ASSESSING THE ENABLING ENVIRONMENTAL FACTORS FOR LARGE-SCALE LPG COOKSTOVE ADOPTION

Prepared for: The Global LPG Partnership

Prepared By: Jeannie McKinney

Master of Public Policy Candidate
The Sanford School of Public Policy
Duke University
Faculty Advisor: Subhrendu K. Pattanayak

Abstract

Approximately 2.8 billion people around the world still cook their meals and heat their homes with solid fuels. In addition to being inefficient, the use of solid fuels for cooking leads to high levels of pollution, deforestation, and severe environmental health concerns. Household air pollution is responsible for 4.3 million premature deaths annually, contributing 5% of the global disease burden and making indoor air pollution the most significant environmental risk factor in the world. Though clean, renewable energy is the optimal solution, liquid petroleum gas (LPG) cookstoves are currently being used as one significant option to transition away from solid fuel cooking systems. This paper systematically appraises large-scale LPG cookstove programs to determine (i) what common factors enable or limit adoption and sustained use of LPG in low- and middle-income countries, and (ii) what lessons can be learned concerning the policy implications for future programs.

This paper reports on a systematic review of published literature using established search engines to appraise large-scale LPG cookstove programs and initiatives. Data extraction of quantitative, qualitative, and case studies was conducted to determine commonalities in enabling environmental factors across programs. 10 studies from Africa, Asia, and South America met the inclusion criteria, and these were used to identify trends in enabling environmental conditions established for supporting LPG dissemination.

Factors such as financial mechanisms (e.g. equipment and fuel subsidies), market development (e.g. business involvement), regulations (e.g. government support), and other policy mechanisms (e.g. user training) were found to have helped enable LPG's widespread adoption and/or continued use. Although there does not appear to be one set of factors that guarantee LPG use, there appears to be evidence that government support, market development, and policy mechanisms are notably advantageous. Ultimately, despite limitations in the quantity of evidence, this systematic review provides a starting point for assessing the different kinds of support needed for planning and execution of programs to encourage more effective adoption and sustained use of LPG as a cooking fuel.

Introduction

In 2014, the World Health Organization (WHO) released a report estimating that approximately 2.8 billion people around the world still cook their meals and heat their homes with solid fuels. In addition to being inefficient, the use of solid fuels for cooking - defined as "wood, animal dung, charcoal, crop wastes and coal" - is highly polluting (WHO, 2014). For families residing in low and middle-income countries (LMICs), this lifestyle can result in deadly levels of pollution known as HAP, or household air pollution (Puzzolo et al, 2016).

Most significantly to the health and wellbeing of these LMICs, HAP includes harmful emissions of particulate matter, carbon monoxide, and nitrogen dioxide. In 2009 WHO estimated that HAP was responsible for 4.3 million premature deaths annually, contributing 5% of the global disease burden and making indoor air pollution the most significant environmental risk factor in the world (WHO, 2014). In particular, women and children under the age of 5 are disproportionately affected by the negative externalities of solid fuel burning (WHO, 2014). Inefficient biomass burning also adds to outdoor ambient air pollution and affects climate change by releasing methane, carbon monoxide, and black carbon into the atmosphere (Lewis & Pattanayak, 2012). Furthermore, the unsustainable harvesting of firewood has been reported to cause significant environmental degradation as well as disruption to forest ecosystems and biodiversity (Lucon et al, 2004).

In addition to air pollution and environmental effects, negative social impacts arise from the use of traditional cookstoves as well. The more time spent collecting fuel and cooking, the less time is left for women and children to focus on income-related activities (Brooks et al., 2016). The relatively low or no cost of biomass fuels also gives the perception that this cooking method costs less than any of the improved technologies, which require more upfront capital investment (Puzzolo et al, 2016).

Over the last 40 years many different types of stakeholders, from non-governmental organizations to national governments, have worked to spread the adoption of improved cookstove (ICS) technology in order to mitigate these negative externalities associated with solid fuel burning (WHO, 2014). Such programs and efforts can vary in scale from community to national-level projects. Many of these interventions have been focused on the use of ICSs to "reduce the amount of fuel required, fuel gathering time, and cooking time—all of which have the potential to improve health and increase household income" (Lewis & Pattanayak, 2012). However, the classification of ICS can encompass many different technologies and fuel types, and a differentiation between the benefits and costs of each must be recognized.

More specifically, most projects and programs in the past have focused on the adoption of improved biomass cookstoves. While these solid fuel systems are often more efficient than the traditional solid fuel cookstove, they have been shown to have variable but limited effects on HAP and do not often meet the WHO's Air Quality Guidelines (AQG). Laboratory emissions results do not seem to compare to real-world applications, and "despite often achieving reductions of 50% or more, mean post-intervention levels of $PM_{2.5}$ and CO have been found to be still considerably above the WHO-AQG levels" (Puzzolo et al, 2016). Though ICS do serve as a good transition option, WHO (2014) suggests that a movement away from biomass burning to cleaner fuel technologies is needed to significantly lower health and air pollution impacts.

Clean fuel cookstoves - such as those that run on biogas, solar, alcohol, electricity, and liquid petroleum gas (LPG) - have been found to have significantly lower emissions rates than

traditional cookstoves and most improved biomass stoves (WHO, 2014). Switching from dirty fossil fuels to these cleaner alternatives will help reduce exposure and risk of acute lower respiratory infections (ALRI) and other HAP-related health issues (Puzzolo et al, 2016). Furthermore, there are several "associated benefits in user costs, cleanliness, convenience, and environment" (Budya & Arofat, 2011) as well as local and global environmental benefits (Jeuland & Pattanayak, 2012). For these reasons, WHO recommends that agencies and stakeholders "work to increase access to, and sustained use of, clean fuels as widely and rapidly as is feasible" (2014).

While a direct transition to these cleaner technologies may be the most attractive option, researchers recognize that there are several barriers to overcome in order to develop a more clean stove-friendly enabling environment. For instance, cost is frequently seen as a barrier, and price has been found to be negatively associated with clean fuel adoption (Lewis & Pattanayak, 2012). Furthermore, though adoption of completely clean, emissions free fuels, i.e. solar technologies, would be most preferable, Puzzolo et al found that evidence suggests "poor coordination of manufacture and marketing has so far limited the adoption and use of low-cost, high-quality solar cookers" (2016).

Though a fossil fuel, LPG cookstoves are a cleaner alternative that might be able to bridge the gap between biomass and renewable fuel technologies (Jeuland & Pattanayak, 2012). The development of natural gas fields has grown significantly around the world in order to meet the increasing demand of gas for cooking and electricity. Consequently, LPG prices were halved between 2014 and 2015; with increased fracking, prices are expected to continue to drop (World LPG Association, 2015). However, although middle and high-income families rely on LPG in many countries, low-income households continue to have lower adoption rates (Jeuland & Pattanayak, 2012). Furthermore, the majority of the available research has taken place in household and community-level programs (Puzzolo et al, 2016). More research is needed to identify exactly what factors create an enabling environment for large-scale LPG cookstoves and encourage their adoption. As Puzzolo et al states, "a system-wide perspective is particularly important for [LPG], as [its] sustained use depends not only on initial stove acquisition and affordability for refills, but also on consistent and reliable fuel availability and accessibility" (2016).

Literature Review

A sizeable body of literature and research has accumulated around the implementation of improved cookstoves in developing countries. However, the majority of this research is comprised of individual case studies, focused on the adoption of interventions that 1) are smaller-scale, e.g. at the community level, and 2) run on solid fuel sources, e.g. biomass, instead of LPG or another clean source (Puzzolo et al, 2016).

Lewis and Pattanayak (2012) published one of the first systematic reviews in the environmental health and cookstove research field; they conducted a vote counting meta-analysis on 32 research studies to identify drivers of ICS adoption. Generally speaking, most researchers recognize that barriers to widespread ICS adoption persist and include access, income, price, and a lack of information (Jeuland et al, 2015). Government support and financing also appear to be critical for enabling adoption (Puzzolo et al, 2016).

There have been a few large-scale national programs that have worked to implement and support the transition to LPG cookstoves, from which researchers have tried to identify potential

enabling and disabling factors. For instance, in 2011 researchers Budya and Arofat evaluated a national project by Indonesia to convert cooking fuel from kerosene to LPG in over 50 million households. In their analysis, the authors noted that the asymmetric dissemination of information and a lack of proper marketing was a significant initial barrier for Indonesia. However, Budya and Arofat identified large initial capital, strong support and involved participation from prominent government officials, and direct coordination with people of power in the local communities as enabling environment factors that ultimately led to increased uptake (2011).

Similarly, in 2015 Kimemia and Annegarn used surveys to research the attempts of the South African government to institute a national LPG cookstove campaign. Though this was not an effort to lower HAP, this was a large-scale campaign to free up electricity that would prevent blackouts and that was therefore seen as a socio-economic endeavor households ultimately supported over the long-term. Barriers such as a lack of subsidies and support for businesses, as well as a lack of information about the safety of LPG, have kept the fuel's continued use from spreading more broadly (Kimemia & Annegarn, 2015).

However, while these studies have been successful at identifying a few potential factors to improve an LPG cookstove-enabling environment, in the above cases it appears that these communities already had the predisposition and policy setting that would allow for easier adoption. For instance, Budya and Arofat point out that Indonesia not only had a strong central government in the early 2000s, but they also only had one national oil company that controlled both the kerosene and LPG supply systems (2011). Similarly, the South African government was willing to support the switch to LPG, through systems like regulatory actions, to lower the strain on the electricity grid (Kimemia & Annegarn, 2015). As Jeuland et al (2015) points out, "choosing locations with strong enabling environments likely implies bias toward locations with a relatively high supply of similar quasi-public goods." In essence, applying and scaling up the findings from individual case studies at such supportive locations would not be an effective way to identify potential global factors.

According to findings from Lewis and Pattanayak's (2012) systematic review, it is easier to determine which factors are associated, not just correlated, with adoption of ICSs and clean fuels when synthesizing and analyzing data from several case studies. Through their review of the major types of ICSs, they found a few general trends. For example, Lewis and Pattanayak found an association between cleaner fuel adoption and socioeconomic status. Furthermore, as with both of the Budya and Arofat (2011) and the Kimemia and Annegarn (2015) studies, Lewis and Pattanayak also highlighted the importance of disseminating information. They found that "a positive influence of education and location suggests that strengthening the information and communication aspects of social marketing and extending the supply-chain into rural areas could increase adoption" (Lewis & Pattanayak, 2012).

My research ultimately takes its cues from a more recent study: Puzzolo et al published a systematic review in January 2016 that assessed 44 case studies using different types of clean fuel cookstove technologies.[1] A range of enabling and limiting factors were identified for four different types of interventions (biogas, solar, alcohol, and LPG) across household, community, and national levels. Conducted in 2013, this review was the first of its kind to use several mixed methods to "examine factors that enable or limit adoption and sustained use of clean fuel cooking

[1] This project is therefore a partnership between Duke University (represented by Jeannie McKinney, Hannah Girardeau, and Subhrendu Pattanayak) and the Global LPG Partnership (represented by Elisa Puzzolo).

options in LMIC" (Puzzolo et al, 2016). The researchers were able to identify that there were seven different categories of factors that were found to be important across case studies as enabling or inhibiting clean fuel cookstove adoption. Some were considered critical, including "the ability to meet cooking needs, being able to pay for the clean stove and fuel, having access to reliable and affordable fuel supply, and ensuring safe operations" (Puzzolo et al, 2016). Most interestingly, though, was the finding that these factors are all inter-related, and, because of the lack of quantitative and analyzable data, the researchers suggested further study in order to determine the magnitudes of each factor's impacts.

It should be noted that, because there were relatively few published studies for some of the clean fuels that Puzzolo et al were looking to review, the type of data gathered ultimately restricted opportunities for analysis (2016). Furthermore, the Puzzolo et al review was accomplished with studies published no later than 2012; already there is more to learn about clean fuel technology and ICS adoption in the last four years (2016). For instance, Brooks et al (2016) published a study from North India on the impact of clean fuel cookstoves on household's continued solid fuel use. The researchers discovered that ICS adoption led to consistent reductions in the amount of biomass fuel consumption, time spent cooking on traditional stoves, and time spent collecting biomass fuels. However, stove stacking often took place because households seemed to prefer different stoves for certain types of cooking; in terms of policy, this finding suggests that incentives like subsidies and education campaigns would not be sufficient factors to create an enabling environment that would convince households to use ICSs for all purposes (Lewis et al, 2015).

Policy Questions

(i) What common 'success criteria' or enabling conditions can be identified across country experiences in scaling-up LPG?

(ii) How do the identified enabling conditions operate in context and influence the success of large-scale LPG cookstove programs, measured in terms of adoption and sustained use?

Methods

The aim of my research is to examine the literature on opportunities and barriers facing liquid petroleum gas (LPG) cookstove adoption on a regional or national scale. Starting with the factors identified by previous reviews, I will focus specifically on the enabling environment for large-scale cookstove adoption and sustained use – namely financial policies (e.g., subsidies), market development (e.g., promotion and business strategies), regulatory standards (e.g., government support and legislation), and other policy mechanisms (e.g., program monitoring and user training).

In using the framework of Puzzolo et al (2016), I am defining adoption as "the initial technology acquisition and use for less than one year from acquisition." Sustained use will be considered long-term use, covering utilization of an LPG cookstove from one year and beyond. Of the studies included in this review, adoption was often used without any further definition (e.g. Denton, 2004; Edwards & Langpap, 2005; Heltberg, 2005). Other terms to discuss initial uptake

included “began using” (Andadari et al, 2014), “conversion” (Budya & Arofat, 2011), or “shift”, as in from one fuel to another (Andadari et al, 2014). In regards to the term sustained use, synonyms included “continue to use” LPG, “sustainability of the intervention,” or a version of “retain[ing]” the intervention or program (Kimemia & Annegarn, 2016; Mohlakoana & Annecke, 2009).

The research will aim to gain a wider understanding of these mechanisms and to assess how these factors interact to change the rate of adoption and penetration of LPG cookstoves. To do this, I used the following analytical methods. First, I conducted a systematic review of the literature and case analyses published in English since 1980. Studies were chosen using the set of exclusion and inclusion criteria described below. Second, I synthesized the data using the “best fit” framework synthesis method to examine the evidence in selected case studies. Finally, these findings are summarized in tables and accompanied by a narrative review of the findings and conclusions.

The limitations of my analysis by year and language are driven by time and feasibility constraints. My client, the Global LPG Partnership, and I have chosen 1980 as the starting point for case research because the number of people using solid fuel for cooking as remained relatively constant since then; approximately 2.8 billion people have used solid fuel sources for the last 36 years (WHO, 2014). In terms of language barriers, there may be an opportunity to widen this search to other languages in the future; however, this expansion was beyond my capabilities for the scope of this project.

Systematic Review

While the academic and scientific fields of clean fuel cookstoves have been growing in recent years, other research must be done before identified factors of an enabling environment for LPG cookstoves can be considered global or transferrable. In order to find potential barriers and enablers that might apply to LPG cookstove implementation on a more national or global scale, a systematic analysis of the current research might be helpful. According to Mallett et al (2012), systematic reviews “involve identifying, synthesizing and assessing all available evidence, quantitative and/or qualitative, in order to generate a robust, empirically derived answer to a focused research question.” Though already popular in the realms of public health and policy, as Mallett et al (2012) and Snilstveit, Oliverc, and Vojtkovain (2012) noted, systematic reviews are also being used more frequently in the context of international development. As Puzzolo et al note, there are qualitative, quantitative, and case studies that need to be assessed (2016). My client and I put together a data extraction form (Appendix A) to integrate these findings. For ease of use and comparison, this form was condensed into an Excel spreadsheet.

Inclusion Criteria

I focused my review specifically on literature and case studies that concentrated on large-scale LPG adoption. I gathered evidence using the following research components and methodology:

a. Key Search Terms

Intervention	Specification
LPG *"LP gas"* *"liquefied petroleum gas"*	*Cook** *Domestic* *Residential* *House** *Stove*

b. Databases and Sources for Searches

- **Publications/Multidisciplinary electronic databases & internet source**
  - Science Direct
  - Web of Science
  - SCOPUS (EMBASE)
  - Ovid (MEDLINE*)*
  - Social Science Research Network (SSRN)
  - Google Scholar

- **Grey literature and specialist search**
  - Global LPG Partnership
  - International Institute for Sustainable Development (IISD)
  - United Nations Development Programme (UNDP)
  - UK DFID
  - World Bank
  - World LP Gas Association

c. Other Requirements

The systematic review analyzed literature using the following criteria:

- **Type and scale of intervention:** Analyses in a large-scale, household setting; can include medium-scale regional or city interventions thru national-scale policy initiatives. Will assess smaller cases if represented as part of a larger program.

- **Type of intervention setting:** Interventions that take place in low- and middle-income countries, or resource-poor areas of other countries.

- **Type of studies:** Case studies, policy analyses, and quantitative studies that examine the influence of the "enabling environment" on the success of LPG programs only if (i) based on empirical evidence and (ii) include enough description of LPG financing, market context, regulations, policy and/or programmatic features.

- **Type of study outcomes:** Studies must measure and report on relevant outcomes, e.g., LPG cookstove adoption.

Exclusion Criteria

Studies and literature were excluded from this review if they did not meet the above inclusion criteria or meet one of the following:

- Do not focus on LPG in a household cooking environment at a city or national scale (e.g. autogas, LPG used in health facilities).

- Do not focus on national or regional LPG initiatives.

- Focus only on the impact of LPG use on indoor or outdoor air pollution.

- Studies superficially reporting on LPG experience from one or several countries, focusing only on demographic data or lacking in-depth analysis and description of the wider LPG national/regional context.

A full list of references for the 54 studies that were read and omitted during the eligibility stage, as well as a table of exclusion criteria, can be found in Appendix E.

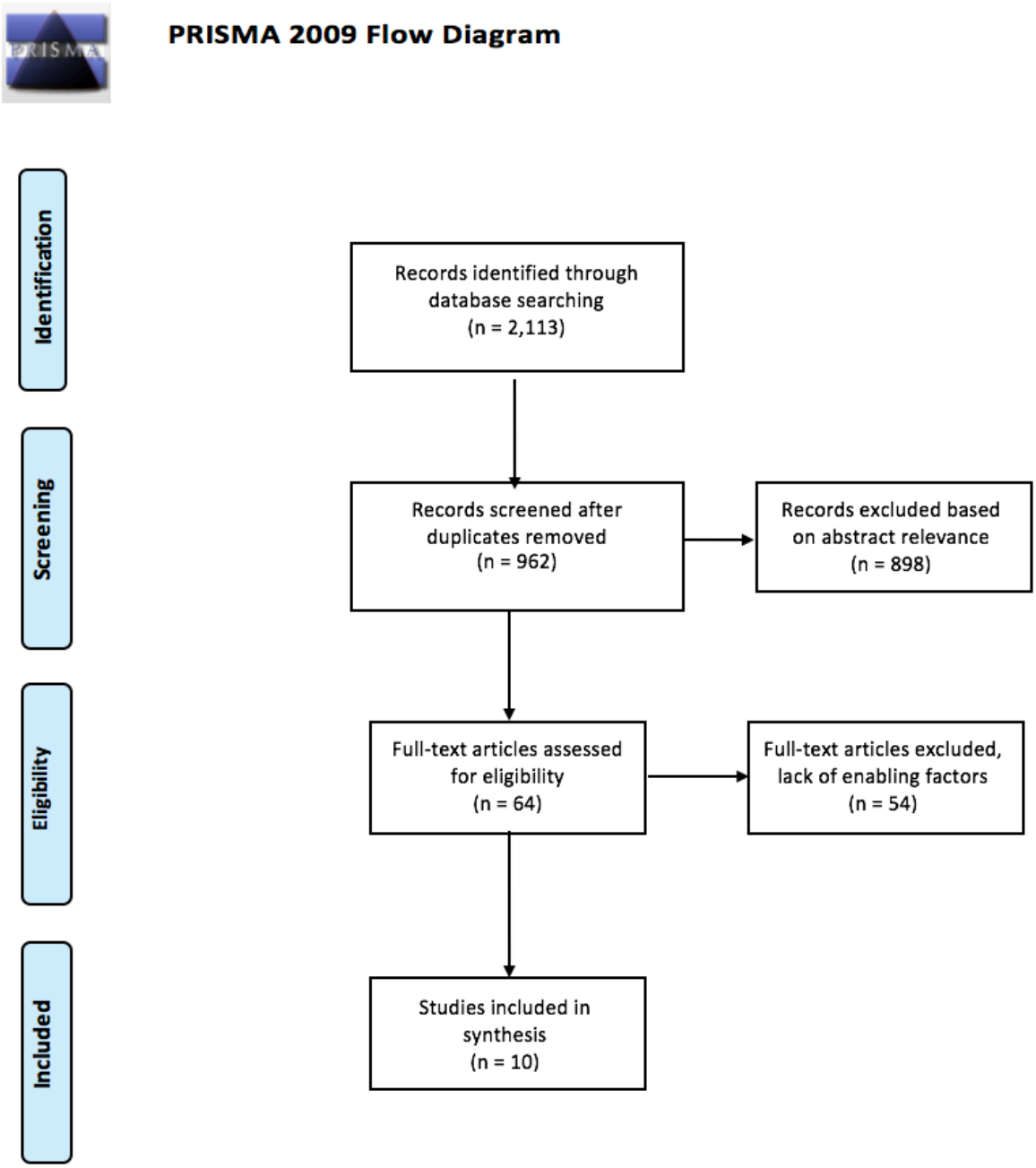
Quality Appraisal

In addition to meeting the above inclusion and exclusion criteria, studies and literature will also be subject to an assessment of risk for bias before the data is synthesized. Studies will be appraised using the Atkinson and Sampson (2002) criteria, as adapted by Puzzolo et al. (2014), for evaluating the quality of case studies (see Appendix C). A summary table of the results from this assessment can be found in Appendix D. Studies were scored on a continuous scale, receiving 1 point for meeting each assessment question; 0 points for "maybe" if a question was inapplicable or unclearly answered; and -1 points if an assessment question was not met. Out of 14 points total, studies were considered low quality if they received 0-4 points; medium quality if they received 5-9 points; and high quality if they received 10 or more points. Of the ones appraised in this review, all studies are either medium or high quality.

Data Extraction

I used the four-stage flow diagram as proposed by Moher et al (2009) for searching and eliminating studies. Known as PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis), this method defined the different stages of the systematic review process (Figure 1 following). I also used a data extraction form (Appendix A), as referenced earlier, for extracting data from each study.

Figure 1. Research Flow Chart



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit www.prisma-statement.org.

Findings

The exact detailed methodology and results can be found in Appendix B. After an initial scan of the multi-disciplinary electronic databases and grey literature, I did an additional quality control check through Google Scholar. Due to the difference in algorithm requirements between this search engine and the other scientific research databases, I used Google Scholar only to ensure that my database scan did not miss any of the top hits. To do this, I cross-referenced the top search results for pairs of key terms with my database search results. While my search in Google Scholar did find approximately 20 new citations, the search did not turn up any new studies that met this review's inclusion requirements. My research yielded a total 2,113 papers (Figure 1 above), of which only 10 met my criteria (Table 1 below). These studies utilized a combination of surveys and research to determine adoption and sustained use of LPG for cooking within five different countries: Brazil, Guatemala, Indonesia, Senegal, and South Africa.

Excluded studies represented a range of analysis from various countries. These include Bangladesh, Brazil, China, Ecuador, Fiji, Ghana, Guatemala, India, Indonesia, Mexico, Nigeria, Senegal, South Africa, and Thailand. While all of these countries have some interaction with LPG in the cooking realm, the studies themselves did not fit into this review for several reasons. India, for example, implemented a new strategy in recent years for LPG dissemination, and all of the studies identified were outdated (Kumar et al, 2016). Other studies focused only on air pollution reductions, instead of the enabling environment for adoption. A full list of references for the 54 studies that were read and omitted during the eligibility stage, as well as a table of exclusion criteria, can be found in Appendix E.

Table 1. Studies included in systematic review.

Reference	***Location***	***Study Type***
Andadari, R. K., et al. (2014)	Indonesia	Survey
Budya, H. and M. Y. Arofat (2011)	Indonesia	Case Study
Coelho, O. & Goldemberg, J. (2013)	Brazil	Policy Analysis
Denton, F. (2004)	Senegal	Policy Analysis
Edwards, J. & Langpap, C. (2005)	Guatemala	Quantitative
Fall, A., et al. (2008)	Senegal	Survey
Heltberg, R. (2005)	Guatemala	Quantitative
Kimemia, D. & Annegarn, H. (2016)	South Africa	Survey
Lucon, O., et al. (2004)	Brazil	Policy Analysis
Mohlakoana, N. & Annecke, W. (2009)	South Africa	Survey

Synthesizing Evidence and Analysis

While there are several different types of methods used to analyze evidence from a systematic review, I chose to use the "best fit" framework synthesis method. Carroll et al (2011) explains this methodology as an approach that is "augmentative and deductive (building on this existing model or framework), rather than grounded or inductive (starting with a completely blank sheet)". Such a best-fit approach built on the existing ideas in Lewis and Pattanayak (2012) and Puzzolo et al. (2016), rather than creating a new model. The domains already identified in these reports provide a relevant framework for understanding how mechanisms interact together to help create an enabling environment for the large-scale adoption of LPG cookstoves. The enabling environmental factors identified in the reviewed studies have been grouped using Puzzolo et al's delineation of financial policies, market development, regulatory standards, and other policy mechanisms.

Findings in Enabling Environment

Of the 2,113 papers that matched the initial key terms, only 10 met the inclusion and exclusion criteria and discussed in-depth various factors of an enabling environment. A factor was considered relevant to this review if the authors identified its relationship as having some sort of connection or influence on the adoption or sustained use of LPG. For example, the study might mention that a factor led to successful diffusion of LPG, or "successfully encouraged people to switch" from one cooking source to another (Andadari et al, 2014). In Budya & Arofat (2011), factors were referred to as "important institutional program aspects", "unique advantages", or "key factors". Denton (2004) identified a missing factor as a "major constraint". Factors were also often described as "necessary" to (Kimemia & Annegarn, 2016), "influencing" (Mohlakoana & Annecke, 2009), or "associated" with (Heltberg, 2005) LPG use.

The results are summarized in Table 2 below. Coincidentally there were two studies identified for each country. A checkmark was given for factors identified in each analysis, totaled out of the 10 studies presented in this paper. Of the factors considered, most frequently identified were 1) the existence of other energy fuel or business regulation, and 2) LPG infrastructure expansion as being present in 9 of the 10 studies. However, it is difficult to compare the size of the effect – or the strength of the impact – of each of these factors because of the lack of continuity between studies. For instance, only certain countries reported national numbers. While Mohlakoana and Annecke (2009) and Kimemia and Annegarn (2015) both reported on South Africa's national LPG program, the former focused on a part of Cape Town while the latter studied only the Atteridgeville Township. Below is a brief description of the LPG cookstove situation in each country, detailing particular differences.

Table 2. Common factors present during adoption and/or sustained use of LPG.

Domain	Factor	Brazil*		Guatemala		Indonesia		Senegal*		South Africa		Total
Financial Mechanisms	Equipment subsidy					✔	✔	✔	✔	✔	✔	6
	Fuel subsidy	✔	✔			✔	✔	✔	✔			6
	Retail/Program subsidy					✔	✔	✔	✔	✔	✔	6
Market Development	Business involvement	✔		✔		✔	✔	✔	✔			6
	LPG infrastructure expansion	✔	✔	✔	✔	✔	✔	✔		✔	✔	9
	Promotional efforts					✔	✔			✔	✔	4
Regulatory Standards	LPG regulation	✔				✔	✔					3
	Other energy fuel or business regulation	✔	✔	✔	✔	✔	✔	✔		✔	✔	9
	Government and/or utility involved in implementation	✔	✔			✔	✔	✔	✔	✔	✔	8
Other Policy Mechanisms	Monitoring and program adaptation						✔	✔			✔	3
	User training and education									✔		1
	Involvement of local community						✔			✔		2

*The fuel subsidy in Brazil was fully removed in 2002; in Senegal, all but 20% has been removed.

Brazil

LPG made its introduction into Brazil as a cooking fuel over 70 years ago. According to Lucon et al (2004) and Coelho & Goldemberg (2013), the government subsidized the fuel itself to regulate LPG final prices for consumers from 1950 until 2001. Over 90% of all Brazilian households used it as of 2000, though not necessarily as the sole cooking source, and the government was spending about US$100 million annually to support it. Standards were also set to regulate businesses in the distribution and supply of LPG refills (Lucon et al, 2004). Consumption decreased in 2002 as an immediate response to the subsidy removal, and wood fuel consumption started to rise. The government committed heavily to the electrification of the country as well, though rural areas still depended on other fuel sources over electricity. However, due to rapid urbanization, economic growth, and anti-deforestation movements, from 2006 to 2010 LPG use for cooking began to rise again (Coelho & Goldemberg, 2013). A law passed in 2002 created a program for gas assistance to transfer subsidies for residential LPG to low-income families, an allotment of R$15 every two months (Lucon et al, 2004). This value has not changed with the price increase and volatility over the years, however, and so this resurgence in LPG consumption was mostly seen in upper income classes as the fuel subsidy removal left low-income families at a disadvantage (Coelho & Goldemberg, 2013).

Indonesia

Indonesia began a project in 2007 to convert 50 million households to use LPG instead of kerosene as their primary cooking fuel. The program, run entirely by the only nationally-owned utility, Pertamina, disseminated a free start-up package consisting of one LPG cylinder, a one-burner stove, a hose, and a regulator. The government supported the program with regulations and

financial assistance to increase subsidized LPG use and decrease subsidized kerosene use. In short, they allowed Pertamina to implement operations through their own distribution system and network, and they granted more permits to manufacturers and retailers of LPG cylinders in order to increase access. Initially, Pertamina launched three test phases in order to determine best distribution practices, eventually settling on a method that allowed the sole national utility to manage everything from a country-level while working with local stakeholders for distribution (Andadari et al, 2014). Private investment accounted for almost 90% of the business surrounding LPG infrastructure growth. Pertamina similarly leveraged its pre-existing relationships with kerosene providers to encourage their transition into the LPG business and prevent significant problems. By the end of 2009, 42 million kits had been distributed across Java, Bali, and Sumatra (Budya & Arofat, 2011).

The fuel has been subsidized since the program's initiation. However, while 69% of those Budya & Arofat (2011) surveyed were still using their LPG cookstove as a primary cooking source, Andadari et al (2014) found in their study that only about 20% of households surveyed used LPG as their only cooking fuel. The rest of each household's cooking was supplemented with biomass fuel options. According to Andadari et al, this might be because Indonesia's program more greatly benefitted middle and high-income households in suburban areas than low-income households and rural areas. The LPG program did manage to distribute a high number of kits across the entire country for initial adoption. However, despite the fuel subsidy the infrastructure for fuel dissemination may still limit sustained use in the poorer, more rural areas (Andadari et al, 2014).

Senegal

From 1974 through the early 1990s, Senegal's government promoted the adoption of LPG by subsidizing LPG cooking equipment, fuel, and program distribution. Fall et al (2008) reports that a cooking stove with a 2.7 kg LPG cylinder was subsidized in 1974. In 1983 another cooking stove with a larger 6 kg LPG cylinder was supported when the program adjusted to accommodate input received from consumers (Fall et al,2008). Private investment grew, as the program encouraged businesses to expand production and infrastructure (Denton, 2004; Fall et al 2008). Policies that impacted the cost of wood-cutting and raised the sale price of coal had a positive impact on increasing LPG use (Denton, 2004). The Senegalese government also supported retailers by exempting all imported LPG equipment from duty taxes and by subsidizing the price of gas until 1998. However, infrastructure to setup refilling centers outside of urban areas and cities was still lacking compared to growth, and consumers in rural areas tended to pay more for LPG refills if they could gain access to it at all (Denton, 2004).

At the time of the subsidy withdrawal, over 85% of Senegalese households were cooking with LPG. According to Fall et al (2008), the "progressive withdrawal of the government subsidies on LPG and [the] unpredictable oil market [had] a detrimental effect on LPG consumption among the peri-urban poor, effectively reducing access." However, while Denton (2004) recognized the loss of most of the subsidy, the study pointed out that this general fuel subsidy was not necessarily reaching the lowest income households anyway; the poor had better access to smaller, unsubsidized cylinders, while the subsidized 2.75 and 6 kg cylinders were more profusely used by the middle and upper-middle class.

South Africa

In order to prevent the rolling blackouts of 2005 and 2006 from taking place again in the future, the South African government worked with Eskom, the sole national utility, to implement an LPG cookstove distribution program. A two-burner gas stove with a 5 kg LPG cylinder and three vouchers for fuel refills were distributed free to households in a kit (Kimemia & Annegarn, 2016). The government also financially supported Eskom's project to utilize the utility's pre-existing network and distribution facilities. A pilot test of 100,000 households in Cape Town found that 89% of families still used LPG as their primary fuel one year later (Mohlakoana & Annecke, 2009). Seven years after the program's implementation in 2006, Kimemia and Annegarn found that over 60% of households continued to use LPG as their primary cooking fuel source (2015). Those interviewed cited the initial free handout of an LPG cookstove kit and the time savings benefits as reasons for continuing sustained use of the fuel, and cited electricity tariffs as reasons for not switching back to electric stoves (Kimemia & Annegarn, 2016). However, those who had switched back to electricity cited the lack of a fuel subsidy, the volatility of LPG pricing, and lack of infrastructure and supply as reasons for discontinuing use. According to Kimemia and Annegarn (2016), if the fuel itself were subsidized in a manner similar to the current subsidy for electricity use – which gives free electricity to households for the first 50 kWh – then LPG use could increase even more.

Similar to Indonesia, the implementation of this program through the national utility allowed for a large-scale initiative that included several different efforts to increase accessibility and awareness. Eskom worked with local service providers and businesses across the nation handled the initial kit rollout and LPG distribution. Coordination to promote the transition occurred through things like radio spots, councilor meetings, and television advertisements (Mohlakoana & Annecke, 2009). Furthermore, while there is still a stigma around the safety of using LPG as a cooking fuel, an education campaign has helped decrease concerns and spread information about best use practices (Kimemia & Annegarn, 2016).

Guatemala

In Guatemala, LPG has seemingly become the second-most used cooking fuel without the direct financial or regulatory support of the government (Edwards & Langpap, 2005). 78% of the population use LPG, behind electricity at 95% in urban areas. However, with 46% of citizens also reporting fuelwood use, it is clear that fuel stacking is occurring on a large scale in households across the country (Heltberg, 2005). Credit availability appears to be correlated with fuelwood use, and researchers argue that LPG stove prices are a barrier to entry, and stove subsidies could improve LPG penetration – especially in rural areas (Heltberg, 2005). In 2000, "the average price of a new stove in Guatemala was approximately equal to the average cost of feeding one child for an entire year" (Edwards & Langpap, 2005).

Furthermore, while policies exist to support electrification, there do not appear to be any direct national policies that support the spread LPG. The market has seemingly found other ways to drive itself; while infrastructure appears to be more robust and complete in urban areas, many rural communities are still able to access LPG as well (Heltberg, 2005). However, more studies are needed to determine if this kind of fuel stacking and use of LPG in Guatemala is helping reduce air pollution or protect against deforestation; Edwards and Langpap (2005) argue that more

government intervention is needed if fuel substitution and cleaner air are the ultimate goals.

Analysis

Subsidies of different types can make a difference. Overall, I found that the governments of Senegal and Indonesia utilized subsidies on LPG cookstove and equipment, fuel, and program/retail distribution itself. Researchers from all four papers on these programs highlighted the strong governmental support for LPG dissemination as part of each country's success in initial adoption rates (see Table 1 above for the list of studies). However, the removal of such subsidies in Brazil and Senegal has implications that I will discuss below. South Africa, on the other hand, implemented programs that financed the distribution and supplied a free cookstove and fuel canister at initiation, but did not offer any assistance for fuel refills beyond that.

While it may be obvious that making something cheaper will drive more people will use it, there seem to be other implications and factors tied to these financial devices that impact the success of uptake and sustained use of LPG as well. A subsidy is a frequently discussed instrument to change fuel consumption from biomass to cleaner cooking alternatives. However, as evidenced by the studies above, there are different ways that subsidies might be used, and these options can have varying effects. For instance, the countries with equipment and cookstove subsidies at program initiation all had high adoption rates; however, fuel subsidies seem to have more of an effect on sustained use. Even if a subsidy is used to support initial adoption of the equipment, a lack of support for continued LPG fuel purchasing may hinder long-term use. Though the poor need subsidies most, they are not always the ones who are able to take advantage.

Fuel subsidies help control for price volatility, yet there are still other factors at play that can impact a fuel subsidy's effectiveness. In Indonesia, the general subsidy seems to have benefited the middle and upper classes more than the lowest class. The lack of a fuel subsidy in South Africa, and the removal of those in Senegal, led to a decrease in LPG cookstove use. Only in Guatemala, where the market and access of other fuels has made a difference, and Brazil, where other outside factors such as urbanization had an impact, did LPG rise on its own.

Market development can help increase access and use. In countries where private businesses got involved, or the government included program efforts to specifically expand LPG infrastructure, accessibility of the fuel increased alongside continued use. The national utilities of Indonesia and South Africa were able to leverage their relationships with businesses and suppliers to increase availability and improve distribution of the stoves and fuel. However, for countries without large national utilities, encouragement from the government to promote business investment could be helpful. Regulations to remove all duty taxes from LPG-related equipment in Senegal, for instance, could be one such possible avenue.

Regulation of both the LPG market and other fuel sources can increase adoption. Interestingly, regulations for other energy fuel sources, as well as those that drove the LPG fuel market, often existed in countries that had these large-scale LPG programs. Tariffs on electricity consumption (South Africa), regulations that raised prices of wood-cutting and coal (Senegal), and standards withdrawing kerosene (Indonesia) all appeared alongside efforts to increase LPG.

Program's need to adapt. In Indonesia, South Africa, and Senegal, where programs were able to adapt to the users' demands, LPG penetration appears to have increased. Senegal met the demand for bigger stoves, and Indonesia and South Africa were able to adjust their program efforts after initial test phases. This ability to adapt could make a difference for a country like Guatemala, where users often cited the LPG's insufficient ability to cook tortillas properly; if stoves could somehow be modified to meet this demand, perhaps less fuel stacking would occur (Edwards & Langpap, 2005).

User training spreads benefits and safety awareness. Increasing awareness of the cleanliness, time savings, health benefits, and other practical positives of transitioning to LPG use appeared to impact sustained use (Andadari et al, 2014; Fall et al, 2008; Mohlakoana & Annecke, 2009). In areas where there was no formal user training or education attached to the program, concerns about LPG use arose. For instance, in Indonesia accidents related to cooking with LPG have increased with adoption. A lack of user training accompanying the program's implementation could have influenced this, and local NGOs in Indonesia worked to get involved in filling this gap (Budya & Arofat, 2011).

Community involvement can increase infrastructure and use. Efforts to expand programs to reach both urban and rural communities appear to have been strengthened by the involvement of stakeholders such as local businesses, government, and non-governmental organizations. South Africa and Indonesia's programs involved local governments and local businesses in the distribution process, and both had higher adoption rates than any of the other countries analyzed. In Senegal, private investment did not extend far beyond central urban areas; efforts to include more local stakeholders and expand refill centers and infrastructure may have increased sustained use (Fall et al, 2008).

Conclusions

This paper reports on a systematic review of published literature to appraise large-scale LPG cookstove programs to determine (i) what common factors enable or limit adoption and sustained use of LPG in low- and middle-income countries, and (ii) what lessons can be learned concerning the policy implications for future programs. However, this research is not comprehensive. The details of each program or country's LPG cooking distribution were restricted and limited in their discussion, as the focus was often on reporting a general overview of the situation and not specific factors. Not all of the studies reviewed reported on all aspects of the enabling factors outlined.

Nonetheless, some trends are clear from a policy perspective. These studies demonstrated that subsidizing LPG fuel could have the most significant impact of the identified environmental factors, if done effectively. Financial support for gas could be 1) more narrowly targeted towards poor households and rural areas, and 2) varied based on fuel container size and accessibility across communities so that those most in need receive the most benefit. These studies also showed that policies leading to governmental regulations for LPG, policies towards other energy sources, and support for retailers impacts adoption and sustained use. This might be because such national support of a network and infrastructure would allow for equipment and fuel to more easily reach urban and rural areas all across the country. However, further research needs to be done to

determine how countries with more than one major utility can take sufficient advantage of such effects.

This systematic review has worked to identify different categories of enabling environmental factors that might foster or inhibit LPG cookstove adoption and sustained use. Although there does not appear to be one set of factors that guarantee LPG use, there does appear to be evidence that government support, market development, and policy mechanisms are notably advantageous (see Table 2). Factors such as financial mechanisms (e.g. subsidies), market development (e.g. business involvement), regulations (e.g. government support), and other policy mechanisms (e.g. user training) were found to have helped enable LPG's widespread adoption and continued use. However, none of these facts operate in isolation; in all five countries, other factors impacted the effectiveness of these programs as well. Ultimately, more research will be needed to make conclusions about the way these factors can be leveraged in a generalizable LPG cookstove program.

Bibliography of Works Cited

Andadari, R. K., Mulder, P., & Rietveld, P. (2014). Energy poverty reduction by fuel switching. Impact evaluation of the LPG conversion program in Indonesia. Energy Policy, 66, 436-449. Retrieved from doi:10.1016/j.enpol.2013.11.021

Atkins, C., & Sampson, J. (2002). Critical Appraisal Guidelines for Single Case Study Research. *ECIS 2002 Proceedings,* Paper 15. Retrieved from http://aisel.aisnet.org/ecis2002/15

Brooks, N., Bhojvaid, V., Jeuland, M., Lewis, J., Patange, O., & Pattanayak, S. (2016). How much do alternative cookstoves reduce biomass fuel use? Evidence from North India. *Resource and Energy Economics*, 43, 153-171. Retrieved from http://dx.doi.org/10.1016/j.reseneeco.2015.12.001

Budya, H., & Yasir Arofat, M. (2011). Providing cleaner energy access in Indonesia through the megaproject of kerosene conversion to LPG. *Energy Policy*, 39 (12), 7575-7586. Retrieved from http://dx.doi.org/10.1016/j.enpol.2011.02.061

Carrol, C., Booth, A., & Cooper, K. (2011). A worked example of "best fit" framework synthesis: A systematic review of views concerning the taking of some potential chemopreventive agents. *BMC Medical Research Methodology*, 1(29). Retrieved from http://www.biomedcentral.com/1471-2288/11/29

Coelho, S. T., & Goldemberg, J. (2013). Energy access: Lessons learned in Brazil and perspectives for replication in other developing countries. Energy Policy, 61, 1088-1096. Retrieved from http://dx.doi.org/10.1016/j.enpol.2013.05.062

Denton, F. (2004). Reducing the gap between projects and policies: a comparative analysis of the "butanisation" programme in Senegal and the Multifunctional Platform (MFP) experience in Mali. Energy for Sustainable Development, 8(2), 17-29. Retrieved from doi:http://dx.doi.org/10.1016/S0973-0826(08)60456-1

Edwards, J. H. & Langpap, C. (2005). Startup costs and the decision to switch from firewood to gas fuel. Land Economics **81**(4): 570-586. Retrieved from doi:http://dx.doi.org/10.3368/le.81.4.570

Fall, A., Sarr, S., Dafrallah, T., & Ndour, A. (2008). Modern energy access in peri-urban areas of West Africa: the case of Dakar, Senegal. Energy for Sustainable Development, 12(4), 22-37. Retrieved from doi:10.1016/S0973-0826(09)60005-3

Gangopadhyay, S., Ramaswami, B., & Wadhwa, W. (2005). Reducing subsidies on household fuels in India: How will it affect the poor? Energy Policy, 33(18), 2326-2336. Retrieved from doi:10.1016/j.enpol.2004.04.024

Heltberg, R. (2005). Factors determining household fuel choice in Guatemala. Environment and Development Economics **10**(03): 337-361. Retrieved from https://doi.org/10.1017/S1355770X04001858

Jeuland, M., Bluffstone, R., & Pattanayak, S. (2015). The economics of household air pollution. *Annual Review of Resource Economics*, 7, 81–108. Retrieved from DOI: 10.1146/annurev-resource-100814-125048

Jeuland, M. A., & Pattanayak, S. K. (2012). Benefits and costs of improved cookstoves: assessing the implications of variability in health, forest and climate impacts. *PloS One* 7(2), e30338.

Kimemia, D. & Annegarn, H. (2016). Domestic LPG interventions in South Africa: Challenges and lessons. *Energy Policy* 93, 150–156. Retrieved from http://dx.doi.org/10.1016/j.enpol.2016.03.005

Kumar, P., Kaushalendra Rao, R., & Reddy, N. H. (2016). Sustained uptake of LPG as cleaner cooking fuel in rural India: Role of affordability, accessibility, and awareness. *World Development Perspectives, 4*, 33-37. doi:http://dx.doi.org/10.1016/j.wdp.2016.12.001

Lewis, J. J., Bhojvaid, V., Brooks, N., Das, I., Jeuland, M. A., Patange, O., & Pattanayak, S. K. (2015). Piloting improved cookstoves in India. *Journal of health communication*, *20*(sup1), 28-42.

Lewis, J. & Pattanayak, S. (2012). Who adopts improved fuels and cook stoves? A systematic review. *Environmental Health Perspectives*, 120 (5), 637–645. Retrieved from http://ehp.niehs.nih.gov/1104194/

Lucon, O., Teixeira Coelho, S., & Goldemberg, J. (2004). LPG in Brazil: lessons and challenges. *Energy for Sustainable Development*, 8 (3), 82-90. Retrieved from http://dx.doi.org/10.1016/S0973-0826(08)60470-6

Mallet, R., Hagen-Zanker, J., Slater, R., & Duvendack M. (2012). The benefits and challenges of using systematic reviews in international development research. *Journal of Development Effectiveness*, 4 (3), 445-455. Retrieved from http://dx.doi.org/10.1080/19439342.2012.711342

Moher, D., Liberati, A., Tetzlaff, J., Atlman, D., and The PRISMA Group (2009). Preferred

Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLOS Med,* 6(7). Retrieved from http://doi.org/10.1371/journal.pmed.1000097

Mohlakoana, N., & Annecke, W. (2009). The use of liquefied petroleum gas by South African low-income urban households: A case study. Journal of Energy in Southern Africa, 20(4), 2-10.

Puzzolo, E., Pope, D., Stanistreet, D., Rehfuess, E., & Bruce, N. (2016). Clean fuels for resource-poor settings: A systematic review of barriers and enablers to adoption and sustained use. *Environmental Research,* 146, 218–234. Retrieved from http://dx.doi.org/10.1016/j.envres.2016.01.002

Snilstveit, B., Oliver, S., & Vojtkova, M. (2012). Narrative approaches to systematic review and synthesis of evidence for international development policy and practice. *Journal of Development Effectiveness*, 4 (3), 409-429. Retrieved from http://dx.doi.org/10.1080/19439342.2012.710641

World Health Organization (WHO). (2014). Indoor Air Quality Guidelines: Household Fuel Combustion. World Health Organization Geneva. Retrieved from http://www.who.int/indoorair/guidelines/hhfc/HHFC_guidelines.pdf

World LPG Association (WLPGA). (2015). Cooking with Gas: Why women in developing countries want LPG and how they can get it. Retrieved from https://esmap.org/sites/esmap.org/files/WLPGA%20-%20Cooking%20with%20LP%20Gas%20Report%20-%20FINAL%20%20PbP_OPTIMIZED.pdf

APPENDICES

Appendix A: Data Extraction Form

Category[2]*:* *Date of extraction:* *Researcher:*

Section	Comments
Title	
Author(s), year	
Authors´ Institution(s)	
Peer-reviewed (yes/no), name of journal or report series	
REACH (scale and coverage of intervention)	
Country, Region/Location	
Description of target population (geographic coverage, numbers targeted, demographic characteristics)	
Duration/dates of intervention project/programme	
Scale and size of programme (regional, national or int.)	
Setting characteristics (urban vs. rural, seasonal climate, access to roads and transport infrastructure, etc.)	
Characteristics of households reached compared to non-participants or to target population (e.g. baseline fuel/s used, socioeconomic characteristics, education etc.)	
INTERVENTION / EFFECTIVENESS	
Baseline fuel(s) and technologies	
Intervention fuel and technology (including measures of personal exposure, safety or time/fuel savings if reported)	*[Specify if LPG cylinder size and number of burners if reported]*
STUDY METHODOLOGY	

[2] *Quantitative study*: based on empirical evidence (e.g. surveys etc.)
Case study: if in relation to a particular programme/project
Policy analysis: analytic piece of work based on a range of information, not related to a specific project

Study methodology	
Sampling and number of participants	
Quality issues (Validity/ repeatability etc.)	
Data collection methods	
Data analysis	
IMPLEMENTATION (Program and Societal level factors)	
Description of implementation strategy including underlying theory, if any	
Implementing agency / organization / company etc. (or a combination of these) and other participating organization	
Cost of intervention (time or money) from the implementer perspective	
Consistency of implementation across staff/time/settings/subgroups (not about differential outcomes, but process)	
Preparation for reliability of supply chain and price fluctuations	
Community involvement; including women's engagement, and how these factors have affected adoption and sustained use of the intervention	
User and/or provider training	
Adaptations made to intervention during program/project roll out (i.e. was the intervention delivered as intended?)	
Other factors important to implementation, including policy and regulatory environment.	

ADOPTION / MAINTENANCE

Dimensions (D)	Sub-dimensions	Aspects to consider	Main findings
1. Enabling environment	• Existing energy policies	• Governmental policies across fuels: - Existing energy policies on biomass energy for cooking / space heating • Existing energy policies on LPG for cooking (including subsidies)	
	• Political stability	• Description of political environment, corruption etc.	
	• LPG regulation and enforcement capacity	• Adequacy and stability of market rules for cylinder-based LPG • Adequacy of enforcement • Adequacy of rules for institutional support	
	• Existing health policies on HAP	• Existing health policies for the prevention and control of Noncommunicable diseases (NCDs)/ household air pollution (HAP)	
2. LPG industry and market structure	• LPG consumption	• National consumption of LPG for cooking by geographical distribution (if reported) and as compared to other household cooking fuels	
	• LPG infrastructure	• LPG domestic production vs. importation and availability of LPG terminal • LPG storage capacity / filling plants • Extent and quality of road network	
	• Cylinder infrastructure and distribution model	• Cylinder ownership (marketer vs. customer-owned) • Existing rules for controlling the introduction of cylinders into the market • Testing and replacement of damaged cylinders	
	• LPG sale points and end-user acquisition	• Cylinder acquisition: cylinder exchange or direct filling • Cylinder deposit scheme (how much users need to pay for the initial	

		deposit) • Ease of access to cylinder refills	
	• Safety, standards and norms	• Safety of, and options for, cylinders and valves • Norms applied to imported cylinders/valves • Safety of the refilling operation and measures in place to guarantee no under-filling • Testing and re-certifying cylinders • Standards of safety for the transportation of LPG in bulk and in cylinders	
3. Energy pricing and costing	• End-user prices for household cooking fuels	• Existing end-users prices of energy (EPE) and price competition for wood, charcoal etc. • LPG price regime • Government taxes and subsidies on LPG and competing products (including import duties) • Description of any long-term subsidies/incentives and plans for continuity or phase-out, and their effects on adoption/sustained use	
4. Consumer demand	• Awareness	• Level of awareness • Capacity to educate consumers • Existing programs or campaigns	
	• Affordability	• Ability of consumers to pay for equipment and fuel purchase • Consumer finance / access to financial options	
	• Accessibility	• Measures to reduce distance to point of sales • Reliability of supply	
	• User support and education	• Maximizing best-use and safety	
5. User and community perceptions	• User needs & safety perceptions	• Ability to meet cooking needs • Aspiration / perceived convenience • Perceived safety / fear of explosions • Knowledge of safety practices	

Appendix B: Database Scan Results

Results from multi-disciplinary database scan

Database	Results	Terms Used	Date Searched
Web of Science	535	TS= (lpg OR "liquid petroleum gas" OR "LP gas") AND TS= (cook* OR stove OR domestic OR residential OR house*)	02/12/17
SCOPUS (EMBASE)	1,039	TITLE-ABS-KEY (lpg OR "liquid petroleum gas" OR "LP gas") AND TITLE-ABS-KEY (cook* OR stove OR domestic OR residential OR house*)	2/21/17
Ovid (Medline)	145	lpg OR "liquid petroleum gas" OR "LP gas" AND cook* OR stove OR domestic OR residential OR house* (using multi-field search)	2/21/17
Science Direct	371	lpg OR "liquid petroleum gas" OR "LP gas" AND cook* OR stove OR domestic OR residential OR house* (Using abstract, title, keywords)	2/21/17
Social Science Research Network (SSRN)	0	lpg OR "liquid petroleum gas" OR "LP gas" AND cook* OR stove OR domestic OR residential OR house*	2/21/17
Cumulative Total	**2090**		
After duplicates removed	**942**		

Google Scholar Quality Check Methodology

Terms Used	Results	Number Checked	New Records Found	Records Added into Study	Date Searched
lpg + cooking	19,500	20	0	0	03/20/17
lpg + stove	7,430	20	2	0	03/20/17
lpg + domestic	34,700	20	4	0	03/20/17
lpg + residential	20,200	20	8	0	03/20/17
lpg + household	23,200	20	6	0	03/20/17
Cumulative Totals	**105,030**	**100**	**20**	**0**	

Appendix C: Quality Appraisal Form

Case Study Evaluation Criteria from Puzzolo et al. (2014), as adapted from Atkins and Sampson (2002):

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 information 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 stakeholders?	**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	
There is no 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:**

Appendix D: Summary of Quality Appraisal Results

Studies were scored for quality based on the following point system:

Yes = 1

Maybe or Not Applicable = 0

No = -1

Total Score of 0-4 = Low Quality

Total Score of 5-9 = Medium Quality

Total Score of 10-14 = High Quality

		Study By Author									
		Andadari et al. (2014)	*Budya & Arofat (2011)*	*Coelho & Goldemberg (2013)*	*Denton (2004)*	*Edwards & Langpap (2005)*	*Fall et al. (2008)*	*Heltberg (2005)*	*Kimemia & Annegarn (2016)*	*Lucon et al. (2004)*	*Mohlakoana & Annecke (2009)*
Ways and quality of reporti	Aim and objectives reported?	1	1	1	1	1	1	1	1	1	1
	Adequate description of research context?	1	1	1	1	1	1	1	1	1	
	Adequate description of study design?	1	1	0	0	1	1	1	1	0	1
	Sampling information?	1	1	0	0	1	1	1	1	0	1
	Different views from stakeholders?	0	0	0	1	-1	0	-1	1	0	1
	Data collection information?	1	1	0	0	1	1	1	1	1	1
	Description of analysis methods used?	0	1	1	0	1	1	1	1	1	1
	Enough data presented to allow the reader to verify findings?	0	1	0	1	1	1	1	1	0	1
	Limitations described?	1	0	1	1	1	-1	-1	1	-1	-1
Bias	Authors not closely associated with implementers?	1	-1	1	1	1	1	1	1	1	1
	Conclusions made with data?	1	1	1	0	1	1	1	1	0	1
Appropriatenes	Use appropriate methods for ensuring the data analysis expressed participan viewst?	0	0	0	0	0	0	0	0	1	1
	Place the findings in the context of interest?	1	1	1	1	1	1	1	1	1	1
	Suggest if and how the findings might be transferable?	1	1	0	1	1	1	1	1	1	-1
	Total Score	10	9	7	8	11	10	9	13	7	9

Appendix E. Studies Omitted Based on PDF (Exclusion Criteria and References)

Exclusion Criteria	Number Excluded
Discussed LPG as Overall Energy Mix for Cooking	16
Focused on Emissions	12
Other Discussion of LPG (e.g. demographics, costs)	11
Outdated (e.g. India)	6
Hypothetical Scenario or Recommendation	6
Background Reading	3
Total	54

Countries Represented: Bangladesh, Brazil, China, Ecuador, Fiji, Ghana, Guatemala, India, Indonesia, Mexico, Nigeria, Senegal, South Africa, Thailand

Studies Omitted

Adelekan, I. O., & Jerome, A. T. (2006). Dynamics of household energy consumption in a traditional African city, Ibadan. *Environmentalist, 26*(2), 99-110. doi:10.1007/s10669-006-7480-2

Ahmad, S., & de Oliveira, J. A. P. (2015). Fuel switching in slum and non-slum households in urban India. *Journal of Cleaner Production, 94*, 130-136. doi:10.1016/j.jclepro.2015.01.072

Albalak, R., Bruce, N., McCracken, J. P., Smith, K. R., & De Gallardo, T. (2001). Indoor respirable particulate matter concentrations from an open fire, improved cookstove, and LPG/open fire combination in a rural Guatemalan community. *Environmental Science & Technology, 35*(13), 2650-2655.

Alkon, M., Harish, S. P., & Urpelainen, J. (2016). Household energy access and expenditure in developing countries: Evidence from India, 1987-2010. *Energy for Sustainable Development, 35*, 25-34. doi:10.1016/j.esd.2016.08.003

Amegah, A. K., Jaakkola, J. J. K., Quansah, R., Norgbe, G. K., & Dzodzomenyo, M. (2012). Cooking fuel choices and garbage burning practices as determinants of birth weight: a cross-sectional study in Accra, Ghana. *Environmental Health, 11*. doi:10.1186/1476-069x-11-78

Annecke, W. (2007). LPG improving the lives of women in Africa. *Propane Canada, 40*(2).

Bansal, M., Saini, R. P., & Khatod, D. K. (2013). Development of cooking sector in rural areas in India—A review. *Renewable and Sustainable Energy Reviews, 17*, 44-53. doi:http://dx.doi.org/10.1016/j.rser.2012.09.014

Begum, B. A., Paul, S. K., Hossain, M. D., Biswas, S. K., & Hopke, P. K. (2009). Indoor air pollution from particulate matter emissions in different households in rural areas of Bangladesh. *Building and Environment, 44*(5), 898-903. doi:10.1016/j.buildenv.2008.06.005

Bharambe, G. P., Phalke, R. A., Tanksale, A. N., Shaikh, M. S., Kale, S. A., & Ieee. (2013). *LPG Price Hike in India: Awaking Renewable Energy*.

Chen, M., & Yang, X. D. (2015). Situations and challenges of household energy consumption in Chinese small towns. *Energy and Buildings, 107*, 155-162. doi:10.1016/j.enbuild.2015.08.017

D'Sa, A., & Murthy, K. V. N. (2004). LPG as a cooking fuel option for India. *Energy for Sustainable Development, 8*(3), 91-106. doi:http://dx.doi.org/10.1016/S0973-0826(08)60471-8

Dabadge, A., Josey, A., & Sreenivas, A. (2016). From LPG connections to use: Realising smokeless kitchens for all. *Economic and Political Weekly, 51*(16), 47-50.

Gangopadhyay, S., Ramaswami, B., & Wadhwa, W. (2005). Reducing subsidies on household fuels in India: how will it affect the poor? *Energy Policy, 33*(18), 2326-2336. doi:10.1016/j.enpol.2004.04.024

Gasca, J., Ortiz, E., Castillo, H., Jaimes, J. L., & Gonzalez, U. (2004). The impact of liquefied petroleum gas usage on air quality in Mexico City. *Atmospheric Environment, 38*(21), 3517-3527. doi:10.1016/j.atmosenv.2003.12.042

Gautam, S. K., Suresh, R., Sharma, V. P., & Sehgal, M. (2013). Indoor air quality in the rural India. *Management of Environmental Quality, 24*(2), 244-255. doi:10.1108/14777831311303119

Guptaa, G., & Kohlin, G. (2006). Preferences for domestic fuel: Analysis with socio-economic factors and rankings in Kolkata, India. *Ecological Economics, 57*(1), 107-121. doi:10.1016/j.ecolecon.2005.03.010

Hart, W., Gist, R., & Otto, K. (2010). Global LPG markets begin recovery from recession. *Oil and Gas Journal, 108*(20), 62-69.

Howells, M., Victor, D. G., Gaunt, T., Elias, R. J., & Alfstad, T. (2006). Beyond free electricity: The costs of electric cooking in poor households and a market-friendly alternative. *Energy Policy, 34*(17), 3351-3358. doi:http://dx.doi.org/10.1016/j.enpol.2005.07.006

Isihak, S., Akpan, U., & Adeleye, M. (2012). Interventions for mitigating indoor-air pollution in Nigeria: A cost-benefit analysis. *International Journal of Energy Sector Management, 6*(3), 417-429. doi:10.1108/17506221211259655

Jana, C., & Bhattacharya, S. C. (2016). Sustainable cooking energy options for rural poor people in India: an empirical study. *Environment, Development and Sustainability*, 1-17. doi:10.1007/s10668-016-9774-y

Jannuzzi, G. M., & Sanga, G. A. (2004). LPG subsidies in Brazil: an estimate. *Energy for Sustainable Development, 8*(3), 127-129.

Johnson, M., Lam, N., Brant, S., Gray, C., & Pennise, D. (2011). Modeling indoor air pollution from cookstove emissions in developing countries using a Monte Carlo single-box model. *Atmospheric Environment, 45*(19), 3237-3243. doi:http://dx.doi.org/10.1016/j.atmosenv.2011.03.044

Karimu, A., Mensah, J. T., & Adu, G. (2016). Who Adopts LPG as the Main Cooking Fuel and Why? Empirical Evidence on Ghana Based on National Survey. *World Development, 85*, 43-57. doi:http://dx.doi.org/10.1016/j.worlddev.2016.05.004

Kumar, P., Kaushalendra Rao, R., & Reddy, N. H. (2016). Sustained uptake of LPG as cleaner cooking fuel in rural India: Role of affordability, accessibility, and awareness. *World Development Perspectives, 4*, 33-37. doi:http://dx.doi.org/10.1016/j.wdp.2016.12.001

Lee, S. C., Li, W.-M., & Ao, C.-H. (2002). Investigation of indoor air quality at residential homes in Hong Kong—case study. *Atmospheric Environment, 36*(2), 225-237. doi:http://dx.doi.org/10.1016/S1352-2310(01)00435-6

Lewis, J. J., Hollingsworth, J. W., Chartier, R. T., Cooper, E. M., Foster, W. M., Gomes, G. L., . . . Pattanayak, S. K. (2017). Biogas Stoves Reduce Firewood Use, Household Air Pollution, and Hospital Visits in Odisha, India. *Environmental Science and Technology, 51*(1), 560-569. doi:10.1021/acs.est.6b02466

Lewis, J. J., & Pattanayak, S. K. (2012). Who adopts improved fuels and cookstoves? A systematic review. *Environmental Health Perspectives, 120*(5), 637.

Li, X., Lin, C., Wang, Y., Zhao, L. Y., Duan, N., & Wu, X. D. (2015). Analysis of rural household energy consumption and renewable energy systems in Zhangziying town of Beijing. *Ecological Modelling, 318*, 184-193. doi:10.1016/j.ecolmodel.2015.05.011

Lloyd, P. J. D., & Rukarto, H. (2001). The potential of LP gas for household energy in South Africa. *Journal of Energy in Southern Africa, 12*(1), 329-335.

Martinez-Gomez, J., Ibarra, D., Villacis, S., Cuji, P., & Cruz, P. R. (2016). Analysis of LPG, electric and induction cookers during cooking typical Ecuadorian dishes into the national efficient cooking program. *Food Policy, 59*, 88-102. doi:10.1016/j.foodpol.2015.12.010

Martinez-Negrete, M., Martinez, R., Joaquin, R., Sheinbaum, C., & Masera, O. R. (2013). Is modernization making villages more energy efficient? A long-term comparative end-use analysis for Cheranatzicurin village, Mexico. *Energy for Sustainable Development, 17*(5), 463-470. doi:10.1016/j.esd.2013.05.004

Miah, M. D., Kabir, R., Koike, M., Akther, S., & Shin, M. Y. (2010). Rural household energy consumption pattern in the disregarded villages of Bangladesh. *Energy Policy, 38*(2), 997-1003. doi:10.1016/j.enpol.2009.10.051

Mukhopadhyay, R., Sambandam, S., Pillarisetti, A., Jack, D., Mukhopadhyay, K., Balakrishnan, K., . . . Smith, K. (2012). Cooking practices, air quality, and the acceptability of advanced cookstoves in Haryana, India: an exploratory study to inform large-scale interventions. *Glob Health Action, 5*(1), 19016.

Naeher, L. P. (2000). Particulate matter and carbon monoxide in highland guatemala: indoor and outdoor levels from traditional and improved wood stoves and gas stoves. *Indoor Air, 10*(3), 200-205.

Patra, D. (2015). Access and transition to LPG cooking fuel by households in Rural India: An assessment of policy and action *Energy Security and Development: The Global Context and Indian Perspectives* (pp. 162-182).

Patra, D. C. (2012). The case of LPG. *Economic and Political Weekly, 47*(49), 77-78.

Peck, A. E., & Doering Iii, O. C. (1976). VOLUNTARISM AND PRICE RESPONSE: CONSUMER REACTION TO THE ENERGY SHORTAGE. *Bell J Econ, 7*(1), 287-292.

Peng, W. Y., Hisham, Z., & Pan, J. H. (2010). Household level fuel switching in rural Hubei. *Energy for Sustainable Development, 14*(3), 238-244. doi:10.1016/j.esd.2010.07.001

Pongsapich, A., & Wongeskiarttirat, W. (1994). URBAN HOUSEHOLD ENERGY-CONSUMPTION IN THAILAND. *Energy, 19*(5), 509-516. doi:10.1016/0360-5442(94)90047-7

Prasad, R. D., Bansal, R. C., & Raturi, A. (2016). A review of Fiji's energy situation: Challenges and strategies as a small island developing state. *Renewable and Sustainable Energy Reviews*. doi:http://dx.doi.org/10.1016/j.rser.2016.10.070

Puzzolo, E., Pope, D., Stanistreet, D., Rehfuess, E. A., & Bruce, N. G. (2016). Clean fuels for resource-poor settings: A systematic review of barriers and enablers to adoption and sustained use. *Environmental Research, 146*, 218-234. doi:http://dx.doi.org/10.1016/j.envres.2016.01.002

Rao, P. S. C., Miller, J. B., Wang, Y. D., & Byrne, J. B. (2009). Energy-microfinance intervention for below poverty line households in India. *Energy Policy, 37*(5), 1694-1712. doi:http://dx.doi.org/10.1016/j.enpol.2008.12.039

Rehman, I. H., Kar, A., Banerjee, M., Kumar, P., Shardul, M., Mohanty, J., & Hossain, I. (2012). Understanding the political economy and key drivers of energy access in addressing national energy access priorities and policies. *Energy Policy, 47, Supplement 1*, 27-37. doi:http://dx.doi.org/10.1016/j.enpol.2012.03.043

Rosas-Flores, J. A. (2017). Elements for the development of public policies in the residential sector of Mexico based in the Energy Reform and the Energy Transition law. *Energy Policy, 104*, 253-264. doi:10.1016/j.enpol.2017.01.015

Shrestha, R. M., Kumar, S., Martin, S., & Dhakal, A. (2008). Modern energy use by the urban poor in Thailand: a study of slum households in two cities. *Energy for Sustainable Development, 12*(4), 5-13. doi:10.1016/S0973-0826(09)60003-X

Singhl, A. L., & Jamal, S. (2013). A comparative analysis of Indoor air pollution due to domestic fuel used in rural and urban households: A case study. *Transactions of the Institute of Indian Geographers, 35*(2), 287-298.

Tomaschek, J., Kober, R., Fahl, U., & Lozynskyy, Y. (2016). Energy system modelling and GIS to build an Integrated Climate Protection Concept for Gauteng Province, South Africa. *Energy Policy, 88*, 445-455. doi:http://dx.doi.org/10.1016/j.enpol.2015.10.041

Tripathi, A., Sagar, A. D., & Smith, K. R. (2015). Promoting clean and affordable cooking: Smarter subsidies for LPG. *Economic and Political Weekly, 50*(48), 81-84.

Wang, X. H., Li, K. Q., Li, H., Bai, D., & Liu, J. R. (2017). Research on China's rural household energy consumption - Household investigation of typical counties in 8 economic zones. *Renewable & Sustainable Energy Reviews, 68*, 28-32. doi:10.1016/j.rser.2016.10.004

Wang, Y. T., & Bailis, R. (2015). The revolution from the kitchen: Social processes of the removal of traditional cookstoves in Himachal Pradesh, India. *Energy for Sustainable Development, 27*, 127-136. doi:10.1016/j.esd.2015.05.001

Watkins, E. (2010). Indonesia unveils long-term oil, gas plan. *Oil and Gas Journal, 108*(2), 37-38.

Wu, F. Y., Wang, W., Man, Y. B., Chan, C. Y., Liu, W. X., Tao, S., & Wong, M. H. (2015). Levels of PM2.5/PM10 and associated metal(loid)s in rural households of Henan Province, China. *Science of the Total Environment, 512*, 194-200. doi:10.1016/j.scitotenv.2015.01.041

Zhang, J. C., & Kotani, K. (2012). The determinants of household energy demand in rural Beijing: Can environmentally friendly technologies be effective? *Energy Economics, 34*(2), 381-388. doi:10.1016/j.eneco.2011.12.011

Zhang, Q. Y. (2004). Residential energy consumption in China and its comparison with Japan, Canada, and USA. *Energy and Buildings, 36*(12), 1217-1225. doi:10.1016/j.enbuild.2003.08.002