User training	• Training in use of solar cookers	Burkina Faso (139), India (141), Kenya (140), South Africa (19)	CS=4 *(3=M; 1=W)*
Post-acquisition support	• Availability of support	India (141), Kenya (140), South Africa (21)	CS=3 *(2=M; 1=W)*
Monitoring and quality control	• Monitoring of implementation	Kenya (140)	CS=1 *(1=W)*

QL=qualitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *Factors are supported by findings in either rural (140), urban (139, 141) or mixed settings. **Quality of evidence not comparable across different study design.

5.3.8 Equity consideration in relation to solar cookers

In relation to urban/rural location, increased adoption was reported in places where wood was scarce and savings from reduced purchasing of wood could have a positive impact (19). Solar cookers were, however, usually unaffordable for poorer households (98, 137, 141). Instead, it was noted that better-off families appreciated the savings that could be made on more expensive modern fuels (19).

With respect to gender, time savings from less wood collection and less need to watch over food closely may have a positive impact on women, as free time was reported to be used for income-generating activities (137) and domestic work (137), and for time spent within the community (138). On the other hand, the time that women spent on fuel collection was not always valued (low opportunity cost) (140), and neither were other social and economic benefits from solar cooking (140). Also, delays in serving meals as a consequence of solar cooker use (i.e. not having a hot dinner ready to be served) were reported to have triggered domestic abuse in some families (140).

Table 5.23: Characteristics of included studies on solar cookers, by study category

Author (year) *(reference no.)*	**Country/ Setting**	**Study design and sampling**	**Data collection**	**Data analysis**	**Quality appraisal***	**Adoption (A) vs sustained use (S)**	**Technology characteristics**
			QUALITATIVE STUDIES (QL)				
Otte (2009) *(137)*	Tanzania (rural)	SSI (not specified), 5 KIIs and PO	Interviews with women users, project co-ordinators and other staff	'Meaning categorisation' according to seven dimensions	Strong	A	Box and parabolic cookers
Sesan (2012) *Findings on solar cookers (98)*	Kenya (urban**)	15 SSIs, 9 KIIs, PO	Interviews with women users and stakeholders	Method not stated; descriptive narrative	Moderate	A	CooKit (panel cooker)
Velasco (2008) *(80)*	Mexico (rural)	10 SSIs, PO	Interviews with women users	Method not stated; descriptive narrative	Weak	A	HotPot solar oven
			QUANTITATIVE STUDY (QN)				
Levine and Beltramo (2012) *(108)*	Senegal (rural)	Phased randomised controlled study (n=50 HHs) with 50% cookers distributed at baseline and 50% after 6 months to control groups	Baseline survey + self-reported utilisation monitoring survey at 6 months	Multivariable approach adjusting for confounders	Strong	A	HotPot solar oven

Author (year) *(reference no.)*	Country/ Setting	Study design and sampling	Data collection	Data analysis	Quality appraisal*	Adoption (A) vs sustained use (S)	Technology characteristics
			CASE/POLICY STUDIES (CS)				
Ahmad (2001) *(141)*	India (urban)	Interviews (n=28), workshops and PO	Repeated interviews with users and disusers, including husband/wife and children	Descriptive narrative	Moderate	S	Box cooker
Baptista et al. (2003) *(140)*	Kenya (rural)	KII (n=unknown) and field-tests	Phone and face-to-face interviews with stakeholders	Descriptive narrative	Weak	A	HotPot solar oven
Biermann et al. (1999)/Sejake (1998)*** *(21, 138)*	South Africa (rural/urban)	A one-year comparative field-test of cookers (n=66 HH users, n=30 controls)	Weekly interviews and FGDs with families owning a specific cooker for certain amount of time	Descriptive narrative	Moderate	A	Seven different including box and parabolic cookers
Toonen (2009) *(139)*	Burkina Faso (urban)	Survey (n=86, of whom 59 were beneficiaries)	Self-reported use of solar cookers by women users	Descriptive narrative	Moderate	A/S	CooKit (panel cooker)
Wentzel and Pouris (2007) *(19)*	South Africa (rural/urban)	Review of empirical studies (survey n=100; market studies n=200, etc.).	Range of methods including interviews at homes, telephone interviews, observation, and focus groups; detail not described	Descriptive narrative based on synthesis of multiple empirical studies	Moderate	A/S	Different models, including box and parabolic cookers

FDG=focus group discussion; SSI=semi-structured interview; KII=key informants interview; PO=participant observation; HH=household.

*Quality appraisal of studies was conducted using three separate quality assessment tools resulting in an overall score of strong, moderate or weak. It is, however, important to note that quality appraisal across study designs is not directly comparable. **This study was conducted in a peri-urban setting. ***These two published studies describe the same pilot project conducted in South Africa so they have been treated as one study and results are combined.

5.4 Alcohol fuels

5.4.1 Introduction

Promotion of alcohol-based fuels for household cooking (such as ethanol and methanol, available usually as liquids but also in gel form) is a relatively recent development. Bio-ethanol is a liquid that can be produced by sugar fermentation from various types of biomass feedstock including sugar-based materials (e.g. sugar cane, sorghum), starches (e.g. cassava, maize) and cellulose-based products (e.g. wood, grasses and agricultural residues) (24). The ideal feedstock depends on climate and soil conditions, as well as the available technology (142). The ethanol–water mixture produced after fermentation needs to be further purified by distillation. The higher-quality ethanol stoves require hydrous ethanol (95 percent), with a maximum water content of 4–10 percent (25). Denaturating agents (e.g. bitter tasting substances) and colorants are usually added to ethanol to discourage users from drinking it as an alcoholic beverage. Methanol is mainly produced from fossil fuels such as natural gas or oil products and its production cost is less than for ethanol (26). Its potential for the household cooking market may therefore be greater in countries with natural gas supplies (143). Gelfuel is a much higher-viscosity fuel produced when denatured liquid ethanol is mixed with a gelling agent (e.g. calcium acetate or cellulose) and water, resulting in a combustible gel (144). However, limited gelfuel stove programmes seem to be in operation today as gelfuel has the disadvantage of not providing sufficient heat (and hence energy to the pots) and the initial gelfuel stoves which were promoted during the ‘Millennium Gelfuel Initiative’ had serious performance limitations, which resulted in very low adoption rates by consumers (25).

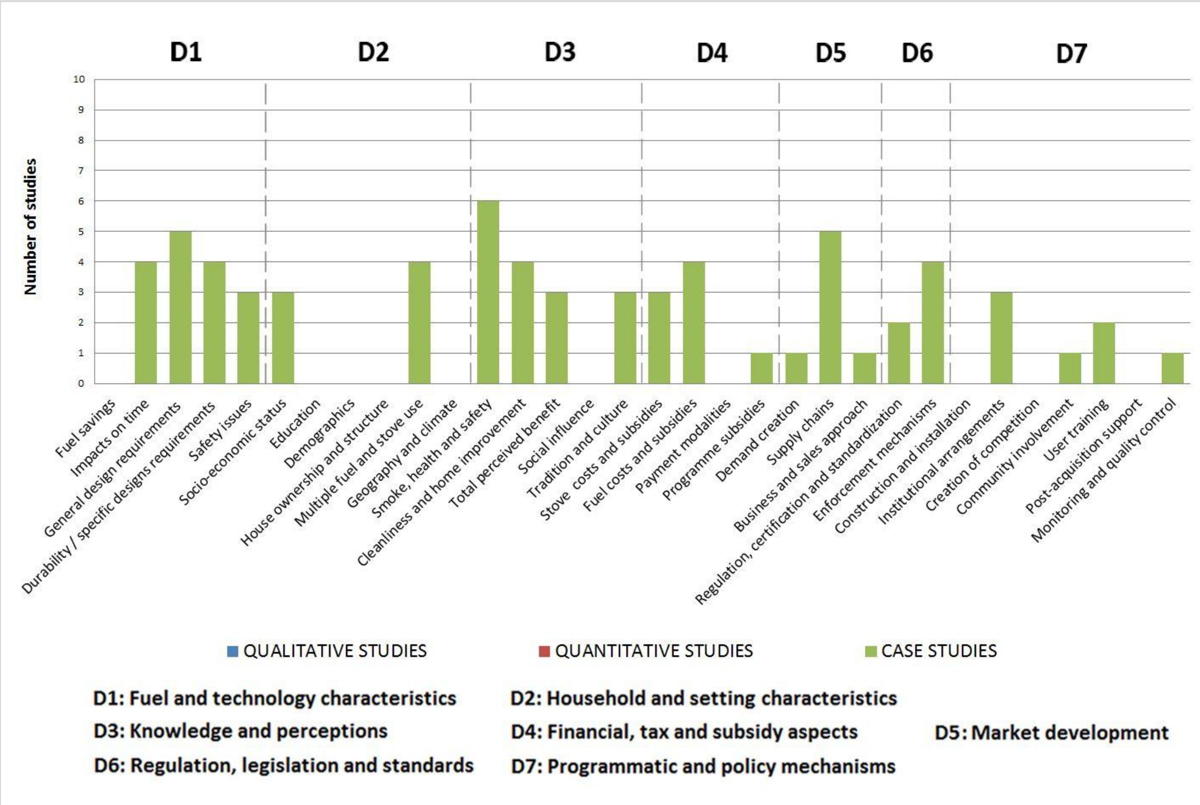
5.4.2 Studies meeting inclusion criteria

A total of six case studies were identified providing empirical evidence on factors influencing the uptake of alcohol-fuelled stoves. Three of the studies were reports of small-scale projects to assess the feasibility of larger-scale promotion of alcohol fuels carried out in Ethiopia (145), Brazil (146) and Nigeria (147). Studies focused on testing users’ satisfaction with imported stove technology, including willingness to pay for the fuel after an initial free fuel supply of one to three months. The Madagscar study, (available online as two separate reports [i.e. components A and B] (25, 148) separately included in this review) was a comprehensive assessment utilising mixed methods to investigate socio-economic factors and user perceptions of ethanol fuel and ethanol stove preferences in two communities (Ambositra and Vatomandry). The study focused on substituting ethanol for charcoal in one and charcoal and wood in the other, and is. The last included study was a case study describing the activity of a small company producing ethanol in Indonesia (149).

Five of the included studies reported on the use of locally produced and denatured ethanol and one study is based on denatured methanol (147) (both fuels in the form of liquid preparations, available as refillable plastic bottles or canisters). In terms of quality, one study was scored as strong, four as moderate, and one as weak. Detailed study characteristics are summarised in Table 5.31 at the end of this section.

Figure 5.4 illustrates the 22 factors identified across the seven domains for alcohol fuel adoption and use. Despite the fact that all domains were represented, with only six studies this evidence base is quite limited. As the majority of the 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 alcohol fuel. This is particularly reflected in Domains 1 and 3, although supply chains within Domain 5 were also investigated in most of the studies. Following sensitivity analysis excluding the one weak study, the number of factors with supporting evidence was reduced to 17, with loss of this information from Domains 4, 5 and 7. Given the paucity of studies, the findings for alcohol fuels should be seen as tentative, with results pertaining to an early stage in the process of implementation.

Figure 5.4: Factors influencing the uptake of alcohol fuels across seven domains (D1–D7), by study type and number of studies



One other issue relating to the lack of breadth of evidence is that the majority of experience with alcohol fuels related to a single type of stove, the Dometic 'CleanCook', (with single or double burners). This reflects the widely acknowledged quality and safety of this stove and fuel canisters, but also the lack – to date – of suitable alternatives and specifically local production in the countries where use has been studied.

5.4.3 Domain 1: Fuel and technology characteristics

Time savings: One of the main reported advantages of cooking with alcohol-fuelled stoves was time saving as a result of both faster cooking and being able to carry out other tasks while cooking (25, 145, 148). One litre of ethanol used on the CleanCook normally provides 4 to 4.5 hours of cooking at full power (that is at ~1.5 kW) or up to 8 hours of cooking at lower power settings).

Based on results from the feasibility studies, one litre of fuel is generally sufficient for one day of cooking (based on three meals for a family of five), which translates to 7 litres per week (147). Five litres per week were usually considered insufficient to meet family needs (145, 146).

General design requirements: In terms of design requirements imported stove models were considered of high quality, efficiency and speed (25, 145, 147, 148), with substantial reduction in household pollutant concentrations. Measured reductions were available from some studies, including for example large reductions in 24-hour average kitchen concentrations of CO and PM2.5[5], and personal CO for women and children, among groups of households using ethanol with the CleanCook stoves, in comparison with traditional charcoal and wood stoves in the study from Madagascar which used a quasi-experimental design (148). Adjustable cooking speed was valued (145) and promotion of stove models with a second burner to allow cooking with more than one pot was recommended by users (146, 148).

Durability and specific designs requirements: Suggested design improvements included secure pot supports (147) for either smaller (146) or larger pots (148) and larger-capacity canisters (the standard fuel canister in the CleanCook stove was 1.2 litres) (147). In one study, the main complaints reported were wastage of fuel during refilling of the canister (25) and some difficulties in lighting the stove (25).

Table 5.24: Domain 1. Fuel and technology characteristics: alcohol fuels

Factor	Examples	Country and settings*	Type and quality of evidence**
Impacts on time	• Cooking time	Ethiopia (145), Madagascar (25, 148), Nigeria (147)	CS=4 *(1=S; 3=M)*
General design requirements	• Efficiency and speed	Brazil (146), Ethiopia (145), Madagascar (25, 148), Nigeria (147)	CS=5 *(1=S; 4=M)*
Durability and specific designs requirements	• Design improvements to meet users' needs	Brazil (146), Madagascar (25, 148), Nigeria (147)	CS=4 *(1=S; 3=M)*
Safety issues	• Risk of explosions • Quality of equipment	Brazil (146), Madagascar (25), Nigeria (147)	CS=3 *(1=S; 2=M)*

CS=case studies; *S*=strong; *M*=moderate. *Factors are supported by findings in either urban (145, 147) or rural/urban settings (25, 146, 148) **Quality of evidence not comparable across different study design.

Safety issues: A low risk of fuel leakage and no risk of explosion were described by users using imported alcohol-fuelled stoves (i.e. the CleanCook) (146, 147), since the fuel is not pressurised and it is fully retained by a densely packed refractory ceramic fibre contained inside the canisters, so no leakage occurs even if the cooker tips over. Also, in the Madagascar study, a lower risk of burns was reported in comparison to traditional stoves (25, 146, 147) (see Domain 3).

5.4.4 Domain 2: Household and setting characteristics

Socio-economic status: To date, the ethanol market and the small-scale feasibility studies have been mostly targeted at middle-income households already using purchased fuels

[5] PM 2.5: particulate matter of a diameter of up to 2.5 micrometers

such as charcoal (25), kerosene (145) and LPG (to a limited extent) (146), against which ethanol fuel can compete on price (25).

Multiple fuel and stove use: The included studies presented limited information on characteristics of households and settings that might influence adoption of fuel switching to alcohol fuels. Households selected to take part in pilot studies reported high use of the new stoves, but also simultaneous use of kerosene (145), LPG (146) and/or other traditional fuels (148). This seems to have been in part due to insufficient ethanol being available during the feasibility study periods to meet cooking needs for the entire family (145).

Table 5.25: Domain 2. Household and setting characteristics: alcohol fuels

Factor	Examples	Country and settings*	Type and quality of evidence**
Socio-economic status	• Income level	Brazil (146), Ethiopia (145), Madagascar (25)	CS=3 *(3=M)*
Multiple fuel and stove use	• Use of traditional fuels • Inadequate availability of ethanol fuel	Brazil (146), Ethiopia (145), Madagascar (25, 148)	CS=3 *(3=M)*

CS=case studies; *M*=moderate. *Factors are supported by findings in either urban (145) or rural/urban settings (25, 146, 148). **Quality of evidence not comparable across different study design.

5.4.5 Domain 3: Knowledge and perceptions

Smoke, health and safety: The quantitative component of the Madagascar intervention study (upon which the adoption case study was based) (148) reported a statistically significant reduction in headaches and eye irritation among women due to smoke reduction, as well as a significantly reduced occurrence of burns in both women and children using ethanol fuel/stoves compared to traditional fuel/stoves (148). Alcohol fuels were also perceived by users to be safer than kerosene and LPG, especially in relation to the risk of explosions (145–147). However, use of poor-quality stoves (during the initial option appraisal stage – not used in evaluation study) (25) or unpatented/not standardised models disseminated in Indonesia (149) raised safety concerns and fears about fire. In addition, despite the inclusion of denaturants which have a bitter taste, the issue of ingestion of fuel by children was not fully documented in the included studies and should not be overlooked until this has been more carefully evaluated, as the fuel may be purchased and stored in soft drink bottles (148). The issue of adults obtaining ethanol fuel to augment or substitute alcoholic beverages is also reported, but to date little information is available on the potential or actual health risks (148).

Cleanliness and home improvement: Increased home and kitchen cleanliness (from reduced smoke and soot) and improvement of indoor air quality were also reported as positive factors that can favour adoption (25, 147, 148).

Total perceived benefits: Alcohol fuels are considered high-quality fuels (145), and convenience for cooking is valued by users (146–148).

Tradition and culture: Some users complainted about lack of smoky taste (146), and in Madagascar there were some difficulties in cooking the full range of traditional foods during cooking tests (25).

Table 5.26: Domain 3. Knowledge and perceptions: alcohol fuels

Factor	Examples	Country and settings*	Type and quality of evidence**
Smoke, health and safety	• Perceived and measured health benefits • Safety concerns and benefits	Brazil (146), Ethiopia (145), Indonesia (149), Madagascar (148), Nigeria (147)	CS=6 *(1=S; 4=M; 1=W)*
Cleanliness and home improvement	• Cleaner home • Cleaner vessels	Nigeria (147), Madagascar (25, 148)	CS=3 *(1=S; 2=M)*
Total perceived benefit	• Overall perceived advantages	Brazil (146), Ethiopia (145), Madagascar (148), Nigeria (147)	CS=4 *(1=S; 3=M)*
Tradition and culture	• Mixed findings on suitability for preparing local dishes	Brazil (146), Ethiopia (145), Madagascar (25)	CS=3 *(3=M)*

QL=qualitative studies; QN=quantitative studies; CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *Factors are supported by findings in either urban (145, 147) or rural/urban settings (25, 146, 148). **Quality of evidence not comparable across different study design.

5.4.6 Domain 4: Financial, tax and subsidy aspects

Stove cost and subsidies: Both the upfront costs for stove purchase and the costs of fuel were considered to be high by users participating in these early-stage field studies (25, 146). Although stoves were given free in these studies, the cost of imported stoves may be a barrier for many potential low- and middle-income users. However, locally manufactured stoves should help to reduce ethanol stove prices and facilitate initial adoption (25, 149).

Fuel costs and subsidies: Among the key barriers to ethanol use were inadequate fuel availability on the local market, and a relatively high price. That said, one study found that full market-based pricing could still complete with traditional purchased fuels, notably charcoal in Madagascar (25). Following a period of fuel being available free during feasibility studies, use of ethanol/methanol and willingness to continue paying for the fuel was variable and mostly influenced by household income (146, 147). Fuel cost was certainly a barrier for low-income households (146), but an increase in demand irrespective of price rise over time was also reported for middle-income households in one study (147). In addition, distance from fuel supply affected uptake (146), which needs to be carefully considered when fuel is not produced in local distilleries and therefore needs to be imported or transported over relatively long distances (25).

Programme subsidies: The included studies did not provide any direct empirical evidence on this aspect, as stoves were provided free during the small-scale feasibility studies. Similarly, fuel was donated to study participants. In Indonesia, abolition of national subsidies on existing fuels (e.g. on kerosene) could facilitate the switching to ethanol, as the fuel could be sold at a competitive price; local production also offers opportunities for local business development and jobs creation (149).

Table 5.27: Domain 4. Financial, tax and subsidy aspects: alcohol fuels

Factor	Examples	Country and settings*	Type and quality of evidence**
Stove costs and subsidies	• Initial stove costs • Availability of initial subsidies	Brazil (146), Indonesia (149), Madagascar (25)	CS=3 *(2=M; 1=W)*
Fuel costs and subsidies	• Price of fuel and refilling costs • Fuel subsidies	Brazil (146), Indonesia (149), Madagascar (25), Nigeria (147)	CS=4 *(3=M; 1=W)*
Programme subsidies	• Government support • Financial incentives	Indonesia (149)	CS=1 *(1=W)*

CS=case studies; *M*=moderate*; W*=weak. *Factors are supported by findings in either rural (149), urban (147) or both settings (25, 146). **Quality of evidence not comparable across different study design.

5.4.7 Domain 5: Market development

Demand creation: Empirical evidence on effective mechanisms to enhance demand for alcohol fuels among prospective users is unfortunately very limited in the few available studies. The Indonesian study, however, suggested that marketing strategies for local communities and partnerships with local distributors could assist with market penetration (149).

Table 5.28: Domain 5. Market development: alcohol fuels

Factor	Examples	Country and settings*	Type and quality of evidence**
Demand creation	• Strategies used to increase demand	Indonesia (149)	CS=1 *(1=W)*
Supply chains	• Supply infrastructure • Road infrastructure and distance from supply • Fuel availability, importation and stock	Brazil (146), Ethiopia (145), Indonesia (149), Madagascar (25, 148), Nigeria (147)	CS=5 *(4=M; 1=W)*
Business and sales approach	• Factors favouring market expansion	Indonesia (149)	CS=1 *(1=W)*

CS=case studies; *M*=moderate*; W*=weak. *Factors are supported by findings in either rural (149) or urban (145, 147) or rural/urban settings (148). **Quality of evidence not comparable across different study design.

Supply chains: In terms of supply, investment in in-country production of ethanol and distribution was considered more important than issues of fuel importation (148, 149). Access to raw materials and local processing facilities are considered key to sustained ethanol production (25, 149). Lack of a low-cost ethanol supply and the geographical distance between suppliers and users, limiting availability of fuel, were both reported to be barriers to uptake (145–147). With regard to promoting local manufacturing of stoves, quality and safety issues must be carefully addressed before a successful local market can be set up (25, 149).

Business and sales approaches: Selling ethanol stoves at a comparable price to kerosene/LPG stoves and increasing the availability of basic infrastructure (including feedstock processing and stove production facilities) could facilitate sales (149).

Aspirational LPG users may also provide a potential market for ethanol, as the possibility of buying ethanol in small quantities (i.e. by the litre, rather than in bulk quantities needed for LPG refilling) was reported to be an incentive for prospective ethanol users taking part in the study (146).

5.4.8 Domain 6: Regulation, legislation and standards

Regulation, certification and standardisation: National/regional legislation was found necessary to support fuel production, for example in providing market incentives for local ethanol micro-distilleries (146) and also for fuel transportation as regulations restricting transportation and distribution of alcohol-based liquids can create serious barriers to wider dissemination of this fuel (149). Appropriate tax legislation for the use of ethanol as a household fuel (as opposed to use in alcoholic beverages) is very important if this fuel is to be affordable (146).

Enforcement mechanisms: A few studies have emphasised the importance of appropriate enforcement of taxation strategy and standards for stoves and fuel storage, in order to ensure quality, functionality and safety of stoves and fuels (25, 147, 149). Lack of patented stove designs has resulted in imitated, poor-quality stove copies being sold to customers, with consequent users' complaints as a result of having purchased defective and potentially risky devices (149).

Table 5.29: Domain 6. Regulation, legislation and standards: alcohol fuels

Factor	Examples	Country and settings*	Type and quality of evidence**
Regulation, certification and standardisation	• Fuel production • Fuel transport • Taxation policy	Brazil (146), Indonesia (149)	CS=2 *(1=M; 1=W)*
Enforcement mechanisms	• Design standards and certification	Brazil (146), Ethiopia (145) Madagascar (25), Nigeria (147)	CS=4 *(1=S; 3=M)*

CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *Factors are supported by findings in either rural (149) or urban (145, 147) or rural/urban settings (25, 146). **Quality of evidence not comparable across different study design.

5.4.9 Domain 7: Programmatic and policy mechanisms

Institutional arrangements: Evidence of factors governing the success of ethanol introduction on a national market suggested that fuel availability, sustained production and price are important (25, 146, 149). Findings showed that, if alcohol is to find a place as a household fuel, strategic large-scale investment and supportive polices are required to address local production (or importation), taxation, transport and sales (146, 149). The 'overlap' with the legal and illegal alcohol beverage markets also needs to be institutionally regulated (25).

Community involvement: Training in ethanol production (e.g. from local crops) and empowering local communities through business activities for wider dissemination were highlighted as a means of increasing production and promoting uptake (149). It is important however that this be properly managed so agriculture for fuel production does not adversely impact on food crops and land use (see also equity considerations, below) (148).

User training: The feasibility studies reported here paid special attention to training in stove use, fuel refilling and stove cleaning through frequent follow-up visits (25, 147), and concluded that training in fuel refilling was particularly important to ensure safe use of fuel and stoves (25, 147).

Monitoring and quality control: The role and importance of monitoring was not discussed among the included studies; however, it was acknowledged that quality control measures should be taken into account and these should include aspects such as feedstock processing (149).

Table 5.30: Domain 7. Programmatic and policy mechanisms: alcohol fuels

Factor	Examples	Country and settings*	Type and quality of evidence**
Institutional arrangements	• Strategic government policy on production, supply and price • Distinction of fuel and beverage 'markets'	Brazil (146), Indonesia (149), Madagascar (25)	CS=3 *(1=S; 1=M; 1=W)*
Community involvement	• Planning and managing crop products for fuel production	Indonesia (149)	CS=1 *(1=W)*
User training	• Training in safe stove and fuel use	Madagascar (25), Nigeria (147)	CS=2 *(1=S; 1=M)*
Monitoring and quality control	• Monitoring of implementation	Indonesia (149)	CS=1 *(1=W)*

CS=case studies; *S*=strong; *M*=moderate; *W*=weak. *Factors are supported by findings in urban (147), rural (149), or rural/urban settings (25, 146, 148). **Quality of evidence not comparable across different study design.

5.4.10 Equity considerations in relation to alcohol fuels uptake

The six studies included in this review offer limited evidence on the prospects for alcohol fuels (and in particular for bio-ethanol) to reach poorer households, although some benefits of this are acknowledged and apply especially in rural settings. The development of local micro-distilleries, for example, has the potential to help alleviate poverty among rural populations with access to the necessary feedstock crops, etc. (146, 148). It was suggested in one study that an increase in family income might also help in discouraging farmers from moving to cities in search of job opportunities, thereby reducing rural-to-urban migration (146). The case studies from Madagascar recommended that use of land for sugar cane, cassava or other types of feedstock to produce bio-ethanol needs effective management and strategic, large-scale investment to ensure that high yields can be achieved sustainably, and non-interference with food crops (148). The reports also suggested that this could be achieved through creation of medium- and small-scale biofuels enterprises, which should involve farmers and local communities, to target poverty reduction (148).

Gender and regional (urban/rural) issues in relation to adoption of alcohol-based fuels are not directly explored in the included studies, but similar considerations and benefits to those reported for other clean fuels can be envisaged in relation to alcohol fuel adoption.

Table 5.31: Characteristics of included studies on alcohol fuels, by study category

Author (year) *(reference no.)*	**Country/ Setting**	**Study design and sampling**	**Data collection**	**Data analysis**	**Quality appraisal***	**Adoption (A) vs sustained use (S)**	**Fuel used****	**Stove**
CASE/POLICY STUDIES (CS)								
Couto (2007) *(146)*	Brazil (rural/urban)	Pilot intervention study with 100 HHs (repeated surveys over three months)	Face-to-face interviews with participants	Descriptive narrative	Moderate	A	Ethanol	Dometic CleanCook (1 burner)
Imam (2011) *(149)*	Indonesia (rural)	KII with stakeholders (n=5)	Face-to-face and telephone interviews	Descriptive narrative	Weak	A	Ethanol	Locally produced E-stoves
Murren (2006) *(145)*	Ethiopia (urban)	Pilot intervention study with 409 HHs, (repeated bi-weekly surveys over 3 months and qualitative interviews with users)	Face-to-face interviews with participants	Descriptive narrative	Moderate	A	Ethanol	Dometic CleanCook (assumed 2 burners)
Obueh (2008) *(147)*	Nigeria (urban)	Pilot intervention study with 150 HHs, (repeated bi-weekly surveys over 3 months)	Face-to-face interviews with participants	Descriptive narrative and frequencies	Moderate	A	Methanol	Dometic CleanCook (assumed 2 burners)
Practical Action Consulting (2010) – Component B *(25)*	Madagascar (rural/urban)	Controlled cooking tests and comparison of cooking stoves with interviews and FGD (n=8).	Face-to-face interviews with participants	Descriptive narrative and statistics	Moderate	A	Ethanol	Imported CleanCook (1 burner)
Practical Action Consulting (2011) – Component A *(148)*	Madagascar (rural/urban)	Socio-economic cross-sectional survey (n=270) and exposure monitoring	Face-to-face interviews with participants	Multivariable approach[#] adjusting for confounders	Strong	A	Ethanol	Imported CleanCook (1 burner)

FDG=focus group discussion; SSI=semi-structured interview; KII=key informants interview; PO=participant observation. *Quality appraisal of studies was conducted using three separate quality assessment tools resulting in an overall score of strong, moderate or weak. It is, however, important to note that quality appraisal across study designs is not directly comparable. **Fuel previously denaturated. [#]Multivariable approach=summary of factors associated with adoption after adjustment for potential confounders/covariates.

5.5 Summary of findings in relation to clean fuels

5.5.1 Overview of main issues for uptake

A summary of the main issues for adoption and sustained use of the four clean fuels considered in this chapter is provided below.

- **LPG:** This 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, with lower-income and rural populations using a mix of LPG and traditional (solid) fuels and stoves appropriate to their 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 that require a strong policy and management response.
- **Biogas:** Production and use of this fuel is 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, it 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 was 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 and 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.
- **Solar:** This method of 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, and training of users to plan ahead for their cooking requirements, in particular given the need to use the cooker during the middle part of the day. It may, however, have more potential than realised so far as an option complementing other fuels and technologies, not least as it can save on fuel collection and costs, particularly of expensive clean fuels. To date production and marketing of low-cost, high-quality cookers has been constrained by what would appear to be piecemeal and poorly co-ordinated strategy.
- **Alcohols:** 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 as to the situations and circumstances where it is most likely to succeed, but as a renewable, safe, clean and relatively cheap fuel (compared to LPG) it would appear to have considerable potential certainly 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.

5.5.2 Costs associated with uptake of clean fuels

The costs of switching to and continuing to purchase clean fuels are among the more important factors determining adoption, the extent to which these fuels are used (that is, the proportion of cooking done with clean compared to traditional fuels), and sustained use. Broadly, there are three components to these costs: (i) the initial outlay for the technology, (ii) the ongoing purchase of fuel (when applicable), and (iii) system maintenance; these vary significantly between the fuel types and are summarised in Table 5.32 below. Furthermore, as a consequence of the high costs of one or more of these components, factors impacting on affordability including subsidy, credit arrangements and loans have been found to be very important for adoption and sustained use. These are complex and – particularly in the case of subsidy – controversial areas of policy.

Table 5.32: Costs associated with clean fuel adoption and use

Fuel	***Initial costs***	***Ongoing costs***
LPG	High cost of stove, pipe, regulator and gas bottle, although small bottles with a single burner can be more affordable.	Refill of LPG bottles is costly, and linked to fluctuating oil prices. For most systems, the bottles are exchanged, requiring payment for the full contents of the bottle. Generally low maintenance costs.
Biogas	Very high cost of construction of biogas plant, piping and stove; substantial capital financial support for installation has been the norm, however.	With sufficient livestock or other suitable feed, fuel costs are zero, but labour is required to manage and maintain the plant. Repairs may be (very) costly.
Solar	Moderately high cost for high-quality stoves, particularly those imported.	No fuel cost, and if good quality the stove should be maintenance-free.
Ethanol/ methanol	High cost of stove, especially of the high-quality imported models, but in contrast to LPG the fuel storage bottle can be relatively cheap.	Fuel costs are lower than for LPG and can compete with charcoal. Low maintenance cost.

6. Discussion

The foregoing chapters have described the evidence on factors affecting the uptake of ICS and clean fuels, assessed through a mixed-method systematic review based on 101 studies from 29 developing and middle-income countries. In this section, we consider the extent to which the relative importance of the identified factors can be ascertained, the degree of commonality in factors across solid fuel stoves and the four types of clean fuels, and how the nature and quality of evidence available affects reliability and generalisability of the findings.

6.1 Relative importance of enabling and limiting factors

The range of factors identified across domains for ICS and each of the four clean fuels is summarised in Table 6.1. This may present a challenge for efficient policy-making, and as a consequence the question of which of these factors is most important is critical.

As noted in section 3.6, prioritisation requires both a suitable method and an evidence base that supports such assessment, and it is not clear that either of these is available. Specifically, the heterogeneity inherent in this set of studies makes comparative assessment difficult, and only the quantitative studies using multivariable regression provide any formal analysis of independently associated factors. Yet, even then, outcomes vary considerably across studies, so combining this evidence to rank factors would not be reliable. Consistency of findings offers some guide to importance, but many factors fulfil this criterion, and lack of evidence does not mean a factor is unimportant. An example of this last point is that relatively few studies report on standards and regulation, but this is more a reflection of the historical lack of policy attention in this field, which is quite counter to the effort now being put into developing stove standards with ISO along with regional testing centres and the national regulation governing certification which can be expected to follow[6]. Consequently, attempts to identify the most important factors are bound to rely mainly on judgement at this stage.

Against this background of methodological constraint on prioritisation, the assessment of the evidence as reported in Chapter 4 and 5, suggests that **all domains** and **all the identified factors** within them can influence adoption and/or sustained use of ICS and clean fuels, although the extent of that influence is often dependent on the setting and specific stove/fuel combination. While some of these factors would appear critical, such as affordability and the ability of the technology to cook traditional meals, meeting these criteria does not guarantee that a stove or fuel will be adopted, or that it will be used in a sustainable way. Such factors can therefore be considered **necessary** but not **sufficient**, and indeed many other factors play a part in ensuring adoption and continuity of use over time.

For example, even if a woman is initially encouraged to purchase an improved stove and is able to pay for it, if the stove does not suit her family's needs and the more common

[6] See www.cleancookstoves.org/blog/standards-and-testing-2012-highlight-and-2013-outlook.html and www.iso.org/iso/catalogue_detail?csnumber=61975

foods cannot be prepared, the stove will not be used on a regular basis. Even if it meets all these requirements and she begins to use it, if the stove breaks after a year of use and she cannot afford to repair it, or has no access to parts and the necessary assistance, it will fall into disuse. Therefore, while affordability (whether as a result of price, household income, availability of finance, or a combination of these) and meeting users' needs are prerequisites for success, many other factors from across the domains will ultimately determine whether households adopt, use, maintain and replace improved stoves and clean fuels over time, and the extent to which these interventions displace traditional stoves and fuels. Which is the necessary combination of factors depends on the settings (e.g. households and community targeted, local/national policies), circumstances (e.g. programme and support frameworks) and, of course, fuels and technologies used.

This suggests that, rather than attempting to identify a small number of critical factors, a systematic and systemic assessment of the domains and corresponding factors should be carried out in order to identify those factors that are most relevant to the setting/programme under consideration. Additionally, some factors operate primarily at household and community level while others operate primarily at programme and societal level, indicating that both levels need to be taken into account during planning and implementation.

6.2 Common and distinct factors for solid fuel stoves and clean fuels

As shown in Table 6.1, the vast majority of factors are common to all or most of the interventions. Indeed, it is surprising that uptake and sustained use of such different technologies are largely determined by the same factors operating across the seven domains. Yet there are also a few important differences, which usually reflect specific requirements for one or more of the clean fuels.

For example, for all technologies stove and fuel costs play an important role in influencing uptake. Indeed, characteristics of the fuel and cooking technology itself have the potential to act as enablers or serious barriers to adoption and use. High-quality design and construction, in particular, is critical for meeting users' needs and, ultimately, for significantly reducing emissions and improving safety across ICS, LPG and gas stoves, and ethanol, biogas and solar cookers. On the other hand, safety aspects associated with risk of burns and fires are more relevant for solid fuel stoves, while explosions are more relevant to LPG (and to some extent alcohol stove use), and less relevant to biogas and solar cookers. The availability of livestook and land to build a digester is a critical determinant of biogas adoption, and is a factor specific to that fuel.

Absence of evidence for some of the listed factors, especially for LPG, solar cookers and alcohol fuels, must be treated with caution, as this may be a result of the more limited number of included studies. Specifically, very few quantitative and qualitative studies were identified for these fuels.

Table 6.1: Common and distinct factors influencing uptake of ICS and clean fuels

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

6.2.1 Impact of perceived opportunity cost of time

A theme found to be particularly important across all five interventions is the influence of perceptions about opportunity cost (particularly in relation to time savings) on adoption of interventions, and the implications of this for policy.

Improved stoves and clean fuels can save time in two main ways, first by reducing fuel collection time and second through more efficient cooking processes. The latter can arise from the ability to cook faster with controllable power and/or through use of multiple pots simultaneously. This aspect is usually highly valued by women and it is a direct benefit that users recognise in almost all the circumstances studied. Moreover, the ability to leave food unattended while cooking with an improved fuel and/or technology enables them to perform additional tasks in the house. With respect to time savings from biomass collection the evidence is mixed but there were multiple examples where the greater availability of labour – and in particular where this involved women and those with less education (i.e. often not in paid employment) – was associated with a low 'value' assigned to the potential time savings. Consequently, the time and other savings from more efficient stoves or modern fuels such as LPG provided less incentive for switching than might have been anticipated. Conversely, there was evidence that where women were engaging in paid employment, the time saving from use of modern fuels was a positive incentive to adoption.

This suggests that programme planning should include assessment of how time savings are valued, 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 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 the fuel.

It should be acknowledged that this issue does not appear to have been extensively studied, and a first step would be to review existing research in related areas of development (with a focus on rural communities and women's time), in order to assess the need for further research on the importance and policy implications of directly addressing opportunity cost valuation as a means to stimulate demand for more time-efficient households energy technologies and fuels.

6.3 Relevance of ICS findings for more advanced solid fuel stove technologies

This section is concerned with the question of whether findings regarding uptake of improved solid fuel stoves derived for stoves of uncertain effectiveness provide a valid basis for determining the factors influencing adoption and sustained use of the more effective technologies increasingly becoming available now, for example low-emission forced draught stoves.

It is likely that despite the absence of recent empirical evidence specific to more modern technologies, the findings reported in Chapter 4 (ICS) are relevant for the following reasons, although some caution is needed. Effectiveness (especially fuel and cost savings and cleanliness), quality, modernity and similar attributes are highly valued by users. As these are (or can be) characteristics of the more modern stove types, it can be expected that this will reinforce demand and continued use. On the other hand, if more advanced solid fuel stoves and clean fuel systems do not meet user needs and are not accompanied by the necessary services and support, they can be expected to fail.

The other critical factor is price, which could easily exclude low-income homes from these improved technologies. This is, however, a complex issue as large-scale production should reduce price (and improve quality), while innovations in financing for both suppliers and potential consumers can clearly be effective in extending access and will need to play a role in future efforts. These points support the view that assessment of the same set of factors should be relevant to currently available modern ICS types and also for clean fuels (and accompanying stoves, storage methods, etc.), as well as to those which will emerge over the coming months and years.

Similar arguments apply to specific types of ICS that are presented in the evidence reviewed. Although it is conceivable that specific findings or recommendations could be made for particular stove types, it must be borne in mind that in any given setting the actual model, cooking and other needs from the stove, fuel availability, delivery mechanism and support, together with the household and community circumstances, will all vary and any one of these may influence success or otherwise. Again, the most practical and effective approach would appear to be to assess the range of factors across all domains, as relevant to the settings and technology, and to plan accordingly.

6.4 Causal linkage or association?

Given the predominant study designs identified in this review, the majority of the findings obtained through individual studies should be seen as associations, rather than as causal linkages. It is principally through the combination of studies, in terms of their multiplicity across settings and different study types (qualitative, quantitative, policy and case studies), that we can draw some conclusions about likely causal effects.

Factors which are identified consistently in different countries and regions, in different types of study, and as enabling (when present/satisfactory) and limiting (when absent/unsatisfactory) are more likely to be causal. Furthermore, qualitative findings will often provide a different perspective, giving explanations for why factors influence adoption and use, which further strengthen the understanding of and therefore the case for causality.

Also, the specificity of some findings, for example the need for training and demonstrations to enhance adoption and use of solar cooking or the need for adequate finance, land and cattle for expensive biogas plants, makes it hard to advance any explanation other than that these factors are having a causal effect on adoption and/or sustained use.

There are, of course, many inter-relationships between the factors identified, and it is impossible to reliably disentangle which are most important. In some of the quantitative studies, multivariable regression methods were used to identify independent associations, but not all quantitative studies employed these methods. Qualitative studies use different perspectives for understanding causation, and few of the case/policy studies presented such detail in analysis. Furthermore, it is through an understanding of these inter-relationships that meaningful and ultimately effective policy can be developed.

6.5 Factors impacting on adoption and sustained use

It is now widely recognised that, while many stove (and some clean fuel) projects and programmes have achieved a degree of adoption across the communities in which they have worked, sustained use, maintenance and replacement have been much less successful. The majority of identified studies provided information on short-term adoption among relatively small-scale projects and programmes, although some studies also provided information on longer-term use. Nevertheless, there are examples where large-scale adoption (such as in China, India and Indonesia) and sustained use (for example in Nepal and Bangladesh for biogas, Brazil for LPG) have taken place. These examples provide important evidence on aspects of scale and sustainability.

Among the clean fuels, studies on biogas offered useful information about biogas production and use over time, collected during inspection of biogas plants and assessment of their functionality several years after installation, some extending for as long as 10 years. Another issue that influences which factors emerge as important for longer-term use is that adopters become a selected group – if those adopting a new technology are predominantly homes with higher incomes, then income may not be identified as influential in determining sustained use and other factors that differ across the 'adopter' group may come into play. The process of adoption and sustained use is dynamic, and takes place at different rates and at different times across the various socio-economically and culturally defined segments of society. Assessment of the status of adoption and change over time within a community, region or country should form part of the planning process outlined in Chapter 7.

Several identified factors clearly impact on initial acquisition of improved household energy options, such as initial cost, access to credit, availability of land or space to build a biogas digester or a built-in improved stove, and user training for correct and safe use of technology. Some of these, notably those concerning price and availability, will also impact on replacement. Other factors, such as the quality of material used for construction/installation, daily operation and maintenance, fuels savings over time, post-acquisition support, and costs associated with repairs, mainly impact on sustained use, although experience of these among existing users will also influence prospective new adopters through social networks – sometimes strongly so.

There are a number of factors which influence the initial decision for acquisition as well as longer-term use. In the case of biogas, for example, availability of feedstock is a motivating factor for plant installation, but it is also an important determinant of security of gas production over time to meet family needs. In addition, supply chains and infrastructure make improved technologies initially accessible to users, but also favour re-purchasing of stoves or stove-parts, availability of spare parts for repairs and follow-up visits by technicians.

6.6 Strengths and limitations of this systematic review

6.6.1 Search strategy

Although a detailed and comprehensive search strategy was used, including searches in multiple grey literature databases, we are aware that much more knowledge is likely to reside in the grey literature. Indeed much practical and valuable knowledge has probably not even been written up. We therefore acknowledge that experience and some evidence and the reporting of recent national or regional campaigns in some countries may have been overlooked, and perhaps even more is unavailable to a review of published sources.

The search terms for improved stoves and clean fuels were extensively piloted in multiple databases prior to running the definitive searches on which the review is based. The two searches were not conducted simultaneously, however, with the peer-reviewed database searching for ICS and clean fuels carried out in July 2011 and June 2012 respectively. The search strategies were purposively adapted to database-specific needs as described in Appendix 2.4.

In terms of language, we were able to carry out screening of papers (titles, abstracts and full texts) in English, Spanish, Portuguese, French, German and Italian, although the majority of studies were published in English. Resources did not permit inclusion of searches of Chinese language databases[7], although a number of English language studies of Chinese experience were included in the review.

6.6.2 Screening of studies and data extraction

The process used for study selection, data extraction and synthesis of included studies included: double, independent screening of studies provisionally included based on title and abstract (10 percent of studies) and of excluded studies (10 percent of studies); double, independent screening on full-text, and double, independent analysis of all qualitative studies in thematic synthesis. While data extraction was only undertaken by one researcher, at least two researchers contributed to developing the synthesis tables for all qualitative, quantitative, policy and case studies. These steps were carried out thoroughly in an effort to maximise objectivity and consistency.

6.6.3 Extent and quality of evidence

The validity of the insights gained through this systematic review is fundamentally determined by the quality of included studies. Established methods were used to assess the quality of individual studies as described in section 2.2.4. The results of quality appraisal are reported within the tables presented in Chapters 4 and 5 and in Appendices 3.1–3.5. Major quality issues related to extensive lack of information, in particular regarding data collection methods and analysis, in some grey literature reports and scientific articles, making a reliable distinction between genuinely poor-quality data collection/analysis vs inadequate reporting difficult. The principal methodological limitations by category of study are summarised below:

- **Qualitative studies:** We recognised that the majority of qualitative studies were only of moderate quality, mainly due to poor description of data analysis methods and poor description of strategies used to establish scientific rigour and reliability.
- **Quantitative studies:** Most of the identified studies were cross-sectional surveys and only provided relatively shallow insights (i.e. not going beyond descriptors of social or housing conditions). Others, however, used relatively sophisticated approaches to understanding the relative impact of various factors and presented robust analysis.

[7] Since completion of this review, UNGACC has awarded funding for a review of Chinese language studies using comparable methods.

- **Policy and case studies:** The strength of these studies is that they provided some of the most important insights for answering our research question (adoption and sustained use). On the other hand, in many cases it was difficult to assess the quality of the evidence, and to distinguish between empirical analysis and subjective author interpretation[8]. Much of the evidence was presented in a descriptive rather than analytical way, although the combination of data and programme experience was often the key to valuable insights.

While the limitations of many of the individual studies are apparent, being able to draw on multiple types of evidence provides strength in two important ways. First, through this methodological approach we have been able to address the full scope of the review. Had we considered only qualitative evidence, for example, this would have offered a detailed understanding of user knowledge and perceptions but provided very little information regarding any of the other domains. Second, findings supported by more than one study type are likely to be more valid or of greater relevance than findings supported by a single study type. Thus, we believe that our methodological approach has led to a more rounded understanding of the issue from different perspectives.

Finally, we are aware that absence of evidence on a potential factor does not mean that it is not important. Further exploration of experience in practice, for example through KIIs with the stakeholders funding, implementing or evaluating programmes, was discussed by the study team but was beyond the scope and time-frame of this systematic review project.

6.6.4 Synthesis and interpretation of evidence

Our approach to synthesis aimed to retain a lot of detail during the initial stages; this detail is successively lost as we move from data extraction through to synthesis according to study type and fuel type, to overall synthesis. While this multi-level approach may appear tedious, it is crucial to ensure that all factors reported in our overall synthesis can be traced back to findings in the synthesis tables as reported in individual studies (for which study type, study quality, setting and other important features are clearly described).

This has important implications for different readers. While most readers will focus on the Executive Summary and Chapters 6 and 7, those particularly interested in one or two domains (or key factors under these domains), or in one specific intervention type, have the opportunity to review the much more nuanced description of findings in Chapters 4 and 5 and relevant appendices.

While consistent findings are a strength, they also represent a weakness as the evidence supporting any given key factor is drawn from a set of studies of highly variable quality conducted in different settings and countries. This contrasts markedly with the situation

[8] The issue of conflict of interest may arise in any study, but this appeared to the research team to be more likely in policy and case studies than other types of studies, because they were frequently written up by one or more authors close to the implementing agency. All data extraction forms include author affiliations and comment on this issue when appropriate, and this is carried over into the summary tables (see Appendices 3.1–3.5).

of a systematic review and meta-analysis of a set of quantitative studies, where heterogeneity is quantified (and constrained by potentially tight eligibility criteria), a pooled effect estimate is calculated and its robustness is explored through sensitivity analyses. For the current systematic review, there is no easy way to capture the effects of heterogeneity on conclusions, and we have therefore retained a 'trail' which allows the reader to delve into the set of studies from which it is derived.

6.6.5 Limitations of evidence on clean fuels

There are important differences between the nature, timing and geographical scope of the evidence available for the four types of clean fuel, in particular:

- LPG is a widely used and well-established fuel in many countries, and consequently has not commonly been the subject of academic study; instead much relevant information is likely to reside within private sector experience. This is unlikely to have been fully captured through our searches of the scientific and grey literature.
- Biogas has gained some popularity in a number of Asiatic countries, and in particular rural China, India and Nepal. This was also reflected in the overall number of studies conducted in these countries and identified in this review. Evidence has being assessed mostly through case studies.
- In addition to the experience reported here, solar cookers have been extensively used in refugee and other emergency settings, which were purposively excluded from our systematic review (see section 2.2.1).
- Ethanol has only relatively recently emerged as a household fuel (and has also been used in refugee and emergency settings, studies of which were excluded). As a result, the empirical evidence available for this review was quite limited.

7. Conclusions and recommendations

7.1 Implementation of findings: proposal for a planning tool

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. It is therefore important to consider all factors that are likely to be relevant in a given setting, and with respect to a specific technology or fuel. Interactions are noted as important, and may operate at the level of individual factors (within and between domains), but also between domains and sets of domains. 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.

The findings from this review provide the basis for the development of a policy planning tool to assess all domains and constituent factors at household and community level as well as regional, national or international level. The tool would consist of domains and key factors being organised in a framework conforming to the main stages in the development and implementation of policies and programmes for increasing access to ICS and clean fuels. A proposal for the content of this tool is described in Table 7.1, covering seven key components. Such a tool would be applicable to both programme planning and in the evaluation of programmes that have already been implemented. The tool would need to developed and subsequently tested and could employ a software interface to ensure that unnecessary data collection is avoided.

Table 7.1: Key components of the proposed policy planning tool

Section	Component	Explanation
I	*Programme information*	A preliminary section to record key information on the setting, fuel and technology (single or multiple) and delivery mechanism.
II	*Framework covering all factors in the seven domains, and key aspects for equity*	The tool would be structured to allow assessment of all domains and factors. This could 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.
III	*Method for assessing the relevance of each factor*	This component would assist in determining the relevance of each factor to the setting, technology and fuel under consideration (section I of this tool). 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 assessments of the relevance in the setting.
IV	*Data collection to assess each factor*	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 that the survey instruments would mainly provide an outline that allows for adaptation to local circumstances, although fully developed survey instruments would be provided where appropriate.
V	*A scheme for assessing how each factor is operating*	Based on the information collected on each factor in section IV, a scheme would be provided to assess whether each factor is acting as a barrier or enabler and (if possible) the extent. A scoring system would be developed to simplify this and allow comparison, while preserving important information on direction and strength of effect.
VI	*Guidance for compiling results for individual factors by domain, and highlighting inter-relationships*	A facility would be built into the tool to compile and display the results for each factor, and to summarise these by domain. In addition, important interactions could be highlighted, some of which may be 'built-in' within the tool to draw attention to common or expected interactions, but also with a component that is user-defined.
VII	*Guidance on application of results*	The final component would provide guidance to users on reviewing the results by factor, by domain, and overall for the purpose of programme planning and evaluation. This guidance would be developed and improved during testing and initial piloting of the tool with programme partners.

7.2 Development and evaluation of the proposed policy planning tool

The development of the proposed policy planning tool will require a multi-disciplinary team working with representatives of key stakeholders from interested countries.

- It is suggested that a draft planning tool be developed in collaboration with a small number of countries. The draft planning tool would then be pilot-tested during the initial planning phases of a policy and/or the evaluation of the implementation of a policy already in place; efforts could focus on both national and local or subpopulation levels in each country. The development and testing of the tool would include seeking new primary evidence on the adoption and sustained use of ICS and cleaner fuels. Revision and refinement of the draft planning tool would be followed by application in the development of more definitive policies, with plans for an evaluation of how the tool has performed as part of overall programme evaluation.
- It is expected that this process of development from initial testing through to application of the refined version would take between 18 months and two years. Depending on the outcome of this process, the tool would be promoted for wider use at the appropriate time.

7.3 Key gaps and needs for extending the evidence base

A number of issues are identified with regard to limitations in the available evidence, and recommendations are made here to address the most important among these. Two general recommendations emerge. First, intervention programmes or initiatives should establish the effectiveness of the stoves and fuels, in particular in relation to reducing emissions and exposure to household air pollution in absolute terms/concentrations 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 studies designed specifically to investigate factors that enable or limit uptake. More specifically, key recommendations for future research studies are:

- There is a need for an upfront, comprehensive research agenda to accompany large-scale regional, national or global initiatives, addressing (i) R&D for technology (where applicable), (ii) effectiveness and (iii) uptake. This should increase the range of perspectives, involving all major stakeholders (which may include beneficiaries, civil society, government and industry).
- Studies investigating uptake should clearly distinguish between adoption, initial use and longer-term sustained use. There is a need for longitudinal studies to investigate sustained use and, where applicable, re-acquisition of technology rather than short-term adoption. For ICS, there is a particular need for studies of sustained use. For clean fuels, we have identified numerous studies on sustained use of biogas (although almost exclusively in Asian countries), whereas for the remaining clean fuels most of the evidence relates to the initial switch and short-term use.
- Due to the timing of the review, no studies were available on the adoption and use of advanced combustion biomass stoves (e.g. forced draft or semi-gasifier models), technologies which hold promise of delivering much lower levels of emissions. It is

important to include this group of technologies in the next round of adoption studies for ICS.

- While there is a reasonable amount of evidence on ICS and biogas (although more in some settings than others), there is still very limited empirical evidence on adoption and use of other clean fuels. One critical aspect requiring increased attention is the fuel-stacking phenomenon and the factors that may influence a more rapid and complete transition to exclusive or near-exclusive use of clean fuels.
- Some of the described domains are much more densely populated with evidence than others. Future intervention programmes and initiatives should strive towards a more comprehensive approach, looking at all domains that are relevant to the setting and interventions concerned. Given the findings of this review, it is recommended that all seven domains be included, as well as incorporating an equity perspective.

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Appendices

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Conflicts of interest
None of the authors has any financial interest in this review topic.

Appendix 2.1: User involvement in different stages of the review process

	Design of review	Interpretation of review results	Communication and dissemination of review results
Those making decisions regarding household energy interventions	- Representatives of DFID, USAID and other donors - Representative of UNGACC consumers group - Representative of US State Department - Energy Ministry, Ghana	- DFID representative - Representative of UNGACC reaching consumers group - Representative of US State Department - Energy Ministry, Ghana	- UNGACC meetings - WHO meetings - Scientific conferences/ meetings - Internet platforms and listservs - Scientific publications
Those implementing household energy interventions	- GIZ - Indian Institute of Technology - Purposive sample of implementing agencies (governments and NGOs)	- GIZ - Indian Institute of Technology	- UNGACC meetings - WHO meetings - Internet platforms and listservs
Those conducting research on household energy interventions	- World Bank - Duke University - University of Johannesburg - Purposive sample of universities/NGOs involved with research	- World Bank - Duke University - University of Johannesburg	- Scientific conferences/ meetings - Scientific publications, (including the forthcoming WHO IAQ Guidelines)

GIZ=Gesellschaft für Internationale Zusammenarbeit, Germany; IAQ=indoor air quality; USAID=United States Agency for International Development.

Appendix 2.2: Inclusion and exclusion criteria

Included studies

Studies were included if they related to projects/programmes/initiatives of relevant cooking fuel and technology options at household or community level involving intervention in the home, and met the criteria listed below.

Types of studies

- In-depth research studies carrying out a qualitative approach to data collection and analysis;
- Quantitative studies that follow standard epidemiological principles;
- Case/policy studies that usually draw on more than one source of information.

For case/policy studies, we applied the following additional inclusion/exclusion criteria:

- The study must be regional (i.e. subnational) or national in focus (not very local in nature hence providing limited learning potential for large-scale dissemination);
- At least one of the main sources of information about reasons for success/failure must be empirical in nature; i.e. based on some documented way of data collection and analysis, rather than subjective story-telling only;
- For empirical data (to ensure reasonable validity and representativeness of findings), at least some information must be provided on sampling, data collection and data analysis;
- The study provides in-depth insights, for example with analysis and/or discussion of the implications of factors identified for success/failure, rather than simply describing factors.

Study setting

- Primary studies/analyses conducted in low- and middle-income countries defined according to World Bank income regions (see Tables A2.1a–c below);
- Studies from urban and/or rural areas.

Types of interventions (cooking fuel and technology options)

- ICS (using solid fuels or kerosene for cooking prior to intervention);
- Cleaner fuels replacing solid fuels or kerosene, including: LPG and gas; and biogas, ethanol and solar cookers.

Excluded studies

Studies were excluded according to the following criteria:

- Studies not based on empirical evidence or based on indirect evidence (e.g. opinions of stakeholders);
- Generality/lack of specificity (i.e. studies related to general energy sector reform rather than specific information on adoption and use of named improved stoves or cleaner fuels in homes);
- Focus on technology effectiveness rather than household uptake and/or scaling up.

List of included countries

Countries meeting our inclusion criteria were selected according to the World Bank income regions' classification on annual income per capita (2011) and reported in the following tables[9]:

Table A2.1a: Low-income economies (US$1,005 or less)

Afghanistan	Gambia, The	Myanmar
Bangladesh	Guinea	Nepal
Benin	Guinea-Bissau	Niger
Burkina Faso	Haiti	Rwanda
Burundi	Kenya	Sierra Leone
Cambodia	Korea, Dem. People's Rep.	Somalia
Central African Republic	Kyrgyz Republic	Tajikistan
Chad	Liberia	Tanzania
Comoros	Madagascar	Togo
Congo, Dem. Rep.	Malawi	Uganda
Eritrea	Mali	Zimbabwe
Ethiopia	Mozambique	

[9] http://data.worldbank.org/about/country-classifications/country-and-lending-groups#Low_income. Countries from the European and Central-Asia regions that have a population using solid fuel of less than 10% were not included in this systematic review. Albania, Azerbaijan, Belarus, Lithuania, the Russian Federation, Ukraine and Turkmenistan were excluded according to the WHO Global Health Observatory latest statistics (http://apps.who.int/ghodata/?vid=34000). Countries for which no information on populations using solid fuel use is currently available (e.g. Bulgaria, Turkey) were not included.

Table A2.1b: Lower-middle-income economies ($1,006 to $3,975)		
Armenia	Indonesia	Philippines
Angola	India	Samoa
Belize	Iraq	Senegal
Bhutan	Kiribati	São Tomé and Principe
Bolivia	Kosovo	Solomon Islands
Cameroon	Lao People's Dem. Rep.	Sri Lanka
Cape Verde	Lesotho	Sudan
Congo, Rep.	Marshall Islands	Swaziland
Côte d'Ivoire	Mauritania	Syrian Arab Republic
Djibouti	Micronesia, Fed. States.	Timor-Leste
Egypt, Arab Rep.	Moldova	Tonga
El Salvador	Mongolia	Tuvalu
Fiji	Morocco	Uzbekistan
Georgia	Nicaragua	Vanuatu
Ghana	Nigeria	Vietnam
Guatemala	Pakistan	West Bank and Gaza
Guyana	Papua New Guinea	Yemen, Rep.
Honduras	Paraguay	Zambia

Table A2.1c: Upper-middle-income economies ($3,976 to $12,275)		
Algeria	Gabon	Palau
American Samoa	Grenada	Panama
Antigua and Barbuda	Jamaica	Romania
Argentina	Jordan	Serbia
Bosnia and Herzegovina	Kazakhstan	Seychelles
Botswana	Latvia	South Africa
Brazil	Lebanon	St Kitts and Nevis
Bulgaria	Libya	St Lucia
Chile	Macedonia	St Vincent and the Grenadines
China	Malaysia	Suriname
Colombia	Maldives	Thailand
Costa Rica	Mauritius	Tunisia
Cuba	Mayotte	Turkey
Dominica	Mexico	Uruguay
Dominican Republic	Montenegro	Venezuela, Bolivarian Rep.
Ecuador	Namibia	

Appendix 2.3: Databases and websites searched

Multi-disciplinary electronic databases

- African Journals Online (www.ajol.info/index.php/index/search)
- African Women Bibliographic Database (www.africabib.org/women.php)
- Applied Social Sciences Index and Abstract (ASSIA)
- British Library for Development Studies (http://blds.ids.ac.uk)
- Campbell Library
- Cochrane Library
- Conference Proceedings Citation Index (part of Web of Knowledge)
- Dart Europe E-theses
- Environmental Sciences and Pollution Management
- Electronic theses online service (EThOS) (http://ethos.bl.uk/Home.do)
- Global Health Database (EBSCO)
- International Encyclopedia of the Social & Behavioural Sciences (IESBS)
- Latin American and Caribbean Health Sciences Information System (LILACS)
- NDLTD (US Dissertation and theses)
- Ovid (MEDLINE)
- Pollution Abstracts
- Proquest Dissertations & Theses (PQDT)
- PsycINFO
- PubMed
- Research for Development (www.dfid.gov.uk/R4D/SearchResearchDatabase.asp)
- Sanitary Engineering and Environmental Sciences (REPIDISCA)
- Scientific Electronic Library Online (SciELO)
- Scopus (EMBASE)
- Science Citation Index (part of Web of Knowledge)
- Social Science Citation Index (part of Web of Knowledge)
- Social Science Research Network (SSRN)
- Social Services Abstracts
- Sociological Abstracts
- Sustainability Science Abstracts
- Web of Knowledge
- 3ie - International Initiative for Impact Evaluation (www.3ieimpact.org/database_of_impact_evaluations.html)

Websites

The following websites of key stakeholder organisations were also independently searched:

- Household Energy Development Organisation Network (HEDON): www.hedon.info
- USAID: www.usaid.gov/who-we-are/resource-portal
- Global Alliance for Clean Cookstoves: http://cleancookstoves.org/
- World Bank Energy Sector Management Assistance Program (ESMAP): www.esmap.org/esmap/
- The Partnership for Clean Indoor Air: www.pciaonline.org/
- Global Village Energy Partnership (GVEP): www.gvepinternational.org/en
- Ashden Awards for Sustainable Energy: www.ashdenawards.org/
- Renewable Energy and Energy Efficiency Partnership: www.reeep.org/
- International Network on Gender and Sustainable Energy (ENERGIA): www.energia.org/
- Practical Action: practicalaction.org/
- Netherlands Development Organisation (SNV): www.snvworld.org/en/regions/world/publications
- Growing Inclusive Market: www.growinginclusivemarkets.org/
- Stockholm Environment Institute: www.sei-international.org/
- Project Gaia: www.projectgaia.com/

Appendix 2.4: Search strategy for electronic databases

1. Search on ICS and LPG

The search string reported below is used as an example of the search run on Scopus (including EMBASE), using the search terms reported in Table 2.1 (Chapter 2).

We combined two main concepts of intervention and uptake, using the Boolean operator 'AND'. These concepts contained a wide number of terms combined using 'OR' and were searched on Title-Abstract-Keywords. Variations adopted for the other databases are reported in Table A2.2 and were influenced by the database organisation for running the search.

Concept 1: Intervention

Free-text terms: **stove* OR **stoves* OR lpg OR "*LP gas*" OR "*liquid petroleum gas*" OR "*liquified petroleum gas*" OR "*liquefied petroleum gas*" OR (*cook** AND *fuel*) OR (*cook** AND *technol**) OR *chulha* OR *chulhas* OR *chulla* OR *chullas* OR *chullah* OR *chullahs*

In those databases where it not possible to search wildcards in front of a word, the word (and associated derivations of the word) were spelt out. For example, in the Sustainability Science Abstracts database the following string for **stove* was adopted: *stove* OR *stoves* OR *cookstove* OR *cookstoves* OR *cook-stove* OR *cook-stoves* OR *woodstove* OR *woodstoves* OR *wood-stove OR wood-stoves*.

Having piloted the search strategy across different databases, searches were conducted using free-text terms rather than controlled terms due to the lack of specificity of controlled terms[10].

In addition, specific names of known improved stoves were piloted in some databases and in the grey literature (including language-specific names such as, for example, *plancha, estufas mejoradas*, etc.), but this approach did not yield additional relevant findings.

Concept 2: Uptake

Free-text terms: *adopt** OR *deliver** OR *dissemin** OR *implement** OR *scale* OR "*scal* up*" OR "*roll* out*" OR "*tak* up*" OR *uptake* OR *accept**

Search limits

We searched literature published from 1980 to 2011. Database searches were mainly conducted on the 'Title, Keyword and Abstracts' or 'Title and Abstracts'.

In some databases, this option was not available and different search field categories were adopted as listed in Tables A2.2 and A2.3. In particular, caution was exercised in searching 'All fields' or 'All text' in selected databases such as Ovid and PsycINFO in order to avoid

[10] For example, in PsycINFO the term 'stove' contains, in addition to relevant headings, headings such as 'arsenic poisoning', 'adult', 'burns' and 'thoracic injuries'.

including too many irrelevant hits due to lack of specificity. All variations reported were initially piloted before running the final search.

Table A2.2: Main electronic databases searched

Electronic Database	**Years included in search**	**Search categories**
Applied Social Sciences Index and Abstract (ASSIA)	from 1980	Title and Abstract
Cochrane Library	from 1980	Abstract, Title, Keywords
Environmental Sciences and Pollution Management	from 1980	Title, Abstract
International Encyclopaedia of the Social & Behavioural Sciences (IESBS)	from 1980	Abstract, Title, Keywords
Ovid (MEDLINE)	from 1980	Keywords[11]
Pollution Abstracts	from 1980	Title and Abstract
ProQuest Dissertation and Theses (PQDT)	from 1980	Title and Abstract
PsycINFO	from 1980	All text[12]
Global Health Database (EBSCO)	from 1980	All text[3]
PubMed	from 1980	Title, Abstract
Scientific Electronic Library Online (SciELO)	N/A	All indexes
Scopus (EMBASE)	from 1980	Abstract, Title, Keywords
Sociological Abstracts	from 1980	Title and abstract
Sustainability Science Abstracts	from 1980	Title and abstract
Web of Knowledge	from 1980	Topic

Smaller databases and those where it was not possible to run combined searches (Table A2.3) were manually searched for each single term falling within the category of interventions (i.e. concept 1), in order to maximise sensitivity. Search outputs (usually including a small number of hits) were then screened on title, and only potentially relevant studies were included in the final comprehensive search, as reported in the flow chart presented in Figure 3.1 (Chapter 3).

[11] The search category 'Keywords' (.mp.) in Ovid includes a search in Title, Abstract, Subject headings, etc. As these Ovid searches are so broad, and in order to avoid a large number of irrelevant hits for authors, terms from concept 1 were only searched in 'Abstracts'.
[12] Similarly, in PsycInfo and Global Health Database, terms from concept 1 were only searched in 'Abstracts'.

Table A2.3: Electronic databases searched only for category of interventions

'Small' electronic database	**Years included in search***	**Search categories**
African Journals Online	from 2003	All fields
African Women Bibliographic Database	from 1986	Keywords
British Library for Development Studies	from 1980	All fields
Campbell Library	from 2002	All text
International Initiative for Impact Evaluation (3ie)	All years	Keywords
Latin American and Caribbean Health Sciences Information System (LILACS)	from 1980	Words
Sanitary Engineering and Environmental Sciences (REPIDISCA)	from 1980	Words
Research for Development	N/A	Not specified
Social Science Research Network (SSRN)	All years	Abstract, Title, Keywords

*Years included in the search and search categories were constrained by the database itself.

2. Search on clean fuels (biogas, ethanol/methanol and solar)

The supplementary search strategy for clean fuels reported in Table 2.2 (Chapter 2) was run independently from the initial search and was piloted across three main databases. At the time of running the search on clean fuels, the DISCOVER platform was also used (which includes databases such as PsycINFO, Global Health, MEDLINE with Full Text, British Library Document Supply Centre Inside Serials & Conference Proceedings).

In DISCOVER (all subjects), terms in the intervention column were searched in 'Title' (ti) and 'Abstracts' (ab) and the search term *alternative fuel* which is not reported in Table 2.2 was also added to the concept 1 column). Results were then combined using the Boolean operator 'AND' with *cook* OR *cooking* OR *cooker* OR *stove* OR *cookstove* OR *domestic* (plural forms are automatically searched). No further combination with the uptake terms (column 2) was run, and the relevance of the study for large-scale adoption was assessed during the screening phase on Title and Abstracts. Use of wildcards such as *cook** were not used in order to avoid inclusion of words not relevant to the topic (such as cookies, cookbook, etc.)

An example of the search string for DISCOVER is reported below:

> ((ab(alternative fuel) OR ti(alternative fuel)) OR ((ab(modern fuel) OR ti(modern fuel)) OR (ab(clean fuel) OR ti('clean fuel')) OR ((ab(ethanol) OR ti(ethanol)) OR (ab(biogas OR bio-gas) OR ti((biogas OR bio-gas))) OR (ab(biodigester OR bio-digester) OR ti((biodigester OR bio-digester))) OR (ab(solar) OR ti(solar)))) AND (ab(cook OR cooking OR cooker OR cookers) OR ab(stove OR stoves OR cookstove OR cookstoves) OR ab(domestic))

In SCOPUS, terms in the intervention concept were searched on 'Title, Abstracts and Keywords' and then combined using the Boolean operator 'AND' with *cook* OR *cooking* OR *cooker* OR *stove* OR *cookstove* OR *domestic* (plural forms are automatically searched). As the number of hits identified in this way was substantial, a further combination of this initial search output with the uptake terms (see Table 2.2) was carried out to increase specificity[13].

[13] Also, the subject areas in SCOPUS (which at the time of search included four options) were piloted prior to runring the final search. The following three out of four subject areas were then selected: 'Health Science', 'Social Sciences & Humanities' and 'Physical Sciences'.

Appendix 2.5: Extraction forms for qualitative studies

Section	Comments
Title	
Author(s), year	
Institution(s)	
Peer-reviewed (yes/no)	
Study Design	
Aim of the study	
Theoretical assumptions (if any)	
SETTINGS	
Country/Region/Location	
Rural vs urban	
Population studied	
Time period in which the study was undertaken	
INTERVENTION	
Implementer	
Baseline fuel and technology	
Intervention fuel and technology	
Duration/dates of the intervention project or programme	
Scale and size of programme	
METHODOLOGY	
Study methodology	
Sampling and number of participants	
Quality issues: (e.g. validity/repeatability/trust worthiness)	

Data collection		
Analysis		
BARRIERS and ENABLERS IDENTIFIED – complete where information available		
	Principal findings and conclusions (insert details where applicable)	**Equity considerations: geography, poverty, gender**
Household and settings characteristics		
Knowledge and perceptions		
Fuel and technology characteristics		
Financial, tax and subsidy aspects		
Regulation, legislation and standards		
Market development		
Programmatic and policy mechanisms		
FINAL COMMENTS		
Additional results relevant to scaling up		
References		
Comments		

Appendix 2.6: Extraction forms for quantitative, policy and case studies

Section	Comments
Title	
Author(s), year,	
Institution	
Peer-reviewed (yes/no)	
Study type	
SETTINGS	
Country/Region/Location	
Rural vs urban	
Population studied	
Time period in which the study was undertaken	
INTERVENTION	
Implementer (if specified)	
Baseline fuel and technology	
Intervention fuel and technology	
Approach type	
Duration/dates of intervention project/programme	
Scale and size of programme	
METHODOLOGY	
Study methodology	
Sampling and number of participants	
Quality issues	
Data collection	
Analysis	

BARRIERS and ENABLERS IDENTIFIED – complete where information available		
	Principal findings and conclusions (insert details where applicable)	**Equity considerations: poverty, gender, urban vs rural**
Household and settings characteristics		
Knowledge and perceptions		
Fuel and technology characteristics		
Financial, tax and subsidy aspects		
Regulation, legislation and standards		
Market development		
Programmatic and policy mechanisms		
FINAL COMMENTS		
Additional results relevant to scaling up		
References		
Comments		

Appendix 2.7: Criteria[14] for assessing quality of qualitative studies

1. Quality of reporting	
Context of study	
Were the aim and objectives clearly reported?	**Yes/Partly/No** **Aim and Objectives:**
Was there an adequate description of the context in which the research was carried out?	**Yes/Partly/No** **Intervention:**
Methodology	
Was there an adequate description of the sample and the methods by which the sample was identified and recruited?	**Yes/Partly/No** **Description:**
Was there an adequate description of the methods used to collect the data?	**Yes/Partly/No** **Description:**
Was there an adequate description of the methods used to analyse the data?	**Yes/Partly/No** **Data collection methods:**
Was there enough data presented to allow the reader to verify findings and/or interpretation?	**Yes/Partly/No** **Description:**
2. Use of strategies to increase reliability and validity	
Were there attempts to establish the reliability of the data collection tools (e.g. by use of interview topic guides, interview schedules or other attempts)?	**Yes/Partly/No** **Description:**
Were there attempts to establish the validity of the data collection tools (e.g. with pilot interviews)?	**Yes/Partly/No** **Description:**
Were there attempts to establish the reliability of data analysis methods (e.g. by use of independent coders or other described methods)?	**Yes/Partly/No** **Description:**
3. Extent to which findings reflected participant perspectives and experiences	
Did the study use appropriate data collection methods to enable the participants to express their views?	**Yes/Partly/No** **Description:**
Did the study use appropriate methods for ensuring the data analysis was grounded in the views of the participants? (Validity/trustworthiness)	**Yes/Partly/No** **Description:**

[14] Adapted from Harden et al. 2009 (40).

Appendix 2.8: Criteria[15] for assessing quality of quantitative studies

Liverpool University Quality Assessment Tool (LQAT)				
Study ID (Author, year and date of extraction): **Study design:** **Brief – study methods:**				
	WEAK	**MODERATE**	**STRONG**	**REASON and IMPLICATION**
SELECTION PROCEDURES **(population/sample size, sampling method)**				
BASELINE ASSESSMENT **(baseline fuel/stove intervention details and how distributed)**				
OUTCOME ASSESSMENT **(assessment of scaling up/adoption/use)**				
ANALYSIS/CONFOUNDING **(how data analysed/presented)**				
IMPACT **(applicability/impact of findings to review)**				

[15] The tool has been independently appraised against other quality assessment instruments (see Voss and Rehfuess 2012 [43]).

Appendix 2.9: Criteria[16] for assessing quality of policy and case studies

1. Ways and quality of reporting	
Were the aim and objectives of the study clearly reported?	**Yes/Partly/No** **Aim and Objectives:**
Was there an adequate description of the context in which the research was carried out?	**Yes/Partly/No** **Intervention/Programme:**
Was there an adequate description of the study design used?	**Yes/Partly/No** **Description:**
Was there any infromation on sampling (sample size and how it was identified)?	**Yes/Partly/No** **Description:**
Was there any attempt at representativeness and/or to report on different views from stakehodlers?	**Yes/Partly/No** **Data collection methods:**
Was there any information on data collection?	**Yes/Partly/No** **Description:**
Was there an adequate description of the methods used to analyse the data?	**Yes/Partly/No** **Description:**
Was there enough data presented to allow the reader to verify findings and/or interpretation?	**Yes/Partly/No** **Description:**
Are limitations to the study acknowledged and described?	**Yes/Partly/No** **Description:**
2. Bias	
Any risk of bias due to author(s) being closely associated with the implementers?	**Yes/Partly/No** **Description:**
Are conclusions made well grounded in the data?	**Yes/Partly/No** **Description:**
3. Appropriateness	
Did the study use appropriate methods for ensuring the data analysis expressed the views of the participant?	**Yes/Partly/No** **Description:**
Does the study place the findings in the context of interest?	**Yes/Partly/No** **Description:**
Does the study suggest if and how the findings might be transferable to other settings?	**Yes/Partly/No** **Description:**

[16] Adapted by Atkins and Sampson (2002) (44).

Appendix 3.1: Summary tables for ICS

A. Summary for qualitative studies

Author/year, location, setting	Baseline and intervention fuel and technology	Description of programme	Study design	Population studied, sample size and analysis	Issues regarding quality and interpretation
Pandey 1989 [17] *(qualitative component)* Central Nepal Dhading district *Rural*	3 models of traditional mud stove: Chulo, Chuli, Angena (biomass). Combined use of 2 or more stoves was often found at household level. 2-pot improved cookstove: Bikase Chulo (biomass).	National programme started in 1984 with about 35,000 stoves distributed by time of study. Part of the Nepal Community Forestry Development Project (CFDP). Stoves distributed on a first-come, first-served basis.	Mixed-methods approach. Qualitative methods included: SSIs and PO. Interviews conducted by a female researcher in Nepali language. Interview topic guide piloted in 10 housholds.	*Sampling*: 25 women from high (Brahmin and Cheetri) castes: 10/25 ICS users and 15/25 non-ICS users. Participants (ICS users and non-users) selected from 3 villages from a fuelwood-scarce area, based on willingness to participate. *Analysis:* Method not stated; descriptive narrative.	*Quality score:* Medium This PhD dissertation was primarily designed to be quantitative, with support from qualitative findings. Data analysis of qualitative findings not described. quality score Findings only relate to high caste women who had greater interest in exploring the new technology.
Jagoe et al. 2006a *(qualitative component)* India Bundelkhand region (Niwari, Radhapur and Thona districts) *Rural*	Traditional stove (fixed and movable) (biomass). 2 stove models: (i) 1-pot fixed stove with chimney: Anandi (ii) 2-pot fixed stove with chimney: Sukhad.	Regional programme, 1,500 stoves (and 500 improved lighting devices). Funding received from the Shell Foundation in 2003 to carry out the project and implemented by the Appropriate Rural Technology Institute (ARTI). Evaluation took place between 2004 and 2005.	Mixed-methods approach. Qualitative methods include: repeated FGDs and KII conducted at baseline and follow-up (12 months). Qualitative data were collected to support cross-sectional survey data.	*Sampling*: 2 FGDs carried out at baseline (n=11, 4 men, 7 women) and at follow-up (n=8, 4 men, 4 women) across the 3 study sites. *Analysis:* Framework analysis.	*Quality score:* Moderate Purpose of the study and methodology well described. FGDs designed with the purpose of representing different groups within the community.

[17] Quantitative findings from this study were included as part of the published journal article Pandey and Yadama (1992) (66).

Author/year, location, setting	Baseline and intervention fuel and technology	Description of programme	Study design	Population studied, sample size and analysis	Issues regarding quality and interpretation
Anderson 2007 India Western Maharashtra state (Nanegaon village) *Rural*	2-pot traditional mud stove (primarily wood, and also dung used during the monsoon season). 2-pot improved Bhagyalaxmi cement stove (cast iron grate, unvented).	Regional. Stoves disseminated by ARTI (independently from the National Programme on Improved Chulha [NPIC] since 2001) in a market-led context. This study was conducted 2 years after introduction of the Bhagyalaxmi stove in the village. Stoves were purchased by villagers at subsidised rates and by instalments.	Ethnographic case study, including: (i) FGD and SII with local women; (ii) KII with co-ordinator of ARTI stove evaluation project and with translator of the research study; (iii) PO during 6 randomly selected days to observe women starting the fire, cooking, collecting firewood, making cow dung cakes and cleaning the stove. Snowball sampling used.	*Sampling*: 3 FGDs with 7-8 village women (FGD included: improved stove users only, traditional stove users only, and a mix of both). 3 SSIs: with improved stove user, traditional stove user, a user of both stoves. Full transcription in Marati, translation into English by external translator, checking of translation conducted by the FGD facilitator. *Analysis:* Editing analysis style (i.e. hermeneutic approach).	*Quality score:* Strong Well-presented Master's dissertation, with data collection and data analysis well described. Author's interpretation based on a large number of supporting quotes Findings relate directly to aims. Issues with results transferability are also described.
Jagoe et al. 2007a *(qualitative component)* India Maharashtra state (Pune and Phaltan areas) *Rural*	Traditional chulha stoves (biomass). 2 models of 2-pot ICS with a grate in the base of the combustion chamber: (i) Bhagalaxmi (no chimney) (ii) Laxmi (with chimney).	National programme funded by Shell Foundation in 2003 and implemented by ARTI. Programme aimed to deliver 100,000 improved biomass stoves in a market context.	Mixed-methods approach. Qualitative methods included: FGDs and KII at baseline, 6 and 12 months follow-up, conducted in the two rural areas.	*Sampling*: FGDs with rural women from ICS and traditional stove groups (age 15-45 years living with a child of 5 years or less). No men agreed to take part in the study. All transcripts were translated into English. *Analysis:* Framework analysis.	*Quality score:* Moderate Methodology well described. No specific details provided about the KIIs but sufficient data are presented to support overall findings.

Author/year, location, setting	Baseline and intervention fuel and technology	Description of programme	Study design	Population studied, sample size and analysis	Issues regarding quality and interpretation
Gordon et al. 2007 Mongolia Ulaanbaatar *Urban*	Traditional stoves (coal). Improved stoves and kits to improve the combustion of existing traditional stoves (coal). No details about whether stoves were subsidised.	Programme implemented by Word Bank (scale not specified). 1,375 ICS were distributed at the time of the study.	Qualitative study design. FGDs and individual interviews conducted with users from the capital city (Ger[18] population). Interviews conducted in Mongolian. Purposive sampling used.	*Sampling*: mix-gender FGDs with 8 participants each, (from 3 districts of the capital). Participants included: improved stove users, traditional stove users and a mixed group using both traditional stoves and ICS. Transcripts translated into English. *Analysis:* editing analysis style.	*Quality score:* Strong Small piece of work with focus on health effects of improved stoves. Study clearly described as well as methods used. Data analysis and findings are explicit.
Simon 2007[19] India South-western Maharashtra state (Pune division) *Rural*	Traditional chulha stoves (biomass). Improved chulha stoves purchased by users and used with locally available biomass fuels. (No central subsidies provided.)	Commercialization of Biomass Fuel and Cooking Devices (CBFCD) programme started in 2003 under direct foreign investments by the Shell Foundation. Dissemination of scalable business practices for the purpose of increasing regional distribution of improved cookstoves.	Qualitative study design. Open-ended interviews, surveys and PO in the Kolhapur, Satara and Sangli districts (selected because they were targets of both NPIC and Shell Foundation programmes). Fieldwork carried out over a 6-month period in late 2005 and early 2006.	*Sampling*: Purposive sampling of 15 stove builders and 40 female stove users interviewed from 4 villages where different levels of ICS coverage were experienced. Interviews conducted in English or in Maharati. Also interviews conducted with 4 NGO programme managers and 7 field officers. *Analysis:* Thematic analysis.	*Quality score:* Strong Detailed PhD dissertation covering the perspectives of stove builders, stove users and NGO field officers. Interviews with stove builders offer a different perspective. Study aims are clearly described and findings are explicit. Sampling methods described in depth and attempt to include different population groups.

[18] Ger is the traditional type of white felt tent in which about half of the Mongolian population lives.
[19] This study is a PhD dissertation available as hard copy only. The corresponding published artiche is: Simon G (2009) Geographies of mediation: market development and the rural broker in Maharashtra, India. *Political Geography* 28(3): 197–207.

Author/year, location, setting	Baseline and intervention fuel and technology	Description of programme	Study design	Population studied, sample size and analysis	Issues regarding quality and interpretation
Troncoso et al. 2007 Mexico Michoacán state (Purepecha region) *Rural*	Open fires (fogón) (primarily wood). LPG also used by some households as complementary fuel. ICS: multi-pot Patsari stove models with chimney, made of clay and sand (biomass, primarily wood). Stoves given as part of the experimental study.	Regional programme, started in 2003 (for 3 years), implemented by GIRA[20], University of Mexico and University of Berkeley. Programme's goal was to install 1,500 ICS in 35 rural communities. Study was carried out 1 year after stoves had been installed, with those who had adopted them and those who had not.	Mixed methods, with predominantly qualitative component. Qualitative methods included: SSIs with rural women and KII with stakeholders (including local authorities, stove builders and NGO members).	*Sampling*: 85 SSIs including: 52 users, 15 non-users, 18 stakeholders. Snowball approach, with sample size decided by saturation. Sampling was from 3 stratified groups: (i) one where access to wood was very good (< than 30 minute walk), (ii) one where it was average (30 to 60 minute walk) and (iii) one where it was scarce (60 minute walk or needed to buy it). *Analysis*: Thematic analysis.	*Quality score:* Moderate Extensive sampling, covering different groups. Interview guide was initially piloted. The limited use of quotes makes it difficult to assess whether authors' interpretation was appropriate. No reference to results from interviews with NGO members and stove builders is reported in the paper.
Velasco 2008[21] Mexico Michoacán state (Purepecha region) *Rural*	Traditional 3-stone open fires and U-type stoves (wood); LPG used by 80% of community population for specific cooking tasks. ICS: multi-pot Patsari stove (wood) (and solar cooker HotPot used in combination with the Patsari stoves).	Stoves disseminated in the Purepecha region by a local NGO (GIRA) in collaboration with other national institutions: Centro de Investigaciones en Ecosistemas (CIEco) and Universidad Nacional Autónoma de México (UNAM). Patsari stoves constructed as part of a rural development integrated programme funded by the Food and Agriculture Organization of the United Nations (FAO) in 2001 and solar cookers built by students from UNAM.	Qualitative study design. Interviews with women and PO of community life, Pastari stove construction and maintenance.	*Sampling*: Purposive sampling of ICS users. 24 households selected: 10 households from the Patamban community using the Patsari stove, in combination with LPG; 14 households from La Lajita community. Among these, 10 households used the HotPot solar cooker in combination with the Patsari stove, *Analysis:* method not stated; descriptive narrative.	*Quality score:* Moderate Short Master's dissertation with highly summarised findings. Only 6 out of 10 households initially sampled in one of the communities were interviewed. Not possible to assess how rigorously the data analsyis and interpretation were, but the author provides sufficient data to support some of the findings.

[20]GIRA (Grupo Interdisciplinario de Tecnología Rural Apropiada/Group for Appropriate Rural Technology) is an interdisciplinary Mexican NGO primarily involved in improved cookstove dissemination campaigns.
[21] This study reports also finding on use of solar cookers, which are separately discussed in Appendix 3.4.

Author/year, location, setting	Baseline and intervention fuel and technology	Description of programme	Study design	Population studied, sample size and analysis	Issues regarding quality and interpretation
Christoff 2010 Mexico Mexico state *Rural*	Traditional open fire (wood). Improved cookstove: either Patsari (most) or Onil stoves.	Wide-scale programme replacing 500,000 stoves across rural communities in 125 municipalities.	Qualitative study design. FGDs with rural women from the 'San Felipe del progreso' who had used either a Patsari or Onil stove for at least 4 months.	*Sampling*: 4 FGDs for a total of 44 participants (9-14 individuals per discussion). Use of audio and video records. Transcriptions from Spanish into English. *Analysis:* Thematic analysis.	*Quality score:* Strong Well-presented Master's dissertation, with extensive use of quotes supporting author's interpretations. Not clearly reported how sample was selected, but the population studied appears to be appropriate and data analysis is sufficiently rigorous.
Chowdhury et al. 2011 Bangladesh Habigonj region *Rural*	Unspecified traditional stoves (wood, cow dung, agricultural residues and tree leaves). Improved mud cookstove with chimney (wood/biomass).	Regional programme with stoves disseminated by the Forest Department under the Noshorgo Support project.	Qualitative study design. Semi-structured questionnaire administered during face-to-face interviews and one FGD with community members.	*Sampling*: Purposive sampling of 70 women among the forest user groups (out of 370 women) (average age 35 years). *Analysis:* Method not stated; descriptive narrative and tables.	*Quality score:* Weak Poor quality of reporting and limited information on data collection, data analysis and results from the FGD.
Sovacool and Drupady 2011[22] Bangladesh Countrywide *Urban/rural*	Traditional stoves (wood, crop residues, dung, tree leaves). Kerosene and electricity account for only for 3% of national energy consumption by source type. Improved 1-, 2-, 3-mouthed clay cookstoves with chimney.	National progamme started in 2006, with 132,000 ICS installed by 2011. Programme aims at installing 5 million by 2015. *Approach*: Stove locally made by the company. Local youths and women trained and involved in manufacturing, selling and repairing ICS. *Implementer*: Grameen Shakti (no-profit Bangladeshi company).	Qualitative study design. 48 SSI interviews and meetings with 19 institutions and communities in 5 locations. Purposive sampling of key stakeholders (i.e. NGO, government agencies, manufacturers and industry groups, financier and development donors, research institutes). 50 community members and households, including employees and customers.	*Sampling*: Interviews conducted over the course of June 2009-October 2010. Fieldwork carried out with simultaneous real time translation into Bengali (including local variations and dialects). No specific details on sampling methods provided. Review of relevant literature also used. *Analysis*: narrative analysis.	*Quality score:* Moderate Aim of this paper was to describe the activity and challenges faced by Grameen Shakti in implementing 3 national programmes in Bangladesh: ICS, Biogas and solar home systems (SHS) programmes. Research methods clearly described, but not the specific number of interviewed participants provided for each of the discussed programmes. Sometimes difficult to identify to which specfic programme findings were related.

[22] This study reports also findings on biogas which are separately discussed in Appendix 3.4.

Author/year, location, setting	Baseline and intervention fuel and technology	Description of programme	Study design	Population studied, sample size and analysis	Issues regarding quality and interpretation
Troncoso et al. 2011 Mexico Michoacán state (Purepecha region) *Rural*	Traditional Lorena stoves (wood/biomass). 3 different models: 2 improved Lorena stove models and 1 improved Patsari stove.	Regional programme with the goal to install 1,500 ICS in the Purepecha region during 2003–06. Local NGO (GIRA) and other insitutions/universities involved. The project included 5 simultaneous research studies. The ICS were given as part of the health study.	Qualitative study design. In-depth, SSIs and PO with members of an implementation team: researchers, NGO team members, managers, technicians, and stove builders. POs were carried out during 2 workshops.	*Sampling*: Purposive sampling with 24 out of 36 members of the implementation programme. Workshops and interviews were audio-recorded and fully transcribed. Interviews with project leader and project co-ordinator were conducted twice, at different times during the project. Method not stated; descriptive narrative (or thematic analysis).	*Quality score:* Moderate This study offers a very clear stakeholders' perspective. Aims and objectives clearly described. Theoretical assumptions also described. Data analysis partially described. Results are presented in a narrative format with limited use of quotes, but authors' interpretation seems accurate.
Person et al. 2012 Western Kenya Nyanza province *Urban/rural*	Traditional stoves (wood and charcoal) and open-fires. Simple portable paraffin or kerosene stoves used for supplementary cooking for gatherings. Upesi Jiko sold at market price (about US$2.00). Additional $1.50 to $3.00 needed for material and labour costs for the installation of the liner into a permanent earthen base.	Regional. Pilot cookstove improvement project carried out in 10 villages, in conjunction with a Kenyan NGO, the Safe Water and AIDS program (SWAP). This programme provides health education and sells health products to community members as an income generating activity in rural villages and peri-urban slums.	Qualitative study design. SSI with a purposive sampling of cookstoves purchasers and cookstoves promoters. Fieldwork carried out from July 2008 to March 2009. 2 bilingual qualitative research assistants conducted interviews in Dholou.	*Sampling*: Purposive sampling of 30 cookstoves purchasers and 10 cookstoves promoters from Luo communities (all women). Women had been using the stove over a range of 2 weeks to 8 months at the time of interview. 40% of them had one or more co-wives. Interviews transcribed and translated into English. *Analysis*: Thematic analysis.	*Quality score:* Strong Aim of the study was to explore the actual experiences of stove promoters in persuading women to purchase and use the stove, and also to better understand the purchaser's perspective, in particular how users secure funds to purchase improved cookstoves. Methods and data analysis well described.

Author/year, location, setting	Baseline and intervention fuel and technology	Description of programme	Study design	Population studied, sample size and analysis	Issues regarding quality and interpretation
Sesan 2012[23] Western Kenya West Koeching *Peri-urban*	Kerosene and charcoal traditional stoves. 6 different interventions including: Upesi charcoal stove, waves spaces, fireless cooker, smoke hood, LPG stove and solar cooker.	Regional. 'Smoke alleviation interventions' for poor communities promoted via participatory market system implemented by Practical Action since 1998. These projects include the Smoke and Health project (1998-2001); the Smoke, Health and Household Energy project (2001-05); and the USEPA smoke alleviation project (2009-10).	Qualitative study design. SSI with users, KII with stakeholders, PO. Fieldwork for the study was conducted over a period of 6 weeks in November and December 2009.	*Sampling*: Selective sampling of 15 users from 13 households (from a total of 357 households that had purchased 1 of 6 improved technologies); KII with 9 stakeholders, including: Practical Action staff members (n=3) and staff members of other development agencies identified through a snowball approach (n=6). *Analysis*: Method not stated; descriptive narrative.	*Quality score:* Moderate The author provides a clear description of the study, which aims to provide an understainding of the cultural aspects, cooking habits and needs of the West Kenyan local population. The sampling strategy seems appropriate for ICS users (less for clean fuel users). Very little information about data analaysis is provided.

[23] This study reports also findings related to solar cookers which are separately discussed in Appendix 3.4.

B. Summary table for quantitative studies

Author/year location, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Mwangi 1992 Central Kenya Nyeri district *Rural*	3-stone open fire stove (wood) or traditional metal stove (charcoal). Different ICS models and fuels: (i) Kenya Ceramic Jiko stoves (charcoal), (ii) Kuni Mbili portable stoves or (iii) kerosene stoves.	*Scale*: National. *Duration*: Since 1989. *Approach*: Market context not clearly specified. Stoves were probably purchased by farmers. Kerosene stoves were subsidised. *Implementer*: Forest Extension Services Division (FESD).	*Study design*: Cross-sectional survey. *Study population:* Small-scale farmer households randomly selected (simple random sampling) from 2 villages in central Kenya.	*Data sources*: Survey administered during interviews with 306 small-scale farmer households. Male or female household heads were interviewed. *Analysis*: Multivariable analysis of factors influencing ICS adoption.	*Main findings:* Factors associated with adoption of Kenya Ceramic Jico and kerosene stoves include: • Age: Older heads of households less likely to adopt these stoves. • Income: Total household expenditure was found to have a positive effect on ICS adoption. • Promotional visits about ICS and hours of radio exposure per day positively affected adoption. Some households reported using their traditional cookstove or adopting more than one improved technology simultaneously.	*Quality score:* Moderate Very detailed information about methods used and sampling approach. Results sometimes not clearly presented. **Quality assessment**[24] Selection: M Baseline info.: M Outcomes: M Analysis: S Impact: M
Pandey and Yadama 1992 Central Nepal Dhading district *Rural*	Primarily wood on traditional stove. Primarily wood on improved stove (unspecified).	*Scale*: National. *Duration*: Since 1984 *Approach*: Stoves given for free, no further details provided. *Implementer*: Not provided.	*Study design*: Cross-sectional survey. *Study population*: Sampling of 100 women in 28 villages from typical project area introducing ICS.	*Data sources*: Interviews with women cooks and observation. *Analysis*: Assessment of impact of perceived attributes of stoves	*Applicability of diffusion of innovation theory to improved stoves:* • Compatibility between innovation and traditional practices greatly increased likelihood of adoption. • Relative advantage and complexity increased likelihood	*Quality score*: Weak Limited information on sampling. Statistical and modelling approach mostly appropriate.

[24] Quality assessment (*S*=strong; *M*=moderate; *W*=weak)

Author/year location, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
				and knowledge (each measured as 4- and 3 -item scales respectively) on stove index (as measure of adoption) in structural equation model.	of adoption. • Knowledge had no effect on likelihood of adoption.	**Quality assessment** Selection: W Baseline info.: W Outcomes: M Analysis: M Impact: W
George and Yadla 1995 India Gujarat state *Rural*	Mostly traditional stove (biomass). 2-pothole ICS: mud or brick Mamta stove with chimney (biomass).	*Scale*: Regional. *Duration*: 1991/1992-ongoing. *Approach*: subsidised distribution. *Implementer*: government and voluntary organisations under national programme.	*Study design*: Cross-sectional survey conducted 10 months after stove installation. *Study population*: Purposive sampling of 3 villages to account for variation in stove type and implementation and systematic random sample of 130 households in each village (390 households).	*Data sources*: Interviews with women cooks (mixed closed and open questions). *Analysis*: Descriptive statistics and correlation coefficients to examine impact of various factors on perceived cost to benefit ratio.	Large variation in perceived cost-benefit ratio between 3 villages; major contributors to score were: • Greater participation in national programme (e.g. participation in user education camps). • More accurate perception regarding availability/accessibility of fuels. • Higher-quality installation of stove and chimney (e.g. adherence to design specifications, chimney installation, after-sales services). • Higher education level.	*Quality score:* Weak Very limited information on study methodology. Analysis not in-depth. **Quality assessment** Selection: M Baseline info.: M Outcomes: W Analysis: W Impact: W
Wallmo and Jacobson 1998 Western Uganda *Rural*	Open fire (biomass). Loreno ICS: 3-pothole and chimney mud stoves.	*Scale*: Regional. *Duration*: Up to December 1995 the programme involved 10 parishes with 683 stoves disseminated. *Approach:* ICS constructed by trained community members	*Study design*: Cross-sectional survey and kitchen performance test. Interviews using questionnaires and direct observations (to substantiate and supplement interviews).	*Data sources*: Data collection on cooking practices, stove promotion and perceptions, stove condition, fuelwood collection, attitudes to conservation, non-adoption of stove,	*Reasons for adoption (stated in text without data):* 3-pot holes allowed pots to cook simultaneously, neighbours or stove promoters encouraged adoption, fuelwood savings, attractive appearance, reduced smoke production, food cooked quickly, status of women enhanced and promoted, less tending required, reduced accidents and improved	*Quality score:* Weak Main focus of study was on reducing fuelwood consumption to reduce deforestation of national parks. **Quality assessment**

Author/year location, setting	**Baseline and intervention fuel and technology**	**Description of Programme**	**Study design and study population**	**Data source and analysis**	**Principal findings relevant to scaling up**	**Issues regarding quality and interpretation**
		and promoted by paid stove promoters. Users had to provide bricks, mud, sand and chimney pipe. *Implementer*: Kibale and Semuliki Conservation and Development Project (KSCDP).	*Study population*: (i) adoption survey compared 81 users with 84 non-users; (ii) kitchen performance test compared 50 users and 50 non-users. Households visited once or twice per day for 4 days. 15-45 minutes per visit.	non-use of stove after adoption and socio-demographic data. *Analysis*: From 'adoption and impact survey' - simple descriptive statistics between users and non-users.	cleanliness. *Reasons for non-adoption: (stated in text without data)*: Lack of bricks or money to buy them, lack of kitchen or permanent house, stove was not traditional stove and/or adversity to change, stove benefits were not perceived, stove did not provide warmth, other family members preferred traditional stove, stove could not accommodate all pan sizes. 48% of users had not abandoned traditional stove. Stated reasons included: pans too large for stove, other family members preferred traditional (because difficult to light fire in Lorena), warmth from open fire, food not cooked properly, available firewood (e.g. reeds) did not burn well in stove, both stove and open fire needed to cook when visitors came.	Selection: M Baseline info.: M Outcomes: W Analysis: W Impact: W Results on adoption patchy and not substantiated with statistics – tabulated results refer to benefits and problems of stoves.
Muneer and Mohamed 2003 Sudan Khartoum state *Urban/rural*	Traditional charcoal and wood stoves (no additional details provided). Improved biomass stoves (no details provided), fuel used not specified (probably firewood and charcoal).	*Scale:* Not clearly specified, possibly national. *Duration:* Results of this study cover the period 1984 – 1998. *Approach:* Not specified. *Implementer*: Energy Research Centre in collaborations with	*Study design*: Cross-sectional survey. *Study population*: Multistage stratified random sampling of women and men, from 10 urban and rural localities of the Omduram area. A final sample of 300 households was used (150 rural and 150	*Data sources*: Survey administered thorough personal interview with selected households. *Analysis*: Linear regression analysis on factors influencing adoption	*Stove use:* Low adoption rates (17.6% of the surveyed households had possessed an ICS during the study period). *Significant variables positively associated with adoption*: • Improved stove's perceived relative advantage (measured on (i) reduction in charcoal and firewood consumption, (ii) time saving, (iii) less smoke, (iv) ease of ICS use and (v) other).	*Quality score:* Strong Valid and repeatable sampling approach. Little information on data collection (including number of men and women interviewed, interviews' modality, gender of the researchers, etc.). Analysis well

Author/year location, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
		local NGOs.	urban households).	(household innovativeness used a dependent variable). Variables that had regression coefficients less than 0.01 (e.g. husband's exposure to information about improved cookstoves) were not included in the final model.	• Educational level (both wife and husband). • Female household members' average educational level. • Wife's exposure to messages about the ICS. *Significant negatively associated variables*: (i) Income, (ii) wife's age and (iii) high price of stove.	presented. **Quality assessment** Selection: S Baseline info.: M Outcomes: M Analysis: S Impact: S
Jagoe et al. 2006b *(quantitative component)* India Bundelkhand region (Niwari, Radhapur and Thona districts) *Rural*	Traditional stoves (fixed and movable) using biomass (mostly wood). 2 ICS models: (i) a 1-pot fixed stove with chimney: Anandi and (ii) a 2-pot fixed stove with chimney: Sukhad. Multiple stove use reported.	*Scale*: Regional. Project called '"Energy Services for Village Households and Rural Enterprises in Bundelkhand', aiming at disseminating 1,500 re-designed stoves through members of women's self-help groups in 20 villages within the study area. *Duration*: From 2003. *Approach:* Social marketing campaigns carried out by selected individuals who were known and respected by target markets. *Implementer:* Local NGO called 'Development Alternatives.'	Mixed-methods approach. Before-and-after-study (12 months) without control. *Study population*: Survey administered to 150 households at baseline, and at 6 months and 12 months after ICS was provided.	*Data sources*: Cross-sectional description of new stove use trends in use by cluster analysis in differences in characteristics of users, by status of use and changes in use. *Analysis*: Before-and-after paired comparison of outcome measures by stove use at follow-up.	*Stove use:* Stove use was mixed, complex and dynamic over 12 months of study. At 6 months after installation only 37.6% of participants were using the ICS as their main stove, but most were using it as their secondary stove. Users increased to 43.3% at the end of 12 months. 52% said this was because it took longer to cook food and 50.6% because it consumed more fuel. *Additional findings*: A minority of users experienced substantial benefits in terms of smoke reduction and health benefits (less respiratory and eye irritation). The majority of households bought the ICS with one payment using savings rather than paying in instalments.	*Quality score:* Weak Study limitations include: no use of a control group and mainly descriptive analysis. The impact of the stoves is mixed and remains challenging to study due to complexity of stove use patterns. **Quality assessment** Selection: W Baseline info.: M Outcomes: M Analysis: W Impact: W

Author/year location, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Jagoe et al. 2007b *(quantitative component)* India Maharashtra state (Pune and Phaltan areas) *Rural*	Traditional chulha stove (biomass). 2 models of improved chulha stoves (biomass) with 2 pot holes and a grate in the base of the combustion chamber: (i) Bhagalaxmi (no chimney); (ii) Laxmi (with chimney).	*Scale:* Regional. *Duration*: Evaluating ICS adoption rates and general monitoring after 1 year from the initial purchasing in 2005. *Approach*: Stoves purchased in one payment using savings for the majority of households; loan arrangements reported in a few cases. *Implementer:* ARTI under funding provided by the Shell Foundation.	Mixed-methods approach. Before-and-after study (12 months) with interventions and controls (n=156 + n=98). *Study population*: Purposive sampling of households which had acquired 1 of the 2 ICS models. Approximately 150 intervention and 150 controls homes from the two selected rural areas were initially selected.	*Data sources*: Open-ended interviews. *Analysis*: Multivariable regression analysis of factors affecting ICS adoption. The main analysis extends over 6 months after initial ICS purchase. A 12-month follow-up survey was originally planned but only data on stove conditions at 12 months were collected.	*Stove use:* Results from the 6-month survey: • No evidence in time reduction for fuel collection. • Statistically significant time reduction for cooking, (i.e. 45 minutes per day). • No evidence of any impact of the intervention on under-5 child location during cooking. • Statistically significant reduction of various health symptoms associated with smoke (e.g. 66% reduction of cough, frequent headaches, etc.). • Majority of households felt the stove was a change for the better (around 50% in Pune and 98% in Phaltan respectively) Results from the 12-month survey: • One-third of households were no longer using the new stoves. • Half of households using the ICS removed the grate. • Cleaning: stove cleaned at least once or twice over a period of 6 months. 40% and 89% of intervention homes paid for the stove with a single full payment, using their own savings.	*Quality score:* **Quality assessment** Selection: W Baseline info.: M Outcomes: M Analysis: M Impact: M Moderate Methods described, including reasons for not using a random sampling approach. The analysis of outcomes was supported by the use of a control group.
Agurto-Adrianzen 2009 Peru *Rural*	Traditional open fire (wood). ICS (wood) consisting of a metal frame/plate (with	*Scale:* Local (39 villages in Andean northern Peru). *Duration:* 2003-04. *Approach:* Distributed free among households	Cross-sectional survey (n=816); stove monitoring survey (n=82% of beneficiaries). Survey data	*Data sources*: Main analysis is on n=283 beneficiary households with data from both surveys.	This study used economic perspective and 2 dimensions to social capital (i) 'bonding' (nature and intensity of relationships within the community) and (ii) 'bridging' (nature and intensity of	*Quality score:* Strong This study is in the context of free distribution, though households needed to provide the mud

Author/year location, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
	pot holes), aluminium chimney, with combustion box made of mud bricks. Not adapted to heating needs, type of wood and cooking needs of the Chalaco area.	requesting it, to about 85% of homes in these villages. *Implementer:* Peruvian NGO - Movimiento para la Realización del Hábitat Social (MIRHAS-PERU).	conducted June to August 2003, prior to stove distribution, with stove use monitoring survey in 2004. *Study population*: 39 villages, in 5 'watershed' areas. *Social capital survey:* Sample – total n=816, with (average) 21 randomly selected households per village, 39 villages. *Stove use survey:* Sample 26 villages, 82% beneficiaries seen.	*Analysis*: 45% of beneficiaries were using the stove as their main way of cooking, rest did not use or used rarely, while 32% had uninstalled. Some 28% reported problems in use. Analysis uses 'those using the stove without problems' as the measure of village success in adoption. Economic models for adoption (several) are described, and analysis carried out using linear and probit regression, with addition of interaction terms. As stove distribution managed by watersheds, this variable used to control for 'unobservable' factors.	links with agents outside the village). Analysis also included individual household characteristics affecting adoption. *Impacts of social capital on adoption*: Effect of high 'bonding' social capital on successful adoption was only found for 'the % adopters without problems', and vice versa. Strength of this effect is not quantified, although there had to be a majority (>51%) of adopters without problems. Similar interaction found for uninstallation among non-users. Impact of network information about problems was more powerful than those about good performance. Findings robust for different measures of social capital *Household-level determinants of adoption*: Wealthier households (assessed by farm assets) and those engaging in previous year in communal activities more likely to adopt. Households with higher number of adults less likely to adopt (possibly due to lower costs of collecting firewood). Households with at least one adult female member more likely to adopt (possibly as women value benefits of ICS more). No evidence that educational level or experience with other agricultural technologies influenced adoption.	bricks. Analysis is complex and based on economic models regarding successful adoption, with assumptions. Main implications for policy are that problems with the stove which affect the initial adoption in a community can have negative effects on wider adoption, and where bonding social capital is strong this will have a greater effect. Study does not provide easily quantified effect estimate but noted to be stronger for 'bad news' discouraging adoption than for 'good news' encouraging it, and quite robust. **Quality assessment** Selection: S Baseline info.: M Outcomes: M Analysis: S Impact: S

Author/year location, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Damte and Koch 2011 Ethiopia Amahra, Oromiya and Tigray regions *Urban*	Open fire almost exclusively charcoal. Intervention stoves: (i) Mirt Biomass Injera stoves (designed by Ethiopian Energy Studies Research Center in 1990s) and introduced in region in 1994; (ii) Lakech charcoal mobile stove introduced in the region in 1991.	*Scale*: Not clearly specified. Probably regional. *Duration*: Survey carried out in 2009. Stoves introduced in 1991 and 1994. *Approach*: Not entirely clear but appears to be market-based approach (wide promotion of stoves within study region). *Implementer*: Mirt Biomass Injera Stoves Market Penetration and Sustainability study.	*Study design*: A survival analysis based on a quantitative survey carried out by Megen Power Limited. *Study population*: 3 towns selected for each of the 3 regions (survey in 9 towns). Stratified sampling (high-sales, low-sales, non-project towns). Sample size proportional to total number of households. Random sampling: 580 in Amhara, 667 in Oromiya, 330 in Tigray.	Survey questions including adoption and characteristics of households (used for this analysis). *Analysis*: Survival analysis carried out: (i) *failure*=adoption of stove; (ii) *duration*=time from introduction to adoption. Looked at household characteristics associated with reduced survival/adoption time using Cox regression.	*Main findings:* • Increased income associated with reduced adoption time. Households in lowest income bracket (<500 Birr) least likely and slowest to adopt whereas those in highest (>2500 Birr) most likely and quickest to adopt (statistically significant) - evidenced in Kaplan-Meier curves. • Rate of adoption increased as technology became more widespread - evidenced by hazard monotonically increasing. • Cox regression identified that education and income increased adoption rates. • Home ownership and separate kitchen associated with increased adoption (Mirt ICS only, which requires additional space and proper installation). • Female headed households only associated with increased adoption of Mirt stove. Regional differences only in Mirt adoption.	*Quality score:* Strong Some data limitation issues discussed (e.g. missing data and variables not included in survey). Presume interview-based survey although not described. Multivariate analysis included mutual adjustment for a number of covariates - advantage of approach. **Quality assessment** Selection: S Baseline info.: S Outcomes: M Analysis: S Impact: S
Bensch and Peters 2011 Senegal Dakar and Kaolack cities *Urban*	Traditional Malagasy charcoal stove. Jambar ICS (metal and clay), with improved efficiency.	*Scale:* Regional. 78,500 ICS disseminated across cities during 2009. *Duration:* Disseminated period 2009. *Approach:* Market-based adoption - users purchased stoves (20-	Cross-sectional survey. *Study population*: Simple random sampling (n=624 households) from 16 quarters of Dakar (n=508) and 4 quarters of Kaolack	Interview-administered questionnaire (SES and cooking related variables). Charcoal weighed. SSIs with key informants (women's groups, producers, local	*Main findings*: Significant differences found between ICS adopters and traditional users: • Number of rooms inhabited. • Bank account ownership. • Highest level of education of mother. • Years of schooling of mother. No differences for occupation	*Quality score:* Moderate Study focus was on consumption of charcoal (in relation to deforestation) - subject of regression analysis. While LPG is predominant fuel -

<table>
<tr><th>Author/year location, setting</th><th>Baseline and intervention fuel and technology</th><th>Description of Programme</th><th>Study design and study population</th><th>Data source and analysis</th><th>Principal findings relevant to scaling up</th><th>Issues regarding quality and interpretation</th></tr>
<tr><td></td><td></td><td>30%).

Implementer: GIZ; Foyers Ameliores au Senegal (FASEN).</td><td>(n=116) where ICS available.</td><td>chiefs) – cross-check quantitative information.

Analysis: Simple descriptive analysis (ICS vs traditional). Main focus of study was patterns of charcoal use (regression) – not presented here.</td><td>(head of house), financial situation, shared kitchen, female head of house, who controls budget.</td><td>frequent duel use for a number of reasons.

<table><tr><th colspan="2">Quality assessment</th></tr><tr><td>Selection</td><td>S</td></tr><tr><td>Baseline info.</td><td>S</td></tr><tr><td>Outcomes</td><td>S</td></tr><tr><td>Analysis</td><td>W</td></tr><tr><td>Impact</td><td>M</td></tr></table></td></tr>
<tr><td>**Inayatullah 2011**

Pakistan

Swat district

Rural</td><td>Traditional 3-stone open fire (biomass)

2 models of ICS (not described), one used for cooking the other for space heating.</td><td>*Scale*: No information about the programme other than reference to the work of an NGO – the Kalam Integrated Development Project (KIDP) – which ceased its activities in Swat in 1998.

No information as to whether the stoves were purchased or given for free. ICS were still produced by local manufacturers after the initial diffusion programme and at the time of the study (2010).</td><td>Cross sectional survey.

Study population: 100 randomly selected households from 2 villages, 20% of which were found to use improved cookstoves.</td><td>Questionnaire administered during face-to-face interviews were with men only.

Analysis: multivariable logistic regression analysis of factors influencing ICS adoption (binary logit model used).</td><td>*Variables significantly associated with ICS use:*
• Education of respondent (positive).
• Monthly household income (positive).
• Total household working members (negative).
• Biomass collection (vs purchase) (negative).

Variables not significantly associated with ICS use:
• Age of respondent.
• Total landholding, total household size.
• Knowledge of biomass hazards.</td><td>*Quality score:* Moderate

Further details of data collection and time from initial adoption not provided. In this area, fuelwood collection is primarily men's responsibility

<table><tr><th colspan="2">Quality assessment</th></tr><tr><td>Selection</td><td>M</td></tr><tr><td>Baseline info.</td><td>M</td></tr><tr><td>Outcomes</td><td>M</td></tr><tr><td>Analysis</td><td>S</td></tr><tr><td>Impact</td><td>M</td></tr></table></td></tr>
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Author/year location, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Miller and Mobarak 2011 Bangladesh Jamalpur and Haita districts *Rural*	Traditional stove (biomass). 2 models of ICS with different characteristics: (i) with chimney (‘health-improving’ stove, that primarily reduces indoor smoke exposure); (ii) without chimney (‘fuel-saving’ stove that reduces fuel consumption through efficient combustion and reduces household expenditure for fuel).	*Scale*: Regional. Research study carried out in 58 villages. *Duration*: not specified. *Approach*: 2 stove models were given for free or subsidised. Participatns were blind as to whether stoves were subsidised, and to what level. *Implementer*: The study was not part of any larger cookstove dissemination campaign. This was a multi-pronged experimental field study to test gender differences in preferences within households, differential pricing and social marketing.	Randomised controlled trial. *Study population*: 3,079 households sampled for 2 sets of independent experiments: • 1st set: intra-household gender differences in ICS purchasing preferences (4 experimental conditions tested). • 2nd set: influence of price and social marketing (including local opinion leaders’ influence on likelihood of adoption vs non adoption); 4 experimental conditions, including a control group, were tested.	Separate interviews with men and women from the same households to explore gender preferences for intervention. *Analysis*: Multivariable regression analysis of (i) preferences by gender and (ii) factors affecting adoption (intention to purchase assessed by ordering a stove), carried out separately for villagers where the stoves were offered for free and where purchased. New ICS acquisition rates (stove orders) and final ICS purchasing rates were also analysed separately. Opinion leaders in each participating village were identified through FGDs with villagers.	The study aimed to evaluate ICS acquisition, through 4 approaches: subsidies vs no subsidies, gendered marketing (i.e. health vs economic aspects), and impact of opinion leaders and social networks. *Key findings*: Women valued health benefits of ICS more than their husbands, but lacked decision-making power. When stove available for free, significant (but not large) gender difference, with women preferring the chimney stove, men preferring the economical stove. When costs applied, both sexes preferred cheaper stove. *Barriers to making a commitment to purchase*: (i) Higher initial purchase price and lack of liquidity, (ii) opinion leader’s influence when leader (personally) did not wish to purchase the ICS. However, opinion leader’s influence declined as households gained knowledge about the stoves, for example from neighbours. *Suggestions:* Marketing campaigns for ICS should not be focused on informing population about health hazards, but to be tailored to target men.	*Quality score:* Strong Complex study conducted with a series of intertwined well-described experiments. **Quality ssessment** Selection: S Baseline info.: S Outcomes: M Analysis: S Impact: S The main outcome was the intention to purchase a stove, not actual adoption, or sustained use of stove. Sustainability of subsidies is not discussed.

Author/year location, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Pine et al. 2011 Mexico Michoacán state *Rural*	Traditional wood stoves or open fires, with some use of LPG and kerosene in communities. Patsari ICS (wood).	*Scale*: Regional. *Duration:* Not stated, but around dates of this survey work (2004-05). *Approach*: Stove provided free of cost to homes participating in health study (this study sample was drawn from the health study sample). *Implementer:* GIRA NGO.	*Study design*: Interviews and observation. *Study population*: A total of 259 households randomly selected from 5 indigenous communities were given Patsari. Repeated monthly home visits up to a maximum of (around) 10 months after the stove was installed. For main analysis at least 3 visits within 5 months were used. The study focused on analysis of factors affecting use in 233 users, but also compared this group with the 26 who never used the stove.	Interviews with households; 233 households made some use of the stove. *Analysis*: For these 233 users, initial step was simple longitudinal analysis of stove use. Second step was univariate multinomial logistic regression, with month of adoption (month of starting to use the stoves) defined as month 1, 2, 3 or later, or non-adopter, used to identify factors that were 'most strongly associated' (not otherwise defined) with time of adoption. Factors from step 2 were then entered into a multivariable multinomial logistic regression. Finally, simple descriptive	*Main factors associated with early ICS adoption*: • Community (key differences between 5 communities were education, use of LPG, occupation of the head of household as farmer, longer duration of residence at home, all of which were associated with earlier adoption). • Reporting irritated eyes (prior to installation). • Use of wood scraps for fuel. • Fewer adults in the home. • Women not working outside the home. • Not having a traditional horseshoe shaped floor-level open fire. Additional analysis suggests problems with the stove were an important influence on continued use.	*Quality score:* Moderate This study examined factors associated with the timing of primary/main use of the Patsari stoves, following free installation (no cost) in the context of a health study. The study does not appear to have been primarily designed to study adoption of the stoves. **Quality assessment** Selection: M Baseline info.: S Outcomes: M Analysis: S Impact: M An issue, discussed by the authors, is the extent to which (at least some of) these findings are generalisable, as opposed to being site specific.

Author/year location, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
				comparison of characteristics of the 233 adopters with 26 non-adopters.		
Pushpa 2011 India Southern region *Rural*	Traditional biomass stoves (no further details provided). Several improved chulha models (unspecified) using biomass.	*Scale:* National – NPIC. *Duration:* 1985-2002 *Approach:* ICS provided free of charge or at subsidised price. *Implementer:* Government of India.	Cross-sectional survey. *Study population*: 492 beneficiary families (no sampling method/data collection specified).	*Data sources*: Not specified. *Analysis*: Analytitical approach without adjustment comparing adopters with rejectors, on a number of selected variables.	*Factors significantly associated with adoption* (comparison between adopters and rejectors): • Family size: smaller families. • Family occupation: small-farm owners compared to those with larger farms. • Age of users: 25-45 (compared to younger and older age groups). • Attitude (i.e. personal factors influencing one's decision to adopt or not new ideas/objects): beneficiaries developed a favourable attitude. *Factors not found significantly associated*: • Annual income. • SES. • Educational status. • Occupational status.	*Quality score:* Weak Poorly presented study with sampling and data collection not described. Not possible to judge about representativeness and validity of the findings, but statistical analysis seems appropriate. **Quality assessment** Selection: W Baseline info.: M Outcomes: M Analysis: W Impact: W
Levine and Cotterman 2012 Uganda Kampala city *Urban*	Traditional charcoal stove. Ugastove improved charcoal stove (subsidised at the retail price of US$7).	*Scale:* Local. *Duration:* not specified. *Approach:* market sale offers, including free trial, time payments, etc. *Implementer:*	Randomised trial of multiple sale offers. *Study population*: ,1690 households randomly selected by cluster random sampling. 4 types of sale	Data collection carried out by salespeople promoting the Ugastove during market visits within the randomly selected	*Main findings:* • Sale offers (with either time payments or free trial) increase the uptake of ICS from 5% to 25%. • Higher uptake (46%) among households who received the combination of the 2 offers (which also included the right to	*Quality score:* Moderate The research methods used were not able to distinguish between relative importances of barriers which

Author/year location, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
	In both cases charcoal is purchased by the urban population.	University of Berkeley supported by a local NGO (Centre for Integrated Research and Community Development) specialised in market-related research about household energy.	offers: (i) *retail price offer* (purchasing on the day or within 1 week from the sale visit); (ii) *free trial* (i.e. paying at the end of the trial period, but without time payments); (iii) *time payments* (but without a free trial); (iv) *novel offer* (i.e. free trial period + time payments + right to return the stove at any time and stop future payments).	houses. 10 households in each neighbourhood received the same type of sale offer. A cross-sectional survey was conducted at the end of the sale offers. *Analysis*: Multivariable logistic regression.	return the stove and stop payments). • Liquidity constraints and concerns about savings and stove durability affected purchasing of the ICS. • Among those households who purchased the ICS through time payments, extra collection visits were often required. • Household size had a larger effect than charcoal expenditure in predicting ICS adoption.No evidence was found that sale offers affected consumer's confidence in the ICS.	affected ICS uptake. Self-reported measures were used. **Quality assessment** Selection: S Baseline info.: M Outcome: M Analysis: S Impact: M
Silk et al. 2012 Kenya Nyanza province *Rural*	Traditional stove (mostly firewood, crop waste and charcoal). Upesi Jiko ICS (without chimney).	*Scale*: local; 1,124 stoves to date. *Duration*: 2008-ongoing. *Approach*: Market-based approach using existing network of vendors, price incentives and product integration. *Implementer*: Nyando Integrated Child Health and Education Project (NICHE), Safe Water and AIDS Project (SWAP, NGO). Funding from the United States Centers for Disease Control and Prevention.	*Study design*: Baseline and follow-up cross-sectional surveys and prospective monitoring. *Study population*: 2-stage random cluster-sampling procedure to identify 60 NICHE villages and 25 households within each village (1,250 households); random sample of 10 NICHE villages (293 households) for pilot phase.	*Data sources:* Interviews and weekly household visits by trained NICHE surveyors. *Analysis*: Chi squared tests to identify statistically significant differences in equity of adoption.	*Factors influencing adoption:* • Older women (above 31 years) and households in highest socio-economic quintiles more likely to adopt. • Education of female head of household and remoteness no effect on adoption. • Two-thirds of adoptions involved promotional offers or price incentives. • Frequent and sporadic users of household water treatment more likely to adopt than 'never' users.	*Quality score:* Moderate Very good sampling and data collection. A lot of missing values in analysis of equity in adoption and no in-depth analysis. **Quality assessment** Selection: S Baseline info.: M Outcomes: M Analysis: W Impact: M

C. Summary table for case studies

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Amarasekera 1989 Sri Lanka Countrywide *Urban/rural*	Traditional 'U'shaped mud stoves and 3-stone open hearths using firewood. Improved cookstoves using firewood (different models developed for rural and urban areas).	*Scale*: National (National Fuelwood Conservation Programme – NFCP). The plan was to install 500,000 stoves by 1995. *Duration*: Initial programme started in 1984. *Approach*: Government-led programme dependent on government agents for distribution, marketing, installation and co-ordination. In the new strategy, the proposal was to replace the government agents with co-op welfare and credit societies and women's organisations.	*Study design*: Surveys were carried out in Colombo city. The urban programme was seeking to exploit the brick and tile industry already in place to mass produce ICS – 100,000 stoves. The rural programme was to have stoves built by the Dutch-assisted programme with the cost of the installation being borne by the user. *Study population*: Not specified. *Analysis:* Descriptive, no statistics and no tables provided.	In one district, at least 81% of users saved 25% of the firewood previously used, and users indicated that time saved cooking was the most favourable aspect of the stove. In the same district, 59% of households used only the new stove while 26% used it often and the open fire occasionally. Decentralisation of stove liner production was being promoted as a means of reducing transportation costs, avoiding overheads and reviving the local pottery industries. Over 100 potter families were trained at the time of the report, but one of the main constraints was the difficulty in training new potters.	*Quality score:* Weak This is a brief case study with no methodology or data collection described. Not possible to draw any conclusions about the success of the programme as it was incomplete at the time of publication.
Mounkaila 1989 Niger Niamey city *Urban*	3-stone open fire and Malgache stoves (biomass). ICS: Mai Sauki stove (a metal stove adapted from a model developed in Burkina Faso).	*Scale*: (not specified). *Duration*: 1993–1994, plus 2 additional years. *Approach*: Market-based approach promoting unsubsidised stoves. *Implementer:* Ministry of Mines with funding from GTZ (Deutsche Gesellschaft für Technische	*Study design*: (i) Baseline survey of households possessing the Mai Sauki stove; (ii) qualitative interviews with opinion leaders. *Study population*: (i) 1,000 households from different districts of the capital city; (ii) 235 households among those possessing the new stove. *Analysis*: Survey results presented in percentages on total number of households	The new stove model was highly publicised by local radio, TV (with 104 spots) and by 'ad hoc evenings' with cooking demonstrations for the ICS promotion. These events were very popular among women. Combining marketing campaigns through mass media and demonstrations were found to be very successful. Wood saving was the main reported stove advantage (89%). Reported reasons for non-adoption: • Lack of money (62%).	*Quality score:* Moderate This is a brief case study based on a mixed-method approach, which makes use of a large representative sample used for a baseline survey. All results

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		Zusammenarbeit), United Nations Development Programme (UNDP) and World Bank (after successful trial project supported by local NGOs).	surveyed.	• Unconvincing message (17.6%).	presented as text description and percentages.
Namuye 1989 Kenya Nairobi and Kisumu cities *Urban*	Traditional charcoal metal stove. ICS: Kenya Ceramic Jiko stove using charcoal.	*Scale*: (not specified) probably national. *Duration*: Not specified Kenya Renewable Energy Development Programme (KREDP) established early 1982). *Approach*: market-based approach promoting unsubsidised stoves. *Implementer:* KREDP – funded by USAID. Also Kenya Energy Non-Governmental Organization (KENGO).	*Study design*: Household survey (interviews). Contact questionnaires for users, producers and promoters of improved stoves. More detailed assessment of cooking practices and fuel consumption. SES through observation. *Study population*: Very little information (none on numbers). Households visited (not more than once) chosen by toss of a coin. Sample primarily made up of low-income households *Analysis*: Simple descriptive analysis (tables and charts) presenting quantitative data on stove production and charcoal fuel consumption.	Reasons for not owning an improved stove: not heard about stove (27%), too expensive (17%). About half of respondents who did not have an improved stove said they wanted one. *Advantages:* Improved speed of cooking, reduced charcoal consumption and easily carried when hot. Less important was appearance. Life span/durability appreciated. *Disadvantages:* Cement came off. Most respondents indicated a reduced price was desirable. *Impact on artisans, entrepreneurs and retailer:*. Income-generating opportunities (especially in rural areas). Women now employed in liner production (pottery traditionally women's work). Expansion of small-scale industries. Estimated that more than 1,000 artisans employed in production and marketing of stoves.	*Quality score:* Weak This is a brief case study of questionable quality/reliability (intensive data collection over 2 days including observations). No information on numbers/refusers, etc. All results presented as text description.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Sawadogo 1989 Burkina Faso Ouagadougou city *Urban*	Traditional 3-stone open fire (wood). Intervention technologies: (i) Ouaga metal stove, developed in 1983: for wood only, 1 hole without chimney; (ii) Burkina Mixte stove introduced in 1984: wood or charcoal, 1 hole no chimney; (iii) Improved 3-stone stove (3PA) – introduced in 1983: one hole no chimney (like traditional stove with space between stones filled; 39% wood save); (iv) Ceramic stove introduced in 1979: terracotta - 1 hole no chimney.	*Scale*: Regional (30 sectors of the city). Over 36,000 total stoves sold. *Duration*: August 1985 and April–May 1986. *Approach*: Cheap metal stoves disseminated in response to deforestation. Training of women from Burkinabe Institute of Energy (IBE) who trained others. *Implementer*: Collaboration between IBE, the Interministerial Commission on the recommendation of the Permanent Interstates Committee for Drought Control in the Sahel (CILSS), and the Ministry of Environment and Tourism.	*Study design*: Case study using qualitative and quantitative methods. Surveys, interviews, participatory observation. *Study population*: Survey conducted in 5 central districts and 5 suburban sectors. 2 families per district/sector chosen – 3 days spent with each family. N=20 total. Also asked opinion leaders (number not stated) about factors influencing use and non-use. *Analysis*: Descriptive information on dissemination including opinion and feedback from qualitative methods.	*Main findings:* Publicity campaign in 1984 through very successful media promotion. Increased cost of wood encouraged purchase of improved stove for reduced wood consumption (incentive). Stoves highly valued (household and opinion leader interviews). *Advantages*: Wood saving main quality recognised. Speed of cooking second advantage (especially metal and ceramic stoves). Other qualities – ‘not messy’, ‘stable’, 3PA ‘not expensive’ and practical because portable. *Disadvantages*: 3PA – short life expectancy, lack of adaptability (one hole), instability, no chimney, blackened pots. Ceramic – not strong/stable. Metal – small door/not strong. Potential solutions to these problems discussed by author. Majority of stoves regularly used (1–3 times per day). Metal and ceramic used more often than 3PA (69% cracked or broken). Repeat training of craftsmen necessary. Need to publicise availability of craftsmen and sales outlets. Sales promotions very effective (1984 and 1987). *Other:* Regulation of firewood cutting had impact on fuel consumption but no correlation between regulation and acquisition of an improved stove.	*Quality score:* Moderate This is a brief case study with use of a mixed-methods approach. All results presented as text description. Potential response bias - reported ‘wood save’ as reason for adoption but not evident in lab tests.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Sudjarwo et al. 1989 Indonesia Sleman and Bantul *Rural*	Traditional Keren stove, using crop wastes and wood. Homes have generally 2 types of stoves: Keren stove for the majority of the cooking and a rectangular mud/brick stove (Pawon) for food needing longer cooking times). Improved 'SAE' pottery wood stove with 2 pot holes (no chimney).	*Scale:* Not specified, probably regional. *Approach:* Stoves sold either direct by producers, or via shops (government), local family welfare organisations. *Duration*: Production 1983-87 included some 250,000 stoves. *Implementer*: Yayasan Dian Desa.	Cross-sectional survey and interviews. Study carried out prior to planning programme expansion, to identify constraints on adoption. *Study population*: 306 'SAE'users; 276 ex-'SAE' users; 418 Keren users, sampling methods not described. Numbers of interviews with producers not reported. *Analysis*: For survey results, simple descriptive analysis (tables and charts). No information on how interviews with producers, etc., were analysed.	• ICS use increased across SES quintiles. • Word-of-mouth communication stated to be important, but data given do not support this. • Stated that Pemberdayaan Kesejahteraan Keluarga (PKK women's organisation) was influential, acting as a promoter and seller, but no supporting data. *Reason for ICS rejections:* • Some users rejected 'SAE' due to poor performance and longer cooking times. 65% of ex-'SAE' users said it took longer to cook. • Lack of durability (19% of ex-'SAE' users). • Crop residue fuels were problematic with the SAE stove. • Altough the kitcen performance test showed 63% reduction in fuel use, in practice, the slower performance in cooking led to users using wood that was too large, which increased wood use. • Cost: 19% of ex-SAE users did not buy another stove due to costs. • Design: 25% of ex-SAE users complained about practicality of design. • Lack of stability of the stove (no data). • Ignorance of proper usage (no data). • It is reported that PKK told households to use the stove, without showing them the advantages, and this led to them not using the stove. • Supply problems, delays, etc., prevented some groups from promoting/selling the stove.	*Quality score:* Moderate This is a brief case study with methods not described in sufficient detail to assess quality. Although based on a mixed-method approach, it seems likely that the survey work was carried out by the NGO overseeing this programme, which may have led to bias.

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Shastri et al. 2002 India Karnataka state *Rural*	Traditional stove (biomass). ICS: Astra stove.	*Scale*: Local. *Duration*: 1983–2001. *Approach*: unsubsidised, market-based approach. *Implementer*: One independent stove entrepreneur, Joshi and Son, in Uttara Kannada district.	*Study design*: Repeated cross-sectional study (1994 and 2001); fuel measurement (2001). *Study population*: Survey: random sample of 150/132 (1994/2001) households identified from full list of households with Astra stoves in top 10 villages. Fuel measurement: random sample of 40 households from 150 households with Astra stove and 25 households with traditional stove in same villages. *Analysis*: Frequencies and descriptive analysis of stove use and fuelwood conservation; descriptive analysis of factors contributing to entrepreneur's success.	*Entrepreneur achieved remarkable success:* • Immediate and sustained use of Astra stove that significantly exceeded average for Karnataka state. • Reported fuel and time savings as well as smoke reductions. *Factors contributing to success:* • Demand-driven approach (i.e. stove construction upon household request). • Profit motive as incentive to ensure quality and sustained demand (entrepreneur). • Full pay-for service and demand for high-quality performance (households). • User education on stove use. • Post-construction service (follow-up visit; free minor repairs, major repairs/reconstruction against charge).	*Quality score:* Strong Sampling and quantitative information well described. Factors contributing to success are not fully empirical, i.e. it is not clear how the relatively general information obtained through the survey has led to the specific success factors identified.
World Bank 2004a *« Tezulutlan project »* Guatemala Baja Verapaz *Rural*	Old ICS models (mostly abandoned) and open fires. Tezulutlan stove (metal-plancha with larger opening and smaller internal chamber). This stove model designed jointly with 20 women from various communities.	*Scale*: Regional (37 communities from 5 municipalities). Tezulutlan Intregrated Rural Development Project. 4,129 stoves built and disseminated. *Duration*: 1998-2003. *Approach*: Stoves given for free or subsidised. No market structure was created throughout the project *Implementer*: Local NGO with funding from	Mixed-methods approach. Structured interviews with users followed by FGDs and interviews with stakeholders. *Study population*: 24 users interviewed from 2 communities (17 were women). 12 users received the stove as donation, 7 paid for the stove, 5 paid for stove and provided local material. 2 FGDs held in each community. With 8-12 women stove users. Interviews carried out in Spanish.	*Findings*: • First evaluation took place after building a small number of stoves, before scaling up. • Promotion through media, with radio messages from community leaders very successful. • Users provided with training. *Enablers*: • Use of local material and stove components available in local hardware stores. • Stove height adjustable in order to suits users' height. • Technicians established a permanent presence in the field in order to	*Quality score:* Moderate Partial details on sampling methods used. Results presented are based on empirical evidence but no statistical analysis was conducted to assess factors influencing adoption. Results from the

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
		Government of Guatemala and the European Union.	*Analysis*: Descriptive.	guarantee stove quality of built stoves and field training. • Participation in stove construction (and stove components replacement) fostered a greater sense of ownership and responsibility for the stove. *Barriers* • Women not aware of places to buy stove or stove parts. • Poor road conditions making it difficult to transport fragile stove components. • Dislike for the firebox door (door either removed or never closed). • ICS unsuitable to cook for large gatherings (people used the open fire for special occasions).	FGDs not described. Findings presented as an overall narrative, with aspects relevant to scaling up clearly described.
World Bank 2004b « *SIF project* » Guatemala Jalapa *Rural*	Old ICS and open fires, using firewood, maize stalks and cobs Plancha-type improved stoves with 4 cooking holes, using firewood.	*Scale*: Local/regional (2 communities: Los Achiotes and Los Gonzales). *Duration*: 1996–2004 (with more than 90,000 stove disseminated up to 2001). *Approach*: Stoves built by private companies contracted through public bidding for 1 year. Stoves highly subsidised (90% subsidies). No marketing structure promoted. *Implementer*: Social Investment Fund (SIF) Improved Stove Project (PEMF).	*Study design*: Mixed methods. Structured interviews with users followed by FGD. Interviews with stakeholders (members of the SIF project Environmental Unity) *Study population*: 10 + 21 users (mostly women) from 2 communities were interviewed. 2 focus groups (1 for each community, 14 and 12 people respectively). Interviews carried out in Spanish without an interpreter. *Analysis*: Descriptive analysis.	*User perceptions (positive aspects):* • Less indoor smoke, improved respiratory health, less eye irritation. • Cleaner kitchens, less firewood used, less time needed for cooking, users performing regular stove and chimney cleaning. *User perceptions (negative aspects):* • Stove construction not flexible: not possible to adapt the height of the stove base to women's needs. • Poor-quality installation of ICS door for inserting the firewood. • Women experienced difficulties in adapting to the ICS (e.g. difficulties in controlling intensity of fire, and splitting firewood into smaller pieces in order to fit into the firebox). • Stove modifications often carried out.	*Quality score:* Moderate Results presented in this report are based on empirical evidence, but no analysis of quantitative data was reported, nor FGD properly discussed and use of quotes reported. Limited details on sampling methods used. Findings presented as an overall narrative, with aspects relevant to scaling up clearly described.

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World Bank 2004c *« Intervida »* Western Guatemala *Rural*	Traditional stoves or open fire (wood). Plancha-type improved stoves with 3 cooking holes, using fuelwood (sold at the price of US$100 or more).	*Scale*: Regional (San Marcos Department). Households were selected, based on their level of poverty and willingness to participate in the project. *Duration*: 1998–2001 (from 2000, a 10-year project up to 2010 was launched). *Approach*: Stoves purchased with subsidies (which evolved during time, up to 70% subsidies), payment to be completed within 1 year of installation. *Implementer*: Intervida (Spanish no profit organisation).	*Study design*: Mixed methods. Structured interviews with users followed by FGD. Interviews with members of staff from the Intervida 'Production and Marketing Unit'. *Study population*: 14 + 18 users interviewed (both men and women) from 2 communities (San Antonio and Cantel). 2 FGD in each community, with 6 + 8 participants each. *Analysis*: Descriptive analysis.	*Stakeholders perspectives*: • Stove construction was initially carried out by a group of men from the community trained by building demonstrations (1998–99); this method failed because of poor construction. The firebox entrance was too small to insert greater quantities of firewood and some women broke the fireboxes. • Quality control of purchased material and stove building was carried out by the implementing organisation. • Training was given only to male community leaders. • Subsidy strategy evolved over time, an inverse relationship was observed (from 1998 to 2000): the more the community was involved/contributed the less there was demand for the improved stoves. *Users views:* • Frequent cases of fires reported due to overheated chimneys and sparks flying out of the chimney • Problems with stove part quality (stove base firebox and chimney) and construction. • Frequent cleaning needed and (reported to be performed by users) • In one community, only male stove owners reported that they received training on stove use and maintenance and they transferred it to the community.	*Quality score:* Moderate Results presented in this report are based on empirical evidence but no statistical analysis of quantitative data was conducted, and no qualitative analysis was described for the FGDs. No details on methods of sampling. Findings presented as an overall narrative, with aspects relevant to scaling up clearly described.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Sinton et al. 2004 China Countrywide *Urban/rural*	Mostly traditional stoves using wood and crop wastes, some coal use. Improved biomass stoves, design not clearly specified, and improved coal stoves disseminated at a later phase of the programme.	*Scale:* National, supporting 860 of the country's 2,126 counties. *Approach:* The programme was designed to provide rural households with more efficient biomass stoves and, later, improved coal stoves. *Duration*: The evaluation was in 2002, but the programmes covered a period commencing in the early 1980s. *Implementer*: Largest programme was the National Improved Stoves Program which was run by the Ministry of Agriculture; the world's largest publicly financed initiative to improve stove function.	*Study design*: Evaluation included a facility survey of 108 government agencies, a household survey of 3,476 households and open-ended interviews. 3 provinces were surveyed using random sampling. *Study population*: National programme, evaluation carried out in 3 diverse provinces, Zhejiang, Hubei, Shaanxi, to represent high medium and low adoption rates. *Analysis*: Descriptive narrative.	*Key findings:* • Despite overstated claims for penetration of improved stoves, most biomass stoves had flues and other 'improved' aspects, However, most coal stoves, even those using improved fuel (briquettes), lacked flues and could not be considered improved. • Large roles for government oversight of quality control and support of R&D were not adequately fulfilled. • Improved stoves in the surveyed households did result in reduced PM concentrations indoors for biomass fuel combinations. • Most results of indoor air-quality monitoring and health surveys were not clear-cut, in part because of the wide variety of fuel and stove combinations used by households. For nearly all household groupings, however, PM4 levels were higher than, and sometimes more than twice as high as, the national standard for indoor air (150 mg PM10/m3). • Coal use was associated with elevated levels of CO in exhaled breath, and improved biomass stoves with lower levels. • Childhood asthma and adult respiratory disease were positively associated with coal use and negatively associated with improved stoves and good stove maintenance.	*Quality score:* Strong This study was an independent evaluation of the China ICS programme. The programme was designed to provide rural households with more efficient biomass stoves and, later, improved coal stoves. However, no clear single definition of what constituted an improved stove made the evaluation problematic.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Masera et al. 2005 Mexico Michoacán state *Rural*	3-stone open fires or 'U'-type traditional cooking stove devices (exclusively wood, or mixed use wood and LPG (used as a complementary fuel[25]). Patsari stove (with 1 or 2entries), sold at a retail price of US$24 (labour costs included).	*Scale*: Regional. Dissemination of 1,500 Patsari stoves in 30 villages. *Duration*: 2003–06 *Approach*: Stoves entirely or mostly subsidised. *Implementer*: National and international institutions (UNAM, Comisión Nacional Forestal [CONAFOR], Instituto Nacional de Ecología [INE] with funding from the Shell Foundation) The work was carried out together with local authorities, NGOs (i.e. GIRA) and other local groups.	Assessment of the project at 18 months, with primary data collected through a survey reported in Valencia 2004[26]. *Study population*: 42 women from 400 households in villages of the Purepecha region, who adopted the Patsari stove were interviewed. *Analysis*: Descriptive presentation of evidence arising from the 5 components of the programme.	Programme implemented in 5 phases, using a participatory approach. • Women trained in stove use. • 20% discount of stove costs for the first 50 stoves built within each village. • Payment in instalments; local suppliers of custom-made parts facilitated feedback on stove design and durability of different materials. • Efficient monitoring package. *ICS advantages:* • Family eats together in the kitchen. • ICS considered as a 'household asset', 70% households made some changes in the house or planned to do in the near future (e.g. painting, cleaning the walls, changing the ceiling, etc).	*Quality score:* Moderate The analysis described in the paper was based on the 5 components characterising the programme. Strategy adopted and implications of each phase are thoroughly described. The empirical data used in the analysis were collected in a separate study, but results are extensively described making it unnecessary to consult the original study.
USAID/Winrock 2008 Northern Peru Lambayeque *Rural*	Traditional open fires (wood). This was a complex (integrated) programme. Technology was a locally designed,	*Scale*: Local. Around 400 homes adopted in 33 out of 60 communities in highland rural area. *Duration*: 2005–07	Empirical data on use, experience, HAP levels and fuel use obtained through a mix of focus groups, feedback from promoters, household surveys (n=169) and measurements of PM4 and CO (n=42).	Report emphasises importance of local champion and good project management, including business management. *Key findings:* • From survey 54% said most effective means of raising awareness (of health risks, benefits of stoves, etc.) was village-	*Quality score:* Moderate This was a 'complex' or integrated intervention and from the data and

[25] Main reasons for low LPG adoption in this region are (i) high investment costs, (ii) cost of purchasing fuel, and (iii) inadequate distribution network.

[26] Valencia A (2004) Improved cookstoves in Michoacán, México: a search for an integrated perspective that promotes local culture, health, and sustainability. MS thesis, Energy and Resources Group, University of California, Berkeley.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
	rocket-type wood-stove (Inkawasina), with chimney.	*Approach*: Majority of stoves adopted through microfinance. Accompanied by extensive community promotion activities with print media, murals and radio spots, etc. Also ran healthy kitchen competitions. Local entrepreneurs trained in production/installation. *Implementer*: Peruvian NGO and Winrock.	*Study population*: Village communities in highland area, altitude 1,800 to 3,200 m. Sampling of homes for surveys and measurements not described. *Analysis*: Actual methodology not described for enabling factors and barriers. Simple frequencies (%) reported for some findings. Analysis of FGDs not described. Standard reporting of PM4 and CO.	level and household promotion. Radio spots less influential, but may have needed to run for longer. • The loan system had problems (animal welfare, mortality, time to repay), but was working for most and seems reasonable to conclude that it facilitated access for many of these families. • Report states that kitchen competitions were effective at getting attention in communities (but evidence not provided). • Substantial fuel saving demonstrated (32%), space heating function is needed in the project area, and there were no complaints about the new stove in this respect. • Stated local entrepreneurs important in developing local market. • A minority (about 3%) of users experienced cracking or collapse of the (local, artisan-produced) rocket elbow, and some had abandoned the stove (rather than having it repaired). • This study was notable in that data on HAP levels are available at baseline, and 12 and 24 months after installation. Reductions substantial at 12 months, but average increased at 24 months, due to cracking, ill-fitting pots, and users leaving stoves smouldering during the day.	analysis available it is difficult to attribute satisfaction or continued use to any one component of the project. It can be assumed that problems with ceramic elbows contributed to (i) poor HAP performance at 24 months and (ii) abandonment of the stoves, but according to the figures reported, only in a small number of homes. Report stated that the GTZ Bolivian programme (which was planning to promote nearly 3,000 of these stoves) intended to mass produce elbows to ensure higher and more consistent quality.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
GERES 2009 Cambodia Kampong Chhanang province *Urban*	Open fires traditional Lao charcoal stoves (made of clay). New Lao charcoal stove.	*Scale*: National. *Duration*: From 2002. *Approach*: Unsubsidised stoves sold under market conditions. *Implementer*: Renewable Energies, Environment and Solidarity Group (GERES – Cambodia), Agence Française de Développement (AFD), with support of the Cambodian Ministry of Energy, Mines and Industry.	*Study design*: Mixed methods. Cross-sectional survey of stove users and qualitative face-to-face interviews with stove manufacturers. *Study population*: 1,600 randomly selected stove users and 51 stove manufacturers. *Analysis*: Descriptive synthesis and statistical analysis carried out with SPSS.	*Dissemination strategy*: 5 main stages implemented within a time frame of 5 years. • Need for a pre-dissemination phase to test the stove, quality check and conduct user surveys, prior to initiating scaling up. • Production quality certified by stove labels to prove that standard requirements are met. • Support needed for stove producers during the initial production phase in order to encourage them to produce the new model and comply with quality standards. *Stove producers' perspectives:* • New Lao stove production generated 4-times higher income. • Producers relied on their own capital to open the ICS business. • Source of employment generation • Producers joined a national association with the following benefits: (i) standardisation of ICS; (ii) improved communication with local authority, recognition of the activity and profession. *New stove users' perspectives:* • Return on investment within 6 months from initial purchasing. • Reduction of wood fuel (firewood + charcoal) expenditure by 5%/ • Time saved: 1.5 hours per week (measured)/ • Cooking easier or more comfortable. *Additional considerations:* • New Lao stove disseminated more among higher level of income categories (which	*Quality score:* Strong Detailed report of a successful large-scale (national) dissemination campaign with a commercial approach. Difficult to evaluate programme's success as report has been prepared by the implementing group. However, evidence is strongly supported by empirical data. Large-scale campaign model is well described and very valuable.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
				buy charcoal from sellers). • ICS not promoted among the poorest social groups.	
Kürschner et al. 2009 Bangladesh Rajshahi division *Urban/rural*	Traditional stove (biomass). Most fuel is bought in cities (generally in large amounts 1 or 2 times a year); rural households generally collect it. Improved mud and clay stoves with chimney (developed by the Bangladesh Council of Science and Industrial Research) and modified by the new programme started in 2007.	*Scale*: National. Sustainable Energy for Development (SED) Program – Improved Cookstove component. *Duration*: from 2007. *Approach*: Market-based dissemination of ICS sold by about 165 partner organisations. *Implementers*: study commissioned by the Poverty-Oriented Basic Energy Services (HERA) of the German Technical Cooperation (GTZ), in cooperation with SED and in collaboration with Energising Development (EnDev).	*Study design*: Mixed methods (open-ended interviews and FGDs) with users, stove builders and partner organisations. *Study population*: Rural and urban households of northwest Bangladesh. 450 open-ended interviews were conducted with a purposive sample of households that have purchased or have been given the ICS. 51 interviews were conducted with stove builders. *Analysis*: Descriptive synthesis of qualitative and quantitative evidence.	*User perceptions*: 80% respondents used their ICS for all cooking, and the majority claimed positive benefits from the stove. *Advantages:* • Smoke reduction reported in 95% of cases and mentioned as a major advantage by 75% of respondents. • Reported fuel savings (14–77%) but results were inconsistent • Time saving resulted from faster cooking and easier cleaning of the kitchen (82% reported a general time saving of about 7 hours per week). Time saved was used for other household work generally. • Money saving as a consequence of fuel savings, with a major impact on urban households. • Fewer cooking-related accidents. *Disadvantages:* • 77% dissatisfied with the service of the partner organisation. • Majority of stove users did not receive any maintenance or were not satisfied with the maintenance service. • Short stove durability: stove worked properly for less than a year. *Financial mechanisms:* • Poor people benefited the most from paying in instalments. • Some of the partner organisations specifically targeted the poorest households with subsidy mechanisms.	*Quality score:* Moderate Methods of data collection partially described (no random sampling possible as users of the improved technology were the target of the study). Although the report seems to have been prepared by the implementing organisation, valuable criticisms of the programme are highlighted.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
				Programmatic considerations: • Lack of after-sales service and attention to long-term usage of ICS. • Lack of monitoring assessment carried out by independent consultancy.	
USAID/Winrock 2009 Bangladesh Sadipur and Parbatur municipalities *Urban*	Hand-constructed traditional mud stoves (biomass). 3 ICS models: (i) 1-pot portable cookstove with grate (US$2-4); (ii) pot fixed model with chimney (US$7); (iii) Griahalaxami (with 2 grates) (US$2-4).	*Scale*: Pilot project launched in 2 municipalities. *Duration*: 2005-07. *Approach*: Unsubsidised ICS purchased by households. *Implementers*: Winrock International in collaboration with two local organisations: Concern Worldwide Bangladesh and Village Education Resource Center.	Cross-sectional baseline survey. *Study population*: Households from poor urban slums. 625 households surveyed, based on a cluster sampling of 25-30 households from a number of wards in each municipality. *Analysis*: Descriptive narrative.	*Dissemination strategy* (5 phases): • Phase 1: establishing a community-level organisation infrastructure, with the creation of community management committees to sustain ICS installation after the end of the pilot project. • Phase 2: raising awareness. • Phase 3: identification of best stove models to meet local needs, followed by purchasing and stove installation. • Phase 4: post-instalment IAP tests. • Phase 5: market development and establishment of entrepreneurs. *Enablers*: • Need to convince people about the value of purchasing a stove instead of self-constructing it. This was possible through high-quality and locally appropriate cookstoves models. • Women as entrepreneurs received micro-loans for stove business. • Road networks helped to maintain entrepreneurs' activities allowing for a bigger market.	*Quality score:* Moderate Methods only briefly described. Report focuses on the 5 main phases of the project and provides useful findings which seem to be accurate.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
World Bank 2010a « *BCSIR programme* » Bangladesh 28 districts, Dhaka and Rajshahi *Urban/rural*	Traditional cookstoves (biomass). 6 different ICS models (US$ 3–6): (i) 1-pot portable cookstoves; (ii) 1-pot semi-submerged stoves; (iii) 1-pot portable stoves for use with sawdust or rice husk; (iv) 1-pot fixed stove with chimney; (v) 2-pot fixed household-sized stoves with chimney; (vi) 2-pot fixed institutional stoves with chimney.	*Scale*: National (28 districts), about 300,000 ICS installed for the entire BCSIR programme (Phase II). *Duration*: 1988–2001. *Approach*: ICS fully subsidised by the government, with households only providing soil. *Implementer*: Government of Bangladesh and partners (i) Bangladesh Rural Development Board (BCSIR) and (ii) Bangladesh Ansar and Village Defence Party (Ansar-VDP).	*Study design*: Literature review supported by interviews with programme implementers, local government agencies, local and technical staff, entrepreneurs and FGDs (no precise details provided). *Study population*: Urban and rural Bangladeshi population. *Analysis*: Literature review and descriptive summary of findings.	*Institutional arrangements:* • Extensive training component (10,000 people) including women fieldworkers. • Programme monitoring carried out at district and sub-district level by government partners. • Users in direct contact with inspectors, technicians and women fieldworkers. • Users given the possibility to discuss performance and usage issues during follow-up visits. • Awareness-raising was supported by national media and local demonstrations. *Technology:* • Uncertainty about post-warranty service. • Blocked chimneys and air inlets. • Households changed stove dimensions during maintenance or made significant changes to the stove (i.e. attaching additional pot hole to a 2-pot stove to convert into a 3-pot stove). *Financial aspects:* • Lack of commercial approach. • Subsidies given in the form of (i) direct subsidies (for installation fees) and (ii) indirect subsidies (for staff cost and training). • There was no support for entrepreneurship development, but many of the trainees started their own stove-making business after the end of the programme in 2001. • Moulds, accessories and technicians' fees were provided for free only to the first 200 households. Subsequently only technicians' fees were provided by the programme.	*Quality score:* Moderate Systematic review of household energy initiatives carried out in Bangladesh (including ICS, biogas and electrification) supported by a great range of empirical methodologies, which however are not reported in great detail in the report. No information on sample size, and sampling methods separately described for each of the discussed programmes.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
World Bank 2010b « *SED Program* » Bangladesh Countrywide *Urban/rural*	Traditional cookstove (biomass). 2 different ICS models (US$3–15): (i) 3-pot fixed stove with chimney (based on a earlier design from BCSIR); (ii) 1-pot fixed stove with chimney.	*Scale*: Countrywide. SED Program – Improved Cookstove component *Duration*: 2004–10. About 45,000 ICS disseminated and 2,500 people trained. The programme is still growing because of the financial input from GTZ. *Approach*: Unsubsidised stoves sold with financial incentives (microcredit and payments in instalments available). *Implementer*: GTZ, financially supported by BMZ and the Government of Bangladesh (Ministry of Power, Energy and Mineral Resources).	*Study design*: Literature review supported by interviews with programme implementers, local government agencies, local and technical staff, entrepreneurs and FGDs (no precise details provided). *Study population*: Urban and rural Bangladeshi population. *Analysis*: Literature review and descriptive summary of findings.	*Institutional arrangements:* • Most of the users did not receive any training for using the ICS; they learnt by observing their neighbours. • Monitoring was led by partner organisations and co-ordinated by GTZ. • Monitoring was sometimes tied in with payment collection visits to those households that took loans to pay for the stove. *Awareness and motivation:* • No community engagement strategy. • Door-to-door marketing. Local staff responsible for identifying people interested in purchasing. • Local exhibition in which local stakeholders, local government representatives and members participated. *Technology*: • Uncertainty about post-warranty service. • Blocked chimneys and air inlets: more dust and soot accumulated. • Chimney difficult to install in a traditional kitchen. • Poor-quality chimneys. *Financial aspects:* • Partner organisations support users with (i) existing microcredit mechanisms and (ii) payments in instalments. • Short paying-back period for microcredit (6 months). • According to fieldworkers, most households were able to afford to pay for the ICS without taking credit. • ICS diversification models and prices	*Quality score:* Moderate Systematic review of household energy initiatives carried out in Bangladesh (including ICS, biogas and electrification) supported by a great range of empirical methodologies, which however are not reported in great details in the report. No information on sample size, and sampling methods were separately described for each of the discussed programmes.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
				needed to reach the poor (cost still too high for the very poor).	
World Bank 2010c « *USAID/Winrock Program* » Bangladesh Sadipur and Parbatur municipalities *Urban*	Taditional cookstoves (biomass). 3 ICS models: (i) 1-pot portable ICS (US$2.3); (ii) 2-pot ICS based on a BCSIR model (US$5.4–7.4); (iii) Grihalaxmi type (1-pot without chimney) (US$3.4).	*Scale*: Local. *Duration*: 2005–07 (with some entrepreneurs still selling ICS and adopters using them after the formal end of the programme). *Approach*: Unsubsidised stoves sold with microcredit mechanisms. *Implementer*: USAID-funded projected implemented by Winrock International, and two local NGOs: Village Education Resource Center (VERC) and Concern Worldwide Bangladesh.	*Study design*: Literature review supported by interviews with programme implementers, local government agencies, local technical staff, entrepreneurs and FGDs (no precise details provided). *Study population*: Urban. *Analysis*: Literature review and descriptive summary of findings.	*Institutional arrangements:* • Special programme focused on training local women as (i) manufacturers, (ii) installers, (iii) retail entrepreneurs. • Monitoring led by stakeholders and entrepreneurs. *Awareness and motivation:* • Community engagement strategy. • Community-based groups created and linked with local health committees to monitor activities, based on a participatory process. • Local media, folk songs and courtyard meetings for households. *Technology:* • Blocked chimneys. • Increased fuelwood consumption. *Financial aspects:* • Microcredit mechanisms. • ICS price varied according to the construction material of the roof of the house (for making the hole for the chimney). Negotiation between the household and the technicians often occurred.	*Quality score:* Moderate Systematic review of household energy initiatives carried out in Bangladesh (including ICS, biogas and electrification) supported by a great range of empirical methodologies, which however are not reported in great details in the report. No information on sample size, and sampling methods separately described for each of the discussed programmes.
Osei 2010 Ghana Countrywide *Urban/rural*	Firewood (rural) and charcoal (urban) on traditional stoves. ICS: Toyola (charcoal) stoves.	*Scale*: 35,000 homes supplied (0.9% of households in Ghana). *Duration*: 3 years (from 2007). *Approach*: Business model. Toyola purchased locally manufactured	*Study design*: Not clear. Business model described. *Study population*: Developers interviewed by author in 2009. *Analysis*: Literature review and descriptive summary of interviews (no empirical data).	Use of credit created cash flow problem reducing ability for expansion. Bank loans increased price, reducing access for poor. Scrap metal required for stove construction (to reduce cost to poor consumers). Availability became constrained due to scrap metal demands from China.	*Quality score:* Weak Poor-quality study. This is a small report of a business model with insights on financial barriers.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
		parts and constructed stoves. Market/local retailers paid deposit (20%) and were given credit to sell stoves. *Implementer*: Toyola Energy Limited company.			No information on methods are provided, nor on data analysis. It offers, however, some information on financial and market aspects which contribute to answering the review question.
Simon 2010 India Western Maharashtra state *Rural*	Traditional stove (biomass). 3 ICS: (i) Bhaglaxmi and Laxmi stoves - NPIC; (ii) unspecified improved stove - Commercialization of Biomass Fuel and Cooking Devices (CBFCD) programme (Shell Foundation)	*Scale*: • NPIC: regional; approx. 2 million. • Shell Foundation: regional. *Duration*: • NPIC: 1984–2002. • Shell Foundation: 2002-ongoing. *Approach*: • NPIC: heavily subsidised distribution. • Shell Foundation: market-based approach. *Implementer*: • NPIC: ARTI and local NGOs. • Shell Foundation: ARTI and local NGOs.	*Study design*: Combination of (i) village-wide initial survey with several hundred women, (ii) follow-up survey and SSIs with 40 women per village, (iii) PO during training classes, village demonstrations and visits with artisans, (iv) open-ended interviews with 11 NGO employees, and (v) open-ended interviews and SSIs with 15 artisans. *Study population*: • Kolhapur district, Sangli district, Satara district. • Women cooks in selected villages. • Artisans. • NGO employees. *Analysis*: No information provided.	*NPIC:* • Social welfare-oriented model: guaranteed sales payments to artisans (employment), guaranteed subsidies to households (affordability). • Authoritative structure and punitive enforcement system. • Outcomes: (i) affordable stove prices, even for poorest households, (ii) standardised stove design does not meet households' needs, and (iii) flat artisan community class system. *ARTI:* • Market-based approach. • Active seeking of customers requires costly and time-intensive marketing campaigns. • Smaller production economies of scale through lack of large bulk orders of raw materials. • Acts of opportunism, seeking out wealthier clientele willing to pay more per stove. • More decision-making power with implementer results in corruption and favouritism.	*Quality score:* Moderate This study is based on fieldwork carried out by the author and already included (see Simon 2007 [72]). However, as this study offers a different perspective of the programme studied, it has been included as a separate document. While methods are carefully described in Simon 2007, details given in that publication on how villages and individuals were selected are not provided here, as well as limited

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
				• Outcomes: (i) culturally appropriate customised design, (ii) higher stove price result in marginalisation of disadvantaged households, and (iii) highly uneven artisan community class system. *Centrally planned vs market-based approaches:* • State-based programmes restrict levels of control over key technology innovation decisions by local partners (negative) and minimise opportunities for corruption (positive). • Market-based programmes assign control over key technology innovation decisions to local partners (positive) and encourage favouritism and corruption (negative).	commentary on data analysis.
Shrimali et al. 2011 India Karnataka state (Uttara Kannada district) *Urban/rural*	Traditional stove (biomass). Improved stove (unspecified).	*Scale:* Variable; number of stoves sold to date in India ranges from 0 to 450,000 per company. *Duration:* Variable; years in stove business range from 1 to 40 years. *Approach:* Market-based, attempting to recover costs. *Implementer:* 10 stove companies.	Structured interviews with company representatives. *Study population:* Any organisation that sells stoves to customers and attempts to recover costs *Analysis:* Qualitative inferences about which of 6 business factors: • Technology and design choices, • Target customers, • Financial model, • Marketing strategy, • Channel strategy, and • Organisational characteristics … had the most important influence on: • Scale (number of stoves sold relative to age of	*Overall conclusions:* • Need for well-designed, commercial products distributed through well-conceived and actively managed supply networks. • Trade-offs between financial sustainability and population reached; potential cross-subsidy mechanisms through commercial customers or higher-income households. • Need for well-designed government assistance towards (i) cultivating stove businesses, (ii) basic and applied research into stove technology, (iii) helping receive carbon credits for less polluting stoves, (iv) publicising dangers of household air pollution from solid fuels, (v) developing standards and efficiency labels, and (vi) eliminating market distortions (e.g. subsidies, taxes). • Models for a hybrid 'social enterprise'	*Quality score:* Strong Clear development of and argument for hypotheses to be tested.Attempt to include the most significant commercial cookstove distribution efforts currently operating in India: (i) list of 14 companies; (ii) interviews with 12 companies; (iii) core dataset comprises 10 companies. Study demonstrates

Author/year, country, setting	**Baseline and intervention fuel and technology**	**Description of Programme**	**Study design, study population and analysis**	**Principal findings relevant to scaling up**	**Issues regarding quality and interpretation**
			organisation.) • Financial sustainability (qualitative judgment).	through (i) patient upfront capital (enterprise funding), (ii) low expectations for return on investment, (iii) urgency to develop and manage the supply chain, and (iv) importation of management and operational know-how from the private sector.	good understanding of limitations in terms of generalisability of findings: • Relatively small sample size of companies. • Large number of possible explanatory factors. • Ultimate fate of most businesses undetermined due to early stage. • Impossible to verify information and potential overstating of (i) business viability and (ii) positive environmental attributes of stoves by respondents.
Barnes et al. 2012a India Western Maharashtra state *Urban/rural*	Traditional mud stoves (biomass). 2 ICS: (i) fixed 1- or 2-pot mud stoves with or without chimney (Laxmi, Grihalaxmi, Parvati,	*Scale*: Regional; approx. 120,000 stoves per year. *Duration*: 1983/84-ongoing. *Approach*: Heavily subsidised distribution under NPIC. *Implementer*:	*Study design*: Combination of (i) brief surveys, (ii) FGDs and (iii) interviews. *Study population*: • Kolhapur district, Sangli district, Satara district; rural and peri-urban villages consisting mostly of low-income households.	*User perceptions:* • Medium- or high-level satisfaction due to (i) involvement of traditional potters and (ii) perceived benefits relating to fuel savings, smoke removal, faster cooking, cleanliness, reduction in health problems (in order of importance). • User complaints primarily related to faulty design and construction leading to design modifications and reversion to	*Quality score:* Strong *Positive aspects:* • Careful selection of districts, blocks, villages and households. • Pilot-testing of methods and

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	Bhagyalaxm); (ii) portable metallic single-pot stoves (Priyagni).	• Regional: 3 government nodal agencies (Rural Development and Water Conservation Department; Maharashtra Energy Development Agency; Khadi and Village Industries Commission), technical backup unit (ARTI). • Local: traditional potters as self-employed workers.	• Household survey among 73 households. *Analysis*: Descriptive analysis for each of 7 domains affecting programme success.	traditional stoves. *Subsidy:* • Beneficiary contributions ranged from nothing to 80%. • Poorest maintenance record for heavily subsidised stoves. • Reluctance of some groups outside the subsidy programme to purchase more expensive stoves on open market. *Operations/procedures:* • Design, development, promotion and sale of stoves through traditional potters. • Technical backup unit provided (i) training on stove-building and certification, (ii) business development training, (iii) financial assistance. • Reasonable profits through sales as part of government-set targets and on open market. • Training of unemployed youth unsuccessful due to perception as casual job rather than profession. • Insufficient interaction between stove designers, users and producers. *Quality control:* • Limited inspection of installed stoves resulting in (i) modification of stove sizes and dimensions and (ii) stove construction by non-certified builders. • Lack of user training (including chimney cleaning). • Limited after-sales services. • No mechanism to ensure that potters purchase materials from approved vendors.	customisation. • Purposive selection and careful conduct of focus groups. *Negative aspects:* • Identification of villages and households by local groups may have produced a biased sample, i.e. selected households may be more likely to view the programme positively. • No information on analysis.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Barnes et al. 2012b India Haryana state *Urban/rural*	Traditional stoves (crop residue and dung). Improved fixed mud or cement 1- or 2-pot stoves with chimney (Mohini, Mohini Hara, Jaitan, Akash, Sohini Hara).	*Scale*: Regional; more than 500,000 stoves or 48% of rural households. *Duration*: 1983–2002. *Approach*: Heavily subsidised distribution under NPIC. *Implementer*: • Regional: government nodal agency (Department of Women and Child Development), technical backup unit (Energy Research Centre, Punjab University). • Local: network of 7,000 village-level women's groups (mahila mandals) and self-employed workers.	*Study design*: Combination of (i) brief surveys, (ii) FGDs and (iii) interviews. *Study population*: • Panchkula district, Fatehabad district, Gurgaon district. • Household survey among 94 households, primarily landless labourers and disadvantaged classes. *Analysis*: Descriptive analysis for each of 7 domains affecting programme success.	*User perceptions:* • Perceived benefits: (in order of importance) less smoke, less soot on vessels and in kitchen, fuel savings, faster cooking, fewer health problems. • Pre-determined stove model for whole district; user complaints primarily related to faulty design and construction; resultant design modifications. • Multiple stoves with improved stoves in outdoor courtyard (heating water, cattle feed) and traditional stoves indoors (cooking food). • Reasons for adoption (in order of importance): (i) request of mahila mandal, (ii) belief that stove programme would be followed by cemented kitchen or sanitary latrines, (iii) presumed legal requirement, (iv) benefits. • Reasons for non-adoption: lack of space, unwillingness to bore a hole in kitchen roof for chimney, lack of information on stove benefits, mahila mandal's preference for other households. *Subsidy:* • Positive: made stoves affordable; ensured short-term adoption. • Negative: devalued stoves; subsidy expectation into future. *Operations/procedure:* • Target-driven programme: overstretched field staff did not generate demand but requested households to adopt. • Re-design of stoves by technical backup unit in response to women's needs obtained through (i) training camps and (ii) feedback surveys in 15 out of 19	*Quality score:* Strong *Positive aspects:* • Careful selection of districts, blocks, villages and households. • Pilot-testing of methods and customisation. • Purposive selection and careful conduct of focus groups. *Negative aspects:* • Identification of villages and households by local groups may have produced a biased sample, i.e. selected households may be more likely to view the programme positively. • No information on analysis.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
				districts. • Insufficient interactions between stove designers, producers and users. • Well-defined implementation strategy with (i) pre-installation survey, (ii) performance-based system rewarding the best-performing women's network, (iii) annual district-wide women's fairs, (iv) mandatory after-sales services, (v) 3-tier monitoring system. • Failure to foster competition between self-employed workers to develop a viable stoves market. *Quality control*: • Problems with (i) faulty stove constructions, (ii) no solutions for indoor chimney outlets. • Lack of user training and awareness-raising activities.	
Barnes et al. 2012c India Karnataka state *Urban/rural*	Traditional stove (biomass). 3 ICS: (i) fixed mud single- and 2-pot stoves with and without chimney (e.g. Astra Ole, Sarale Ole); (ii) portable pottery stoves without chimney (Priagni); (iii) portable metallic stoves without chimney (Swosthee, Chara Ole).	*Scale*: Regional (all 27 districts). *Duration*: 1988–ongoing. *Approach*: Heavily subsidised distribution under NPIC. *Implementer*: • Regional: government nodal agency (Department for Rural Development and Panchayati Raj), technical backup unit (Karnataka State Council for Science and Technology).	*Study design*: Combination of (i) brief surveys, (ii) FGDs and (iii) interviews. *Study population*: • Hassan district (6 villages) and Mysore district (4 villages); rural and peri-urban villages consisting mostly of low-income households. • Household survey among 129 stove users and 61 non-users. • FGDs with 217 women. *Analysis*: Descriptive analysis for each of 7 domains affecting programme success.	*User perceptions*: • Perceived benefits: health, fuel savings, time savings and cleaner kitchen (in order of importance). • User complaints primarily related to faulty design and construction; resultant design modifications. • Non-users stated non-affordability, lack of space, competing household priorities, problems with design, household head's lack of willingness to purchase as main reasons for non-adoption. *Subsidy*: • 50–70% subsidy offered. Users often unaware of or did not understand subsidy. • Self-employed workers collected different rates from different villages.	*Quality score:* Strong *Positive aspects:* • Careful selection of districts, blocks, villages and households. • Pilot-testing of methods and customisation. • Purposive selection and careful conduct of focus groups. *Negative aspects:* • Identification of villages and

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
		• Local: decentralised government machinery at district and block levels, gram panchayats at village level, self-employed workers, stove masons.		*Operations/procedures*: • Technical backup unit developed innovative stove models. • Junior engineers, engaged as technical advisers, initiated switch from target-oriented to whole-village implementation. • Motivated local institutions, through good rapport with residents, achieved prompt collection of beneficiary contributions. • Need for greater interaction between designers, producers and users. *Quality control*: • Improvement and standardisation of production quality, e.g. prefabricated moulds and templates. • Limited training of producers. • Need for better monitoring. • Need for better after-sales services. • Limited user education about stove operation (including chimney cleaning).	households by local groups may have produced a biased sample, i.e. selected households may have been more likely to view the programme positively. • No information on analysis.
Barnes et al. 2012d India Gujarat state *Urban/rural*	Traditional stove (biomass). 1-pot and 2-pot improved stoves with or without chimney (Mamta, Supriya, Priya, Kiran, Sneha, Grihalaxmi, Kamdhenu I and II); primarily Mamta stove with chimney and Sneha stove without chimney.	*Scale*: Regional (all 25 districts). *Duration*: 1983–2005. *Approach*: Heavily subsidised distribution under NPIC. *Implementer*: • Regional: government nodal agencies (initially Forest Department, then Rural Development Department; Gujarat Energy Development	*Study design*: Combination of (i) brief surveys, (ii) FGDs and (iii) interviews. *Study population*: • Surat district (several villages), the Dangs district (several villages), Bharuch distrct (1 village), primarily below-poverty line households. • Household survey among 79 Mamta stove users. *Analysis*: Descriptive analysis for each of 7 domains affecting	*User perceptions*: • Perceived benefits: less smoke, fuel savings, time savings, less soot on vessels and in kitchen, fewer health problems (in order of importance); value assigned to fuel savings depends on fuel availability. • User complaints primarily related to faulty design and construction; resultant design modifications. • Multiple stoves due to (i) opportunity cost of cooking time and (ii) preparation of certain foods on traditional stoves. • No re-purchase of improved stove; reversion to traditional stove or self-construction.	*Quality score:* Strong *Positive aspects:* • Careful selection of districts, blocks, villages and households. • Pilot-testing of methods and customisation. • Purposive selection and careful conduct of focus groups.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
		Agency, Khadi and Village Industries Commission), technical backup unit (Maharaja Sayajirao University in Baroda, Vadodara). • Local: NGOs.	programme success.	*Subsidy*: • Very large subsidy: beneficiaries usually only contributed labour • Divergent views by households, technical backup unit and different nodal agencies on subsidy as (i) critical vs temporary vs unnecessary and (ii) need for targeting households. *Operations/procedures*: • Rural Development Department: bottom-to-top 3-tier system ensured accurate demand estimates. • Gujarat Energy Development Agency: NGOs facilitated quick adaptation to village realities. • Integration of improved stoves with rural housing scheme created synergies. • High NGO drop-out rates due to lack of appropriate incentives (only non-financial, extension of operations into new villages). • Failure to initiate entrepreneurial production and maintenance. *Quality control*: • Lack of standardised construction materials through approved dealers and considerable variation in cost. • Insufficient inspection of stove installations.	*Negative aspects:* • Identification of villages and households by local groups may have produced a biased sample, i.e. selected households may be more likely to view the programme positively. • No information on analysis.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Barnes et al. 2012e India Andhra Pradesh state *Urban/rural*	Traditional stove (biomass). ICS: (i) improved fixed brick, cement and mud 2-pot stoves (Sukhad, Gayathri, Gramalakshmi), mostly with chimney; (ii) portable stoves from housing boards through Indira Awas Yojana housing scheme.	*Scale*: Regional (all 22 districts); 1.4 million stoves in 1995–2000. *Duration*: 1983–2002 (downscaled since 2002). *Approach*: Heavily subsidised distribution under NPIC. *Implementer*: • Regional: government nodal agencies (Non-Conventional Energy Development Corporation; Khadi and Village Industries Commission), technical backup unit (Regional Engineering College at Warangal). • Local: 5–10 chulha development agencies per district, groups of self-employed workers.	*Study design*: Combination of (i) brief surveys, (ii) FGDs and (iii) interviews. *Study population*: 134 households in Mahabubnagar district. *Analysis*: Descriptive analysis for each of 7 domains affecting programme success.	*User perceptions*: • Perceived benefits: time savings, fuel savings, no eye burning, cleaner kitchen, better health (in order of importance). • User complaints primarily related to faulty stove design and back-smoking as a result of no chimney cleaning; resultant stove modifications. • Reversion to traditional stoves after breakdown despite general willingness to pay for repair/replacement of stove parts due to (i) lack of knowledge of operation and maintenance, (ii) one-time subsidy guidance of programme, (iii) unavailability of replacement parts. • Negative views on programme as (i) not delivering promised benefits, (ii) false promises of self-employed workers that stoves would be followed by cooking vessels/asbestos roofs. *Subsidy*: • Variation in subsidies by nodal agency and price discrepancies. • Unawareness by users of extent of subsidy. *Operations/procedure*: • Chulha development agencies could claim subsidy only after nodal agency verified stove installations. • Many abandoned business due to insufficient profit (smaller numbers, larger overheads) with introduction of more durable, expensive stoves. • Operation and maintenance services were not undertaken due to costs exceeding amount offered by government. • Self-employed workers only involved for	*Quality score:* Strong *Positive aspects:* • Careful selection of districts, blocks, villages and households. • Pilot-testing of methods and customisation. • Purposive selection and careful conduct of focus groups. *Negative aspects:* • Identification of villages and households by local groups may have produced a biased sample, i.e. selected households may be more likely to view the programme positively. • No information on analysis.

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
				7-8 months a year. *Quality control*: • Faulty stove construction due to poor on-the-job training of masons and ambitious targets. • Lack of information on stove operation and maintenance. • 100% verification of construction but no quality considerations. • No quality certification process for chimney sets and grates.	
Barnes et al. 2012f India West Bengal state *Urban/rural*	Traditional stove (wood, crop residue and some coal). ICS: fixed 1- and 2-pot stoves made of mud or cement, mostly with chimney (Sohini Seva, Sugam Seva, Kalyani, Paribarbandhu, Kalyani Vishwavidyalaya).	*Scale*: Regional (all 18 districts); 2 million stoves in 1995–2002 period. *Duration*: early-1980s – 2002. *Approach*: Heavily subsidised distribution under NPIC. *Implementer*: • Regional: government nodal agencies (Social Welfare Department, Khadi and Village Industries Commission, West Bengal Renewable Energy Development Agency), technical backup unit (University of Kalyani). • Local: network of 150 NGOs and self-employed workers as motivators and stove builders.	*Study design*: Combination of (i) brief surveys, (ii) FGDs and (iii) interviews. *Study population*: • Jalpaiguri district, Medinipur district, South 24 Parganas district. • Household survey among approx. 100 households. *Analysis*: Descriptive analysis for each of 7 domains affecting programme success.	*User perceptions*: • Perceived benefits: smoke removal, better health, time savings, fuel savings, less soot (in order of importance). • Additional benefits, e.g. simultaneous cooking and supervision of children's studies; less frequent replacement of roof tiles. • User complaints primarily related to (i) women having to climb onto roof to clean chimney and (ii) need to cut fuelwood to required size. • Only 20% of users attended user training; resultant stove modifications and parallel use of traditional stoves. • Willingness to pay for stove modifications. *Subsidy*: • No pricing policy: user contributions to costs varied substantially between NGOs. • Users were aware of subsidy but did not know market price or subsidy pattern. *Operations/procedure*: • Close rapport between NGOs and 3 nodal agencies enhanced bottom-up approach to target setting.	*Quality score:* Strong *Positive aspects:* • Careful selection of districts, blocks, villages and households. • Pilot-testing of methods and customisation. • Purposive selection and careful conduct of focus groups *Negative aspects:* • Identification of villages and households by local groups may have produced a biased sample, i.e. selected households may be more likely to view the

Author/year, country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design, study population and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
				• Competition among NGOs. • Flexible pricing allowed for development and promotion of a wider variety of ICS. • Failure of technical backup unit to react to stove design and training concerns reported by users, self-employed workers and NGOs. *Quality control*: • Stove-parts sets purchased from 8 approved manufacturers. • Parallel construction of stoves by trained and certified self-employed workers (40%) vs self-trained self-employed workers (60%), as high demand for training was not met. • Inadequate monitoring and evaluation of installations. • Unreliable 1-year mandatory after-sales service; subsequent paid after-sales service but reluctance to pay for repairs. • Lack of user training in operation and maintenance.	programme positively • No information on analysis.

Appendix 3.2: Summary table for LPG and gas stoves[27]

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Heltberg 2005 Guatemala Countrywide *Urban/rural*	Focus is on fuel choice, and switching from wood to more modern fuels, especially LPG.	*Scale*: National. *Duration*: Based on analysis of 2000 Encuesta Nacional de Condiciones de Vida (ENCOVI) survey (cross sectional). *Approach*: N/A. No modern fuel subsidies applied in Guatemala at this time. Any fuel switching would have taken place in response to the range of opportunities available to population, mainly market based.	*Study design*: Analysis of cross-sectional national household survey with detailed information on energy use. *Study population:* ENCOVI study was a stratified random, nationally representative sample with 3,424 urban and 3,852 rural household participants. Methods and validity not described, but expected to be of at least moderate quality. Brief mention of 'problems in some areas', including with quantifying amounts of fuel used.	Theoretical discussion of fuel choice, focusing on the household economic model, and emphasising multiple fuel use. Descriptive analysis of the 2000 ENCOVI survey which included a detailed module on household energy use for all purposes. Multinomial regression analysis of factors associated with use of different fuels, stratified by urban and rural setting.	A notable finding was the prevalence of multiple fuel use for cooking, by 48% of urban and 27% of rural homes. Among LPG users (for cooking), 57% of urban and 87% of rural homes also cooked with other fuels (mainly wood, some charcoal). For homes purchasing wood, the costs and proportion of expenditure were higher than for LPG. *Key determinants of fuel choice:* Household expenditure (but not significant in rural areas); per capita daily expenditure of around US$4 or more; fuel prices matter, with higher LPG price discouraging use in rural areas. Household size: small households more likely to use LPG alone; a higher share of females in a household reduces sole use of LPG. Higher educational level was a strong determinant of fuel switching. Number of rooms associated with LPG use in urban areas (wealth indicator); farm households less likely to use LPG; Indigenous groups more likely to use wood in urban areas.	*Quality score:* Strong Similar comments on quality of the ENCOVI study data apply as for Edwards and Langpap (2005) (118). Multiple fuel use (fuel stacking) common in this study. Surveys that ask about primary cooking fuel will miss this information, and one implication is that those reporting use of a clean fuel (LPG) may be using wood or another polluting solid fuel as well. Many of the findings regarding the continued use, or not, of wood, are interpreted in terms of the opportunity cost of collecting and/or buying wood. These costs are especially low for women, and where educational levels are lower. **Quality**

[27] Evidence described relates to partial or sole use of LPG or gas.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
					Distance to fuelwood source not important. Having electricity associated with fuel switching.	**assessment**[28] Selection: S Baseline info: M Outcomes: M Analysis: S Impact: S
Viswanathan and Kumar 2003 India 16 states *Urban/rural*	'Dirty fuels' including firewood and dung. 'Clean fuels' including kerosene, gobar gas and LPG.	*Scale*: National. *Duration*: Not applicable, as no relationship to a specific programme. *Approach*: Not applicable. *Implementer*: Not applicable.	*Study design*: Repeated cross-sectional survey (1983, 1993–94, 1999-2000) at household-level. *Study population*: Large sample collected by the National Sample Survey Organisation every 5 years across all geographical regions of India.	Descriptive cross-sectional analysis and time trends in household fuel use patterns and expenditure shares on clean vs dirty fuels for rural and urban households and across 10 income deciles.	Major differences in fuel use patterns and expenditure shares (i) between Indian states, (ii) between urban and rural populations, and (iii) across income deciles. Affordability (measured as per capita net state domestic product and as per capita consumer expenditure) and accessibility (assessed as subsidised public distribution system for kerosene and as subsidies on LPG and LPG-fuelled pressure cookers) had important impact on fuel use.	*Quality score:* Moderate. No details on sampling or data collection. Only descriptive analysis. Limited applicability of insights to scaling up.
Lucon et al. 2004 Brazil Countrywide *Urban/rural*	Described the supply, use and pricing policy for LPG in the context of the transition from fuelwood during the twentieth century, and other	*Scale:* National. *Approach*: Presentation and analysis of statistics on LPG (and other fuel) use, production and prices. Descriptions of fuel use	*Study design*: Review of statistics on fuel use and prices; discussion of how fuel use responded to changes in policy on subsidies. *Study population*: National, with particular focus on impacts of	Descriptive presentation of statistics on fuel use, production and prices, and some additional analysis of	LPG is available in most homes in Brazil. LPG price was regulated by the government from 1950 to 2001, with the subsidy reaching a level amounting to around 30% of the ex-factory price. Subsidies were costly (US$100 million/year by 2000) and were leading to problems, including illegal use.	*Quality score:* Moderate The paper generally lacks detail on data sources and reliability, and on the empirical basis for conclusions about how low-income families responded to

[28] Quality assessment (S=strong; M=moderate; W=weak)

Author, year and country, setting	**Baseline and intervention fuel and technology**	**Description of Programme**	**Study design and study population (sampling)**	**Data analysis**	**Principal findings relevant to scaling up**	**Issues regarding quality and interpretation**
	residential fuel (natural gas, electricity, kerosene, charcoal).	behaviour in response to price changes. *Duration*: Mainly period 1970–2002. *Implementer*: This is a description of the 'whole market', but has a key focus on the role of government, regulation and fiscal policy.	policy on low income groups.	price changes over time, and costs relative to the minimum wage.	By 1989, measures were in place for a consolidated distribution system for LPG (automatic delivery, plus an emergency delivery system). Starting in January 2002, subsidies were removed. Prices increased by around 20%. It is stated that [empirical basis for this not described] poorer families were very sensitive to price increases and adapted by (i) cooking less often/not using ovens, and/or (ii) reverting to use of fuelwood. In 2002 a new law provided for 'gas assistance' for low-income families, with payment every 2 months (around 9 million families had received this). As the analysis stopped in 2002, there was no substantive follow-up on impacts of this assistance.	price increases. It is also noted that there was (by the 1990s) a well-established distribution network. In their conclusions, the authors take the view that it is important to maintain the LPG network, and that 'subsidies cannot be considered economically, socially or environmentally harmful'.
Edwards and Langpap 2005 Guatemala Countrywide *Urban/rural*	This was an economic analysis study, investigating factors involved in switching from use of biomass to LPG.	*Scale*: National. *Duration*: Based on analysis of a national (cross-sectional) survey. *Approach*: Focus was on start-up costs, hence very relevant to the issue of switching from wood to LPG (clean fuel). Not an implementation programme: this study used national living standards survey to identify	*Study design*: 2 stages (i) analysis of the ENCOVI study, and (ii) economic scenario model. *Study population*: Used data from the 2000 ENCOVI survey, a nationally representative survey of living standards. Sample of 3,424 urban and 3,852 rural homes. Conducted by National Institute of Statistics, with World Bank technical support. No formal description or assessment reported of	*Analysis:* Developed theoretical model of wood consumption that included credit access and price of LPG stove and fuel. Used this to identify variables (from ENCOVI) affecting wood and LPG use. Then applied a	Access to credit had some impact on wood use via facility to purchase LPG stove, but effect size was small overall, and less important in rural setting. Impact of LPG stove price subsidy would be much greater, especially in rural areas. Subsidy on LPG fuel may be regressive, costly and inefficient.	*Quality score:* Strong ENCOVI survey methods not described, but expected to be of at least moderate quality in terms of standardisation and data quality. Economic (model) analysis appears thorough, but highly dependent on assumptions, the validity of which seem reasonable, but are hard to assess. There is a question

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
		factors that may determine wood and LPG use, based on a theoretical model. Then used scenario modelling to quantify impacts of key factors (increased access to credit, and subsidy of LPG stove price).	validity of sampling, data collection or variables used.	scenario model to assess (quantify) the expected impact of stated policy options.		about whether the relationships proposed in the model, and studied in survey data, were causal. **Quality assessment** Selection: S Baseline info: S Outcomes: M Analysis: S Impact: M
Terrado and Eitel 2005 Nicaragua Managua, Leon, Granada *Urban*	Market survey to assess fuel use, and perceptions, etc., regarding switch to LPG. Also interested in ICS, but market drive towards modern fuels in urban area so of limited relevance. No empirical data on solid fuel stove adoption reported. Around 50% of household used LPG already, but 35% used more than one type of fuel.	*Scale:* Applies to the populations and business studies in the 3 urban areas, but these were not described. *Approach*: As this was a market survey, no specific intervention was assessed. *Duration*: Survey during 2001 *Implementer*: Not applicable.	*Study design*: Market survey, using interview-based questionnaires. Sampling not described, but excluded mid-/high-income districts, and very poorest districts. *Study population*: Households (number not stated) and mix of food and fuel sale businesses (number not stated)	*Analysis*: Not described, but simple frequencies (as %) are reported. Around 50% of households studied were using LPG, but fuel stacking was common: 35% of households were using 2 different fuels.	*Key barriers for transition to LPG*: • (High) price of LPG stoves. • Ability to buy wood on daily basis vs high cost for cylinder refill. • Volatility of LPG prices. • 'Problems' with import and delivery of LPG (supply). • Cultural factors (not further specified, but may refer to fact that some preferred taste of wood-cooked food). Fear of explosion was reported, but unclear if this was a barrier. *Reasons given for switching to LPG from wood (enabling factors):* • Most important was that wood is 'dirtier' than LPG (60%). • Next most important was effects of wood use on health. • Less common was that LPG is modern and protects the environment.	*Quality score:* Moderate Although frequencies of major findings were reported, the lack of information about sampling, representativeness, data collection and analysis, makes the validity of these results (very) uncertain. An additional issue is that findings for households and businesses appear to have been combined in the reporting.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
USAID 2005 Mozambique (Cabo Delgado province) *Urban*	Technical assistance to develop a programme to support expanded LPG use in households and small or medium-sized enterprises (SMEs) in Pemba, a township in Cabo Delgado.	*Scale:* Regional. *Approach*: Not applicable (technical assistance). *Duration*: Not applicable. *Implementer*: USAID.	*Study design*: Focus groups and market surveys. The survey was designed based on the findings of the focus groups. Also assessment of the LPG market and the development of a strategy to expand services in northern Mozambique. *Study population*: Population of Pemba. Market research sampling techniques were used.	*Analysis*: Descriptive analysis.	Most people used multiple fuels for their cooking needs. Around half of respondents, while aware of LPG, lacked a comprehensive understanding of it, seeing it as dangerous and unsafe, pointing to the need for an intensive awareness campaign. Level of education and affluence were strongly associated with perceptions: respondents who had had prior experience were much more aware of the benefits. LPG was rated highly as a good cooking fuel and for its clean burning abilities but poorly on price, ease of use and safety. In terms of disseminating messages, TV was seen as the most appropriate, and also word-of-mouth through local community leaders. Among traders, storing LPG was seen as an issue among 84% of respondents, who also saw inherent danger as a further major issue.	*Quality score:* Weak Study offering limited evidence; methods poorly reported and analysis very limited and mainly descriptive.
Pandey and Morris 2006 India *Urban/rural*	Biomass fuels and/or kerosene LPG fuel and stove.	*Scale:* National. *Approach:* LPG subsidy. *Duration*: Early-1990s – ongoing. *Implementer*: Central Indian government (subsidy, central taxes), state governments (state-	*Study design*: Not described. *Study population*: Not described.	*Analysis*: Descriptive analysis based on a range of data sources.	*Continued problems in LPG access despite subsidy:* • High initial cost of connection. • No retail in small cylinder sizes. • High equipment cost. • High price compared to coal and subsidised kerosene. • Rural population continues to use collected biomass fuels. *Negative impacts of LPG subsidy*: • Higher LPG price for industrial, commercial and automobile use.	*Quality score:* Weak Study method poorly described. This was a policy study with no before-and-after intervention perspective. Only descriptive analysis.

Author, year and country, setting	**Baseline and intervention fuel and technology**	**Description of Programme**	**Study design and study population (sampling)**	**Data analysis**	**Principal findings relevant to scaling up**	**Issues regarding quality and interpretation**
		level taxes) and public sector oil companies.			• Inequalities in LPG use, mostly among middle-income groups, urban settings and wealthier states. • Misuse at household level; used for hot water consumption for baths and for powering air conditioning devices. • Distortions at state level; distribution and logistics (e.g. parallel stocking, inventory costs, bottling costs). • Dysfunctionalities for consumers: large families/groups of residences would fare better with large common cylinders/tanks. *Pros and cons of policy options*: • Complete elimination of subsidy. • Directed subsidy to below-poverty-line families. • Across-the-board subsidy with limited entitlement.	
Bates 2009 Sudan Kassala city *Urban*	Biomass fuels and/or charcoal stoves. LPG stove.	*Scale*: Local. 2 projects (i) in Kassala city; (ii) in districts around Kassala and New Halfa. *Duration*: Unclear, started before 2009. *Approach*: Market-based. *Implementer*: Practical Action	*Study design*: Participatory community approach (in order to identify appropriate interventions in terms of technologies and behaviour change). *Study population*: Not clearly specified. 30 households and 1,500 households from the 2 study areas participated in the project. *Analysis*: Not described.	No information given on the analysis method. Success reported in terms of number of adopters.	Successful participatory community approach; all members of the communities adopted LPG by the end of the projects. *Key findings:* A combination of demonstrations of LPG benefits and providing safety information, and microfinance found successful in promoting LPG uptake; post-intervention monitoring carried out; loan payments for purchasing initial equipment and gas bottle and demonstration of safe cooking. *Barriers:* Fear surrounding the use of	*Quality score:* Weak Very small case study with evidence based on the number of adopters in the targeted communities. No methodological information provided, but insights are very relevant to scaling up in small communities.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
		NGO.			LPG and opportunity/cost; drop in price of other fuels (i.e. charcoal) so households revert to less clean fuels.	
Rogers 2009 India Karnataka state (Western Ghats region) *Rural*	Firewood, crops residues, lantana (woody shrub species) on traditional cookstove. LPG stove.	*Scale*: Regional (local); 6,000 connections to date. *Duration*: 2004-ongoing *Approach*: Free provision of LPG stove and scheduled doorstep deliveries of LPG tanks through Namma Sangha; customers pay for LPG connection and tank refills. *Implementer*: Namma Sangha trust, formed by staff of Bandipur Tiger Reserve and volunteers.	*Study design*: Household survey conducted through 15-30 minute face-to-face interviews with heads of households aimed at understanding patterns of LPG usage and probability of adopting LPG. *Study population*: • 17 out of 125 villages located on the northern border of Bandipur Tiger Reserve. • Block A (agriculture-based): 6 villages, 47/39 households with/withouth LPG. • Block B (wage-labour-based): 5 villages, 44/53 households with/withouth LPG. • Block C (livestock-based): 6 villages, 33/32 households with/withouth LPG. • 124 households with LPG/124 households without LPG.	Statistical tests to assess differences in socio-economic patterns between households with and without LPG. Logistic regression analysis of LPG use vs non-LPG use based on explanatory variables: monthly income, ownership of cultivated land, ownership of forest-grazed livestock, use of crop waste, use of lantana, use of fuelwood.	*LPG usage patterns among households with LPG:* • LPG supplements rather than completely replaces solid fuel use. • About 50% of households use LPG frequently enough to necessitate regular refills; about 50% of households do not regularly refill their LPG tank. *Best-fitting logistic regression model for likelihood of adopting LPG:* • Monthly income - positive association. • Cultivated land - negative association. • Use of crop waste - positive association. • Use of lantana - negative association.	*Quality score:* Moderate Quantitative analysis based on a small number of variables. Does not provide in-depth insights and does not allow a prediction of LPG adoption. No information provided on selection of villages or households. **Quality assessment** Selection: W Baseline info.: M Outcomes: M Analysis: M Impact: M Application of statistical tests and logistic regression models and model selection through Akaike information criterion is appropriate and well-described.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
USAID 2010 Haiti *Urban*	Traditional stoves with biomass and charcoal; kerosene use was also reported in urban areas. No baseline intervention. The objectives of the research were (i) to assess the supply and use of charcoal for cooking in Haiti and the potential to use other fuels, such as LPG, and (ii) to design a 5-year replacement programme to achieve large-scale reductions in charcoal consumption by households, food vendors, and other relevant fuel users identified.	*Scale*: National (assumed) *Duration*: Over 6 weeks in September and October 2010. *Approach*: Sought to assess supply and use of different fuels nationally. *Implementer*: USAID funded project conducted by Nexant, Inc.	*Study design*: Survey, interviews and FGDs. *Study population*: Study sample drawn from Port au Prince, Cap Haitien and several other urban and rural areas over a 6-week period. 100 urban households sampled.	No information given on the analysis method.	The number of households using LPG was found to be reduced in post-earthquake Haiti. Of the 100 interviewed households, only 7 were found to be using LPG (not specified whether sole use). When LPG is used, this was usually in combination with other fuels (i.e. kerosene, charcoal and wood). Barriers to reducing or eliminating charcoal were numerous. Lack of abundant distribution channels, supply chain infrastructure and lack of consumer education were the largest barriers to alternative fuel (including LPG) adoption over the long term. A major focus was also placed on the supply chain needs for LPG scaling up. Safety concerns with LPG were present, particularly among younger women, who believed their children might play with the stove, leaving the gas to fill the room creating a risk of explosion. Recommendations included: education campaigns to encourage household uptake, which need to be thorough and long-term enough to alter perceptions about improved technologies. Improved stoves must also be able to accommodate larger pots as families in Haiti tend to be large. Stove portability was seen as important as households tend to cook outside during the dry weather.	*Quality score:* Weak This was a market demand type of study. Focus groups were orientated towards stove acceptability. Sampling poorly described. Total number of participants unclear. Middle- to lower-income households were targeted, as they were most likely to be using charcoal or a mix of fuel. No information provided about approach to analysis.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Elgarah 2011 Morocco *Rural*	Biomass (predominantly rural). LPG (financial subsidy and loans to assist fuel switch).	*Scale*: Microfinance pilot project in rural areas of Morocco. *Duration*: 3-year project (loans paid back to LPG companies who provided credit). *Approach*: Supported by Central Bank of Morocco – microcredit given to entrepreneurs (artisans, craftsmen and labourers). 1-year loans (US$150k) given by 3 LPG companies and paid back over 3 years. *Implementers*: Zakoura Foundation (government microfinance institution), UNDP, World LPG Association and LPG Rural Energy Challenge.	*Study design*: Not fully described. After obtaining loans (microcredit) training was provided in relation to stove advantages, safety and installation of LPG equipment. *Study population*: Entrepreneurs (not specifically looking at adoption/use of LPG). Rationale behind programme was to provide access to clean fuel to poorer rural communities.	Analysis not described. Success ascertained by application for and repayment of loans. No mechanism to assess economic benefits.	*Success:* • High demand (total fund was lent out over 5 months) – indicative of willingness to switch to cleaner fuel. • 135 loans given (27% women – US$135,000 total), 98% repayment (note ≥20% interest rate). • Microfinance concluded to be viable scheme to overcome problem of acquiring LPG equipment for low-income people. • Private/public partnership success. *Barriers (supply):* • Supply (high costs of distribution in rural areas, e.g. poor roads). • Low level of consumption limits commercial viability for distributor. *Barriers (demand):* • High costs for fuel switching (low literacy, lack of awareness, low purchasing power).	*Quality score:* Weak Business case study based on limited and poorly reported empirical evidence. Results judged on application and repayment of loans.
Budya and Arofat 2011 Indonesia Countrywide,	Kerosene only (biomass-using homes were excluded, as project was focused on	*Scale*: National, with over 40 million homes converted to LPG use.	*Study design*: Drew on 3 types of evidence: (i) survey-based data of users during development, and later when more established;	Few details provided on methods of analysis.	Report describes the development and implementation phases, challenges and achievements, and key factors in these. Despite initial market testing,	*Quality score:* Moderate Important case study of large-scale programme which met goals in short

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
excluding most rural areas, Papua and remote islands *Urban/rural*	kerosene to LPG conversion). LPG for cooking, through a very large-scale government-led cooking fuel conversion. Included stove, 3 kg bottle, hose and regulator.	*Duration*: 2007–11. *Approach*: Initial 'package' paid for by the programme, subsequent fuel, etc., purchased by users. Ensured supply by calculating the equivalent energy requirements for LPG, and built distribution and supply by converting kerosene suppliers to dealing with LPG. *Implementer*: Pertmania.	(ii) programme experience describing what was done, problems encountered, etc., based on a 'retrospective policy analysis'; (iii) statistical data from government and Pertamina on fuel sales, levels of subsidy, etc. *Study population*: Development phase: (i) initial market-testing survey in 500 homes, using 'observation/ surveys' on user and community behaviour. No other details provided; (ii) larger market test among 25,000 homes in 2 areas -did not use survey, but 'observed people's reactions as a whole'. Main implementation phase: (i) consumer satisfaction survey carried out by independent research and consulting company, among 550 recipients of LPG package -covered use, costs, problems, expected future use; (ii) a'quick survey' carried out by Ministry of Finance, among 288		working with local government, etc., met with substantial resistance initially in some areas. Goals seem to have broadly been met, in terms of conversions, reductions in kerosene use (and government subsidy), and increase in LPG. Financial savings substantial. *Key success factors*: • 'Led' by presidential decree, budget allocated, legal statutes. • Implementing agency with capacity to manage programme (effective business model). • Strong government policy with one ministry co-ordinating. • Widespread use of the media, socialisation in use of LPG. • Free package (stove, bottle, etc.) at start. • 3 kg bottle helpful. • LPG subsidised (but cheaper for equivalent energy output). • Building a supply network to meet demand. • Standards and certification (but see below). Problems included initial resistance, while ongoing challenges included accidents/explosions due to rapid expansion with varying quality (despite standards), and matching production to demand.	term. Note that this report was written by the main implementing agency identified by the government. Hard to judge objectivity, despite being in a peer-reviewed journal. Very little information on methods used for surveys. Lacks longer-term follow-up, and there is little empirical data on sustainability.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
			(mostly) LPG recipients, residents in large cities only. For both surveys, details of sampling and methods not provided.			

Appendix 3.3: Summary table for biogas

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Daxiong et al. 1990 China Countrywide *Rural* *(Case study)*	Baseline fuel not specified. Biogas development since the 1920s, as part of a movement towards cooking without coal or firewood. More recently the biodigesters built have been of hydraulic design. Fuel includes human and animal dung, and straw.	*Scale*: National (at the time of publication approx. 25 million people were using biogas). *Duration*: Project started in the 1950s. This paper reports on developments to 1990. *Implementer and approach*: The Chinese government provided financial aid to biogas builders and for renovating biogas equipment plants and establishing service institutions. Direct subsidies for biogas digesters available in some underprivileged areas.	Case study based on 2 cross-sectional surveys carried out in 1986. *Study population*: 58 and 242 biogas plants users and plant inspections.	*Data sources*: This paper is based on 2 other published papers: (i) 'The diffusion of rural energy technology in China,' mimeo (Beijing: ITESA, Tsinghua University, September 1986); (ii) 'A survey report for rural energy and Its technologies in Tongliang county: report of Retain project,' mimeo (Beijing: ITESA, Tsinghua University, October 1986). *Analysis*: Not described.	• A proper system of building and managing bio-digesters needs to be in place. • Quality assurance is required for a successful programme. • The key to guaranteeing the amount of biogas generated lies in the feedstock and day-to-day operation; i.e. those who raise a lot of pigs are able to provide a regular supply of pig manure for used in the bio-digesters. • Demographic changes (men moving away from rural villages) are a threat to bio-digester use and sustainability. • Removal of subsidies for initial outlay has resulted in a falling off in construction of bio-digesters. • Main innovations have been the development of standards for design, construction and operation of plants. In addition, considerable research has been carried out on construction materials.	*Quality score*: Weak This case study plots the history of biogas development in China drawing on only 2 reports published in 1986. A micro-economic analysis is reported. Difficult to assess methods used to select the inspected plants. No description of data analysis used.
Dutta et al. 1997 India 8 states *Rural* *(Case study)*	Biomass (firewood, dung cakes, crop residues) and coal. Also use of kerosene and LPG in areas closer to cities. Biogas, plant capacities varying from 2 m^3 to 6 m^3	*Scale*: National Project on Biogas Development (NPBD) *Duration*: 1981–97. NGO-run biogas dissemination from 1992 to 1997 *Approach*: Biogas systems purchased by users, with subsidies	Evaluation of the NPBD through in-depth case study of 12 NGOs spread over 8 states in different agro-climatic regions of the country. Physical inspection of the sampled plants plus household survey and	*Data sources*: Household surveys and inspected biogas plants. *Analysis*: Not described. Simple statistics and graphs provided.	• 81% of 482 surveyed plants were functioning (with some biogas plants having being used for more than 10 years). • Limited availability of firewood reported as an incentive to biogas adoption. • Technical defects were found in plant components in 80% of inspected plants; defective stove parts found in 30% cases.	*Quality score*: Moderate Very detailed case study. No clear specification of sampling methods used for selecting NGOs and participants

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
	(70% of the surveyed plants were of 2 m^3 reflecting the trend of project dissemination to promote small-sized plants).	supporting one-third of initial costs. Also soft loans provided by national banks to cover part of construction costs. *Implementer*: Government of India, with support from local NGOs and international agencies. Focus of this report is the Action for Food Production – Canadian Hunger Foundation (AFPRO-CHF) decentralised multi-agency and multi-model implementation strategy.	interviews with NGO staff (mentioned but not described in detail). *Study population:* Number of interviewed users not specified. 482 plants visited and inspected. Not clear whether interviews were carried out with all 482 biogas system owners.		• Usage-related problems causing a sub-optimal performance of the system frequently identified. Underfeeding (especially in the large plants) was found to be the most common problem. A plant not fed (even for a short period of time) becomes immediately dysfunctional. • Appreciation of slurry as an organic manure was not widely known and the majority of farmers mixed fresh dung with slurry before applying to the fields. • Ineffective repair and maintenance strategy.	interviewed. No clear details on data collection, except for a brief description in the introduction to the book. Findings are however presented with in-depth description of all aspects related to sustained use of biogas plants.
BSP and CEDA 1998 Nepal *Rural and peri-urban* *(Case study)*	Biomass fuels. Biogas (produced using cow, goats and buffalo dung). Biogas digesters sized 4–10 m^3 installed by 3 different companies.	*Scale*: National. Nepal Biogas Support Program (BSP) with 40,284 plants installed up to 1998. *Duration*: Phase II of the BSP from May 1994 to July 1997. *Approach*: Market-based approach with users contacting biogas companies directly, under a subsidy scheme.	Mixed-methods approach: (i) cross-sectional household survey; (iI) structured questionnaires with biogas companies; (iii) FGDs with local people. *Study population:* Initial sample of 866 households (with 800 participating in the study), selected from 3 districts according	Survey questionnaires in English and Nepali. Data collection carried out in 20 days, with one survey team leader and a number of research assistants in each of the sampled districts. Of the total surveyed households, 13% had installed	• The proportion of households installing biogas plants increased with increasing land and also there was a positive relationship between amount of the cultivated land and size of plants installed. • Most small- and medium-scale farmers installing plants were from rural areas and approximately 50% had access to electricity. • About 72% had taken loans from banks. • Only 8% had received support from local NGOs (some financial support or after-sale services).	*Quality score*: Moderate Very thorough sampling description. Sampling representative of the national population, except in terms of caste distribution with sampling not representative of castes living in mountain and hill

Author, year and country, setting	**Baseline and intervention fuel and technology**	**Description of Programme**	**Study design and study population (sampling)**	**Data source and analysis**	**Principal findings relevant to scaling up**	**Issues regarding quality and interpretation**
		Implementer: His Majesty's Government of Nepal, the Netherlands Development Organization (SNV) in co-operation with the Agricultural Development Bank and German financial co-operation.	to geographical spread and representative of technical potential of biogas in Nepal. 54% were in Saptari, about 25% in Kavre and 21.9% in Gulmi. 67% of the sample lived in rural areas. 9 FGDs were conducted, with an average of 8 participants per FGD.	biogas plants and 87% had not installed plants. Respondents were household heads. *Analysis*: Simple statistics using SPSS.	• Of the total 526 households who knew about biogas, 59.9% were willing to install plants. Not all were aware who to contact for plant installation and the cost of it. *Reason for not installing a biogas plant*: No money, (52.7%) lack of manure, (37.1%), no manpower to look after the plants, (22%). 14% had heard negative things about biogas technology.	districts. Only partial interpretation of results with no in depth statistics used.
Bhat et al. 2001 India Karnataka state *Rural* *(Case study)*	Not specified, presumably biomass fuels. Family size biogas plants, ranging from 3 m^3 to 8 m^3: • Early: mostly floating drum biogas plants. • Later: increasingly fixed-dome biogas plants.	*Scale*: Local (3,718 biogas plants built in 1985–99) but as part of Indian NPBD. *Duration*: 1983-ongoing. *Approach*: Subsidised but largely demand-driven programme. *Implementer*: Combination of (i) various state agencies and plantation growers' societies, (ii) local banks and (ii) 15 private trained biogas entrepreneurs.	Case study comprising government data, household survey data, a village survey and interviews with stakeholders. *Study population:* • Selection of Sirsi area due to very high biogas dissemination rate. • Selection of 8 (out of 25) villages with large number of biogas plants, based on accessibility. • Selection of 187 (out of 250) households with biogas plants	*Data sources*: • Government data on number of biogas plants. • Household survey. • Physical survey of villages. • Interviews with biogas entrepreneurs. • Interviews with implementing agencies. *Analysis*: Not described.	Adopting households are farmers with high literacy, relatively high, assured incomes and a large number of cattle. All biogas plants in use and showing high gas sufficiency; >85% of households meet all cooking needs through biogas. Durability, reliability and limited maintenance lead to initial preference for more expensive floating-dome design; less acceptability of cheaper fixed-dome design; adoption of larger plants to increase cooking capacity for guests/plantation workers. Little variation in household cost of smaller/larger plants due to subsidy increasing with plant size; easy access to credit. Well-functioning dissemination network and largely demand-driven	*Quality score*: Moderate Selection of villages and households appears appropriate; No information on how stakeholders were selected for interview. No information on data collection or analysis.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
			• KIIs with 10 biogas entrepreneurs.		programme. Biogas plant construction can ensure livelihoods of biogas entrepreneurs. Competition among builders ensures good-quality construction, and regular follow-up services.	
Planning Commission 2002 India 19 states *Rural* *(Case study)*	Multiple fuels, including biomass and LPG. Family-size biogas plants, mostly Deenbandhu and KVIC models, some Janta models.	*Scale*: National. 28.6 million plants installed (1981/82-2000); 800,000 plants installed during project duration (1995/96-1999/2000). *Duration*: 1981/82 - presumably ongoing *Approach*: Subsidised, target-based programme organised and financed by central government. *Implementer*: Combination of (i) several state agencies at national and state level, (ii) 9 regional biogas training centres at state level, (iii) NGOs and trained technicians at local level.	*Study design*: Combination of (i) household survey and (ii) interviews with officials in state- and district-level agencies as well as regional biogas training centres. *Study population:* 19 states selected based on consultation with ministry and number of biogas plants installed. • 2-6 districts per state. • 1 block per district. • 2 villages per block. • 5 users and 6 non-users of biogas plants per village. Participants in 133 villages: 620 users 744 non-users.	*Data sources*: Household survey and stakeholder interviews. *Analysis*: Not described; narrative text reporting main findings.	Adoption and use primarily among well-to-do farmers; increases with greater income and land ownership; large subsidy may not be critical. Functionality of plants: discrepancies in % of functional plant depending on information source; non-functionality rates differed by (i) plant model, (ii) age of plant, (iii) socio-economic stratum; problems related to construction, operation and social issues. Biogas primarily used for cooking with a range of benefits reported. Several reasons for discontinuing use and limitations to realising biogas potential. Programme limitations include: (i) insufficient staffing, (ii) insufficient funds for training, awareness-raising and turnkey workers, (iii) limited co-ordination between agencies, (iv) poor monitoring despite sophisticated plan, and (v) problems related to availability and quality of repair services.	*Quality score*: Moderate Sampling for household survey well-described but not tailored for a scientific audience; no information on sampling for stakeholder interviews. No information on analysis; purely descriptive. Some contradictory findings and sometimes unclear reporting but nevertheless much in-depth insight.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
de Alwis 2002 Sri Lanka 17 districts *Rural/urban* *(Case study)*	Biomass provides about 52% of the energy used in Sri Lanka. Also, some use of LPG. This review looks at success with biogas systems nationally. No estimate is given of the % of energy used that comes from biogas.	*Scale*: National. *Duration*: This review reports developments up to 2009. Specific surveys were carried out over the period 1984-85 and again in 1996 on the use of biogas systems. *Approach*: Initially, subsidies were offered through donor grants but these have been gradually removed to promote longer-term sustainability, although some NGOs have continued to offer them. *Implementer*: N/A (first survey carried out by ITDG [now Practical Action]).	*Study design*: 2 surveys were carried out over the period 1984-85 and again in 1996 on the use of biogas systems. This review reports reasons for failures of biogas systems based on survey information. *Study population:* National - covers 17 districts. No information about sampling.	*Data sources*: 2 surveys were carried out in 1984 - 85 and in 1996. *Analysis*: No information provided.	• Emphasis more on completing construction rather than quality of the workmanship. • No training was given to users. User education has been a missing factor. • Misconceptions about human waste, which can also be used as a fuel source. • Lack of raw material for fuel due to abandonment of animal husbandry/land clearance. • Lack of easily available water. • The amount of waste needed to supply an average family with their fuel needs is considerably more than can be managed in the average simple biogas system. • No follow-up by installers, and no help available when required from organisations who set up the system. • Problems with cracked domes/functionality of systems. • Emphasis on meeting target numbers, rather than continued use of the system. • Some evidence that the individual household system is not practical, simply because it costs too much.	*Quality score*: Moderate Difficult to assess how evidence-based the findings are or how representative they are of use of biogas systems throughout Sri Lanka.
Bajgain and Shakya 2005 Nepal *Rural* *(Case study)*	Biomass fuels (wood, agricultural residues, animal dung) and kerosene. Biogas produced using cow and	*Scale*: National. (111,395 biogas systems as of July 2003). *Duration*: 1990–2003 (Phases I and II). *Approach*: Market-	*Study design*: Not clearly specified. Use of data taken from the Biogas Users Survey, supplemented by qualitative interviews on client	*Data sources*: Biogas Users Survey 2003/2004 (East Consult). *Analysis*: Not described.	• Increasing client satisfaction reported as the result of growing competition among private companies, technical design modifications and enforced quality control measures being carried out. • Loan and subsidy programme on installation costs of biogas systems	*Quality score*: Weak No clear information on methods provided. It is not possible to assess

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
	buffalo dung, using a small fixed-dome biogas digester. The design works well at altitudes up to 1,500 m.	based approach with 39 participating private companies, under a governmental subsidy scheme. *Implementer*: Nepal BSP.	satisfaction (no more details provided). *Study population:* Biogas users and non-users. 600 participants took part in the Biogas Users Survey.		initially structured to support small- and medium-scale rural farmers and subsequently adjusted to be applied to small biogas systems, favouring the poorest farmers. • Certification of biogas construction companies based upon specific standards which obliges them to provide after-sales service. Private companies sign agreements to meet quality and design standards with SNV/BSP at the beginning of each fiscal year. • Social taboos: dislike of eating food cooked with gas produced from human waste. However, about 80,000 toilets over a total of 111,395 biogas systems were installed and hygiene improvements also reported.	the validity of the findings reported by the Biogas Users Survey as the authors don't provide any clear comment on it. Also, no information on sampling methods, sampling size and data collection for conducting the qualitative interviews reported under the client satisfaction section. Very hard to judge validity of findings; very positive aspects of the programme highlighted.
Ghimire 2005 Bangladesh *Rural* *(Case study)*	Biomass (firewood, dried dung cakes and agricultural waste). Some use of LPG and natural gas. Biogas from cattle dung (cattle includes cow, ox and buffalo), on a fixed-dome design. Biogas plants	*Scale*: National (including BCSIR, LGED programmes) with the target to install and operationalise 36,450 biogas plants. *Duration*: New project starting in January 2006. *Approach*: Differences described	*Study design*: Quantitative and qualitative methods: structured questionnaires and open-ended unstructured interviews with the respective plant user (including family members and some key people in the	*Data sources*: Structured and semi-structured interviews. *Analysis*: Descriptive analysis (based on 66 out 72 sampled households). EPI Info, MS Excel and MS Word used.	• Some of the plants under study were in operation for more than 8 years. Functioning status of biogas plant satisfactory (44% of users). • The majority of the plants under study were under-fed (47%). • 55% not aware of the quantity of feeding material required for the correct functioning. • Final decision to install biogas plant, 57% said that the decision was taken after discussions in the family and with the household	*Quality score*: Moderate Methods of data collection well-described which included 2 stages. Random sampling (with results aiming at being indicative rather than representative).

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
	adapted from a Chinese model of biogas plant (with varying gas pressure). 3 different models were introduced by different projects/periods: BCSIR, Local Government Engineering Department (LGED), Grameen Shakti.	across the various programmes. *Implementer*: SNV (Netherlands) in partnership with the Government owned investment company Infrastructure Development Company Ltd (IDCOL).	communities). *Study population*: 72 biogas households sampled from 8 districts from all the 6 divisions of Bangladesh; 66 households included in the analysis for a total of 486 family members (equal distribution of males and females). 2-stage random sampling method used.		head. • Reasons mentioned for not taking loans to install the plant included: good economic conditions (44%), against the practice of taking loans (21.5%), cumbersome process of loan sanctioning (15%), higher interest rates (3%), lack of collateral to fulfil the requirements of credit institutions (1.5%) and ignorance of the availability of a loan facility (1.5%). • Dearth of effective after-sale services provision (maintenance services were requested from the service providers in various cases and not obtained). • Biogas produced reported to be sufficient for meeting cooking needs in only 24% of households (for a number of reasons such as under-fed plants, small-sized plant, lack of timely maintenance, etc.). • Majority of the latrines not attached to the system; considered 'un-sacred' by 50% of respondents.	Survey questionnaire piloted with a panel of experts from various organisations involved in biogas promotion and extension in Bangladesh. No multivariable analysis conducted.
Kumargoud et al. 2006 India Karnataka state *Rural* *(Case study)*	Baseline not stated explicitly but assumed to be biomass. *Intervention*: KVIC (Khadi and Village Industries Commission) and Deenabandhu model biogas plants.	*Scale*: District. *Duration*: Not stated. *Approach*: Biogas plant adoption is supported by the Indian Government through loans and subsidies. *Implementer*: University of	Cross-sectional survey design administered during face-to-face interviews. *Study population*: 30 villages were sampled in the study (selected based on those with the highest number of biogas plants	*Data sources*: Quantitative survey (data obtained through interview). *Analysis*: Survey results reported proportion of respondents holding particular views.	• High investment for installation was an issue, compounded by bureaucracy in obtaining subsidy. • There is scope to upgrade the knowledge level of plant users. • Water in the gas pipeline was the major operational problem (reported by 48%, n=96, of respondents). • Decrease in biogas production during rainy or winter weather was reported as a major operational	*Quality score*: Moderate Methodology partially described. Only descriptive statistics carried out during the analysis.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
		Agricultural Sciences, Bangalore, India; financial support for the survey provided by the Indian Government.	installed) with a total of 200 respondents being selected to participate.		issue. • Additional advantages included an increase in crop yield due to application of biogas slurry and reduced bills for chemical fertilisers. • Guidance during installation and post-installation care would be useful.	
Jian 2009 South-east China Apricot village *Rural* *(Qualitative study)*	Biomass (firewood, straw, stalks) and coal. Biogas from pig and human waste and shredded straw and stalks on a '3-in-1' household biogas system (or pig-biogas-grain) with a 8-10 m^3 anaerobic digester, supplemented by a pig house and a latrine.	*Scale*: National programme (study carried out in a village in Basin county). *Duration*: from 1997. *Approach*: Governmental subsidies covering one-third of initial installation costs. *Implementer*: Government of China, Basin County Rural Energy Development Office (BCRED).	Ethnography (including interviews with biogas users in the village, PO and documents from local public officers). Quantitative survey to households with no system installed. *Study population:* • 38 SSIs with users. • Survey with 274 households with no systems installed. • 3 case histories in households using biogas regularly. • FGD with 8 men and 4 women non-users. • 2 interviews with BCRED officials.	*Data sources*: Survey, interviews and FGD conducted by the authors with no need for an interpreter. *Analysis*: Not specified. Assumed interviews were recorded and transcribed.	*Key enablers:* Convenience for cooking (reported by all users) and improved sanitation (74%). *Key barriers:* • Finance; 63% stated they were unable to build a system without a loan; 27% stated they need more financial aid from the project. • Labour shortage in relation to managing the biogas system. • Manure shortage. • Maintenance and user support: (i) 82% stated they had never attended a training course; (ii) repair considered very expensive (55%) and no insurance policy provided; (iii) remote rural area users struggled to get technical support and fees for repair are very high. • Lack of proper training on maintenance and system management. • People without formal schooling made up a high proportion of biogas users.	*Quality score*: Strong Very informative piece of work with well-designed and described methodology. The study focused on barriers to adoption from a user's perspective, providing detailed evidence on daily problems faced by farmers in managing and maintaining the biogas system.

Author, year and country, setting	**Baseline and intervention fuel and technology**	**Description of Programme**	**Study design and study population (sampling)**	**Data source and analysis**	**Principal findings relevant to scaling up**	**Issues regarding quality and interpretation**
Mwirigi et al. 2009 Kenya Nakuru and Nakuru North districts *Rural* *(Quantitative study)*	In the comparison group (not using biogas) cooking fuels were mainly firewood and charcoal, but substantial mixed fuel use, including electricity, LPG, and kerosene. Plants include: fixed dome, floating drum and flexible bag.	*Scale*: Probably national. *Duration*: Not described, but appears to cover period from introduction of biogas (1950s) through to 2005/07, although most plants were built in later years. *Approach*: Financial assistance amounting to 50% of fixed-dome and 84% of flexible-bag types was received. Even nationally, this paper reports that biogas plants are very few; a total of 150 listed among the 9,500 farmers in the 2 districts.	Cross-sectional survey with users and non-users. *Study population:* 100 biogas users selected through stratified random sampling, by plant type. 100 non-users (methods of selection not described). 3 types of biogas plant were found (n. in sample): (i) fixed dome (most common) (n=83); (ii) floating drum (n=10); (iii) flexible bag (n=7).	Face-to-face interviews. Questionnaire was pre-tested. Does not describe fieldwork and supervision, etc. Details of data handling not provided. Created composite scores for (i) SES, and (ii) sustainability, resulting in some loss of transparency, although the authors examined the 'internal reliability coefficient' for both. Descriptive analysis using SPSS extends to testing of univariate associations.	Frequent multiple fuel use for cooking among biogas users, and also among non-users. Around 70% of the biogas sample (of whom 85% are using biogas) also used wood and/or charcoal, and lesser numbers (18%) used LPG, and 8% kerosene. At the time of the study, 90% of the fixed-dome plants were in use, but only 40% (each) of the other 2 types. Duration since installation not reported. Only 14% of fixed dome had required repairs, but 40–43% of other types. Reliability of supply daily and annually was high for fixed dome (only 18% reported this as inadequate), and better than for other types. The composite SES score was significantly related to adoption (p=0.004) but not to the composite score for sustainability (p=1.0). *Household enablers*: Higher level of education of the head of the family; higher family income; more animals (cattle) (in this study, cut-off was more than 4); higher market value of cattle owned; farmer practices zero grazing method; larger land area of farm (more than 2 acres in this study); land ownership – have title deeds to land (e.g. can be used as security against loan). Where households had already invested funds in other (modern) energy sources such as electricity, this was a	*Quality score*: Moderate Little information on which to judge validity of data collection and any sources of bias. It is notable that the distribution of SES scores among non-users was mainly (87%) concentrated in the 'medium SES' group, which suggests that cut-offs were not well chosen to allow discrimination. This raises questions about their usefulness in studying the potential influence of key SES variables on adoption and sustainability. Although there are concerns about sampling strategy (lack of description) and hence validity, the study drew the sample from a large population

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
					disincentive. *Enabling knowledge and perceptions:* View that biogas is an affordable alternative to firewood; it is available; reduces backache associated with collecting fuel; aspirational – maintaining standard of living; influence of NGOs; conservation of forests. *Barriers:* Lack of awareness of and knowledge about biogas; perception that using biogas involves a lot of work. *Enabling fuel and technology characteristics:* Faster and more convenient, clean, reduces IAP and is safe. Used also for lighting by about 25% of homes in sample. A key financial enabler was obtaining (and by implication access to) financial support to cover part of the initial cost (which in this study averaged 50% to >80% depending on digester plant type). Barriers were insufficient money, and other (competing) pressing demands on available financial resources.	and included several digester types. Although not empirically demonstrated, the authors argue that larger-scale adoption needs more active promotion. This needs to involve all stakeholders: government, NGOs, farmers, and research and training institutions. **Quality assessment** Selection: W Baseline info.: M Outcomes: M Analysis: M Impact: M
World Bank 2010d « *BCSIR/LGED Biogas Programme* » Bangladesh 16 districts in	Traditional biomass stoves. Fixed-dome biogas plants (though the floating model was also promoted) (US$143–429).	*Scale:* National; 21,000 plants installed by 2004 throughout the country. *Duration:* 1988–2003. *Approach:* Subsidies varied depending on	*Study design*: Case study based on review of evidence including fieldwork visits based on consultation with implementing organisations, implementing	*Data sources*: Literature review and interviews with stakeholders, during fieldwork visits, including visits to large and small partner	*Institutional arrangements:* • Programme-led monitoring scheme, with engineers employed in every district for monitoring plants and providing a troubleshooting service. • Microfinance agencies supported the monitoring mechanism, as households were paid the instalments only if the plant was	*Quality score*: Moderate Systematic review of household energy initiatives carried out in Bangladesh (including ICS,

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
6 divisions *Rural* *(Case study)*		agency. 50% subsidies for plant; money also given to farmers and to collaborating NGOs. *Implementer:* Governmental agencies (i) BCSIR and (ii) LGED.	organisation staff and access to programme areas. *Study population:* No details on sampling reported.	organisations. *Analysis:* No details provided. Purely descriptive findings.	operating properly, necessitating service providers to provide continuous follow-up. • Bio-slurry was promoted as organic fertiliser with the support of the local government and had considerable demand from tobacco growers. *Awareness and motivation:* • Local community groups engaged, in particular, community-based poultry associations. • Promotion through media (radio considered very successful). *Technology :* • BCSIR/LGED biogas plant models reported to be not as efficient as the models disseminated during IDCOL/SNV project. • Local-framed gas stoves and lamps also supplied. *Key barriers to adoption:* • Uncertainties about post-warranty services. • High initial costs. • Lack of livestock due to reduction in cattle numbers. • Inadequate gas production, which often led users to use traditional cookstoves to meet daily cooking needs. • Masons not using good-quality raw material and frequent breakdown of the mixing device.	biogas and electrification) supported by a great range of empirical methodologies, although not reported in great detail in the report. No information on sample size, and sampling methods separately described for each of the discussed programmes.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
World Bank 2010e *« IDCOL/SNV: National Domestic Biogas and Manure Programme »* Bangladesh Countrywide *Rural* *(Case study)*	Traditional biomass stoves. Fixed-dome biogas plants (US$257-500)	*Scale*: National Domestic Biogas and Manure Programme (i.e. semi-private programme). *Duration*: 2006-09. *Approach*: Aimed at establishing a sustainable long-lasting and commercial biogas sector. Subsidies given for all plants. *Implementer*: IDCOL (a government-owned company) and SNV (Netherlands).	*Study design*: Case study based on review of evidence including fieldwork visits and consultation with implementing organisations, implementing organisation staff and access to programme areas. *Study population:* no details on sampling reported.	*Data sources*: Literature review and fieldwork visits, including visits to large and small partner organisations. *Analysis:* No details provided. Purely descriptive findings.	*Institutional arrangements:* • Multilevel monitoring system, with local monitoring carried out by partner organisations and reporting back to a steering committee. Tight monitoring also provided to check whether plants were constructed as per specification, plants verified on site if necessary. • Assistance provided for slurry extension activities. *Awareness and motivation:* • Promotion through local government representatives participating at local demonstrations and workshops and union parishads, other than media. • Word-of-mouth was reported to be very successful. • Trained engineers advised households on what type of biogas plants to acquire, based on the cooking needs of the households and the number of domestic animals (cows) available. *Negative feedback on technology:* • Lack of flexibility in design (i.e. the requirement that the inlet, digester, and outlet were all placed in one straight line was found difficult for people who did not have enough land). • System breakdown reported. • Underground placement of pipes, making monitoring and leak detection very difficult.	*Quality score*: Moderate Systematic review of household energy initiatives carried out in Bangladesh (including ICS, biogas and electrification) supported by a great range of empirical methodologies, which however are not reported in great detail in the report. No information on sample size and sampling methods separately described for each of the discussed programmes.

Author, year and country, setting	**Baseline and intervention fuel and technology**	**Description of Programme**	**Study design and study population (sampling)**	**Data source and analysis**	**Principal findings relevant to scaling up**	**Issues regarding quality and interpretation**
					Financial aspects: • The programme established a biogas credit refinancing facility (7-year credit with a 1-year grace period and at an interest rate of 6%) for the lending and construction partner organisations to lend to the households. • Part of the installation cost paid via subsidies. Remaining payment made in cash or through a microcredit loan from the lending and construction partner organisations at 10–12% interest rate and for a maximum period of 2 years by paying a minimum 15% of plant cost (after subsidy) as down payment.	
Qi and Li 2010 North-east China *Rural* *(Case study)*	Biomass (firewood, crop straw) and coal. Also use of LPG and electricity reported. Biogas (type of system not specified).	*Scale*: National, Eco-Household Project (EHP). *Duration*: not specified. *Approach*: not described. *Implementer*: Chinese Ministry of Agriculture.	Mixed methods including a cross-sectional survey, KIIs and observations. *Study population:* 400 families from the Congzhuling county surveyed (no sampling methods reported). No info on KIIs.	*Data sources*: Interviews with users and non-users (fieldwork conducted in 2009). *Analysis*: Statistics conducted in SPSS, but only descriptive results provided.	Seasonality of biogas production due to cold temperature. Biogas can be used over 3-6 months during the year, leading to only a partial replacement of firewood crop residues and coal. Breakdowns frequently reported due to lack of proper follow-up services and correct management of the system.	*Quality score*: Weak Brief conference paper with very little information on survey methods and qualitative findings not provided. Full paper not identified on the literature search.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
iDE 2011 Bangladesh *Rural* *(Case study)*	Firewood and traditional biomass stoves. Cow-dung or poultry-litter-based biogas plants.	*Scale*: National Domestic Biogas and Manure Programme (15,600 domestic biogas plants installed byl 2010). *Duration*: 2006–09. *Approach*: Aimed at establishing a sustainable long-lasting and commercial biogas sector. *Implementer*: IDCOL (a government-owned company) and SNV (Netherlands).	Mixed-methods approach: (i) cross-sectional survey (conducted yearly) , (ii) FGDs and interviews. *Study population:* 300 randomly selected households from 12 areas of the country.	*Data sources:* Structured questionnaire with users. FGDs with users and non-users. Interviews with stakeholders. *Analysis*: Only descriptive results provided.	*Factors favouring installation:* • Space and livestock availability, and facility to invest and pay instalments where there are loans. • Education. • Occupation (i.e. income). • Economic benefits. • Time savings. • Environmental benefits. • Health benefits. • Non-availability of other fuel sources. *Barriers or reported problems:* • 60% of users had never received any training on the operation of the plant. • Different quality standards across visited plants and different quality of services among the partner organisations. • Level of client satisfaction correlated with the status of functioning of the plant. • Inconsistent presence of skilled personnel. • Lack of adequate knowledge about the use and profitability of bio-slurry. • Lack of a monitoring system to check that partner organisations comply with national standards and to ensure no variation in practice across the country. *Results from FGD:* • Cooking was easier with biogas. • Time saving used for other activities.	*Quality score*: Moderate Annual user survey covering several aspects from reasons for adoption to issues with maintenance and sustained use. Methods well described and sampling seems appropriate. Not clear if the report and the evaluation were prepared by an independent organisation.

Author, year and country, setting	**Baseline and intervention fuel and technology**	**Description of Programme**	**Study design and study population (sampling)**	**Data source and analysis**	**Principal findings relevant to scaling up**	**Issues regarding quality and interpretation**
					• Increased comfort in daily life. • Reported social benefits.	
Sovacool and Drupady 2011 Bangladesh Countrywide *Rural/urban* *(Qualitative study)*	Biomass (firewood and other), kerosene. Small-scale 2-3 m^3 biogas plants; brick and fibreglass biogas units available for customers to choose from. Feedstock used; cow dung and poultry dung.	*Scale*: National; 13,300 biogas plants installed by September 2010, with promotion of fibreglass biogas units from 2004. *Duration*: 1996–2010. *Approach*: Sales with no provision of subsidies or grant to the farmers. The organisation provided 75% of the cost as a loan, recoverable in 2 years with 6% interest. *Implementer*: Grameen Shakti (no-profit Bangladeshi company dealing with biogas systems, ICS and SHS installation, also described in the paper).	Qualitative study with SSI. *Study population:* 48 interviews and attended meetings with 19 institutions and communities in 5 locations. Purposive sampling of key stakeholders including government agencies, NGOs, manufacturers and industry groups, financier and development donors, and research institutes in Bangladesh. 50 community members and households, including employees and customers.	*Data sources*: Interviews conducted from June 2009 to October 2010. Fieldwork carried out with simultaneous real time translation into Bengali (including local variations and dialects). No specific details provided. Review of relevant literature also used. *Analysis*: Reported as an inductive case study with narrative format, combining stakeholders and users perspectives.	• 90% of plants installed as part of the project reported to be still in operation with over 90% of households still using it exclusively to meet their fuel demands. • Biogas generally attracts middle income groups Bangladeshi villagers who are wealthy enough to afford livestock but not able to afford LPG or electricity. Majority of visited systems were mainly in wealthier homes with usually around 12 cows or 200 chickens. • Bio-slurry used as fertiliser, which has reduced the need for chemical fertiliser by 30-40%. • Fiberglass biogas units (as opposed to traditional brick, sand and clay ones) reported as being more convenient and reliable (including quicker to build). • Biogas plants at community scale also promoted during the programme. • Variations in plant performance and methane leaks were frequently reported.	*Quality score*: Moderate The aim of this paper was to describe 3 key programmes implemented by a national company. Research methods clearly described and findings presented in a narrative form, supported by a review of relevant literature. As the paper also describes diffusion of ICS and SHS, the extrapolation of findings related to biogas is more difficult, as benefits reported are often also related to the other programmes.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Christiaensen and Heltberg 2012 South-east China Anhui, Chongqing, Guangxi, Hunan and Hubei provinces *Rural* *(Quantitative study)*	Biomass (firewood, crop) and coal. Majority of sampled villages were electrified, fuelwood easily available, LPG used in around 65% of sample villages and coal used in 59%.	*Scale*: National. Eco-farming project (co-funded by World Bank) aiming at providing household biogas systems to 400,000–500,000 rural smallholders. *Duration*: Eco-farming project started in 2009. *Approach*: Government subsidies (especially to smallholders) covering one-third of initial installation costs. *Implementer*: Government of China with funding from the World Bank.	*Study design*: Cross-sectional survey. *Study population:* 2,700 households from 225 villages spread equally across 3 counties in each of the 5 provinces of rural south-east China. Counties were stratified by physical and economic characteristics. Within each county, 2 townships were selected purposively, and within each township, 2 project and 3 non-project villages. Non-project villages were slightly oversampled (135 non-project vs 90 project villages) to ensure a sufficient number of control villages that have neither the World Bank-supported nor the national biogas programmes. Households were randomly selected.	*Data sources:* Baseline survey conducted during the second half of 2009. 610 households (22.6%) of the total sample had a biogas system installed. *Analysis*: Bivariable and multivariable analyses (including: demographic and educational characteristics of the household, possession of land, the main occupation of the household head and income).	• Statistically significant displacement by biogas of fuelwood (collection time and quantity), crop residues, and the share of all dirty fuels in the fuel mix. • More educated and more wealthy households consumed fewer dirty fuel overall, even though households in the richest quartile also consumed more coal. • Households with more land and livestock used more fuelwood and crop residues and tended to have a higher share of dirty fuels in their energy mix. • Biogas adopters reported time savings (98%), reduced agricultural input costs, biogas used as fertiliser (77%) and reduced use of insecticides as result of applying biogas residues (77%). *Main reasons for not installing:* • Too much labour required to operate (30%). • Lack of financial resources (could not get financing) (19.3%). • Lack of labour resources (12.5%). • Animal shortage; not enough animals supplying manure (10%). • Lack of space for the digester (15.7%). *Main factors influencing biogas uptake decision:* • Households raising animals, larger families and younger heads of household positively correlated with biogas uptake.	*Quality score*: Strong Village sampling methods thoroughly described; household level random sampling method carried out in order to reduce bias on village characteristics and placements effects. **Quality assessment** Selection: S Baseline info.: M Outcomes: M Analysis: M Impact: S Oversampling also conducted in order to ensure a sufficient numbers of controls.

Author, year and country, setting	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
					• Concerning village characteristics: price of coal and average fuelwood collection, village road infrastructure, and number of years since biogas was first introduced in the village were positively associated with adoption. • Quantity of gas generated during the winter sufficient for only half of biogas users. 36% of users said that they had at some point stopped using it, mostly during the first year. Main reasons were: (i) biogas suspension due to insufficient number of animals and technical problems (11%); (ii) lack of sufficient technical training on biogas use and maintenance.	

Appendix 3.4: Summary table for solar cookers

Author, year country, settings	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Biermann et al. 1999/Sekaje 1998[29] North-west South Africa *Rural/urban* *(Case study)*	Firewood on open fires and wood-stoves. Also limited use of gas, paraffin and electricity. 7 different types of solar cookers given to users to be tested.	*Scale*: Regional; Phase 1 of Solar Cooker Field Test. *Duration*: 12 months in 1998. *Approach*: 1-year comparative field-test of 7 different types of solar cooker, given during a placement period. At the end of the study period, both users and non-users involved in the study were given the opportunity to purchase a solar cooker. 4 out of 7 models sold out (mainly because those models were the more affordable to the community). *Implementer*: South African Department of Minerals and Energy (DME) and GTZ.	*Study design*: Randomised controlled trial using mixed methods. Longitudinal study of end-users' acceptance of solar cookers. Also in-depth interviews and FGDs with users. *Study population:* 140 cookers placed in 66 households and 14 institutions (i.e. schools) mainly in rural areas from Northern Cape and North-West Province. Controls groups used.	*Data sources*: weekly questionnaires filled in by fieldworkers during study period. *Analysis*: Simple statistics used.	• The field-test study showed overall positive results in relation to end-user acceptance. Users saved over one-third of their monthly energy expenditure, with the majority of families collecting wood 2 or 3 times a week. • Solar cookers reported to be used to cook 35% of meals and used at least once on 37% of all days. • Cookers used during the hottest hours of the day (10 a.m. to 3 p.m.), suitable for preparing lunch and supper (placing a blanket on the top of the cooker will convert it into a warming-box). Used also for preparing breakfast (21%). • Longer time for cooking required but time saving because the cooker can be `set and left`. This had a favourable impact on the ability of women to reallocate resources within the home as well as strengthening social networks within the community. • 52 out of 66 families wanted the cookers at the end of the project. They paid a deposit and signed a contract to purchase (paying in	*Quality score:* Moderate This project was a study on users' preferences for different types of solar cooker. Results from these field-test experiences led to commercial pilot dissemination of locally produced solar cookers.

[29] These two studies (published in *Solar Energy* and the *Journal of Energy in Southern Africa* respectively) have been combined as both reported on the same solar cooker field test.

Author, year country, settings	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
					instalments).	
Ahmad 2001 India Gujarat state *Urban* *(Case study)*	This paper mentions that solar cookers are a supplementary technology for cooking rather than a replacement technology but no information is given about other 'more traditional methods.' Intervention: box-type solar cookers.	*Scale*: Regional *Duration and approach*: Project was run throughout the 1980s and 1990s and was still running at the time of the study when 45,000 solar cookers had been sold to both urban and rural families. The study was carried out in 1999. *Implementer*: Ministry of Non-conventional Energy Sources and Gujarat State carried out a solar cooker introduction, production and sale programme.	*Study design*: Qualitative case study. *Study population:* 3 urban sites in Gujarat; Vallabh Vidyanagar town, Anand city and Baroda city. 14 users and non-users were interviewed.	*Data sources*: Interviews, workshops and direct observation. *Analysis*: 2 categories of findings provided: objective factors and aspects of practical interest. No further information.	• 34% of families who owned a solar cooker did not use it. • Not possible to cook all traditional Gujarati dishes such as chapatti and bakri, which are generally served with every meal. These had to be prepared by conventional cooking. • Although the solar cooker requires less time, families needed to alter their routine to use it. • Many people do not have access to an appropriate place for cooking in urban Gujarat. Most people use their roofs, but this is not ideal. • Duration of cooking is longer than for other cooking methods. • Operation and maintenance were not considered a problem by most people. • Use of the solar cooker means women can avoid standing for long periods. • A good-quality locally produced solar cooker was not considered unaffordable. They were subsidised by 50% and sold at a fixed price. • Programme developers have not attended to the factors or aspects that are important to users, or their attention has been limited. Thus there has often been a missing link in the development processes of solar cooking projects.	*Quality score:* Moderate Study offering relevant insights on long-term adoption of solar cookers. Methods are not described in detail. No information provided on approach to validity, reliability.

Author, year country, settings	**Baseline and intervention fuel and technology**	**Description of Programme**	**Study design and study population (sampling)**	**Data source and analysis**	**Principal findings relevant to scaling up**	**Issues regarding quality and interpretation**
Baptista et al. 2003 Kenya *Rural* *(Case study)*	Not an intervention study but most commonly people cook with biomass, some on improved stoves. HotPot solar oven.	*Scale*: National. *Duration*: Not stated. *Approach*: The acceptance and penetration of solar ovens in emerging markets has been minimal at best. It is estimated that somewhere between 3,000 and 5,000 rural Kenyans own and use (passive solar ovens). *Implementer*: The Solar Household Energy project team (Team Solar) collaborating with Solar Household Energy Inc. (SHE).	*Study design*: Case study, including phone interviews and face-to-face interviews. In addition, the team conducted field-tests of the HotPot. *Study population*: Interviews with organisations in the USA and Kenya and interviews with NGOs, potential manufacturers, Kenyan governmental officials and Kenyans in Nairobi. No more details supplied.	*Data sources*: Formal and informal interviews (plus field-tests). *Analysis*: The triple-bottom line was used as a framework. It evaluates benefits, products, and business decisions along social, environmental, and economic dimensions.	• Main barriers are consumers having acceptable alternatives or being constrained by economic, social and environmental hurdles and also manufacturers and distributors failing to properly promote passive solar ovens to compete with alternatives and overcome barriers. • The Kenyan government is offering subsidies for the improved jikos (stoves). With the emergence of the fuel-efficient jiko as an alternative; the HotPot is a less compelling alternative technology. • In particular, the cultural change required by families if they are to use solar cookers are a particular barrier (cooking takes longer, preparation needs to start earlier, food tastes different, etc.). • Combining the time, money, and training required to change consumers' habits with solar cooking, and their options for substitute products, including wood, charcoal, jikos, and propane, means that the solar ovens' market appears to have low financial attractiveness in Kenya.	*Quality score*: Weak Very little information provided on methodology and analysis. Not always clear where reported findings were the authors' interpretations of the literature and where they were the views expressed by the case study participants.
Toonen 2009 Burkina Faso Ouagadougou city	Firewood (stove type not described) was the primary energy source for 41%, while for	*Scale*: Local, small-scale; 5 areas of the city. *Duration*: 2005 to 2009.	*Study design*: Quantitative survey, with some additional in-depth interviews and observation. Study based mainly on	*Data sources*: Most results were from the survey. Unclear what, if any, were from other sources.	*Actual use:* (i) Dry season: all used it, at least occasionally, with the median around 3 times per week; (ii) Wet season: n=8 (14%) did not use it at all, and the median fell to between once and twice per week.	*Quality score:* Moderate Wider relevance is limited as small development project with free

Author, year country, settings	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Urban *(Case study)*	20%, wood was combined with charcoal and/or gas.	*Approach*: Working in areas of the city, project provides training in use of solar CooKit stove, and free stove, to motivated households. *Implementer*: Dutch NGO: Stichting voor Urbane Projecten in Ontwikkelingslanden (SUPO).	survey of 86 women involved with project, of whom 59 had received a free solar stove plus training. *Study population:* Not clearly described, but sample drawn from up to 5 areas of Ouadagougou city where project was operating, and which included central and peripheral communities.	*Analysis*: Simple descriptive (tables) plus text, details of data handling not described.	*Factors which encouraged use:* Adjusting to practicalities of solar cooking, e.g. planning in advance, etc., would seem vital for success (this was provided through training). 23 women (about 40%) said solar cookers saved primary fuel, mainly wood in this setting. Also saved time in the sense that food can be left to cook, not requiring regular attention apart from adjusting direction. Taste of food is not impaired. *Barriers:* The main barrier reported was weather conditions (cloud, dust), which is supported by evidence of lower use in the rainy season. Takes longer to cook food than the wood stove. Capacity is insufficient for larger families (but could use 2). Requires change of direction every 30 minutes, but not a substantive problem. *Overall conclusion:* Solar cookers have a place in this setting, but cannot be used on their own, and wood (here) remains the primary fuel.	stoves, but some of the findings would seem to have wider applicability, in particular the limitations with weather conditions. Overall conclusion that solar cookers are unlikely to be sufficient as the sole cooking/fuel source would also likely be widely applicable, but further evidence of this should be sought. Although the study and report were carried out by the implementing organisation, there is no very apparent bias, and the reporting seems balanced.
Wentzel and Pouris 2007 South Africa *Rural/urban* *(Case study)*	Wood (traditional stoves), kerosene, gas and electricity. Solar cookers: a mix (not specified) of box and parabolic types that households	*Scale*: Not described, but small scale (probably no more than a few hundred solar cookers) across 3 locations. *Duration*: Not described, but appears to be over a period of 4-5 years	*Study design*: Case study drawing on synthesis review carried out for GTZ. This reviewed multiple studies of use and factors impacting on use, employing mixed methods. Sampling not	*Data sources*: Series of studies that included a survey via face-to-face interview, a telephone survey, and focus groups. Also drew on 2 studies in refugee camps in Kenya	The various studies report the 'rate of use' (defined as the proportion of cooking where the solar cooker is used) to be between 31% and 38%. Authors derived an average of 31% (an erroneous 95% confidence interval is provided, and there is confusion between random error and bias from over-reporting use). Taking the results at face value,	*Quality score:* Moderate Overall, this is a reasonably well-summarised account of multiple studies over a 5-year period, and the authors recognised that study methods

Author, year country, settings	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
	elected to purchase after a period of testing several types (not all were able to purchase their first choice).	from 1996. *Approach*: Solar cookers promoted (sold, not donated) as part of a package with a more efficient wood stove and heat retention device (details of these, or their adoption, not provided). *Implementer*: DME/GTZ.	described or commented on. *Study population:* This is not described, but in terms of whom the evaluation studies refer to, it includes both users and non-users of solar cookers.	and Namibia (methods not reported). *Analysis*: Methods used in the original studies are not described. Data in this report based on simple descriptive analysis. No other type of analysis is reported.	among homes which purchased a solar cooker, this was used for around 30% of cooking events. Clearly recognised that solar cookers are an additional option, and cannot be the sole cooking solution. Factors affecting adoption/use were reported under 3 headings: • *External conditions*: Higher income was associated with purchase. Scarcity of wood and scarcity and costs of commercial fuels encouraged use. Adverse weather, lack of storage and of a sunny yard area discouraged use. Security (reported in other studies) was not an issue in these South African studies. • *User conditions:* Recognition of the suitability of the stove for cooking staple dishes without concern about how much fuel is used was important. Savings in time collecting wood and in cooking, and savings in fuel costs, were important enablers. Training in adapted kitchen management and demonstrations regarded as essential for success. Lack of black pots discouraged use, as cooking takes a lot longer. • *Technical conditions:* The high price of the stove (due to low volume) made it a risky investment, and discouraged both purchase by households and the product being held by stores that sold other types of stove (and	and types of cooker had varied across studies and time. Understandably, much detail from the original studies was absent, but the lack of comment on some key issues, such as sampling, makes it hard to judge validity of the findings. The authors provide a frank account of the reasons why the commercialisation failed, which appears well-balanced, although the sources of information on this aspect are not attributed. *Equity:* The findings also show that, in practice, the greatest use, and largest monetary savings, were in the better-off group. This was particularly so because the solar stove saved on costs of these expensive fuels, and helped provide energy

Author, year country, settings	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
					provided credit). Insufficient capacity, and poor appearance, materials and packaging discouraged purchase and use. The lack of credit arrangements (e.g. resulting from local stores not holding it as a product) was a barrier to purchase.	security. The implications of these findings for ensuring equity of use and benefits would need consideration for larger scale adoption.
Velasco 2008 Mexico Michoacán state (Purepecha region) *Rural* *(Qalitative study)*	3-stone open fires (*fogón*) and U-type stove (wood); LPG also used for specific cooking tasks. HotPot solar cookers used in combination with Patsari stoves.	*Scale:* Regional. *Duration:* From 2001, under an international programme funded by the FAO. *Approach:* Stoves given as part of an experimental study design. *Implementers:* Not clearly reported.	*Study design*: Qualitative study design, with open-ended interviews with women and PO. *Study population:* 10 households from the Lajita community using the HotPot in combination with the Pastari stove.	*Data sources*: Interviews with users from La Lajita community who showed interest in both the HotPot and the Pastari stoves (after initial visit to the community). *Analysis:* Not specified.	*Key findings*: HotPot use was limited. This was mainly due to being impossible to cook tortillas with it. Hotpot found to be suitable for slow-cooking food such as beans and other meals. It was used in combination with other stoves.	*Quality score:* Weak Very little information on the solar cookers provided for this study. Difficult to interpret findings as the HotPot cooker was installed in combination with Patsari stoves.
Otte 2009 Tanzania Zanzibar, Masasi *Rural* *(Qualitative study)*	Biomass accounts for 90% of total energy use in Tanzania. Most rural women cook on 3-stone open fires using firewood. Intervention was the Sun Oven and the Parabolic (solar) Cooker.	*Scale*: Reports 3 projects at village level, 2 of which are included in the review. *Duration*: Unclear *Approach*: Qualitative *Implementer:* The Solar Africa Network and the Solar Circle.	*Study design*: Qualitative study using interviews and PO. *Study population:* Zanzibar (Solar Africa Network) - covers 5 villages and there are over 120 members in the co-operatives. Masasi (Solar circle): unclear how many people were participating in the project.	*Data sources*: SSIs and observations. *Analysis*: Data were analysed according to 7 identified dimensions using 'meaning categorisation'.	• Time is saved as it is not necessary to watch the food the whole time as with normal firewood. • Time taken; cooking takes longer than with a traditional stove. • Where stoves are produced locally, efforts were being made to improve the efficiency of the stove design. • Cannot be used during rainy season or on cloudy or rainy days. • Lack of availability and/or the high price of firewood and charcoal can contribute to an increased uptake of solar cooking.	*Quality score:* Strong Well carried out study with considerable thought give to validity and reliability including positionality, and the impact the researcher might have on participants' responses.

Author, year country, settings	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
					• Economic affordability is a major issue even where there is an opportunity for payments to be made by instalment. • Local production of solar box cookers contributes towards sustainability.	
Levine and Beltramo 2011 Senegal Thies region *Rural* *(Quantitative study)*	Traditional 3-stone open fire (< 25% owned an ICS). Most households also cook on charcoal and/or gas stoves. HotPot solar oven.	*Scale*: Local, small pilot study. *Duration*: April-October 2008. *Approach*: Randomised controlled trial (exposure study of pollution indoors and respiratory effects). *Implementer*: NGO SHE and NGO Tostan (active in Senegal since 1991).	*Study design*: Phased randomised controlled trial. *Study population:* Simple random sampling. Interested women attending a meeting were selected randomly from a lottery. 25 households randomly selected to receive HotPot at baseline (April 2008) - INTERVENTION. 25 randomly selected households receive HotPot 6 months later (October 2008) - CONTROL. Not all women could be recruited from all villages so total sample size was 790. Also, stove utilisation monitored (computer chips recording temperatures at 30-minute intervals).	*Data sources*: Surveys covered demographics, fuel use, time collecting fuel, cooking practices, self-reported respiratory symptoms (study) and cooking related symptoms. CO (Drager diffusion tubes), fuel type, time cooking, cooking structure measured in a subset of women. Total number of adult equivalents cooked for was assessed. *Analysis*: Simple comparison between intervention and control groups for most variables. Ordinal logistic regression used to analyse of fuel use, wood collection	*Key findings:* • Poor usage: monitors revealed HotPots only used 10% of days. After intensive training this rose to 18%. Villages near the sea had low usage due to winds. Focused on lunch due to (i) largest meal and (ii) lack of sun in evening. Only 7% used HotPot for lunch (50% of respondents indicated due to small size of stove). Most households using stove used it for smaller early evening meal. • Small decline in wood usage in intervention group (1.4 kg (14% of mean) in 7- to 12-person households and no change in those with <7 and >12). • Small drop in time spent collecting fuels for households of <7 but non-significant. • CO actually higher in intervention group than controls - not clear why. • No significant differences in self-reported respiratory conditions BUT children <5 years in control homes actually have fewer respiratory symptoms.	*Quality score:* Strong *Positive aspects of this study include:* validated methods used for data collection (CO, respiratory symptoms, etc.). Stove use monitored objectively. *Negative aspects:* survey conducted in April to October (outside rainy season - begins in September); not clear how generalisable findings would be to other seasons. **Quality assessment** Selection: S Exposure: M Outcomes: S

Author, year country, settings	**Baseline and intervention fuel and technology**	**Description of Programme**	**Study design and study population (sampling)**	**Data source and analysis**	**Principal findings relevant to scaling up**	**Issues regarding quality and interpretation**
				time and self-reported health, controlling for baseline factors.		Analysis: M **Impact**: S
Sesan 2012 Kenya Western region *Peri-urban* *(Qualitative study)*	Kerosene and charcoal stoves. Solar cooker CooKit, given as an option among 6 smoke alleviation interventions (including Upesi stove, waves spaces, fireless cooker, smoke hood + LPG stove).	*Scale*: Regional, United States Environmental Protection Agency (USEPA) project. *Duration*: 2009–10. *Approach*: 'Smoke alleviation interventions' promoted via local market. *Implementer*: Practical Action in partnership with Solar Cookers International.	*Study design*: Ethnographic type of study, including semi-structured in-depth interviews with users and elite groups and PO. *Study population*: 24 interviews split into: (i) 15 citizens from 13 households, and (ii) 9 elite interviews with Practical Action staff members and other members of other development agencies identified through a snowball approach.	*Data sources*: Fieldwork for the study was conducted over a period of 6 weeks in November and December 2009. Interviews were conducted with West Kochieng women. *Analysis*: not specified.	Study aiming at identifying socio-cultural and economic aspects that influence living and cooking practices of the West Kochieng community. An important finding was that a kitchen located outside the house had priority over purchasing smoke alleviation interventions (including solar cookers). *Findings related to use of CooKit:* • Lack of space and money were reported as the main reason for non- adoption (for both solar cookers and Upesi stoves). CooKit sold at the standard price of 1000 Kshs (US$12.42) but none of the sampled households purchased it. • Technical precision requirements such as the specific angle at which the reflective surface of the solar CooKit must be tilted to optimise the sun's rays were reported as a barrier to adoption, especially for older women.	*Quality score:* Moderate Ethnographic work described in great detail and supported by a clear theoretical and methodological approach. Gender and poverty aspects were clearly taken into account in describing the findings. Sample properly designed. Results reported only briefly on solar cookers and reason for non-adoption.

Appendix 3.5: Summary table for alcohol fuels

Author, year and country, urban/rural	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
Murren 2006 Ethiopia Addis Ababa *Urban* *(Case study)*	Charcoal and kerosene stoves. Ethanol on 'CleanCook' stoves (produced by the company Dometic Ltd).	*Scale*: Regional (local), as part of a pilot project to determine user acceptance of a new cooking technology. *Duration*: 2004-06 (18-month pilot project). *Approach*: Ethanol stoves provided as part of the pilot project. *Implementer*: Gaia Association (local Ethiopian NGO).	*Study design*: Bi-weekly user survey of participants taking part in the pilot project. *Study population*: 409 households representing lower-, middle-, and higher-income groups across all 10 of Addis Ababa's sub-cities.	*Data sources*: 2,096 questionnaires filled in by participants on a bi-weekly base. CleanCook stoves were used in each of the homes for 3 months. *Analysis*: Simple descriptive presentation of information on usage and perception of stoves, supported by percentages and graphs. Narratives from interviews used to support results.	• Ethanol fuel considered a very safe cooking fuel; 95% reported it to be safer than kerosene and kerosene stoves. • Ethanol rated as a high-quality cooking fuel. • Over 70% reported ethanol to be more efficient than other common stoves used to meet daily cooking needs. • CleanCook stove found to be time saving and allowed people to do other tasks at the same time as using the stove. • No smell reported. • CleanCook stove fully replaced charcoal or kerosene stoves in 74.6% of cases. • Of the 24% of respondents stating that the kerosene stove was still being used alongside the CleanCook stove in the home, the 2 most common reasons for continued use were: run out of ethanol (67.5%) and additional cooking (21.2%).	*Quality score*: Moderate Only partial information about sampling methods, but sample seems sufficiently robust. Qualitative information provided in the form of quotes, but no details on qualitative data collection and number of interviewed users not reported. Report written by the implementing NGO, hard to judge objectivity.
Couto 2007 Brazil Minas Gerais state *Rural and peri-urban* *(Case study)*	Combination of free fuelwood and LPG (with LPG used as primary fuel for cooking). Ethanol on CleanCook stoves. Brazil is the main international ethanol exporter.	*Scale*: Regional, as as part of a small-scale pilot project. *Duration*: 2006 - for 3 months (with a different starting timing in each of the 3 communities).	*Study design*: Pilot study with cookstoves distributed to selected households and cross-sectional surveys carried out regularly over a 3-month period.	*Analysis*: Simple descriptive presentation of information on usage and perception of the stove (no hypothesis testing or comparison between communities'	• Advantages: CleanCook stove perceived as a better option than LPG stove: it is clean, safe and fast cooking, and ethanol can be bought in small quantities (per litre, rather than paying for a 13 kg LPG canister). • Willingness to pay for ethanol was affected by different aspects: (i) purchase or not of fuelwood, (ii) less availability of money at the end of the month for families living on a	*Quality score*: Moderate Purposive sampling with households initially selected among 12 communities from areas geographically

Author, year and country, urban/rural	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
	Since the introduction of flex-fuel cars in the Brazilian market in 2003 (cars that can use any combination of ethanol-gasoline mix), ethanol demand has increased and consequently the price of ethanol has risen.	*Approach*: Ethanol stoves provided as part of the pilot project. Ethanol was provided for free during the first 12 weeks (5 litres per week). Supply was then stopped in order to explore users' willingness to pay per litre of ethanol. *Implementer*: Project Gaia.	*Study population:* 100 households: 28S households from Son Orione rural community (Betim), 38 households from Santo Antonio urban low-income neighbourhood (Salinas), 20 households from Jatiboca rural community (Urucania). Study participants from one of the communities never paid for the ethanol fuel as it was donated by the local sugar company they worked for. The others purchased ethanol at normal market price.	participants).	fixed income. • Those families able to afford to buy ethanol from the local pump maintained the CleanCook stove after the end of the project. • Main barrier: lack of low-cost ethanol supply (high prices related to the high global demand for ethanol as automotive fuel). *Reported negative aspects of CleanCook stove:* (i) Not all pots fit on burners, (ii) not enough pots, (iii) dirties pot bottoms, (iv) difficult to clean or light, (v) price of ethanol too high for some communities (especially for low-income families) *Suggestions for stove improvement:* (i) more burners, (ii) secure pot supports, (iii) pot supports for smaller pots, (iv) additional oven, (v) built into a stand/table.	located closer to ethanol distilleries in order to get a guaranteed ethanol supply at lower prices than from gas stations. Report written by the implementing NGO, hard to judge objectivity.
Oboueh 2008 Nigeria Delta state (3 study areas) *Urban* *(Case study)*	Fuelwood (mostly), kerosene (and LPG to less extent) in urban centres. CleanCook using denatured methanol (processed from	*Scale*: Regional, as part of a small-scale pilot project. *Duration*: March-May 2007 *Approach*: Methanol stoves provided as part of pilot project.	*Study design*: Cross-sectional survey carried out during the pilot study on a bi-weekly base over a 3-month period *Study population:* 150 households stratified	*Data sources*: Daily fill-out sheet (for a total of 9,230 sheets) + bi-weekly completed questionnaires. *Analysis*: Simple descriptive presentation of	• Acceptability of methanol as cooking fuel: reported to be safe/very safe (97% of participants). • Methanol considered safer than other available fuels (e.g. firewood, kerosene and LPG). • Overall quality of methanol as cooking fuel: considered efficient/very efficient (93% respondents). • Methanol distribution methods: preferred choices ranging between	*Quality score*: Moderate This report presents results from a pilot study, which was not part of a larger dissemination campaign at time

Author, year and country, urban/rural	**Baseline and intervention fuel and technology**	**Description of Programme**	**Study design and study population (sampling)**	**Data source and analysis**	**Principal findings relevant to scaling up**	**Issues regarding quality and interpretation**
	natural gas).	Methanol initially supplied for free (about 4 litres per week), then participants paid for the fuel they used. *Implementer*: Centre for Household Energy and Environment, Project Gaia Nigeria with funding given from USEPA.	according income selected from 17 communities and villages from 3 main cities from the Delta state. 60 households in Asaba (including villages around the city), 45 households in Warri and 54 householdS in Abraka. Quite high level of education reported in the sample size.	information supported by percentages and graphs.	refillable plastic bottles and stove canisters. • Customers satisfied with the quality of stove and fuel (and paid for methanol although the market price had increased during the pilot). • 11% of participants reported to have used kerosene stove during the pilot study when they ran out of methanol. *Suggested stove improvements*: Fixed pot support (25.3%), bigger canister (55%), more burners (13%).	of writing up. Not clearly specified whether the users were randomly selected, but the sampling seems a good representation of the Delta state population. Report written by the implementing NGO, hard to judge objectivity.
Imam 2011 Indonesia Java Island *Rural* *(Case study)*	Kerosene and firewood stoves. Locally constructed E-stoves using ethanol, produced from coconut plantations.	*Scale*: Regional/local. *Duration*: E-stove business production started in 2008. *Approach*: Business-model with stove purchased by users. *Implementer*: Indonesian business company Centre for Integrated Coconut Research (PPKT).	*Study design*: KIIs and observations. *Study population:* Purposive sampling with the 3 PPKT enterprise leaders, an informal village leader and a joint business unit member.	*Data sources*: Case study describing company business and barriers to promote E-stove business. *Analysis*: Not described. All information provided in a narrative form.	*Enablers to ethanol scaling up*: • The abolition of kerosene subsidies by the Indonesian government in early 2008 was a facilitator to fuel switching and ethanol production in rural areas. • E-stoves sold at a market price comparable to kerosene stoves. • Recognition of the need for demand creation and partnership with local distributors to increase market penetration. *Barriers to ethanol scaling up*: • Government regulation restricting transportation and distribution of alcohol-based liquids (including ethanol). • Lack of stove production facility: company relying on others partners	*Quality score*: Weak Business case study focusing on an enterprise-based perspective. Very poor details on methods used. No information provided on approach to validity. No details provided on stove functioning and efficiency.

Author, year and country, urban/rural	**Baseline and intervention fuel and technology**	**Description of Programme**	**Study design and study population (sampling)**	**Data source and analysis**	**Principal findings relevant to scaling up**	**Issues regarding quality and interpretation**
					and local workshops for cookstove production. Therefore difficulties experienced in maintaining quality and adherence to production guidelines and product specification set by the company. • Lack of patent for the stove: poor imitation copies were seen to be detrimental to the market because customer complaints impacted on businesses producing legitimate products.	
Practical Action Consulting 2010 *« Component B »* Madagascar Ambositra and Vatomandry *Urban/rural* *(Case study)*	Traditional wood and charcoal stoves. Kerosene and LPG used only by better-off households Ethanol, tested on 4 different stove models: (i) Proimpex Small stove with a single round burner; (ii) Proimpex Large, stove with single round burner with the addition of 6 small burner openings; both models locally developed and working with 60% ethanol; (iii) locally produced	*Scale*: Regional (local) as part of experimental design. *Duration*: 2010. *Approach*: Ethanol stoves tested during cooking tests and usability survey. *Implementer*: Not programmatic. Study lead by Practical Action Consulting, with funding provided by World Bank.	*Study design:* (i) controlled cooking tests (comparing the 4 ethanol stoves models with improved biomass stoves); (ii) Rapid usability study followed by a FGD. *Study population*: (i) 3 female cooks from Ambositra; (ii) 8 households from Vatomandry, selected to test the acceptability of the 4 ethanol stove models. The FGD was conducted with the same 8 participant households from Vatomandry.	*Data sources:* Interviews with cooks, survey results after use of the stoves for 3 days. *Analysis*: Simple descriptive presentation of information on usage and perception of the stoves	The testing used for this study addressed issues of stove safety, usability, performance, design, efficiency, preferences of cooks/households and initial IAP. Wider issues of commercialisation (including fuel cost, quality and supply, stove manufacturing, cost and supply chain issues) were not addressed. *Results from the usability survey:* • Main concerns related to safety of children knocking over or drinking the fuel, and to the smell of the fuel in some cases. • Feedback from the 3 controlled cooking test cooks (CCT) indicated that the stoves they liked best were the modified wood and the modified charcoal. • Pricing feedback on what people would be prepared to pay for ethanol varied widely and no conclusive result could be drawn. • CleanCook stove delivered the best performance of the 4 ethanol stoves	*Quality score*: Moderate Very small numbers of participants. This study can act as an indicator of likely acceptability, and any corresponding stove development needs, but it cannot be presented as a full assessment of the viability of the stoves in the long term and as part of a commercial scale up.

Author, year and country, urban/rural	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
	stove from the 'Institut Supérieur Polytechnique de Madagascar' (ISPM stove) with single round burner, working with 60% ethanol and locally developed; (iv) CleanCook stove (single burner) manufactured by Domitic (Swedish company) and working with 95% ethanol.				in evaluation screening, CCTs, CCT cooks' feedback and usability test. Main advantages: cleanliness and perceived environmental benefits. • Key challenges with the CleanCook include its imported origin, its upfront cost, and the need for 95% pure ethanol, which may not be as easy to produce in the current local distilleries. • For the locally produced ISPM stove a design review was recommended *Additional comments:* • The stove in which the ethanol is used has an impact on the perception of the fuel, particularly in terms of safety, usability and smell. The success of ethanol introduction is dependent on the function of both the fuel and stove, and it is linked also to fuel issues of price, local availability, quality, purchase volume options and bottle/tank options, denaturing, etc.	
Practical Action Consulting, 2011 « *Component A* » Madagascar Ambositra and Vatomandry *Urban/rural* *(Case study)*	Traditional wood and charcoal stoves. 4 interventions groups (and control – no intervention): (i) raising of awareness, (ii) improved wood, (iii) improved charcoal, and (iv) ethanol – focus of project.	*Scale*: Regional (local) as part of experimental design. *Duration*: 2010 (6 months). *Approach*: Ethanol stoves provided as part of experimental design. *Implementer*: Not	*Study design*: Quasi-experimental before-and-after study but household surveys conducted face-to-face 2-6 weeks and 5 months after introduction of ethanol stoves. *Study population*: 180 in Vatomandry and 144 in Ambositra	*Analysis*: Simple descriptive presentation of information on usage and perception of the stoves obtained from follow-up surveys (no hypothesis testing or comparison between groups).	*Initial positive response:* • It is clean (56.2%, n=18, in Ambositra and 40.6%, n=13, in Vatomandry). • It saves time (40.6%, n=13 in Ambositra and 34.3%, n=11, in Vatomandry). • It is easy to use (50.0%, n=16 in Ambositra). • 53.1% (n=17) of the ethanol stove users in Vatomandry reported that they believed the stove 'makes life easier'. • At 3-6 weeks, 80% used the project stove as main stove. At 5 months this rose to 97% in Ambositra and 77% in	*Quality score*: Strong Small numbers with little comparison between intervention groups. Hard to assess factors associated with adoption (also all stoves given free).

Author, year and country, urban/rural	Baseline and intervention fuel and technology	Description of Programme	Study design and study population (sampling)	Data source and analysis	Principal findings relevant to scaling up	Issues regarding quality and interpretation
		programmatic. Study lead by Practical Action but supported by local NGOs. Idea that study can inform national production of ethanol as a fuel.	(although approximately 30 from each were included in the ethanol fuel arm of the study).		Vatomandry. *Additional findings:* • High use of secondary stove in both regions (8% at 3-6 weeks and 81% at 5 months in Amobsitra, and 75% at 3-6 weeks and 84% at 5 months in Vatomandry). • At 3-6 weeks more than one-third reported ethanol stoves could not cook all food types (declining to 29% and 23% in Ambositra and Vatomandry respectively). • 17 (27.4%) indicated the stove could be improved by increasing the size and including 2 burners. • At 5 months 11% believed the ethanol stove to be 'a bit dangerous'. • Time saving: on average households saved approximately 1.8 hours each day in cooking/cleaning time.	**Quality Assessment** Selection: S Baseline info: M Outcomes: M Analysis: S Impact: S

Appendix 4.1: Synthesis tables for ICS

A: QUALITATIVE STUDIES

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
HOUSEHOLD AND SETTING CHARACTERISTICS	**Socio-economic aspects/ income**	• People engaged in paid labour are more likely to be able to purchase an improved stove (Person et al. 2012)	• Low income and limited access to credit are barriers to adoption (Sesan 2012) • Few people are paid for their work in Kenya which makes ICS unaffordable (Person et al. 2012)
	Household characteristics	• Possibility for adding improved stove to a pre-existing set of stoves already in use (Simon 2007)	• Lack of outdoor kitchen, which is considered a priority household investment in Kenya (Sesan 2012)
		Additional evidence[30]: existing use of LPG (Troncoso et al. 2007, 2011, Velasco 2008)	
	Setting	• Advantage of not needing to walk long distances for wood collection in difficult climates (e.g. monsoon or rainy season (Anderson 2007, Person et al. 2012, Troncoso et al. 2007)	• Cold temperature (-40 degrees) and reliance on stove to provide heat (Gordon et al. 2007) • Drought, famine and political instability limit ability to purchase improved stove (Person et al. 2012) • Exposure to frequent natural disasters such as floods, landslides and tsunamis (Sovacool and Drupady 2011)
KNOWLEDGE AND PERCEPTIONS	**Smoke, health and safety**	• Smoke reduction (Anderson 2007, Gordon et al. 2007, Simon 2007, Troncoso et al. 2011, Velasco 2008) • Reduction in respiratory symptoms/eye irritations/headaches (Christoff 2010, Jagoe et al. 2006a, Simon 2007, Troncoso et al. 2007, Velasco 2008) and improvement in children's health (Jagoe et al. 2007a) • Reduced back pain from not having to bend over the stove during cooking to blow on the fire (Person et al. 2012) • Fewer burns (Christoff 2010, Jagoe et al. 2007a, Simon 2007, Troncoso et al. 2007) • Fear that home could burn to the ground if traditional stove is not carefully supervised (Person et al. 2012) • Women's awareness of the dangers of kitchen smoke increases collective response to cooking interventions (Sesan 2012)	• Lack of awareness of long-term health risks of smoke (Gordon et al. 2007) • No perception of positive health effects after stove adoption (Gordon et al. 2007) and no clear long-term health benefits (Anderson 2007) • Desire for a better-quality coal, as health benefits are limited while coal remains of poor quality (Gordon et al. 2007) • Smoke useful for protection against insects (Jagoe et al. 2006a, Simon 2007) and ash can be used as fertiliser (Jagoe et al. 2006a)

[30] *Additional evidence* refers to the evidence that is not reported as either enabling or limiting uptake.

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		Additional evidence: No smoke reduction with improved stove (Gordon et al. 2007) and no reduction in health symptoms (i.e. irritated eyes, headaches) (Chowdhury et al. 2011)	
	Cleanliness and home improvement	• Kitchen less dirty (Christoff 2010, Gordon et al. 2007, Troncoso et al. 2007), cleaner home environment (Jagoe et al. 2006a) and, overall, kitchen area more appealing (Person et al. 2012, Sesan 2012) • Warmth (Gordon et al. 2007) • Improved quality of time spent with family (Christoff 2010, Jagoe et al. 2007a, Troncoso et al. 2007, Velasco 2008) • Children are able to eat in the kitchen (Velasco 2008)	• More frequent stove cleaning requirement because of ash accumulation (Christoff 2010, Gordon et al. 2007, Pandey 1989) • Stove not effective in warming the house (Jagoe 2006a et al., Troncoso et al. 2007)
	Total perceived benefit/ willingness to pay	• Improved stove seen as value for money (Jagoe et al. 2007a, Troncoso et al. 2007)	• Not perceived as a worthwhile investment (Anderson 2007) • Competing household priorities (e.g. money spent to secure food, build an outdoor kitchen, etc.) (Sesan 2012, Person et al. 2012) • Disillusionment with not receiving promised benefit after adoption (Pandey 1989)
	Social influence	• Positive feedback from relatives and neighbours encourages uptake (Christoff 2010, Pandey 1989) • Popularity in neighbouring villages or among community members (Pandey 1989) • Improved social status in the eyes of relatives or the community (Christoff 2010, Person et al. 2012) • Aesthetic benefits: women's pride in kitchen appearance (Christoff 2010, Troncoso et al. 2007, Velasco 2008), idea of novelty (Christoff 2010) • Experience with innovative/modern agricultural technologies (Pandey 1989)	• Stove adoption decision negatively impacted by neighbours' bad experiences with improved stoves (Pandey 1989)
	Tradition and culture	• Suitability for continuing to use for traditional cooking methods and local cuisine (Christoff 2010) • Improved or equally good food taste (Christoff 2010, Jagoe et al. 2006a) • Ability to cook for a large number of people using the improved stove (Sovacool and Drupady 2011)	• No perceived need for a new stove and change in cooking habits (Anderson 2007, Sovacool and Drupady 2011, Troncoso et al. 2007, 2011) • Improved stove unsuitable to cook for large gatherings (Christoff 2010, Pandey 1989, Person et al. 2012, Troncoso et al. 2007) • Impossible to cook some important traditional meals (Jagoe et al. 2007a, Pandey 1989) • Design does not fit with traditional pots (Christoff 2010, Pandey 1989, Velasco 2008) • Cooking in a standing position with improved stove (Troncoso et al. 2011)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
FUEL AND TECHNOLOGY CHARACTERISTICS	**Savings**	• Fuelwood savings (Chowdhury et al. 2011, Person et al. 2012, Simon 2007, Troncoso et al. 2007, 2011) • Reduced time/risk for fuelwood collection experienced (Jagoe et al. 2006a) • Savings from purchasing less firewood (Person et al. 2012) or coal (Gordon et al. 2007) • Shorter cooking times (Anderson 2007, Jagoe et al. 2007a, Person et al. 2012, Sovacool and Drupady 2011) • Option to cook multiple dishes at the same time (Christoff 2007, Velasco 2008) • Time saved used for other activities (Jagoe et al. 2007a) • Monetary savings due to not needing to visit the medical doctor (Jagoe et al. 2006a, Velasco 2008)	• No savings in fuel expenditure (Jagoe et al. 2007a) • Short walking distances for harvesting free fuelwood and little economic value attached to time spent on wood collection (Troncoso et al. 2007) • Time spent chopping wood into small pieces (Sovacool and Drupady 2011, Troncoso et al. 2007) • More time required for cooking (Pandey 1989)
	Design and performance	• Development of high-quality cookstoves (Troncoso et al. 2011) • Need for simple technology that requires little maintenance (Troncoso et al. 2011)	• Small burning chamber (Anderson 2007, Jagoe et al. 2006a, 2007a) • Stove difficult to light because of the small entrance to the chamber (Troncoso et al. 2007, 2011) • Modifications to the opening for fuelwood (i.e. enlargement) (Christoff 2010, Troncoso et al. 2007) • Versatility of open fire or traditional stove (Troncoso et al. 2007) *Specific design requirements and durability:* • Presence of grate (Anderson, 2007, Jagoe et al. 2007a, Anderson 2007) • Difficult maintenance (Troncoso et al. 2007) and stove performance affected if stove not properly cleaned (Christoff 2010)
	Fuel requirements		• Specific fuel requirements in terms of dryness (Anderson 2007, Troncoso et al. 2007), size (Anderson 2007, Christoff 2010, Pandey 1989, Troncoso et al. 2007, 2011), being unable to use agricultural residues or leaves (Chowdhury et al. 2011, Pandey 1989)
FINANCIAL, TAX AND SUBSIDY MECHANISMS	**Stove costs/ subsidies**	• Village-level stove subsidies (Simon 2007) • Women able to choose to use their own money (usually saved to purchase items such as clothing and food) to buy the improved stove (Person et al. 2012)	• Improved stove perceived to be expensive (Anderson 2007, Gordon et al. 2007) • Households typically have low income and limited access to credit (Person et al. 2012, Sesan 2012) • Preference for self-building a stove rather than paying for an improved stove (Simon 2007)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
			• Household needs to plan and save towards the purchase of an improved stove but there are often last-minute expenses (children's school fees or hospital bills) (Sesan 2012)
	Payment modalities	• Payments in instalments (Jagoe et al. 2006a, 2007a, Simon 2007) • Community lending scheme (Person et al. 2012)	• Separate payments for improved stove purchase and installation (Person et al. 2012) • Health promoters refusing to accept credit, where the likelihood of receiving a complete payment for the stove is very low (Person et al. 2012)
	Programme subsidies	N/A	• Dependence on international aid/donations leading to lack of sustainability (Sesan 2012) • The need for external supplies from donors/programme can prevent stove builders from continuing with their business alone (Troncoso et al. 2011) • Frustration with fulfilling commitments to donors (Troncoso et al. 2011)
MARKET DEVELOPMENT	**Demand creation**	• Demonstrations of improved stove use and its advantages (Person et al. 2012, Simon 2007) • Health promoters use multiple techniques to promote purchasing and use but tend to focus on economic benefits (Person et al. 2012) • Government awards to encourage communities to adopt (e.g. *Clean Village Award*) (Simon 2007)	• Users are not aware that improved stoves are available on the market (Troncoso et al. 2011) • Lack of understanding of local views before developing a marketing strategy and no systematic promotion of improved stoves (Troncoso et al. 2011) • View that outsiders are forcing people to change (Anderson 2007, Chowdhury et al. 2011); scepticism with regards to outsiders (Troncoso et al. 2011)
	Supply chains/ infrastructure	• Improved stove built with local materials (Sovacool and Drupady 2011) • Stoves locally produced by skilled potter groups (Person et al. 2012)	• High cost of primary materials (Simon 2007) • Improved stoves not locally available (Anderson 2007) • Mistrust of stoves built outside the villages (Simon 2007) • Difficulties in stove transportation and finding the necessary supplies to install the stove (Person et al. 2012)
	Business and sales approach	• Attraction of potentially limitless business growth (Simon 2007) • Different cookstove model options available on the market to meet customers' demands (Sovacool and Drupady 2011) • Trained health promoters become sales people within their communities (Person et al. 2012)	• Frustration with having to balance high-quality craftsmanship with administrative and sales tasks (Simon 2007) • Uncertainty about stability of the improved stoves market (Simon 2007) • Being an improved stove technician is not perceived as a dignified job (Sovacool and Drupady 2011)
REGULATION, LEGISLATION AND STANDARDS	**Regulation, certification and standardisation**	• Skilled pottery groups are guided by the Kenya Bureau of Standards to ensure that the ceramic liner dimensions are energy-efficient (Person et al. 2012)	N/A

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
PROGRAMMATIC AND POLICY MECHANISMS	**Construction and installation**	• Users encouraged to destroy their traditional mud stoves prior to installing an improved stove, as an incentive to use the new stove (Pandey 1989)	• Complexity in setting up improved stoves with chimneys (Chowdhury et al. 2011) • Stove cracking and stove parts breaking down (Christoff 2010, Jagoe et al. 2007a) • Distrust of local builders (Troncoso et al. 2007)
	Institutional arrangements	• Polycentric organisational structure, with several offices spread throughout the country (Sovacool and Drupady 2011) • Company engaging national and district-level policy-makers and donor organisations in energy projects (Sovacool and Drupady 2011)	• Short-term programmes (usually related to strict donor funding schedules) (Sesan 2012)
	Community involvement	• Involvement of users in early stages of design and dissemination process (Troncoso et al. 2011) • Community involvement in brokering agreements with local village government and NGOs (Simon 2007) • Villagers' willingness to win local monetary incentives through the use of improved stoves (Simon 2007) • Women's involvement with stove enterprises (i.e. marketing of stoves to their peers) (Sesan 2012)	• Limited project sustainability with only one out of many women's groups established still active at the end of the project (Sesan 2012)
	User training	• First 2 weeks with improved stove considered critical for becoming familiar with the new technology (Troncoso et al. 2007) • Desire to receive training in order to be independent of outside technical support (Christoff 2010)	• Initial frustration with learning how to use the improved stove (Christoff 2010, Troncoso et al. 2007)
	Post-acquisition support	• Support to users during initial phase of improved stove implementation (Troncoso et al. 2011)	• Ongoing costs with stove breakdown or repair (Simon 2007) • Dependence on technicians who do not address all users' requests and scheduled follow-up monitoring visits not performed (Christoff 2010) • Constraints from commitments with NGOs (i.e. more priority given to building improved stoves than to following-up stove usage) (Troncoso et al. 2011) • Deterioration in quality of post-sale service due to company expansion and insufficient number of staff (Sovacool and Drupady 2011)
EQUITY CONSIDERATIONS	**Poverty**	• Stove donations reach the poorest households (Troncoso et al. 2007) • Brokering agreements to get stove subsidies allows marginalised households to purchase improved stoves (Simon 2007)	• Food security more important than purchasing an improved stove (Sesan 2012) • Market mechanisms fail to deliver benefits to poorest households (Jagoe et al. 2006a, Simon 2007) • Poorest women do not have the means to pay for an improved stove (Troncoso et al. 2007)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
	Gender	• Women are able to build their own stoves (Christoff 2010) and are independent of external technical support (Christoff 2010) • Women are able to conduct brokering agreements to get monetary incentives/loans for the purchase of improved stoves (Simon 2007)	• Men take decisions in the households (Troncoso et al. 2007) and control spending (Anderson 2007) • Male authorisation required for building a kitchen and/or purchasing an improved stove (Sesan 2012). Outdoor kitchen considered a priority (Sesan 2012) • Men not sufficiently targeted during dissemination campaigns (Anderson 2007, Troncoso et al. 2011) • Many men are reluctant to work with an organisation associated with women's empowerment (Sovacool and Drupady 2011) • Women's ability to purchase depends on their position of power in the household (first wife, favoured wife, mother-in-law) and access to cash (Person et al. 2012)
	Urban/rural location	N/A	• Remote areas need to be provided with the tools to maintain stove function (Christoff 2010) • Government more orientated towards increasing urban energy supply rather than targeting rural areas (Sovacool and Drupady 2011)

B - QUANTITATIVE STUDIES (ICS)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
HOUSEHOLD AND SETTING CHARACTERISTICS	**Socio-economic aspects/income**	• Income (Damte and Koch 2011, Inayatullah 2011) or household wealth as assessed by assets (Agurto-Adrianzen 2009, Silk et al. 2012) • Household expenditure per capita; higher total household expenditure (Mwangi 1992); home ownership (Damte and Koch 2011) • Number of rooms in household (Bensch and Peters 2011) • Ownership of bank account (Bensch and Peters 2011) • Practising household water treatment (as a measure of SES or health awarness) enhances adoption (Silk et al. 2012)	N/A
		Additional evidence: • Family income not associated with uptake (Muneer and Mohamed 2003, Pushpa 2011) • Occupational status not associated with adoption (Pushpa 2011)	
	Education	• Education (Damte and Koch 2011, George and Yadla 1995, Inayatullah 2011, Miller and Mobarak 2011, Muneer and Mohamed 2003, Pine et al. 2011)	• No association with education (Agurto-Adrianzen 2009, Pushpa 2011, Silk et al. 2012)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		• Women: years of schooling, higher education level, female household members' average education (Bensch and Peters 2011, Muneer and Mohamed 2003) • Men: years of schooling, higher education level (Inayatullah 2011, Muneer and Mohamed 2003) • Women's education associated with aspirational choice of healthier stove, independent of price (Miller and Mobarak 2011)	
	Demographics	• Female head of household (Damte and Koch 2011); at least one female adult member (Agurto-Adrianzen 2009) • Women not working outside the home (Pine et al. 2011) • Younger age (below 25) (Mwangi 1992, Pushpa 2011) • Kenyan women above 31 years more likely to adopt than younger women (Silk et al. 2012)	• Women's age not associated (Muneer and Mohamed 2003) • Larger number of adults in household (Inayatullah 2011, Agurto-Adrianzen 2009, Pine et al. 2011) or larger family size (Levine and Cotterman 2012, Pushpa 2011) • Family size not found to be associated (Mwangi 1992)
	Household characteristics	• Separate kitchen (Damte and Koch 2011) • Longer duration of residence at current home (Pine et al. 2011) • Higher adoption rates among labourers without land and small-scale farmers, compared to those with larger farms (Pushpa 2011) • Existing use of LPG (Pine et al. 2011) • Accurate perception regarding availability/accessibility of fuels (George and Yadla 1995) • Having a 3-stone open fire rather than a traditional fogón at home associated with early adoption (Pine et al. 2011)	• Lack of kitchen or permanent house (Wallmo and Jacobson 1998) • Collecting rather than buying biomass fuel (Inayatullah 2011) • Existing fuel stacking acts as a barrier to exclusive use of ICS (Jagoe et al. 2006b)
KNOWLEDGE AND PERCEPTIONS	**Smoke, health and safety**	• Reduced smoke (Jagoe et al. 2007b, Pandey and Yadama 1992, Wallmo and Jacobson 1998) • Reduced health symptoms associated with smoke (Jagoe et al. 2007b) • Reporting that irritated eye problems prior to adoption (Pine et al. 2011) lessen after improved stove use (Jagoe et al. 2007b) • Fewer accidents (Wallmo and Jacobson 1998)	• Lack of recognition of any benefits (Wallmo and Jacobson 1998)
	Cleanliness and home improvement	• Improved cleanliness (Wallmo and Jacobson 1998) and cleaner kitchen (Jagoe et al. 2007b)	N/A
	Total perceived benefit/willingne	• Perceived change for the better (Jagoe et al. 2007b) • Positive perceptions of the improved stove (Pushpa 2011)	• Improved stoves do not provide enough warmth (Wallmo and Jacobson 1998)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
	ss to pay	• Perceived advantages of improved stove, despite complexity of technology (Pandey and Yadama 1992) • Superiority of improved stove relative to traditional practices (Pandey and Yadama 1992) • Improved stove's relative advantage (based on 5 parameters) (Muneer and Mohamed 2003)	
	Social influence	• Stronger social networks within community (Pine et al. 2011, Wallmo and Jacobson 1998); greater sustained use when more people use improved stove (Agurto-Adrianzen 2009) • Opinion leaders' positive perceptions about improved stoves are influential (Miller and Mobarak 2011) • Households engaging in communal activities (Agurto-Adrianzen 2009) • Experience with innovative/modern agricultural technologies (Mwangi 1992, Pandey and Yadama 1992) • Perception of increased status for women (Wallmo and Jacobson 1998) • Attractive stove appearance (Wallmo and Jacobson 1998)	• Social networks reduce use if problems are experienced by others (Agurto-Adrianzen 2009) • Opinion leaders are influential, with negative opinions more powerful as a barrier than positive perceptions as an enabler (Miller and Mobarak 2011) • Experience with agricultural technologies not associated with adoption (Agurto-Adrianzen 2009)
	Tradition and culture	• Stove design meets cooking needs (e.g. number and size of potholes) (Wallmo and Jacobson 1998)	• Reluctance to change reported by the main cook and/or other family members (Wallmo and Jacobson 1998) • Inability of improved stoves to accommodate all pot sizes (Pandey and Yadama 1992, Wallmo and Jacobson 1998) • Improved stove alone is not sufficient for larger gatherings (Wallmo and Jacobson 1998) • Inability to prepare standard dishes on improved stoves (Pandey and Yadama 1992)
FUEL AND TECHNOLOGY CHARACTERISTICS	**Savings**	• Fuelwood savings (Miller and Mobarak 2011, Pandey and Yadama 1992, Wallmo and Jacobson 1998) • Food cooked quickly (Wallmo and Jacobson 1998) • Less tending of stove required (Wallmo and Jacobson 1998) • Reduced cooking time (Jagoe et al. 2007b, Pandey and Yadama 1992)	• Perceived greater fuel consumption (Jagoe et al. 2006b) • Longer time for cooking (Jagoe et al. 2006b)
	Design and performance	• Not experiencing problems with the stove (Pine et al. 2011) • Greater compatibility between improved stoves and traditional practices (Pandey and Yadama 1992) • Stove able to cook several items at once (Wallmo and Jacobson 1998)	• Dislike of the grate (often leading to grate removal) (Jagoe et al. 2007b) • Improved stove does not provide enough smoke for curing food (Wallmo and Jacobson 1998)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		Specific design requirements and durability: • Safe stove, which reduces accidents and burns (Wallmo and Jacobson 1998)	*Specific design requirements and durability:* • Concerns about purchased stove's durability (Levine and Cotterman 2012) • Cannot accommodate all sizes of pots (Wallmo and Jacobson 1998)
	Fuel requirements		• Inability of improved stoves to use all available fuels (Pandey and Yadama 1992, Wallmo and Jacobson 1998)
FINANCIAL, TAX and SUBSIDY MECHANISMS	**Stove costs/subsidies**	• Price is an over-riding factor in choosing between alternative improved stoves (Miller and Mobarak 2011) • Reducing stove prices by 50% increases stove orders and purchases (Miller and Mobarak 2011) • Subsidy effective at improving initial adoption (Miller and Mobarak 2011)	• Lack of funds or liquidity (Miller and Mobarak 2011, Wallmo and Jacobson 1998) • High cost prevents purchase (Levine and Cotterman 2012, Miller and Mobarak 2011), especially of higher-quality technologies (Miller and Mobarak 2011)
	Payment modalities	• Majority of households are able to pay for the stove in a single full payment (Jagoe et al. 2007b) • Payments in instalments for stove purchasing (with extra households visits often required to complete payments) (Levine and Cotterman 2012); no late fees charged to cover higher collection costs (Levine and Cotterman 2012) • Social desirability for stove pre-payments; payments in instalments avoided for (i) fear of stigma associated with debts, (ii) risk of stove removal after trial period (due to lack of cash at time of payment collection) (Levine and Cotterman 2012)	• Single scheduled payment for improved stove after free trial period (Levine and Cotterman 2012) • Risk of revenue loss due to failure to complete improved stoves payments because (i) nobody at home during collection visits, (ii) households moved away, (iii) refusal to pay, (iv) households paid less than amount owed (Levine and Cotterman 2012)
MARKET DEVELOPMENT	**Demand creation**	• Use of community peers and opinion leaders for joint promotion of health messages and household products (Silk et al. 2012) • Paid promoters in community (Wallmo and Jacobson 1998) • Extensive promotional visits to houses (Mwangi 1992) • Women's exposure to messages about the improved cookstove through media/exhibitions/posters (Muneer and Mohamed 2003) • Early adopters who maintain and use improved stoves may influence others (Pine et al. 2011) • Rate of adoption increases as technology becomes more widespread (Damte and Koch 2011)	• Marketing campaigns focused on informing population about health hazards of smoke are not sufficient to encourage individuals to abandon traditional practices (Levine and Cotterman 2012, Miller and Mobarak 2011)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
	Business and sales approach	• Combining stove sale and stove installation within a single transaction (Silk et al. 2012) • Time-limited promotional offers and price incentives, in particular when timed to follow crop harvests that provide additional income (Silk et al. 2012) • Combination of free trial period, time payments and the possibility of returning stove (Levine and Cotterman 2012) • Product integration of improved stoves with household water treatment interventions, as a combination of (i) community peers, (ii) promotional incentives, and (iii) product integration (Silk et al. 2012)	• Mistrust of door-to-door salespeople (Levine and Cotterman 2012) • No evidence that sales offers affect consumer confidence in improved stoves (Levine and Cotterman 2012)
REGULATION, LEGISLATION AND STANDARDS		N/A	N/A
PROGRAMMATIC AND POLICY MECHANISMS	**Construction and installation**	• Adherence to design specifications in stove construction (George and Yadla 1995) • High-quality installation of stove and chimney (George and Yadla 1995)	N/A
	Institutional arrangements	N/A	N/A
	User training	• User education camps organised prior to/after improved stove installation, particularly effective when organised on a neighbourhood basis (George and Yadla 1995)	N/A
	Post-acquisition support	• Explicit strategy for post-installation user support (George and Yadla 1995)	N/A
	Monitoring and quality control	N/A	N/A
EQUITY CONSIDERATIONS	**Poverty**	N/A	N/A
	Gender	• Women could benefit from forms of community co-operation that consist of paying a small amount of money and using the total amount collected to obtain cooking utensils (Muneer and Mohamed 2003) • Building the improved stove with product attributes that appeal to men is a promising marketing strategy (Miller and Mobarak 2011) • Differing gender preferences with respect to specific technology choices (Miller and Mobarak 2011)	• Stove cost too high for women's purchasing power (Miller and Mobarak 2011, Muneer and Mohamed 2003) • Aspirational choice may not lead to actual adoption, if husband makes decision based on cost (Miller and Mobarak 2011)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		• Women may find ways to influence their husbands in favour of obtaining an improved cookstove (Miller and Mobarak 2011)	
		Additional evidence: Women more than men value health benefits associated with ICS use (Miller and Mobarak 2011)	
	Urban/rural location	• Urban/rural location and remoteness are not associated with adoption (Silk et al. 2012)	

C - CASE STUDIES (ICS)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
HOUSEHOLD AND SETTING CHARACTERISTICS	**Socio-economic aspects/income**	• SES (Sawadogo 1989, Sudjarwo et al. 1989) • Higher income (Shrimali et al. 2011, Sudjarwo et al. 1989)	
	Education	• Educational level (Sudjarwo et al. 1989)	• Insufficient education (Amarasekera 1989)
	Household characteristics	• Appropriate placement of stove inside the house (Barnes et al. 2012b,d, Masera et al. 2005) • New kitchen areas built to accommodate the new stove (USAID/Winrock 2008) • Households that purchase rather than collect biomass (Shrimali et al. 2011) • LPG or kerosene use (Shrimali et al. 2011) • Different stove models used for daily cooking or cooking for large gatherings (Sudjarwo et al. 1989) • Opportunity cost of fuel collection and value attached to fuel savings varies depending on fuel availability (Barnes et al. 2012d)	• Lack of space for improved stove (Barnes et al. 2012b,c) • Households use improved stove in combination with traditional stoves (Amarasekera 1989, GERES 2009, Sudjarwo et al. 1989), and cook with a mix of fuels (Barnes et al. 2012c, Masera et al. 2005) • Use of multiple stoves to prepare several dishes simultaneously as a way of minimising fuel costs, especially in poor households where all adults work (Barnes et al. 2012d)
	Setting	• Improved stoves that also work well during the rainy season are more in demand (Mounkaila 1989) • Urban households (Shrimali et al. 2011) • Opportunity cost of fuel collection and value attached to fuel savings is also influenced by urban vs rural location (GERES 2009, Kürschner et al. 2009)	• Rainy season (Barnes et al. 2012b, Mounkaila 1989) • Open fires frequently used to keep warm at high altitude (World Bank 2004b) • Gas stoves often used in households closer to urban centres (World Bank 2004b)
KNOWLEDGE AND PERCEPTIONS	**Smoke, health and safety**	• Smoke reduction (Barnes et al. 2012a,b,c,d,f, Shastri et al. 2002, Sudjarwo et al. 1989, World Bank 2004b) • Reduction in coughing (Barnes et al. 2012e, World Bank 2004b), may be due to less indoor smoke and/or less blowing to keep fire going (Barnes et al. 2012e) • Reduction in health problems (Barnes et al. 2012a,b,c,d,e,f, World Bank 2004c) including improved respiratory health and less eye irritation (World Bank 2004b) • Reduction in burn risk (GERES 2009, Namuye 1989) • Fewer visits to pharmacy to treat respiratory illness (Barnes et al. 2012f)	• No awareness of health risk of smoke (Masera et al. 2005) • Smoke considered essential in elimination of pests (Barnes et al. 2012a) • Increase in smoke production (Mounkaila 1989)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
	Cleanliness and home improvement	• Cleaner kitchen (Barnes et al. 2012a,b,c,d,e,f, World Bank 2004b,c) • Cleaner vessels/pots (Barnes et al. 2012a,b,c,d,e,f) • Less soot production (Namuye 1989) • General home improvements (Masera et al. 2005) • Family can eat together (Masera et al. 2005) • Children can study indoors (Barnes et al. 2012e,f) • Less frequent replacement of roof tiles due to reduced exposure to heat and smoke (Barnes et al. 2012f) • Families using the stove as a table for eating (World Bank 2004b)	• More ICS cleaning needed (Barnes et al. 2012b), especially for the chimney (World Bank 2004c) • Increased blackening of pots (Mounkaila 1989)
	Total perceived benefit/willingness to pay	• Household investment in ICS is made with expectation of rapid return (Mounkaila 1989) • High theoretical willingness to re-purchase improved stove, provided stove or relevant parts are available (Barnes et al. 2012c,e) • Households receptive to idea of paying a higher price for ICS rather than constructing stoves themselves (USAID/Winrock 2009)	• Competing household priorities (Barnes et al. 2012c) • Lack of willingness to pay (Barnes et al. 2012c) • Lack of perceived ICS benefits (Mounkaila 1989) • Frustration with not receiving promised benefits after adoption (Barnes et al. 2012e) • Stove not suitable for meeting heating needs (Barnes et al. 2012b)
	Social influence	• Information from community and neighbours (Namuye 1989, Sudjarwo et al. 1989, Mounkaila 1989) • Involvement of traditional stove builders encourages satisfaction with programme (Barnes et al. 2012a) • ICS possession perceived as indication of increased SES (Namuye 1989) • Aesthetics of stove (Masera et al. 2005, Namuye 1989)	• Lack of membership of self-help groups (which promote adoption primarily among members) (Barnes et al. 2012b,c) • Negative feedback from users (Barnes et al. 2012c)
	Tradition and culture	N/A	• Lack of suitability for cooking all foods (Barnes et al. 2012d)
FUEL AND TECHNOLOGY CHARACTERISTICS	**Savings**	• Fuel savings (Amarasekera 1989, Barnes et al. 2012a,b,c,d,e,f, GERES 2009, Kürschner et al. 2009, Mounkaila 1989, AmarasekeraNamuye 1989, Sawadogo 1989, Shastri et al. 2002, World Bank 2004a,), although perceptions of fuel savings are not always consistent with measured fuel savings (Sawadogo 1989) • Monetary savings (GERES 2009, Kürschner et al. 2009) and raised household living standards (e.g. better-quality food) as a result of fuel savings (Mounkaila 1989) • Time savings (Amarasekera 1989, Barnes et al. 2012c,d,e,f, GERES 2009, Kürschner et al. 2009, Shastri	• Increase in fuel use/consumption (Barnes et al. 2012a,b,c,e, World Bank 2010c) • Poor performance with longer cooking times (Barnes et al. 2012b,c,e, Sudjarwo et al. 1989)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		et al. 2002Amarasekera), used for other household work (GERES 2009, Kürschner et al. 2009) or for income generation (GERES 2009) • Faster cooking (Barnes et al. 2012a,b, Kürschner et al. 2009, Namuye 1989, Sawadogo 1989, Shastri et al. 2002, World Bank 2004a), may be due to greater stove efficiency and/or switch from one to several pot holes (Barnes et al. 2012b,e)	
	Design and performance	• Careful R&D to develop innovative stove models (Barnes et al. 2012c) • National stove competitions to identify promising designs for local adaptation (Sinton et al. 2004) • More improved stove model availability gives choice to suit needs (USAID/Winrock 2009) Cooking easier and more comfortable (GERES 2009) *Specific design requirements and durability:* • Lifespan and durability (Amarasekera 1989, Namuye 1989), for example through stove insulation (Amarasekera 1989) or use of reinforced materials (World Bank 2004a) • Portability (Namuye 1989) • Stability (Sawadogo 1989)	• Culturally/locally inappropriate stove designs (Barnes et al. 2012a,b,c,d,f) or programmatic promotion of 'one-size-fits-all' model (Barnes et al. 2012b, Simon 2010), leading to stove modification by users (Barnes et al. 2012a,c,d,e,f, World Bank 2004a, 2010a) and/or reversion to traditional stove (Barnes et al. 2012a,c,d,e,f) • Difficulty using stove (Sudjarwo et al. 1989, World Bank 2004b) and controlling intensity of flame (compared to use of open fire) (World Bank 2004b) *Specific design requirements and durability:* • Lack of durability (Kürschner et al. 2009, Sudjarwo et al. 1989) • Lack of stability while preparing meal (Mounkaila 1989)
	Fuel requirements	• Suitability for cooking with any biomass fuel (including agricultural residues) (Sudjarwo et al. 1989)	• Problems with using all available fuels (Simon 2010, Sudjarwo et al. 1989) • Reluctance to cut firewood to required size (Barnes et al. 2012f) • Stove entrance too small for wood fuel and stove damaged by the women attempting to insert firewood too large for the opening (World Bank 2004c)
FINANCIAL, TAX AND SUBSIDY ASPECTS	**Stove costs/ subsidies**	• Large stove subsidies increase uptake (Barnes et al. 2012a,b,f) • Use of local materials lowers stove costs (World Bank 2004a) • Economies of scale through government-led bulk orders of stoves or raw materials (Barnes et al. 2012a,b, Simon 2010) • Flexible stove pricing policies encourage promotion of a	• Cost prevents initial purchase (Barnes et al. 2012c, Mounkaila 1989, Namuye 1989) or re-purchase (Sudjarwo et al. 1989) • Large stove subsidies devalue stoves (Barnes et al. 2012a,b); poorest maintenance record among households that received greatest subsidies (Barnes et al. 2012a) • Wide-ranging subsidies may discourage uptake by

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		wider variety of stoves (Barnes et al. 2012f) • Standardisation of stove prices (Mounkaila 1989) • Different ICS prices for different models ensures stoves within purchasing ability of the poor (World Bank 2010b) • Fixed improved stove costs negotiated between household and technicians in relation to local costs for the material (World Bank 2010c) • ICS prices kept constant in order to avoid price changes affecting demand (World Bank 2004b) • Combination of subsidies and community payments proportionate to households' ability to pay (World Bank 2004a) • Subsidisation of certain stove components, material and/or transport (World Bank 2004a,c)	ineligible groups (e.g. middle-income classes) (Barnes et al. 2012a) • Subsidy expectation into the future prevents re-purchase at market price (Barnes et al. 2012b,e) and creates long-term reliance on subsidies (Barnes et al. 2012d) • Users unaware of subsidy or do not understand subsidy pattern (Barnes et al. 2012c,e,f) • National guidelines for one-time village subsidy prevent re-purchase and undermine programme sustainability (Barnes et al. 2012e) • Absence of formal pricing policy allows NGOs to collect variable user contributions (Barnes et al. 2012f)
	Payment modalities	• Facility to pay in instalments (Kürschner et al. 2009, Masera et al. 2005, World Bank 2010b) • Loan systems facilitate ICS access for many families (USAID/Winrock 2008) • Availability of loans through microcredit mechanisms (USAID/Winrock 2009, World Bank 2010b) • Stove purchase on credit for poor (funded through fuel savings) (Osei 2010) • Lack of consumer finance no major obstacle with more affluent target populations (Shrimali et al. 2011) • Expanded consumer finance (e.g. microfinance) likely to increase uptake (Shrimali et al. 2011)	• Lack of facility to pay in instalments for some users (USAID/Winrock 2009) • Payback period for microcredit too short (World Bank 2010b) • Use of credit creates cash flow problem for companies and stops expansion (Osei 2010) • Interest charges for payments in instalments (World Bank 2010b) • No credit available for people without means to pay (World Bank 2004a)
	Programme subsidies	• Initial funds provided to artisans to start business (Kürschner et al. 2009, USAID/Winrock 2009) • Loans to rural energy companies (Sinton et al. 2004) • Upfront capital to finance development of stove business (i.e. customer research, stove design, establishment of supply channels) as one of the strongest differentiators of successful businesses (Shrimali et al. 2011) • Magnitude and stability of enterprise finance is more important than its source (e.g. private, government tax, government grants, government R&D support, carbon credits) (Shrimali et al. 2011) • Direct programme subsidies for services of stove builders and indirect subsidies for staff training and awareness-generation (Sinton et al. 2004)	• High drop-out rates and substandard construction among implementers due to lack of financial incentives (Barnes et al. 2012d,e) • No incentive provided to artisans for long-term stove maintenance (Kürschner et al. 2009) • Commission-based salaries for manufacturers usually insufficient, leading to dissatisfaction (Kürschner et al. 2009) • No support for entrepreneurship development (World Bank 2010a) • No credit for improved stove programme due to low stove cost (World Bank 2010a) • Dependence on international aid/donations leading to lack of sustainability (World Bank 2004a,b,c)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		• Counties participated in co-funding the national programme (Sinton et al. 2004) • Provision of free moulds, accessories and technician fees during start-up phase (World Bank 2010a) • Risk minimisation for stove retailer through (i) credit, (ii) guaranteed purchase of stove parts, and (iii) payment only for those stoves sold (Osei 2010)	• Financial institutions not open to collaboration on improved stoves project (World Bank 2004b)
	Taxation	• Tax benefits to rural energy companies (Sinton et al. 2004) • Tax implications as a result of recognition of improved stoves as renewable energy devices (Shrimali et al. 2011)	• Complicated fiscal arrangements between multiple implementing agencies (Barnes et al. 2012d)
MARKET DEVELOPMENT	**Demand creation**	• Demand-driven approach encourages long-term use (Shastri et al. 2002) • Building consumer awareness is critical; commercial companies invest at least 10% of operation expenses in (i) media marketing, (ii) product demonstrations, and (iii) marketing (Shrimali et al. 2011) • Full pay-for-service by householders creates demand for high-quality stove construction and installation (Shastri et al. 2002) • Publicity campaigns through media including radio, TV and newspapers (Masera et al. 2005, Mounkaila 1989, Sawadogo 1989, USAID/Winrock 2009, World Bank 2004a, 2010a,c), of particular importance for early adopters (Shrimali et al. 2011) • Mass media are successful in bringing the message to rural poor (Namuye 1989) • Awareness-raising through promoters and ICS sellers (Namuye 1989, Sudjarwo et al. 1989), NGO staff members (World Bank 2010b), women's organisations (Sudjarwo et al. 1989), community leaders and community forums (World Bank 2004a,b) • Various village-level activities, such as workshops (Masera et al. 2005), village assemblies, user camps (Barnes et al. 2012a,b, USAID/Winrock 2008, World Bank 2010a,b,c) • Product demonstrations (Mounkaila 1989, USAID/Winrock 2009) facilitate personal contact with stoveand are the most important driver of adoption in the market-place (Shrimali et al. 2011)	• Lack of information about ICS availability and benefits (Barnes et al. 2012b, Namuye 1989) • Failure to create demand (Barnes et al. 2012b, Kürschner et al. 2009) • No marketing structure created (World Bank 2004a,b,c) • Coercive promotion leads to adoption but subsequent rejection (Barnes et al. 2012b, Kürschner et al. 2009, Sudjarwo et al. 1989) • Deliberate misinformation of users suggesting that improved stoves are a legal requirement (Barnes et al. 2012b) • False promises that stoves would be followed by other benefits (e.g. free cooking vessels, asbestos roofs, cement kitchens or sanitary latrines) (Barnes et al. 2012b,e) • Overambitious targets and overstretched field staff prevent generation of latent demand and favour coercive stove promotion (Barnes et al. 2012b) • Active seeking of customers requires costly and time-intensive marketing campaigns, leading to lower sale volumes (Simon 2010) • Communities that are used to building their own cookstoves require special targeting (USAID/Winrock 2009)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
	Supply chains/ infrastructure	• Good road infrastructure (USAID/Winrock 2009) • Decentralisation of stove liner production to reduce transportation costs (Amarasekera 1989) • Establishment of a network for cookstove dissemination (World Bank 2010a) • Use of existing production and dissemination networks (Mounkaila 1989) • Need for well-conceived and actively managed supply chains (e.g. regular sales data) (Shrimali et al. 2011) • Management of 1 supply chain (i.e. stove) easier than management of 2 supply chains (i.e. stove plus fuel) (Shrimali et al. 2011) • Stove components available in local hardware stores (World Bank 2004a)	• Poor condition of roads makes transport of fragile stove components difficult (World Bank 2004a) • Users' lack of access to certain stove components (World Bank 2004a) • Supply problems and delays for outlets (Sudjarwo et al. 1989) • Poor supply chain for stove parts, e.g. unavailability of scrap metal increases consumer costs (Osei 2010) • Poor supply chain for stove repair, e.g. replacement parts cannot be regularly re-purchased (Barnes et al. 2012e) • Women not aware of places to buy stove or stove parts (World Bank 2004a,b)
	Business and sales approach	• Specialisation in production of stove parts (Masera et al. 2005, Osei 2010) and possibility of users purchasing stove parts separately (World Bank 2004a,b) • Profit motive and need for longer-term income ensures quality construction and sustained demand (Shastri et al. 2002) • Incremental approach (i.e. new stove with traditional fuels) easier to implement (Shrimali et al. 2011) • Inclusion of commercial/institutional customers (e.g. restaurants, street vendors) reduces payback period and facilitates cross-subsidisation (Shrimali et al. 2011) • Key business skills in marketing and operations are critical for success of business (Shrimali et al. 2011) • Need for modest but realistic expectations about returns from stove business (Shrimali et al. 2011) • Direct sales from manufacturers to consumers are more profitable for manufacturers but more time-consuming (Sudjarwo et al. 1989) • Shop owners take orders on behalf of stove entrepreneurs (USAID/Winrock 2009) • Reasonable profits for stove builders through combination of sales under government programme and on open market (Barnes et al. 2012a) • Expected greater income generation for stove builders through market-based approach (Kürschner et al. 2009) • Need for well-designed stoves (Shrimali et al. 2011),	• Failure to initiate entrepreneurial production and maintenance (Barnes et al. 2012d) • Radical 'total cooking solution' (i.e. new stove with new fuel) potentially difficult to implement (Shrimali et al. 2011) • After-sales service not considered important for success of business (Shrimali et al. 2011) • Seasonality affects rate of stove production and sales (Sudjarwo et al. 1989) • Only seasonal employment and insufficient earnings under government programme for stove builders (Barnes et al. 2012b,c,e), need for second source of income (USAID/Winrock 2009) • Inability to purchase stove and chimney separately undermines re-purchase of stove (Barnes et al. 2012c) • Indirect sales via retailers generate higher profits for retailers than for manufacturers, (Sudjarwo et al. 1989) • Lack of large bulk orders of raw materials leads to reduced economies of scale (Simon 2010)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		favoured by market-based approach (Simon 2010) • Businesses favour mass-production over artisanal approach (Shrimali et al. 2011) • Artisanal production provides employment and promotes programme sustainability (GERES 2009, Masera et al. 2005, Namuye 1989, Osei 2010) • Stove builders focus almost exclusively on ICS production as a source of income (GERES 2009)	
REGULATION, LEGISLATION AND STANDARDS	**Regulation, certification and standardisation**	• Regulation of wood supply has a positive impact on firewood consumption (Sawadogo 1989) • National network to standardise quality of stoves across producers/distributers (GERES 2009) • Certification system to standardise stoves (Sinton et al. 2004) or stove manufacturers by standards agency (Barnes et al. 2012e) • Stove parts sets purchased from approved manufacturers ensure reasonable quality (Barnes et al. 2012f) • Development of standards and efficiency labels for improved cookstoves (GERES 2009, Shrimali et al. 2011) • Standardisation of production quality through prefabricated moulds (Barnes et al. 2012c) or stove labels to guarantee construction standards (GERES 2009) • Documented technical specifications (World Bank 2004b)	• Market distortions through LPG and kerosene subsidies (Shrimali et al. 2011) • Financial speculation on raw materials implies need for state control (Mounkaila 1989) • Lack of standardisation of stoves (Namuye 1989) or stove components (Barnes et al. 2012e, World Bank 2004a)
	Enforcement mechanisms	• Need to enforce standards (Sinton et al. 2004), for example through penalties to revoke artisan accreditation in cases of non-compliance (Simon 2010) • Central sourcing of materials (Barnes et al. 2012b), procurement of materials from designated suppliers (Shastri et al. 2002) • Regular monitoring to ensure quality standards (GERES 200)	• No mechanism to ensure that stove parts are purchased from approved vendors (Barnes et al. 2012a) • Absence of approved dealers results in lack of standardised stove construction materials and considerable variation in procurement rates (Barnes et al. 2012d) • Chimney sets produced by certified manufacturer are not used by programme (Barnes et al. 2012f)
PROGRAMMATIC AND POLICY MECHANISMS	**Construction and installation**	• Flexibility of construction with stove height adjustable in order to allow individual height preference (World Bank 2004a) • Stove construction which guarantees longer durability (World Bank 2004a) • Need for a pre-dissemination phase (GERES 2009) • Training of stove builders (Barnes et al. 2012a,b, GERES 2009, Kürschner et al. 2009, Sinton et al. 2004),	• Inadequate construction or installation of stove can lead to back-smoking (Barnes et al. 2012c,d,e), cracked pottery liners (Barnes et al. 2012c,e) or ceramic elbows (USAID/Winrock 2008) • Poor-quality firebox (World Bank 2004b), inadequate soldering of stove burners supports (World Bank 2004c) and no possibility of altering stove height (World Bank 2004b)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		comprising both stove construction (Barnes et al. 2012a,b,c,d,e) and entrepreneurship (Barnes et al. 2012d)	• Some stoves not working (Kürschner et al. 2009) • Inappropriate or poor-quality chimney (World Bank 2010b), e.g. small chimney diameter (World Bank 2004b) • Difficulties in installing chimney in traditional kitchen (World Bank 2010b) and reluctance to make a hole in the roof for chimney (Barnes et al. 2012b) • Inadequate installation of chimney can lead to (i) water-leakage (e.g. no sealing), (ii) smoke indoors (e.g. without hole in roof) or (iii) stove placement outdoors (Barnes et al. 2012a,b,c) • Fear of hot chimney (summer) or leakage (rainy season) (Barnes et al. 2012c) • Frequent cases of fires reported due to overheated chimneys and sparks flying out of the chimney (World Bank 2004c) • Stove construction by untrained/poorly trained stove builders leads to faulty stoves, faulty installation (Barnes et al. 2012a,b,c,e,f) and stove design modifications (Barnes et al. 2012a) • Difficulties with training new potters (Amarasekera 1989) • High drop-out rates of trained stove builders (especially unemployed youth) due to perception as casual job, rather than profession (Barnes et al. 2012a)
	Institutional arrangements	• Organisational synergies through integration with rural housing scheme (Barnes et al. 2012d) • Bottom-up institutional approach to estimating stove demand (Barnes et al. 2012d,f) • One central co-ordinating agency simplifies monitoring and supervision (Barnes et al. 2012b) • Contracting directly from central to county level reduces administrative costs and delays (Sinton et al. 2004) • Previous experience with rural energy programmes (Sinton et al. 2004) • Need for government to fund basic and applied research into stove technology (Shrimali et al. 2011) • Need for government to publicise health risks associated with household air pollution (Shrimali et al. 2011)	• Insufficient interaction among programme staff at all levels (Barnes et al. 2012a,b,c,f, World Bank 2004b) • Lack of interaction between organisations implementing stove projects in the same area/region (World Bank 2004b,c) • Poor planning (e.g. lack of designated households, village festivals) and social taboos (e.g. lower-caste stove builders working in higher-caste households) lead to limited output by stove builders (Barnes et al. 2012c) • No programmatic control allows stove builders to collect varying contributions from different villages/users (Barnes et al. 2012c,f) • Lack of an efficient feedback system to inform

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		• Commitment of central, national or international funding agencies to generate interventions with an established supply chain component (Simon 2010) • Market-based programmes assign control over key technology innovation decisions to local partners (Simon 2010) • Need for oversight measures to check financial transactions (Simon 2010) • State-based programmes minimise opportunities for corruption (Simon 2010) • Government can act as aggregator to ensure that stoves receive carbon credit (Shrimali et al. 2011)	implementers about project progress (World Bank 2004b) • Poor programme management (World Bank 2010a) • Lack of national household energy policy (World Bank 2010a) • Market-based approaches encourage favouritism and corruption (Simon 2010) • State-based programmes restrict control over key technology innovations (Simon 2010) • Government-funded programme lacks a commercial approach (World Bank 2010a) • Dependence on government agents for distribution of stove parts, marketing, installation and co-ordination (Amarasekera 1989) • Target-driven programmatic approach promotes focus on numbers and encourages faulty stove construction (Barnes et al. 2012e,f)
	Community involvement	• Good relationships between implementers and community are critical (Barnes et al. 2012c); involvement of local NGOs allows swift adaptation to village realities (Barnes et al. 2012d) • Involvement of community, in particular women, in (i) stove design and construction (Barnes et al. 2012b,e, Masera et al. 2005, World Bank 2004a) and (ii) stove distribution (Barnes et al. 2012b) including entrepreneurial activities (USAID/Winrock 2009) • Participation in stove construction (and stove component replacement) fosters a greater sense of ownership and responsibility for the stove (World Bank 2004a)	• No consumer-testing before programme implementation (Barnes et al. 2012a) • Lack of community engagement strategy (World Bank 2010b)
	Creation of competition	• Identification of stove distributors with the greatest motivation to disseminate improved stoves (GERES 2009) • Competition among local implementers (Barnes et al. 2012f) • Performance-based system to reward the most successful women's network (Barnes et al. 2012b) • Healthy kitchen competitions to encourage healthy and orderly kitchens (USAID/Winrock 2008) • Competition between counties for funds with the best placed to go forward first (Sinton et al. 2004) • Programme preference for villages with high household	• Failure to foster competition between stove builders (Barnes et al. 2012b)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		demand (Barnes et al. 2012a), whole-village implementation approach (Barnes et al. 2012c,d)	
	User training	• User education by stove builders on initial stove use and how to obtain best performance (Masera et al. 2005, Shastri et al. 2002) • Users learn from observing their neighbours (World Bank 2010b) • Local capacity building through extensive training components as part of the programme (World Bank 2004a,b, 2010a) • Training in stove use and maintenance provided (World Bank 2004a) • External monitor contracted to supervise the training (World Bank 2004a)	• Insufficient activities to promote user awareness and user training (Barnes et al. 2012b,c,e.f), in part because of insufficient funds (Barnes et al. 2012a) • Lack of knowledge/training about correct improved stove usage (Barnes et al. 2012a,c,f, Sudjarwo et al. 1989, World Bank 2010b) and maintenance (Kürschner et al. 2009) • Blocked chimneys (Barnes et al. 2012a,b,c,d,f, World Bank 2010a,b) due to lack of knowledge/training on need to clean chimney (Barnes et al. 2012a,c,f) and perception as a difficult/tedious task (Barnes et al. 2012a,b,d) • Supplied instruction manual not as useful as hands-on training (Kürschner et al. 2009)
	Post-acquisition support	• Post-construction visits to check for problems and ensure that good practices have been adopted (Shastri et al. 2002) • Mandatory, free after-sales service (Barnes et al. 2012b, World Bank 2010a) • Combination of guaranteed, free after-sales service for minor repairs and paid services for major damage/reconstruction of stove (Shastri et. al 2002)	• Lack of and/or poor quality of after-sales service (Kürschner et al. 2009, Barnes et al. 2012a,c,e,f), due to (i) unavailability of stove builders during construction season (Barnes et al. 2012f) and (ii) insufficient funds (Barnes et al. 2012a, Kürschner et al. 2009) • No formal policy for paid after-sales service makes users reluctant to pay for repairs (Barnes et al. 2012f) • Uncertainty about post-warranty service (World Bank 2010a,b) • Need for self-supporting commercial efforts to maintain and repair improved stoves (Sinton et al. 2004)
	Monitoring and quality control	• Upfront stove quality control (Mounkaila 1989) to prevent substandard stoves from entering the market (Sudjarwo et al. 1989) • Monitoring of programme performance and stove installation (Barnes et al. 2012b, World Bank 2004a, 2010a,c) • Immediate verification of stove installations and subsequent follow-up checks (Barnes et al. 2012e) • Pre-installation (Barnes et al. 2012b,c) and post-installation surveys (Barnes et al. 2012e, GERES 2009) • Direct and continuous supervision of technology transfer	• No monitoring during construction and after installation (i.e. stove design, stove performance) (Barnes et al. 2012e,f, Kürschner et al. 2009, Masera et al. 2005, USAID/Winrock 2009, World Bank 2004a) • No independent monitoring of implementation/project evaluation (Kürschner et al. 2009, World Bank 2004a,c) • Insufficient inspection of stove installations (Barnes et al. 2012a,c,d, Kürschner et al. 2009) due to understaffing (Barnes et al. 2012d) and insufficient funds (Barnes et al. 2012e)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		during the initial phase of stove construction and stove use ensures standardisation of procedures and stove quality (GERES 2009, World Bank 2004a) • Users are able to discuss performance and usage issues during follow-up visits (World Bank 2010a)	• No user-based surveys after stove installation (Barnes et al. 2012a) • Non-responsiveness to design and training concerns reported by users, stove builders and local implementers (Barnes et al. 2012f) • Greater vulnerability to problems related to quality and more complex solutions (e.g. component reliability, battery performance) (Shrimali et al. 2011) • No technical support available to certify the quality of stove components (World Bank 2004a,b)
EQUITY CONSIDERATIONS	**Poverty**	• Programme preference for families below the poverty line (Barnes et al. 2012a,d) and lower income groups (Barnes et al. 2012a) • Affordable stove prices even for poorest households (Simon 2010) • Graded subsidies effective at reaching poor households (Barnes et al. 2012a, Kürschner et al. 2009) • Poor benefit more from paying in instalments (Kürschner et al. 2009) • Poor pay with credit, which maximises access (Osei 2010) • Different stove models and prices for higher- vs lower-income households (Barnes et al. 2012b, World Bank 2010b) • Cost minimisation through cheaper materials (Osei 2010)	• Poorer households have more pressing household priorities (Amarasekera 1989) • Stoves are more often bought by high- and middle-income groups (Namuye 1989) as stove cost is too high for the very poor (World Bank 2010b) • Poor people with limited education not motivated to purchase as limited opportunity cost due to free fuel collection (Amarasekera 1989, GERES 2009) • Poverty is a significant obstacle to creating a commercial market for stoves (World Bank 2004c) • No marketing to the poor, as they generate less income (GERES 2009) • Programme carried out in better-off areas as implementation required local co-funding, and as aim was other than to alleviate poverty (Sinton et al. 2004) • Illiterate people are unable to read instruction manuals and instead require direct training (Mounkaila 1989) • Commercial stove companies do not target '"ottom of the pyramid' households (Shrimali et al. 2011) • Marginalisation of disadvantaged households as a result of market-based approaches and higher stove prices (Simon 2010)
	Gender	• Women involved in pottery production (Namuye 1989) • Women trained as entrepreneurs to motivate households to adopt, and also for construction, installation and retail (USAID/Winrock 2009, World Bank 2010a,c) • Micro-loans for opening stove businesses only offered to	• Insufficient targeting of men, who control household financial resources, during cookstove campaigns (Mounkaila 1989) • Perceived low status of being a stove builder among men (Kürschner et al. 2009)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		women (USAID/Winrock 2009) • Women's organisations are powerful in improved stove promotion (Sudjarwo et al. 1989) • Women gain access to and interact more effectively with households (World Bank 2010a)	• Male family members do not assist with chimney cleaning (Barnes et al. 2012f) • Men are preferentially selected as technicians and entrepreneurs (World Bank 2010b) • Women, who are used to constructing their own stoves, frequently alter stove design leading to poorer stove performance (World Bank 2010a) • Women offering technical support find it difficult to travel long distances and offer technical assistance in a timely fashion due to household responsibilities (World Bank 2010b) • Some women not allowed by their husbands to work outside the home as stove entrepreneurs (USAID/Winrock 2009)
	Urban/rural location	• Programme preference for high population density areas (Barnes et al. 2012a) • Small-scale pottery industries make more profits in urban vs rural areas (Namuye 1989) • Commercial strategy is more feasible in urban settings since users pay for fuelwood and are more willing to pay for an improved stove (Amarasekera 1989) • Stove businesses are more likely to target urban households (Shrimali et al. 2011)	N/A

Appendix 4.2: Synthesis table for LPG and gas stoves

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
HOUSEHOLD AND SETTING CHARACTERISTICS	**Socio-economic aspects /income**	• High income (Edwards and Langpap 2005, Rogers 2009) • Affordability as dominant factor for LPG use (Viswanathan and Kumar 2005) • Household expenditure per capita, which needs to reach a threshold level for complete fuel switching (as opposed to mixed use) (Heltberg 2005) • Having electricity associated with LPG use (Heltberg 2005) • Number of rooms in urban houses (probably a wealth effect) (Heltberg 2005)	• Household with income below given threshold (US$100/month in Mozambique) unlikely to switch to fuel costing >10% of income (USAID 2005)
	Education and demographics	• Education strongly associated with switch to LPG (Heltberg 2005)	• Higher share of females in household (i.e. high availability of female labour) reduces opportunity costs of continued wood collection, limiting exclusive use of LPG (Heltberg 2005) • Indigenous ethnicity (Heltberg 2005)
	Household characteristics	• Use of crop waste is associated with greater LPG use (Rogers 2009) • LPG introduced a long time ago and available in most households (Lucon et al. 2004)	• Farm/rural households less likely to use LPG (i.e. wood opportunity cost) (Heltberg 2005) • Use of lantana (i.e. woody shrub species) collected by households that do not have access to crop waste is associated with less LPG use (Rogers 2009) • Number of livestock not associated (may not provide sufficient supplementary income or encourage fuelwood collection during grazing activities) (Rogers 2009) • Ability to buy wood on a daily basis (Terrado and Eitel 2005)
		Additional comments: • Use of mixed fuel common in Guatemala (which may favour the uptake of an additional fuel such as LPG) (Edwards and Langpap 2005) • Wood is the preferred LPG substitute in poorer areas (Lucon et al. 2004) and a combination of LPG and biomass traditional fuels is more frequently reported in rural areas (Elgarah 2011, Heltberg 2005)	
	Setting	• Urban setting (Heltberg 2005, Pandey and Morris 2006, USAID 2005) • Smaller households more likely to use LPG exclusively (Heltberg 2005) • Wealthier states (Pandey and Morris 2006)	• Less access to credit in rural areas (Edwards and Langpap (2005) • Relatively high LPG price in rural areas (USAID 2005)
KNOWLEDGE AND PERCEPTIONS	**Smoke, health and safety**	• Wood considered dirtier than LPG with negative health effects (Terrado and Eitel 2005)	• Lack of knowledge about safe use of LPG (Bates 2009) • Perception that LPG is dangerous or toxic (USAID 2005, Bates 2009) • Fear of LPG explosions (Budya and Arofat 2011, Terrado and Eitel 2005) • Safety concerns in relation to LPG use especially among younger

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
			women (USAID 2010)
	Total perceived benefit	• Having prior experience with LPG increases awareness of LPG benefits and willingness to adopt (Bates 2009, USAID 2005) • Willingness to switch to clean fuels (Elgarah 2011)	• Lack of awareness (Elgarah 2011) and knowledge about LPG in poor communities (USAID 2005) • Drop in price of traditional fuels (e.g. charcoal) encourages reversion to biomass fuels (Bates 2009)
	Tradition and culture	• Frequency of LPG use depends on affordability, but also on cooking habits (USAID 2005); • Respect of traditional cooking practices is a driver for adoption (USAID 2010) • Households in urban areas are more likely to buy ready-made food (i.e. tortillas) (Heltberg 2005) • Familiarity with the use of LPG (Lucon et al. 2004)	• Cultural factors (not further specified) act as a barrier (Terrado and Eitel 2005) • Some dishes are traditionally cooked outside on charcoal (USAID 2005)
FUEL AND TECHNOLOGY CHARACTERISTICS	**Savings**	• Cooking with LPG expected to be quicker (main reason for switching) (Terrado and Eitel 2005) • Expected cost savings from less purchasing of biomass (Heltberg 2005)	
	Design	• LPG stoves need to be suitable to adapt to local pot sizes and shapes (with larger pot often used by rural families) (USAID 2010)	• Safety risks due to leaks and poor-quality equipment (Bates 2009, Budya and Arofat 2011)
FINANCIAL, TAX AND SUBSIDY ASPECTS	**Stove cost and subsidies**	• Stove and bottle initially provided for free (Budya and Arofat 2011) • Subsidy on LPG stoves has greater effect than credit (Edwards and Langpap 2005) • Availability of subsidies on LGP pressure cookers (Viswanathan and Kumar 2005)	• High cost of LPG stoves/fuel switch (Bates 2009, Elgarah 2011, Pandey and Morris 2006,Terrado and Eitel 2005) • High cost of initial connection/access charge (Pandey and Morris 2006) • Stove ownership is found to affect firewood consumption directly and to make stove owners more responsive to changes in the price of LPG (Edwards and Langpap 2005)
	Fuel cost and subsidies	• Government subsidies for LPG (Lucon et al. 2004, Elgarah 2011, Viswanathan and Kumar 2005) • Direct subsidy to below-poverty-line households (Pandey and Morris 2006) • Across-the-board subsidy with limited entitlements promotes gradual reduction in entitlements and gradual modification of consumer expectations (Pandey and Morris 2006) • Use of small 3 kg bottles reduces refill costs (Budya and Arofat 2011)	• High cost of LPG cylinder refill (Elgarah 2011, Pandey and Morris 2006, USAID 2005, Viswanathan and Kumar 2005) • LPG price is the main reason for resistance to switching (Edwards and Langpap 2005) • Increased costs incurred by government due to parallel subsidised/unsubsidised LPG distribution and logistics systems (Pandey and Morris 2006) • Large families and groups of residences would fare better with large but unsubsidised common LPG cylinders/tanks (Pandey and Morris 2006) • Danger of major problems with subsidy arrangements due to (i) variability in international LPG prices and exchange rates and (ii) increasing number of connections (Pandey and Morris 2006) • Disadvantages of direct subsidy to below-poverty-line households

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
			include (i) non-consumers taking up connection in name of households that are not eligible and (ii) risk of multiple connections and (iii) need for efficient administrative structure (Pandey and Morris 2006) • Misuse of subsidised LPG for hot water consumption and air conditioning devices (Pandey and Morris 2006), and vehicles (Lucon et al. 2004) • Removal of national subsidies leads to 20% increase in LPG price (Lucon et al. 2004) and complete removal may lead to political mobilisation (Pandey and Morris 2006)
	Payment modalities	• LPG stove and gas bottle paid for with loans (Bates 2009) • Availability of credit (Edwards and Langpap 2005) • Payment in instalments (USAID 2005, Bates 2009)	• Differing interests in tax revenues by central and state governments (Pandey and Morris 2006)
	Programme subsidies	• Provision of financing facilities for retailers (USAID 2010) • Microfinance/loans for rural entrepreneurs to purchase equipment and set up LPG business (Elgarah 2011) and for training purposes (i.e. selling LPG and ensuring its safe use) (Bates 2009)	N/A
MARKET DEVELOPMENT	**Demand creation**	• Education campaigns must be thorough and long-lived enough to alter current perceptions (USAID 2010) • Consumer profiling needed for effective marketing (USAID 2005) • Widespread promotion through media (Budya and Arofat 2011) including audiovisual material in different local dialects to target illiterate people (Elgarah 2011) • Safe cooking events organised by women's development associations (Bates 2009)	• Lack of consumer education and awareness programmes a barrier to LPG/alternative fuel adoption (Elgarah 2011, USAID 2005, 2010) • LPG companies do not target the segment of the population that could potentially use LPG (USAID 2005) • Slow rate at which staff are trained to meet demand (Bates 2009)
	Supply chains/ infrastructure	• Reliability of supply (USAID 2005) • Conversion of kerosene suppliers to selling LPG to ensure adequate supply in rural areas (Budya and Arofat 2011) • Planning for total LPG supply requirements based on kerosene to LPG energy output ratio (Budya and Arofat 2011) • Measures to consolidate LPG distribution system (automatic delivery system) (Lucon et al. 2004) • Need for an extensive network of retailers and to ensure adequate LPG supply at national level (USAID 2010) • Setting up infrastructure for continuing LPG stove distribution beyond end of project (Bates 2009)	• Lack of abundant distribution channels and supply chain infrastructure among largest barriers to alternative fuel adoption over the long term (USAID 2010) • Difficulties with LPG import and supply (Lucon et al. 2004) • Lack of LPG availability (Terrado and Eitel 2005, USAID 2005) • Traders do not stock LPG due to (i) lack of sufficient demand and (ii) safety risks (USAID 2005)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
	Business and sales approach	• Reduced LPG costs through market expansion, including by (i) bulk transportation, (ii) generating greater demand, and (iii) credit to increase commercial use (USAID 2005) • Need for early-management structures able to cope with increasing number of customers wishing to switch to LPG (Bates 2009) • Microfinance/loans for rural entrepreneurs to purchase equipment and set up LPG business (Elgarah 2011)	• No commercial viability due to low level of consumption in rural areas and limited purchasing power (Elgarah 2011) • No effective retail in small cylinder sizes (Pandey and Morris 2006)
REGULATION, LEGISLATION AND STANDARDS	**Regulation legislation and standardisatio n**	• Government support at highest level (presidential decree, legal statutes and budget) for conversion from kerosene to LPG (Budya and Arofat 2011) • Need for oversight and regulation to control LPG price volatility (Pandey and Morris 2006) • Need for LPG policies and specific legislation, including review of importation practices (USAID 2010) • Legislative support provided as 'gas assistance' for low-income households (Lucon et al. 2004)	• Government policy on pricing to control margins, taken by distributors, in order to reduce regional price variations (USAID 2005) • Volatility of LPG prices (Terrado and Eitel 2005) • Rapid, insufficiently regulated expansion leads to unsafe products (Budya and Arofat 2011)
	Enforcement mechanisms	• Introduction of standards and certification (which however did not avert all problems with safety) (Budya and Arofat 2011)	N/A
PROGRAMMATIC AND POLICY MECHANISMS	**Institutional arrangements**	• Presence of responsible implementing agency (state oil company) considered vital (Budya and Arofat 2011) • One ministry to co-ordinate other ministries and stakeholders (Budya and Arofat 2011) • Institutional arrangements needed to address price volatility (Pandey and Morris 2006) • Need to ensure adequate LPG imports (USAID 2010)	N/A
	User training	• Provided through creation of women's development associations and demonstration of safe use of the fuel (Bates 2009)	N/A
	Monitoring and quality control	• Post-intervention monitoring provided (Bates 2009)	N/A

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
EQUITY CONSIDERATIONS	**Poverty**	• Legislative support for gas assistance for low-income families (Lucon et al. 2004) • Microfinance as viable scheme to overcome problem of acquiring LPG equipment for low-income people and develop new markets (Elgarah 2011) • Specific awareness campaign to target the poorest, illiterate people (Elgarah 2011) • Personalised payment plans to suit the customer (Elgarah 2011)	• Initial start-up cost of LPG adoption (LPG stove and cylinders) very expensive (equivalent to the average household's total monthly salary) (Rogers 2009); especially for those living in poverty (Bates 2009, Elgarah 2011) • Poorer families sensitive to LPG price increase and adapted by (i) cooking less often and (ii) reverting to use of wood (Lucon et al. 2004) • LPG companies do not target the segment of the population that could potentially use LPG (USAID 2005) • Subsidy mostly directed at middle income groups who are likely to use LPG regardless of subsidies (Pandey and Morris 2006) • Universal price subsidy often does not reach the poor (Viswanathan and Kumar 2005)
	Gender	• Women trained by the Women's Development Association as entrepreneurs for selling LPG stove sets (Bates 2009)	N/A
	Urban/rural location	• Urban areas have higher concentration of educated and relatively affluent people and are more aware of LPG benefits (USAID 2005) • Affluent urban respondents do not perceive LPG as a very expensive fuel (USAID 2005)	• High cost of distribution in rural areas (e.g. poor road infrastructure) (Elgarah 2011, USAID 2005) • Higher LPG price in rural areas (nearly tripled), especially for communities at a distance from the capital (USAID 2005) • Price of LPG discourages use in rural areas (Heltberg 2005) and access to credit for purchase of an LPG stove is less available in rural areas (Edwards and Langpap 2005) • Rural households less aware of LPG and the benefits it can bring to them (USAID 2005)

Appendix 4.3: Synthesis table for biogas

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
HOUSEHOLD AND SETTING CHARACTERISTICS	**Socio-economic aspects/income**	• Biogas users belong to higher-income groups (Christiaensen and Heltberg 2012, Ghimire 2005, Jian 2009, Mwirigi et al. 2009, Planning Commission 2002, Sovacool and Drupady 2011, iDE 2011) • Majority of installed biogas plants found among higher castes (BSP and CEDA 1998) • Higher income is associated with better maintenance and functional use of biogas plants (Planning Commission 2002)	N/A
		Additional evidence[31]: • Households working in agriculture, services, business and as professionals (BSP and CEDA 1998, iDE 2011) • Access to electricity and toilets in the majority of the households prior to installation of plant (BSP and CEDA 1998)	
	Education	• Literacy rate higher than national/state average (Bhat et al. 2001, BSP and CEDA 1998, Ghimire 2005, iDE 2011) or village average (Jian 2009) • People with a higher level of education are more willing (i) to install a plant (Mwirigi et al. 2009); (ii) to consume less dirty fuel overall (Christiaensen and Heltberg 2012); and are (iii) more aware that banks can provide loans for plant installation (BSP and CEDA 1998)	N/A
		Additional evidence: No impact of educational attainment of head of households (Planning Commission 2002)	
	Demographics	• Biogas installed in households with larger family size than the national average (over 6 people) (BSP and CEDA 1998, Ghimire 2005, iDE 2011) • Average number of male family members higher than female members (iDE 2011)	• Small family size (Christiaensen and Heltberg 2012) or reduction in family size over time (Planning Commission 2002) • Widespread outmigration of working-age adults from rural areas to cities (Christiaensen and Heltberg 2012, de Alwis 2002, Jian 2009), leaving women and the elderly to look after the biogas system (Daxiong et al. 1990)
	Household characteristics	• Permanent ownership of land favours ability to obtain financial loans (Mwirigi et al. 2009) • Greater functionality of plants among households working in animal husbandry and cultivation (Planning Commission 2002)	• Biogas implants are permanent and cannot be relocated if family moves (Sovacool and Drupady 2011)

[31] *Additional evidence* refers to the evidence that is not reported as either enabling or limiting uptake clearly.

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		Land owned and operated • Larger land ownership (BSP and CEDA 1998, Ghimire 2005, Planning Commission 2002) and having title deeds to the land (Mwirigi et al. 2009) • Space near the house as pre-requisite to constructing a biogas digester (Christiaensen and Heltberg 2012, iDE 2011) • igher and assured incomes associated with reliable agricultural production (e.g. arecanut as high-income perennial crop) (Bhat et al. 2001)	*Land owned and operated* Lack of sufficient land/space to construct the digester (Christiaensen and Heltberg 2012, Jian 2009) or to manage the bio-slurry (iDE 2011)
		Animal holding • Livestock availability is a prerequisite (Christiaensen and Heltberg 2012, iDE 2011) • Large cattle holdings (Bhat et al. 2001, Daxiong et al. 1990, Mwirigi et al. 2009, Planning Commission 2002, Sovacool and Drupady 2011), allowing all cooking needs to be met through biogas (Bhat et al. 2001) • Farmers practising zero grazing method (Mwirigi et al. 2009) • Higher market value of cattle owned (Mwirigi et al. 2009) • Availability of cow dung (Mwirgi 2009), including dung collected from neighbours' livestock (Ghimire 2005, World Bank 2010d)	*Animal holding* • Insufficient livestock (Planning Commission 2002) to produce a good quantity of biogas (de Alwis 2002) • Decline of household pig-farming (negatively affected by lack of effective veterinary medicine and insurance) (Daxiong et al. 1990, Jian 2009) and cattle size over time (Ghimire 2005) negatively affects adoption/use • Animal ownership fluctuation due to seasonality (Christiaensen and Heltberg 2012) or drought (Dutta et al. 1997)
	Multiple fuel and stove use	• Non-availability of other fuel sources (iDE 2011), including wood (Dutta et al. 1997) or LPG (Bhat et al. 2001) • Biogas considered the second cheapest option after free fuel collection (Dutta et al. 1997) • Biogas used in addition to traditional biomass fuels/LPG and natural gas (Ghimire 2005), to extend the life of LPG cylinder (de Alwis 2002)	• Ease of buying coal and collecting wood negatively affect biogas adoption (Christiaensen and Heltberg 2012, Jian 2009) • Preference for LPG due to lower upfront costs and tedious daily operation of biogas plant (Planning Commission 2002) • Preference for coal in terms of time savings, which can be used for income generating activities (Daxiong et al. 1990) • Households already invest in other 'modern' sources of energy (e.g. electricity) (Mwirigi et al. 2009) • Electricity not considered expensive (Jian 2009) • Inexpensive sources of other fuels or cooking devices negatively impact on use of biogas plants (Planning Commission 2002)
	Settings	*Climate* • Annual average temperature of 18.5˚C is optimal for biogas production (Jian 2009) • The rainy season is the best time for biogas plant performance	*Climate* • Cold temperatures during winter months reduce digestion speed (Christiaensen and Heltberg 2012, Ghimire 2005)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		(in terms of both gas and bio-slurry production) (iDE 2011)	• No gas production below 10˚C, which limits biogas availability to 3-6 months during the year (Qi and Li 2010) • Reduced gas supply during winter due to low pressure and need to use other fuels (Planning Commission 2002, Qi and Li 2010)
		Altitude, geographical position and access to infrastructures • Biogas system works well at altitudes up to 1,500 m (Bajgain and Shakya 2005) • Percentage of functional biogas plants increases with greater distance from roads, probably due to lack of alternative convenient fuels (Planning Commission 2002)	*Altitude, geographical position and infrastructure* • High altitudes (above 2,000 m)/cold settings reduce gas production (Christiaensen and Heltberg 2012, Jian 2009) • Exposure to frequent natural disasters (e.g. floods), especially on the coast (Sovacool and Drupady 2011, World Bank 2010d) • Limited rainfall (e.g. in Maharasjtra farmers are forced to sell their cattle during drought) (Dutta et al. 1997) • Rugged terrain implies higher costs for biogas installation (Bajgain and Shakya 2005)
KNOWLEDGE AND PERCEPTIONS	**Smoke, health and safety**	• Reduces indoor smoke and is safe (Mwirigi et al. 2009) • Health benefits (Ghimire 2005), in particular for women (Planning Commission 2002) reported also from toilet attachments (Bajgain and Shakya 2005) • Reduced incidence of eye disease and cough (iDE 2011, Kumargoud et al. 2006) and reduction in dieases caused by mosquitoes (iDE, 2011) • Reduced backache associated with collecting wood (Mwirigi et al. 2009) • Reduction of fire-induced accidents (iDE 2009) • Procedures to avoid mosquito breeding in slurry outlet (Bajgain and Shakya 2005)	• Concerns about infectious disease through handling cow dung (de Alwis 2002)
		Additional evidence: • Inadequate knowledge and no clear understanding of how biogas can positively impact on health (Jian 2009) • Increased breeding of insects (de Alwis 2002), including of mosquitoes after biogas plant construction (Bajgain and Shakya 2005)	
	Cleanliness and home improvement	• Clean cooking fuel (Planning Commission 2002) • Greater cleanliness of environment (Planning Commission 2002, iDE 2011), of kitchen (Sovacool and Drupady 2011) and cooking vessels (Ghimire 2005, Planning Commission 2002)	N/A

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		• Biogas used also for lighting purposes (Bajgain and Shakya 2005, Kumargoud et al. 2006, Mwirigi et al. 2009) • Helps rural sanitation (Jian 2009, Kumargoud et al. 2006) • Simultaneous construction of an improved kitchen and toilet connected to digester (Christiaensen and Heltberg 2012) and increased use of sanitary latrines (iDE 2011)	
	Total perceived benefit/willingness to pay	• Perception of improved quality of life (Ghimire 2005, Jian 2009) and convenience for cooking (iDE 2011, Jian 2009, Mwirigi et al. 2009) • Affordability (Dutta et al. 1997, Mwirigi et al. 2009) • Satisfaction with biogas system (Planning Commission 2002, Jian 2009, Sovacool and Drupady 2011, Christiaensen and Heltberg 2012) highly correlated to the status of functioning (iDE, 2011) • Economic benefits (Ghimire 2005) and cost savings due to not buying other fuels (e.g. kerosene) (Sovacool and Drupady 2011, iDE 2011) • Savings from reduced agricultural input costs (Christiaensen and Heltberg 2012), in particular for chemical fertilisers (Ghimire 2005, Kumargoud et al. 2006, Planning Commission 2002) • Biogas residues used as insecticides (Christiaensen and Heltberg 2012) or as fish feed (iDE 2011) • Possibility of generating income by selling the slurry as fertiliser (Sovacool and Drupady 2011, World Bank 2010d) or gas to other households (iDE 2011)	• Inadequate knowledge about biogas and its multiple benefits (Jian 2009, Mwirigi et al. 2009, Planning Commission 2002) • Biogas operation and maintenance considered very labour intensive (Christiaensen and Heltberg 2012, Jian 2009, Mwirigi et al. 2009, Planning Commission 2002, Sovacool and Drupady 2011) • Other more pressing demands (Mwirigi et al. 2009) • Perception that cash value of biogas lower than advertised (Jian 2009) • People have tended to perceive biogas as offering savings rather than earnings, where income is people's main concern (de Alwis 2002) • Previous experience with inferior-quality bio-digesters led to many people being unwilling to build another one (Daxiong et al. 1990)
		Additional evidence: • Users not fully aware of bio-slurry economic benefits (i.e. users fail to preserve/dry bio-slurry which can be used to generate income) (iDE 2011, Jian 2009) • Majority of households meet all cooking needs through biogas (Bhat et al. 2001, Planning Commission 2002)	
	Social influence	• Enhanced social prestige and status (Kumargoud et al. 2006, Mwirigi et al. 2009) • Enhanced social interactions and the advent of biogas considered as a sign of urbanisation (iDE 2011) • Neighbours' positive experiences (Bajgain and Shakya 2005, Christiaensen and Heltberg 2012) • Years since biogas was first introduced in village is positively associated with adoption (Christiaensen and Heltberg 2012)	• Social taboos: concerns about using human waste (BSP and CEDA 1998, iDE 2011, Sovacool and Drupady 2011) • Connection to latrine is considered unacceptable for socio-cultural and religious reasons, especially among older people (Ghimire 2005, Kumargoud et al. 2006) • Dislike of food cooked with gas produced from human waste (Bajgain and Shakya 2005, de Alwis 2002), fear of not being visited by friends and relatives if tea is prepared using human waste (Ghimire 2005)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
			• Adverse reactions to smell of dung and of animals in close proximity to dwelling (de Alwis 2002, Jian 2009) • Appliances often visually unattractive (de Alwis 2002) • Biogas perceived as technology for deprived people (i.e. those who use it see it as second-grade option) (de Alwis 2002). • Negative image of biogas use among small minority (Mwirigi et al. 2009) • Pig dung is unlikely to be used in Muslim countries (Sovacool and Drupady 2011)
	Tradition and culture	N/A	• Users continue to use traditional stoves for specific cooking and/or other tasks due to taste preferences or inconvenience of biogas (Dutta et al. 1997, Planning Commission 2002) • Wood preferred as families enjoy sitting around a fire on cold days (Jian 2009)
	Environmental and agricultural aspects	• Increasing crop yield due to application of biogas slurry (Bhat et al. 2001, iDE 2011, Kumargoud et al. 2006) or use of biogas residues to soak seeds before planting (Christiaensen and Heltberg 2012) • Forest conservation (Ghimire 2005, Mwirigi et al. 2009) and other environmental benefits (i.e. clean surroundings, use of waste material) (Ghimire 2005) • Higher subsidies for forest and hilly areas to encourage forest conservation (Bhat et al. 2001)	• Slurry not converted into fertiliser can pollute nearby water sources (iDE 2011, Sovacool and Drupady, 2011) • Farmers feel that slurry is not good enough to replace chemical fertilisers (Dutta et al. 1997)
		Additional evidence: Agricultural schools and animal production schemes indicate poor understanding of value of biogas systems (de Alwis 2002)	
FUEL AND TECHNOLOGY CHARACTERISTICS	**Time and fuels savings**	• Greater energy efficiency (Kumargoud et al. 2006, Qi and Li 2010) and fuel savings (Planning Commission 2002) • Time savings due to less or no fuelwood collection (Bajgain and Shakya 2005, Christiaensen and Heltberg 2012, Ghimire 2005) • Faster cooking (Christiaensen and Heltberg 2012, iDE 2011, Mwirgi 2009) from cooking multiple dishes in parallel (Ghimire 2005, Kumargoud et al. 2006, Planning Commission 2002, Sovacool and Drupady 2011) from use of multiple burners (iDE 2011)	N/A
	General design characteristics	• Different types of digesters available (Mwrigi 2009) • Large differences in functionality (Planning Commission 2002) and duration and complexity of installation (Sovacool and Drupady 2011) depending on type of biogas plant (e.g. methane	• Variable system performance (Sovacool and Drupady 2011) due to flaw in equipment or too few animals (Christiaensen and Heltberg 2012, Qi and Li 2010) • Insufficient gas production to cover cooking needs

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		leakage tends to be more common with brick vs fibreglass systems) (Sovacool and Drupady, 2011) • Household preference for smaller plant sizes due to (i) fewer cattle, (ii) suitability for small family, (iii) better functioning, (iv) ease of operation, and (v) less maintenance (Planning Commission 2002) • High gas sufficiency (Planning Commission 2002) due to all available dung used for biogas production and high dung-to-gas conversion efficiency (Bhat et al. 2001) • Small fixed-dome design working well at altitudes up to 1,500 m (Bajgain and Shakya 2005)	(Christiaensen and Heltberg 2012, de Alwis 2002, Dutta et al. 1997, Ghimire 2005, Kumargoud et al. 2006, Qi and Li 2010, Planning Commission 2002, World Bank 2010d) • Lack of flexibility in design (i.e. the requirement that the inlet, digester and outlet are all placed in one straight line, difficult for people who do not own enough land) (World Bank 2010e) • Issues with plant dimensions (World Bank 2010d) • Households tend to adopt larger plants than needed to ensure additional cooking capacity for guests and plantation workers (Bhat et al. 2001) • Need for design optimisation so that biogas can be stored in order to meet demand during peak hours (Ghimire 2005)
	Durability and specific designs requirements	• Durability (i.e. no corrosion), reliability and need for little post-installation maintenance results in initial preference for floating-dome designs despite greater cost (Bhat et al. 2001) • Following proof of workability, acceptance of cheaper fixed-dome design (Bhat et al. 2001) • Use of single, double or triple burners (with the latter being installed in bigger-sized digesters) (iDE 1011)	• Several technical failures (Ghimire 2005), including absence of moisture traps in gas lines leading to blockage (de Alwis 2002, Ghimire 2005, Kumargoud et al. 2006) and leakages (Jain 2009) • Size of inlet tank too small or too big (Ghimire 2005) • Poor conveyance system vulnerable to damage and vandalism (Ghimire 2005) • Frequent breakdown of brick biogas system (World Bank 2010e) or of the mixing device (World Bank 2010d), and cracks in dome and/or digester walls (de Alwis 2002, Dutta et al. 1997) • Poor-quality gas stoves with lack of primary air intake and damage to gas-regulating knob (Ghimere 2005) • Altitude and cold settings require special design adjustments at extra cost (Qi and Li 2010), such as thermal insulation (Jian 2009) and warm water feeding to maintain gas production during the winter (Bajgain and Shakya 2005)
	Safety issues	*Additional evidence:* To ensure safety and avoid gas leakages, regular inspections of the digester and pipes are needed (Jian 2009) and main gas valves of proven quality have to be installed and operated before and after the use of gas (Ghimire 2005)	
	Plant feeding and operational issues	• Use of materials other than human and animal dung, such as poultry droppings (Ghimire 2005, iDE 1011, World Bank 2010d) • Promotion of use of human waste to increase biogas production (Bajgain and Shakya 2005) • Water collection not considered a problem (e.g. hand pumps available) (Ghimire 2005)	• Underfed digesters due to non-availability of feeding materials (Christiaensen and Heltberg 2012, Jian 2009, Planning Commission 2002) fewer cattle (Ghimire 2005, World Bank 2010d), insufficient user awareness (Ghimire 2005) or shortage of manpower (Planning Commission 2002)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
			• Labour shortage in relation to managing the biogas system/livestock (Jian 2009) • Underfeeding more often identified in large plants (Dutta et al. 1997) • Incorrect proportions of dung and water (Kumargoud et al. 2006) with (i) tendency to increase volume of water (Dutta et al. 1997) [to compensate for lack of sufficient feeding material (Ghimire 2005)], or (ii) reduced quantity of water (de Alwis 2002, Sovacool and Drupady 2011) • Digester does not work properly unless slurry is regularly stirred (Jian 2009, Planning Commission 2002) • Failure to empty units after digestion period due to unwillingness as process is labour-intensive (Jian 2009) or due to lack of manpower (de Alwis 2002) • Use of unsuitable raw materials (e.g. garlic, onion) causes malfunctioning (de Alwis 2002, Jian 2009); straw and grass difficult to unload and results in blockage of digester unless pre-treated (Daxiong et al. 1990, Jian 2009) • Much manual labour invested in collecting water and feeding the plant (Ghimire 2005, Planning Commission 2002)
FINANCIAL, TAX AND SUBSIDY ASPECTS	**Plant cost and subsidies**	• Government subsidy as motivating factor for installing biogas plant (Ghimire 2005, Mwirigi et al. 2009, Planning Commission 2002); varies in size from 25% of costs (Planning Commission 2002) to approx. 35% of costs (Jian 2009) and 50% to >80% of costs (Mwirigi et al. 2009) • Different subsidy models: fixed subsidy irrespective of plant model or size (Planning Commission 2002) vs variable subsidy in relation to plant type (Mwirigi et al. 2009), plant size (Bhat et al 2001, Bajgain and Shakya 2005) and geographical location (Bhat et al. 2001)	• High initial cost (de Alwis 2002, Jian 2009, Kumargoud et al. 2006, Planning Commission 2002, World Bank 2010d) and lack of financial resources for installation (Christiaensen and Heltberg 2012) • Subsidy amount is not sufficient to cover installation costs and costs of building the latrine and pig-house (Jian 2009, Kumargoud et al. 2006) • High failure rates of larger plants due to higher subsidies as incentive for decision on plant size (Planning Commission 2002) • Removal of subsidies for initial outlay results in a falling off in construction of bio-digesters (Daxiong et al. 1990)
	Payment modalities	• Plants mainly constructed without loans (Ghimire 2005, Planning Commission 2002); loans from friends and relatives preferred to avoid interest rates (Ghimire 2005) • Easy access to credit from multiple agencies (i.e. co-operative	• Need for a loan to install the digester (Bajgain and Shakya 2005, Jian 2009) • Money pressure to repay loans in less time than the agreed monthly instalments (iDE 2011)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		credit and marketing societies, growers' societies, commercial banks) (Bhat et al. 2001) and regional development banks (Bajgain and Shakya 2005, de Alwis 2002) • Financial assistance provided to build the digester (Mwirigi et al. 2009) • Availability of loans to pay for the system (iDE 2011) or for purchasing of raw materials (Dutta et al. 1997) • Formation of village-level institutions (e.g. self-help groups) that provide credit to members (Dutta et al. 1997)	• Households stopped paying monthly instalments due to lack of adequate after-sales support (World Bank 2010d) • No loans available to purchase cattle to increase biogas uptake (World Bank 2010d,e) • Bureaucracy in obtaining subsidy and delay in release of subsidy (Kumargoud et al. 2006) • Removal of subsidies leading to decrease in the construction of biogas digesters (Daxiong et al. 1990) • People who received grants do not feel they lose much if the system fails to operate properly (de Alwis 2002) • Some better-off homes attempt to manipulate data to qualify for subsidies and assistance (Sovacool and Drupady 2011)
	Programme subsidies	• Sufficient government programme financing towards staff support in implementing agency (Planning Commission 2002) • Financial incentives provided by government for each biogas plant commissioned (Bhat et al. 2001) • Additional central subsidy for linking plant with toilet (Planning Commission 2002) • Promotional activities and institutional support as part of a national biogas support programme for development of the biogas market (Bajgain and Shakya 2005) • National programme with subsidised provision of biogas digesters to smallholders, with simultaneous construction of an improved kitchen (Christiaensen and Heltberg 2012) • Availability of government subsidies provided directly to farmers or as a grant to collaborating NGOs (Ghimire 2005, iDE 2011, World Bank 2010d)	• Insufficient funding, in particular in relation to training, publicity and awareness (through regional biogas development and training centres) and fixed installation fees per plant (e.g. for so-called turnkey workers or rural energy technicians) (Planning Commission 2002) • Need for additional financial support from government (Jian 2009) • Combination of central subsidy and state-level subsidy towards socio-economically disadvantaged groups resulted in (i) adoption independent of sufficient cattle, (ii) no financial contribution from beneficiaries, and (iii) high rates of non-functionality (Planning Commission 2002)
MARKET DEVELOPMENT	**Demand creation**	• Marketing carried out by local company (Sovacool and Drupady 2011), service provider/mason or turnkey worker/rural energy technician (Planning Commission 2002, Ghimire 2005, Bajgain and Shakya 2005) • Companies investing more in personal contact or demonstrations of biogas plants/technology show better achievements (BSP and CEDA 1998) • Promotion through local government representatives participating in local demonstrations and workshops (World Bank 2010e) • Newspapers and media (World Bank 2010e); also radio as the	• Problems operating and maintaining the plant observed by non-users discourages uptake (Ghimire 2005, Jian 2009) • Generating publicity is a neglected area and centrally prepared advertising materials rarely reach the village level (Planning Commission 2002) • Very limited promotional strategies adopted by some biogas companies (BSP and CEDA 1998)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		most prominent source of information (BSP and CEDA 1998) • Combination of media, fair exhibitions, leaflets and intensive biogas campaigns in selected villages (Planning Commission 2002) • Encouragement by local NGOs (Ghimire 2005, Mwirigi et al. 2009, World Bank 2010e) or village-level motivators associated with them (Dutta et al. 1997) • Informal channels (e.g. relatives and friends) and seeing functional plants of neighbours (BSP and CEDA 1998, Ghimire 2005, World Bank 2010e)	
	Supply chains	• Plants mainly installed where basic infrastructure services already exist (Ghimire 2005), including village roads (Christiaensen and Heltberg 2012) • Supply aspects (including equipment, technical support and service) provided by partner organisation as part of an overall national programme (iDE 2011)	• Lack of road infrastructure in rural areas results in higher costs of installation and repair services (Bajgain and Shakya 2005, Jian 2009) • Incomplete construction of plants due to non-supply of construction material, labour and masons (Planning Commission 2002)
	Business and sales approach	• Prospective users able to select fibreglass or brick biogas units (Sovacool and Drupady 2011) • Type and size of plants selected based on advice from service providers (Ghimire 2005) or trained engineers (World Bank 2010e) • Possibility of purchasing livestock in shops (Sovacool and Drupady 2011) • Customer satisfaction due to accurate information on biogas potential and use (avoiding false expectations) (Bajgain and Shakya 2005) • Livelihood for entrepreneurs ensured by income generated through plant construction activity (Bhat et al. 2001)	• No market competition for repair (i.e. repair business is not profitable when there are only a few users in remote villages) (Jian 2009)
REGULATION, LEGISLATION AND STANDARDS	**Regulation, certification and standardisation**	• National design standards (Bajgain and Shakya 2005, Daxiong et al. 1990) • Standards for construction and operation of plants developed, including most appropriate construction materials (Daxiong et al. 1990) • Certification of biogas construction companies based on standards and obligation to provide after-sales service (Bajgain and Shakya 2005) • Focus on establishing quality control procedures and developing standards for biogas plants (World Bank 2010e)	• Some people install the systems to satisfy regulatory bodies as a solution to waste disposal, not aware that gas can be used as fuel source (de Alwis 2002)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
	Enforcement mechanisms	• Subsidy payments only for companies with certified programme quality standards; signed agreements between companies and Biogas Support Programme at the beginning of each fiscal year (Bajgain and Shakya 2005) • Enforcement through inspection visits (Bajgain and Shakya 2005, World Bank 2010e) and penalties for non-compliance with high-quality construction (Bajgain and Shakya 2005) • Strict quality control measures (World Bank 2010e)	• No verification of technical standards, which were set by service providers (Ghimire 2005)
PROGRAMMATIC AND POLICY MECHANISMS	**Construction and installation**	• Biogas system constructed by skilled local masons with good understanding of biogas plants (Bajgain and Shakya 2005, Daxiong et al 1990, Ghimire 2005) • Appliances (including gas stoves, gas lamps, gas vales, slurry mixer and water drains) produced by local manufacturers (Bajgain and Shakya 2005) • Biogas plants built by biogas service stations responsible for construction, selling, management and technical consultancy (Daxiong et al. 1990) • Biogas technician training conducted through regional training centres (Bajgain and Shakya 2005) • Systems placed on higher or raised ground to avoid floods during rainy season (Ghimire 2005) • Gas transmission: overhead method preferred (iDE 2011)	• Local masons lacking adequate training in constructing the system, resulting in poor-quality or non-functioning biogas digesters (iDE 2011, Planning Commission 2002, World Bank 2010e) • Insufficient number of training sessions and poor-quality training of masons, staff of implementing agencies and turnkey workers; poor attendance at training sessions due to low stipend rates for trainees (Planning Commission 2002) • Masons not using good-quality raw materials (World Bank 2010d) • Problems related to construction (e.g. broken foundation, broken digester wall, crack in dome, corroded gas holder) (Planning Commission 2002) • Incomplete plants due to unavailability of materials, mason not available or delay by implementing agency and shortage of funds (Planning Commission 2002) • Labour-intensive installation (Sovacool and Drupady 2011), in particular waxing of finished dome (Ghimire 2005) • Lack of technical staff during installation (Kumargoud et al. 2006) • Common defects in installation such as improper location of inlet pipe and inlet tank (Ghimire 2005) or the overall system (e.g. poor ground characteristics) (de Alwis 2002) • Underground placement of pipes, making monitoring and leak detection very difficult (World Bank 2010e) • Top filling of dome (often missing) as protection against vandalism and as a means of insulation during winter season (Ghimire 2005) • No slurry pit constructed, with slurry flowing out of displacement chamber into nearby water (Ghimire

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
			2005, iDE 2011) • Water trap not installed (Dutta et al. 1997) • Methane leakage from pipes (Dutta et al. 1997) or manhole cover due to improper seals (Jian 2009, Sovacool and Drupady 2011) • Poor quality appliances (clay stoves, lighting) leading to odour nuisance (de Alwis 2002)
	Institutional arrangements	• Biogas declared part of national energy development agenda (Chinese People's Congress 1997) (Jian 2009) • National targets and annual plans for installation of biogas systems (Bajgain and Shakya 2005; Planning Commission 2002) • Close institutional partnerships and co-ordination between stakeholders (Bajgain and Shakya 2005) including local government (World Bank 2010d) • Well-functioning dissemination network involving multiple agencies (Bhat et al. 2001) • Strengthening local capacity and collaboration with private sector (Bajgain and Shakya 2005) • Involvement of the private sector (iDE 2011, Sovacool and Drupdady 2011)	• Unrealistic targets and no effective mechanism to ensure their realisation (Planning Commission 2002) • Poor co-ordination between agencies involved (Planning Commission 2002) • No convergence with other rural development programmes (Planning Commission 2002) • Insufficient personnel (Planning Commission 2002) without clear job responsibilities (de Alwis 2002) • No identification of programme staff with programme, due to staff paucity, no exclusive assignment to biogas programme and frequent transfer of positions (Planning Commission 2002) • High drop-out rates among turnkey workers/rural energy technicians who organise/supervise full process due to (i) no engagement in programme, (ii) time-limited contractual arrangements, and (iii) frustrations with low job fee and partial retention of fee (Planning Commission 2002)
	Creation of competition	• Competition for client satisfaction among builders (Bajgain and Shakya 2005), encouraging (i) good construction, (ii) regular follow-up services and (iii) entrepreneurs offering help with procedural difficulties in obtaining subsidies (Bhat et al. 2001)	N/A
	Community involvement	N/A	N/A
	User training	• User training provided for minor repairs (Sovacool and Drupady 2011) • One-day group training to users provided by company as part of installation process (Bajgain and Shakya 2005) • User training on safe biogas operation and maintenance (Bajgain and Shakya 2005) • Additional training during annual maintenance visits (Bajgain and Shakya 2005)	• Technical training in biogas plant maintenance, operation and repair not provided (BSP and CEDA 1998, de Alwis 2002, World Bank 2010d) or insufficient (Bajgain and Shakya 2005, Christiaensen and Heltberg 2012, Ghimire 2005, iDE 2011, Jian 2009, Kumargoud et al. 2006, Planning Commission 2002) • Lack of knowledge about proper operation, maintenance and repair of biogas digesters (Ghimire

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
			2005, Jian 2009, Qi and Li 2010) • Increased user training does not necessarily result in a greater level of plant functionality (Planning Commission 2002) • Lack of training on how to use biogas slurry (Bajgain and Shakya 2005, Christiaensen and Heltberg 2012) • Problems related to system operation include: (i) failure to stir digester slurry (Jian 2009, Planning Commission 2002), (ii) empty units after digestion period (de Alwis 2002, Jian 2009), (iii) coverage of digester to continue biogas production on cold days (Jian 2009), (iv) regular inspection and cleaning of pipes, gas holder, burner and storage vessels (de Alwis 2002, Jian 2009, Kumargoud et al. 2006, Planning Commission 2002) • Need for annual maintenance work: cleaning to collect old slurry, repainting of steel parts and cleaning/repairing digestion compartment (Jian 2009, Planning Commission 2002)
	Post-acquisition support	• Systems found fully operational after several years (Bajgain and Shakya 2005, Bhat et al. 2001, Dutta et al. 1997) • Compulsory after-sales services, encompassing 3 service calls at no cost and free repair during 3-year period (Bajgain and Shakya 2005) • Service charge for after-sales services (Sovacool and Drupady 2011) • Quality control/post-construction services to ensure high performance through (i) free 6-month guarantee on plants and (ii) 3-year warranty for free follow-up services for repair and maintenance provided by entrepreneurs (Bhat et al. 2001) • Combination of free repair services during warranty period and repair services against payment after warranty period (Planning Commission 2002)	• Poor (Christiaensen and Heltberg 2012) or no (de Alwis 2002) follow-up services provided by installers • Lack of support to fix technical problems such as the breakdown of mixing device (World Bank 2010d), dome valve (Dutta et al. 1997), defects at the water trap, air adjuster and burners (Dutta et al. 1997) and damage to gas stove, including heavy corrosion (Ghimire 2005) • Quality of services offered by the partner organisations vary considerably (iDE 2011) • Repair services and trained technicians unavailable (de Alwis 2002, iDE 2011, Planning Commission 2002), insufficient (Ghimire 2005, World Bank 2010d) or of poor quality (Qi and Li 2010) • Lack of awareness about repair programme (Planning Commission 2002) • Repair services requiring payment are not accorded priority by households (Planning Commission 2002) • Distance to after-sales services (BSP and CEDA 1998); for example, few repair stations in area, requiring villagers to undertake expensive and time-consuming travel to obtain technical advice (Jian 2009)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
			• Uncertainties about post-warranty services (World Bank 2010d), no insurance available to cover risks (Jian 2009) • High cost of repair (Christiaensen and Heltberg 2012, Planning Commission 2002), entirely paid by biogas systems owners (Jian 2009)
	Monitoring and quality control	• Establishment of quality control procedures (Bajgain and Shakya 2005, World Bank 2010e) • Multilevel monitoring system, with local monitoring carried out by partner organisations reporting back to a steering committee (World Bank 2010e) • Programme-led monitoring scheme, with engineers employed in every district to monitor plants and provide troubleshooting services (World Bank 2010d) • Monitoring mechanism linked to channelling of subsidy (i.e. microfinance agencies support the monitoring, as households pay the instalments only if the plant is operating properly, necessitating service providers to provide continuous follow-up) (World Bank 2010d) • Masonry charges paid directly by plant owner to ensure quality of construction and installation (Dutta et al. 1997) • Inspection visits (Bajgain and Shakya 2005, World Bank 2010e)	• Obligations to inspect plants and issue certificate for subsidy release at block/village level, district level and state level not met due to (i) lack of staff and (ii) restricted movement due to inadequately low fixed fee (Planning Commission 2002)
EQUITY CONSIDERATIONS	**Poverty**	• State-level subsidies in addition to central subsidies for socio-economically disadvantaged groups (Planning Commission 2002) • Loan and subsidy programme on installation costs initially used to support small- and medium-scale rural farmers, subsequently adjusted to favour the poorest farmers (Bajgain and Shakya 2005)	• Poverty is a barrier to adoption where cheaper fuels are available (Jian 2009) • Biogas users tend to belong to upper- and middle-income groups who have sufficient land and livestock (Christiaensen and Heltberg, 2012, iDE 2011, Jian 2009), and who are unable to afford LPG or electricity (Sovacool and Drupady, 2011) • Combination of central subsidy and state-level subsidy for socio-economically disadvantaged groups resulted in (i) adoption independent of sufficient cattle, (ii) no financial contribution from beneficiaries, and (iii) high rates of non-functionality (especially among lower castes) (Planning Commission 2002) • Biogas technology perceived as technology for deprived people; those who use it see it as second-grade option (de Alwis 2002)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
	Gender	• Final decision to install biogas plant taken after family discussions (Ghimire 2005) • Women carry out many biogas-related activities, and report considerable time savings (Ghimire 2005) • Benefits of biogas technology often valued differently by men and women in the same family (e.g. monetary savings, faster cooking and timely meals valued more by men; cleanliness valued more by women) (Dutta et al. 19997) • NGOs involved in the Indian biogas programme had women staff employed as fieldworkers/motivators (Dutta et al. 1997) Similarly in Bangladesh, user training had a focus on women, as local women could play the role of motivators and also be engaged as biogas masons (World Bank 2010e)	• Men are the primary decision-makers in relation to biogas plants (Dutta et al. 1997, Ghimire 2005) • Disapproval of the system by the male elder of the family (Kumargoud et al. 2006)
	Urban/rural location	• Biogas adoption is positively associated with village road infrastructure (Christiaensen and Heltberg 2012) • Higher subsidies for forest and hilly areas to encourage forest conservation (Bhat et al. 2001)	• Rural areas struggle to get technical support (Jian 2009) and experience increase in fees due to delivery costs (Bajgain and Shakya 2005) • Repair business is not profitable when there are only a few users in remote villages (Jian 2009) • Lack of roads and rugged terrain lead to higher costs for installation of biogas systems (Bajgain and Shakya 2005) • Sourcing spare parts in rural areas is difficult and costly (de Alwis 2002) • Distance to after-sales services (BSP and CEDA 1998), for example, few repair stations in the area, requiring villagers to undertake expensive and time-consuming travel to obtain technical advice (Jian 2009)

Appendix 4.4: Synthesis table for solar cookers

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
HOUSEHOLD AND SETTING CHARACTERISTICS	**Socio-economic aspects**	• Household with higher income (Wentzel and Pouris 2007)	• Poor people unable to afford the cooker (Ahmad 2001, Baptista et al. 2003, Otte 2009, Sesan 2012)
	Demographics	N/A	N/A
	House ownership and structure	• Convenience for urban users living in detached houses or on top floors of apartment buildings where the cooker can be easily stored (Ahmad 2001).	• No access to an appropriate place for cooking in urban settings for many people. Roofs often used, but these are usually shared spaces so they are not secure. (Ahmad 2001). • Need to carry the solar cooker out to the roof and back to home on a daily base (Ahmad 2001) • Lack of a storage area in the home for the cooker (Otte 2009, Wentzel and Pouris 2007) • Lack of a sunny yard area (Wentzel and Pouris 2007)
	Multiple fuel and stove use	• Households used to fuel mixing; solar stoves beneficial in reducing consumption of other fuels (e.g. gas, paraffin and wood) (Biermann et al. 1999/Sejake 1998) • Likelihood of greater rate of adoption in places where: (i) wood is a scarce resource (Velasco 2008, Wentzel and Pouris 2007), (ii) women face high risk while collecting wood (Velasco 2008), and (iii) commercial fuels are scarce and expensive (Otte 2009, Wentzel and Pouris 2007)	• Fuelwood gathered for free (Baptista et al. 2003) • Availability of other cheaper improved stoves (e.g. jikos) (Baptista et al. 2003) • Familiarity with traditional stoves and fuels (Sesan 2012)
	Settings/ climate	• Favourable climatic conditions (sun shines 270 days per year) (Ahmad 2001) and areas exposed to high solar irradiation (Biermann et al. 1999/Sejake 1998)	• Dependence on weather conditions reported as a major pitfall, with problems when cloudy/raining, and in dusty conditions (Otte 2009, Toonen 2009, Wentzel and Pouris 2007). Also wind reduces the ability to cook (Levine and Beltramo 2011)
		Additional evidence: Solar cookers used during the hottest hours of the day (10am to 3pm); not possible to cook in the evenings and in the early morning (Biermann et al. 1999/Sejake 1998)	
KNOWLEDGE AND PERCEPTIONS	**Smoke, health and safety**	• Women report having better health since they have been using a solar cooker (as a consequence of no smoke production) (Otte 2009) • Use of the solar cooker means women can avoid standing for long periods (Ahmad 2001) • Children given more responsibility for cooking (as handling a solar cooker presents no dangers	• Reflection from the cooker can be painful on the eyes (Otte 2009)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		compared to traditional open fire) (Sejake 1998)	
		Additional evidence[32]: • No statistically significant difference on self-reported health data between the treatment and control group (Levine and Beltramo 2011) • No CO reduction in intervention groups using solar cookers (but study reports that households were also using fire and traditional stoves to meet needs), so this finding remains unclear (Levine and Beltramo 2011)	
	Total perceived benefit/ willingness to pay	• Most women participating in the study said the stoves met their needs well (Levine and Beltramo 2011) • Lack of availability (Sejake 1998, Velasco 2008) or the high price of firewood (or coal or other fuels) can facilitate the use of solar cooking (Baptista et al. 2003, Otte 2009)	• Many potential solar cooker owners do not see the logic in owning 2 cooking devices when one device like a jiko can work all the time (Baptista et al. 2003) • In many locations, free firewood or charcoal are easily available and easier to use than solar cooking (Baptista et al. 2003)
	Social influence	• Positive impact on social networks as (i) women have more time to spend with neighbours and (ii) the cooker can be loaned to neighbours when they ask for it (Sejake 1998) • Money saved thanks to the use of the cooker can be used to buy and offer more food to the community during communitarian weekly meals (generally on Sunday) (Sejake 1998)	• Inability to cook for a large number of adult males reported as a reason for poor usage by 19% of study participants (Levine and Beltramo 2011) • Meat must be chopped into small pieces for cooking but larger pieces of meat are preferred by Kenyans, and families can be seen as inhospitable by not offering the larger chunks of meat to their guests (Baptista et al. 2003) • If a meal does not provide enough food to satisfy everyone and still have leftovers, it is seen as an embarrassment to the family. Since many solar cookers only hold a limited quantity of food, this can be an issue (Baptista et al. 2003)
	Traditional and culture	• Solar cooking is well known and the idea of cooking by solar energy is culturally accepted (Ahmad 2001) • Good results in cooking with solar energy including cooking traditional dishes (Ahmad 2001, Biermann et al./Sejake 1998 1999, Otte 2009) • Very good for cooking dishes that require slow cooking (Sejake 1998, Velasco 2008) and for preparation of ghee because of the advantage of low temperature heating of milk/cream (Ahmad 2001) • Generally, families are happy with the taste	• Some daily food cannot be cooked in a solar cooker (i.e. chapatti, bakri, tortillas, etc.) which have to be prepared by conventional cooking (Ahmad 2001, Velasco 2008) • Changes the taste of food, including lack of smoky taste (Baptista et al. 2003) • If one family member participating in the study was unhappy with the taste of food, the solar cooker was not used (Ahmad 2001) • Use of solar cookers requires a drastic behaviour change (Baptista et al. 2003) and change to daily routine: (i) need to start cooking early, and (ii) plan ahead (Ahmad 2001). • Optimal cooking time ends at 4p.m. with a solar cooker;

[32] *Additional evidence* refers to the evidence that is not reported as either enabling or limiting uptake clearly.

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		(Toonen 2009), colour and texture of the food (Ahmad 2001) and also taste of food reported to be improved (Otte 2009) • Suitable for cooking lunch, and also supper if the meal is prepared early and left in the cooker to keep it warm (Sejake 1998) • Used for boiling water on a routine basis, for washing up purposes or for preparing tea (Biermann et al. 1999/Sejake 1998) • Used for ironing: metal iron placed over the cooker to heat up rather than placing it in an open fire (Sejake 1998)	keeping food warm until dinnertime late in the evening can be an issue (Baptista et al. 2003) • Cooker not considered a focal point for family gathering (Velasco 2008) • Some Kenyans believe food cooked in the sun must be a result of 'black magic' or that if food is left outside without a sentinel, an enemy may pass by and give it the 'evil eye' (Baptista et al. 2003) • Kenyans used to cooking in enclosed spaces rather than in an open area (Sesan 2012)
FUEL AND TECHNOLOGY CHARACTERISTICS	**Savings**	• Time saving due to less wood collection (Biermann et al. 1999/Sejake 1998, Wentzel and Pouris 2007) • Time saved as no need to continuously stir and watch the food (Baptista et al. 2003, Otte 2009, Sejake 1998, Toonen 2009, Wentzel and Pouris 2007) • Time gained is mainly used for income generating activities and domestic work (Otte 2009) • Saving of alternative primary fuel (mainly wood) (Toonen 2009) experienced by smaller households (Levine and Beltramo 2011) • Money saving due to a reduced need to purchase biomass fuels (Biermann et al. 1999/Sejake 1998, Otte 2009) • Savings in fuel costs leading to greatest use of the solar cooker in areas where savings on commercial fuels is highest (Wentzel and Pouris 2007)	• Duration of cooking is longer than with other cooking methods (Ahmad 2001, Baptista et al. 2003, Levine and Beltramo 2011, Otte 2009, Toonen 2009) • Time can be saved as cooker does not require full attendance but it does need to have its position adjusted once or twice which requires a presence in the home (Ahmad 2001); needs to be adjusted every 30 minutes or so but (Toonen 2009), in Kenya there are concerns about theft and food contamination, which mean that many Kenyan's watch over their passive solar ovens, preventing activities away from it (Baptista et al. 2003) • Lack of properly painted black pots (usually sold together with the solar cooker) discouraging use as cooking takes a lot longer with normal un-blackened pots; this was reported as a main reason for not using solar cookers by 11% of non-users (Wentzel and Pouris 2007)
		Additional evidence: No difference reported in fuel use (and weights) and time spent gathering – could be due to poor usage (19%) (Levine and Beltramo 2011)	
	Design and performance	• Different designs suited to different sized families. In this instance small families preferred the REM5, and large families the SK12 (Biermann et al. 1999/Sejake 1998). • Operation and maintenance of box cookers are not considered a problem for most people (Ahmad 2001) • Cooker can be converted into a warming-box when a blanket is placed on the top (Sejake 1998)	• Large household size (more than 6 people) exceeds solar cooker cooking capacity (Levine and Beltramo 2011, Wentzel and Pouris 2007) although it could be possible to use 2 solar cookers (Toonen 2009) • Heavy and bulky solar cooker, difficult to handle by women and carried out to the roof top on a routine basis (Ahmad 2001) • Occupies a large space for storage (Otte 2009) • Not possible to regulate the heat (Ahmad 2001)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
			• Technical precision requirements for cooking (i.e. specific angle at which the reflective surface of the CooKit must be tilted to optimise the sun's rays) (Toonen 2009). This requirement was found particularly difficult by older women, who perceived solar cookers to be suitable only for younger women (Sesan 2012) • Differences in thermal performance noted between cookers resulting in longer or shorter cooking times (Biermann et al. 1999/Sejake 1998)
FINANCIAL, TAX AND SUBSIDY ASPECTS	**Stove cost and subsidies**	• Government subsidies available (up to 50% subsidies given by Gujarat state) to promote box type solar cooker (Ahmad 2001) • Where cookers become too old, users can buy new ones at a subsidised price (Ahmad 2001) • CooKit sold at an affordable cost (i.e. lower than the money spent on firewood) (Toonen 2009)	• Affordability is a major issue. The high price, even where there is an option to pay in instalments is a major disincentive (Otte 2009). Similarly, a significant portion of the rural Kenyan population is so poor that they cannot afford even the cheapest cookers without large subsidies (Baptista et al. 2003) • High stove cost (Sesan 2012)
	Payment modalities	• Payments in instalments (Otte 2009) • Microcredit through local co-operation is offered to promote solar cookers (Baptista et al. 2003) • Various households purchased the solar cooker at the end of study period through fuel savings from cooker use (Biermann et al. 1999/Sejake 1998)	• A small number of intervention group dropped out as they could not meet initial payment for the subsidised cooker (Levine and Beltramo 2011)
	Programme subsidies	N/A	N/A
MARKET DEVELOPMENT	**Demand creation**	• Media advertisements including newspaper (Ahmad 2001) and the radio (Otte 2009) • Workshops organised to show women how to use the cookers and how to make handicrafts (Otte 2009) • One project promoted the cookers as part of a business enterprise for dyeing wools to be used for handicraft production and this was quite successful (Otte 2009) • Steadily rising prices of conventional energy sources for cooking over the life of the solar cooker programme (Ahmad 2001)	• People within the village know each other, so if one villager reports a negative story about the use of solar cookers, other villagers will be influenced (Otte 2009) • Having a market restricted to NGOs donating solar cookers disrupts market-based strategies and could stagnate the promotion and acceptance of the product (as users do not invest in the product and are less incentivised to reap its benefits) (Baptista et al. 2003) • Poor appearance and poor packaging discourage users from purchasing as cookers are not perceived as high-quality products in which they should invest their money (Wentzel and Pouris 2007)
	Supply chains, infrastructure	• Local production of cookers has contributed to project sustainability (Otte 2009) • Availability of box solar cookers that are locally	• Lack of supply parts (Baptista et al. 2003) • Expensive importation costs, taxes and shipping costs (Baptista et al. 2003)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		manufactured (Ahmad 2001)	• High costs associated with material prices, distribution and transport (Wentzel and Pouris 2007)
	Business and sales approach	• Solar cookers are sold in sales outlets at fixed prices, promoted by local manufacturer or state energy agency (Ahmad 2001)	• Solar cookers very expensive because of low demand (Wentzel and Pouris 2007) • Purchase seems like a risky investment, discouraging stores that sell other types of cooking stove to stock solar cookers (Wentzel and Pouris 2007)
REGULATION, LEGISLATION AND STANDARDS	**Regulation and legislation**	N/A	N/A
	Enforcement	N/A	N/A
PROGRAMMATIC AND POLICY MECHANISMS	**Institutional arrangements**	• Proposed establishment of a consortium of organisations working together for market development of passive solar ovens (Baptista et al. 2003) • The initial focus of a dissemination campaign should be on (i) reducing product costs and (ii) structuring financial incentives for the manufacture of solar cookers, and also distribution and training (Baptista et al. 2003)	• The Ministry of Energy's focus on promoting jiko stoves and apathy in investing resources in promoting passive solar ovens will limit the dissemination of solar cooking in Kenya (Baptista et al. 2003) • Programme developers have not attended to the factors or aspects that are important to users. Thus there has often been a missing link in the development processes of solar cooking projects (Ahmad 2001) • Lack of institutional support (Biermann et al. 1999)
	User training	• User training to adjust to practicalities of solar cooking, e.g. planning in advance, etc., is crucial for success (Toonen 2009, Wentzel and Pouris 2007). • Cookers come with an instruction manual written in local language (Ahmad 2001)	• Inadequate training for users (Baptista et al. 2003) • Provision of training considered costly (Baptista et al. 2003)
	Post-acquisition support	• The programme provides advice which can be accessed either by calling into the office or by telephone (Ahmad 2001) • People appointed as 'monitors' in order to provide technical support to families involved in the project across study areas (Biermann et al. 1999)	• Lack of follow-up (Baptista et al. 2003)
	Monitoring and quality control	• Systematic monitoring needed for effective promotion of solar cooking device (Baptista et al. 2003)	N/A
EQUITY CONSIDERATIONS	**Poverty**	• Promotion of the cookers as part of a business enterprise for dyeing wools to be used for handicraft production (Otte 2009)	• More people would like to have participated in the project but could not afford the cooker (Otte 2009) • The project did not reach the poorest sector (Ahmad 2001) • A significant portion of the rural Kenyan population is so

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
			poor that they cannot afford even the cheapest cookers without large subsidies (Baptista et al. 2003, Sesan 2012)
	Gender	• Free time, as no need for wood collection, has a positive impact on social networks (Sejake 1998). • More resources can be shared between households and women may take advantage of lending their solar cookers to their neighbours in order to obtain other favours in exchange (Sejake 1998) • Monetary saving from cooking with solar energy used to buy more food for the sunday dishing club, reinforcing social networks (Sejake 1998) • Husbands and teenage sons have more responsibility for wood collection as the resource has become scarcer and more physically demanding. Thus, a reduction in wood collection frees men's time too, allowing more involvement of men in the community (Biermann et al. 1999/Sejake 1998)	• Most men in Kenya do not place a high priority on the time that their wives spend collecting fuel, limiting the value and benefits of cooking with a solar cooker (Baptista et al. 2003) • Dinner that is not hot and ready to be served to the man of the house when he wants it may lead to domestic abuse in some families (Baptista et al 2003)
	Urban/rural location	• Greater rate of adoption in places where wood is a scarce resource (Velasco 2008, Wentzel and Pouris 2007), or where women face high risk while collecting the wood fuel (Velasco 2008), and also where commercial fuels are scarce and expensive (Wentzel and Pouris 2007)	• Fuelwood gathered for free (Baptista et al. 2003) • People do not have appropriate places for cooking in urban settings and use their roofs for cooking. This implies carrying out and bringing back the cooker every day, which is physically demanding for women (Ahmad 2001)

Appendix 4.5: Synthesis table for alcohol fuels

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
HOUSEHOLD AND SETTING CHARACTERISTICS	**Socio-economic aspects/income**	• Ethanol market expected to target middle-income households already making use of LPG (Practical Action Consulting 2010)	• Low-income households unable to afford fuel refilling costs once the free trial period has expired (Couto 2007)
	Household characteristics	*Additional evidence*[33]: Most of the participants use ethanol/methanol stove as main stove a few weeks after initial adoption (Couto 2007, Murren 2006, Obueh 2008, Practical Action 2011)	
		• LPG is considered unsafe and the 13 kg canister is expensive to buy, which may favour ethanol adoption (Couto 2007)	• High use of secondary stove (Practical Action Consulting 2011), (i) because of running out of ethanol (Murren 2006), or (ii) for performing additional cooking tasks (Couto 2007, Murren 2006)
	Setting	N/A	N/A
KNOWLEDGE AND PERCEPTIONS	**Smoke, health and safety**	• Significant reduction in headaches, eye irritation and burns among women and children (Practical Action Consulting 2011) • Smoke reduction (Murren 2006, Practical Action Consulting 2011) • Ethanol considered a safe/very safe cooking fuel (safer than kerosene (Murren 2006) or LPG (Couto 2007, Obueh 2008) • No accidents (in the form of injuries, burns or explosions) reported over the 3-month study period (Obueh 2008) • No risks for children reported (Couto 2007) • Frequent explosions with kerosene stoves encourages households to prefer methanol stoves (Obueh 2008)	• Some safety concerns due to fear of fire (Practical Action Consulting 2011) • Customer complaints of safety issues caused by lack of adherence to stove production guidelines and specification (Imam 2011)
	Home improvement and cleanliness	• Cleaner kitchen (Practical Action Consulting 2011) • Overall cleanliness and perceived environmental benefits (with CleanCook stove rated as the cleanest among the different stoves tested) (Practical Action Consulting 2010) • Improvement of indoor air quality (Obueh 2008)	N/A
	Total perceived benefit/willingness	• High adoption rates. Stove easy to use (Practical Action 2011)	N/A

[33] *Additional evidence* refers to the evidence that is not reported as either enabling or limiting uptake clearly.

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
	to pay	• Convenience for cooking: satisfaction with the new methanol-fueled stoves (97%) (Obueh 2008); high efficiency and performance (93%), considered more efficient than other traditional stoves by 64% of responders (Obueh 2008), as fast as LPG for cooking (Couto 2007) • Ethanol considered a high-quality fuel (98%) and better quality than kerosene (95%) (Murren 2006) • Willingness to pay for ethanol is affected by: (i) free fuelwood gathering or fuelwood purchasing, (ii) money availability at the end of the month (for families living on a fixed income) (Couto 2007)	
		Additional evidence: Blackened pot bottoms difficult to clean. This is likely to be due to denaturants added to ethanol sold at pumps (usually a small amount of kerosene or gasoline) to render ethanol unsuitable for making beverage spirits (Couto 2007)	
	Traditional and culture	N/A	• Cannot cook all foods (Practical Action Consulting 2011) • Food cooked with ethanol has not the same taste as food cooked with woodstoves (Couto 2007)
FUEL AND TECHNOLOGY CHARACTERISTICS	**Savings**	• Speed of cooking reported as the main advantage of the CleanCook stove) (Practical Action Consulting 2010) • Ability to do other tasks while cooking (Murren 2006) • Time savings calculated to be an average of 1.8 hours per day (Practical Action 2011) and participants quotes report time saving of 3 hours (Murren 2006) • No need to buy fuels as bio-ethanol can be produced at household level (e.g. if possessing a coconut plantation) (Imam 2011) • Ethanol has longer-lasting cooking power (hours/litre) compared to kerosene (Imam 2011)	• Households participating in the pilot study were allotted 5 litres of alcohol fuel per week, which was not sufficient for meeting cooking needs, especially for larger families (Murren 2006, Obueh 2008)
	Design and performance	• CleanCook stoves considered very efficient (Murren 2006) and do not require any pre-heating time (Practical Action Consulting 2010) • Adjustable cooking speed (Murren 2006) • Fuel canister from which alcohol fuel is absorbed onto a refractory mass, which prevents leakage or spillage (Obueh 2008) • Suggestions for stove improvement include: (i) more burners (Couto 2007, Practical Action 2011), (ii) increase	• Negative features: (i) not all pots fit on burners, and (ii) difficult to light (Couto 2007) • Bad smell (Practical Action Consulting 2010) • Wasted fuel when refilling the CleanCook canister (Practical Action Consulting 2010) • Proimpex and ISPM stoves need to warm up before placing the pot on the stove (Practical Action Consulting 2010) • Safety concerns reported when the regulator and the

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		in burner size (Practical Action 2011), (iii) secure pot supports for smaller pots/larger pots (Couto 2007, Obueh 2008), (iv) additional oven (Couto 2007), (v) stove built into a stand/table (Couto 2007), and (vi) larger capacity canister (Obueh 2008) • No reported risk of explosion due to fuel leakage or stove malfunction (Couto 2007) • Fuel not pressurised, eliminating the danger of explosion (Obueh 2008)	fuel container are made of plastic (Practical Action Consulting 2010)
FINANCIAL, TAX AND SUBSIDY ASPECTS	**Stove and fuel costs**	• Locally manufactured stoves and lower fuel prices could facilitate adoption (Imam 2011, Practical Action Consulting 2010)	• Price of ethanol considered too high for some communities participating in the pilot study (especially for low-income households) (Couto 2007) • Upfront cost of the stove and the need for 95% pure ethanol (which may not be as easy to produce in the current local distilleries) (Practical Action Consulting 2010)
	Programme subsidies	• Abolishment of kerosene subsidies by the Indonesian government provided as key reason for starting the ethanol business (Imam 2011) • Availability of commercial loans from local banks in order to set up a production business for small companies (Imam 2011) • Need to get subsidies to cover the costs that the company provides to community groups (Imam 2011)	N/A
MARKET DEVELOPMENT	**Demand creation**	• Ethanol stove marketed to local communities through participatory mechanisms (Imam 2011) • Partnership with local distributors to increase market penetration (Imam 2011) • Demand for alcohol fuel increased after use of the new stove during the pilot, irrespective of fuel price increments (Obueh 2008)	• Business company reports of not having been able to keep up with very high market demand for their locally produced Indonesian E-stoves (Imam 2011)
	Supply chains/ infrastructure	*Fuel supply and micro-distilleries* • Need for nearby ethanol suppliers (i.e. pumps to be easily reachable by households members) (Couto 2007) • Possibility of buying ethanol in small amounts (per litre) is largely perceived to be advantageous (rather than buying LPG in 13 kg canister). Ethanol is therefore considered a valid alternative to LPG stoves (Couto 2007) • Micro-distilleries could keep ethanol costs down for	*Fuel supply and micro-distilleries* • Lack of low-cost ethanol supply. Large-scale ethanol companies have benefited from increase in global demand for ethanol as automobile fuel, but this has led to an increase in ethanol prices for locals (Couto 2007). Also, ethanol fuel shops closed and limited availability of fuel (Practical Action Consulting 2011) • Long distance between communities and nearest fuel supplier is a potential barrier (Couto 2007)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		more local purposes (Couto 2007) • Residual sugarcane bagasse can be used for cattle feed and additional residues can be used as fertilisers in the fields (Couto 2007)	• Delivery and suppliers not always consistent (Murren, 2006) • Micro-distilleries cannot sell ethanol as a domestic fuel in the national Brazilian open market (Couto 2007) • No infrastructure for methanol distribution. Some users showed dissatisfaction with methanol distributed in stove canisters. Many suggested using refillable plastic bottles rather than canisters (Obueh 2008)
		Stove manufacturing and stove supply • Need to develop a business plan around local manufacture for stove and fuel production prior to scale up (Obueh 2008) • Stove bodies can be manufactured locally thanks to metal availability (to reduce importation costs) (Couto 2007)	*Stove manufacturing and stove supply* • Lack of stove production facility: company relying on others partners and local workshops for cookstove production (Imam 2011) • Lack of access to raw materials and to raw-material processing facilities (i.e. coconuts) (Imam 2011)
	Business and sales approach	• Availability of basic infrastructure makes sales easier (Imam 2011) • Stove sold at a price comparable to kerosene stoves (Imam 2011) • LPG users could provide a potential market for ethanol, especially if its retail price falls and the price of traditional fuels rise (Practical Action Consulting 2010) • Possibility of buying ethanol per litre (rather than in bulk quantities) valued by users (Couto 2007)	• Production centre set-up costs and lack of access to financial services with low interest rates and minimum collateral (Imam 2011) • Stoves copied and sold off by other companies as the original product (Imam 2011) • Scaling back production to avoid accidents caused by possible product defects released on the market by imitators (Imam 2011)
REGULATION, LEGISLATION AND STANDARDS	**Regulation, certification, standardisation**	• State law that provides incentives to micro-distilleries (Couto 2007)	• Government regulation restricting the transportation and distribution of alcohol-based liquids, including ethanol (Imam 2011)
	Enforcement mechanisms	• Patented design for CleanCook used in pilot studies (Murren 2006, Obueh 2008, Practical Action Consulting 2011)	• Design not patented leading to risk of imitations. This exposes the business company to customers' complaints and possible legal issues caused by defective products sold by competitors (Imam 2011) • Low-quality locally manufactured stoves can raise safety issues (Practical Action Consulting 2010)
PROGRAMMATIC AND POLICY MECHANISMS	**Construction and installation**	N/A	• Lack of adherence to product guidelines (Imam 2011)
	Institutional arrangements	• Success of ethanol introduction is function of both the fuel and the stove, in terms of fuel issues of price, local	• Lack of own production facility to locally produce the ethanol E-stoves (Imam 2011)

Domain	Key themes	Findings on ENABLERS	Findings on BARRIERS
		availability (Couto 2007), quality, purchase volume options and bottle/tank options as well as ethanol specific requirements like denaturing (Practical Action Consulting 2010)	• Need to get permission from local government officials and local chiefs before start working with communities (Imam 2011)
	Users training	• Consumer acceptance is key to ethanol promotion and scaling up (Practical Action Consulting 2010) • Participants in the pilot study were highly trained on how to use, refill and clean their stoves and were visited on a daily basis for the first 2 weeks after stove distribution (Obueh 2008)	N/A
	Community involvement	• Training programmes on coconut processing and quality control were organised for the community (Imam 2011)	N/A
	Monitoring and quality control	N/A	• Difficulties experienced in maintaining quality and adhering to production guidelines and product specifications set by the company (Imam 2011)
EQUITY CONSIDERATIONS	**Poverty**	• Additional products (other than just ethanol) can be produced by distillation and generate income (Couto 2007) • Use of land for sugarcane to produce sugar and ethanol requires a strategic and large-scale investment to ensure high yields can be sustainably achieved (Practical Action Consulting 2010)	• Many users participating in pilot project expressed their willingness to pay per litre of ethanol. At the end of the pilot, however, only families able to afford to buy ethanol (which were not the poorest) continued to use it. Also, very few families reported being able to afford to pay for the CleanCook ethanol stove (Couto 2007)
	Gender	N/A	N/A
	Urban/rural location	• Micro-distilleries have the potential to increase family income in a rural population, encouraging farmers to not leave the countryside in search of job opportunities in the city (Couto 2007)	N/A

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