Dissemination and Adoption of LPG for Household Energy Needs: An Evaluation Study in Cameroon

The LPG Adoption in Cameroon (LACE) Study: Study Protocol

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List of Acronyms

CO: Carbon Monoxide
DfiD: Department for International Development, UK
ECM: MicroPEM for children
EU: European Union
GLPGP: The Global LPG Partnership
FGD: Focus Group Discussion
HAP: Household air pollution
KCC: Kosan Crisplant Cameroon S.A.
LPG: Liquefied Petroleum Gas
LWG: National LPG Working Group
MINEE: Minister of Water and Energy
PM: Particulate matter
RTI: Research Triangle Institute
SE4All: Sustainable Energy for All
WHO: World Health Organization

Executive Summary

Study rationale

The burden of disease attributed to household air pollution (HAP) currently stands at around 4 million premature deaths per year. Key evidence reviews carried out for the recently published WHO guidelines recommend greater emphasis on access to clean fuels, whilst recognizing the challenges of achieving this in lower income countries and settings, and the reality that most households use multiple fuels and technologies.

Two critical areas of evidence require to be strengthened, to enhance political and donor commitment to meet this aim. Firstly that transition to clean fuels such as LPG can be achieved and sustained among lower income homes and communities and secondly that the use of clean fuels such as LPG in these settings will meet safety standards and will result in the substantial reductions in HAP required for preventing the disease burden.

Overview of the existing program within which the research will be conducted

Cameroon is an early-stage LPG market with limited penetration over the national territory with 6% of households currently using LPG however the government of Cameroon has expressed desire to expand using of LPG to 60% of the population by 2030. Together with the Cameroon Government, the Global LPG Partnership (GLPGP) has initiated the development of a National LPG initiative to include policy and regulatory enhancement and all necessary investments and interventions along the LPG value chain.

GlocalGaz is a product of Kosan Crisplant Cameroon S.A, a subsidiary of Kosan Crisplant international, a leading company in the LPG industry. GlocalGaz has distributed and promoted use of LPG since in 2006 and is now an established and trusted LPG company that serves end-users and distributors across the national territory, with more limited/ sporadic presence in the Northern Regions. GlocalGaz currently partners with a number of distributors to ensure its products reach the consumer. The chain of sales between GlocalGaz and end-users includes both direct selling to consumers (11% of direct sales take place in Limbe) and through distributors and retailers, boosting geographical coverage. GlocalGaz is now planning further expansion in LPG supply (from 5% market share to 20% within the next five years), to serve peri-urban and rural areas more extensively. The planned strategy will address last-mile distribution barriers, including lack of sales outlets in rural locations, inconsistent availability of LPG when a cylinder refill is required, and will explore which type of financial offers can best support and stimulate the switch to LPG, especially among less wealthy households.

GlocalGaz is a company with a strong commitment to safety (with unique safety features in the LPG market) and service quality (ensuring exact quantities of purchased LPG are supplied to the consumer through the filling process). The company therefore offers a valuable model for expansion of LPG supply in Cameroon and potentially in other countries.

The proposed study aims at assessing the GlocalGaz activities in the context of the national LPG market and policy in order to (i) identify enhancements required to current practice and (ii) inform other similar initiatives aimed at promoting LPG diffusion and sustainable scaling up in Cameroon and more widely. Other commercial LPG operations will, of course, be considered whilst evaluating user perspectives through the evaluation process.

Description of the proposed mixed methods research to be embedded within the existing program

This mixed methods study will run over a twelve-month period. The approach draws on methods for the evaluation of complex interventions, and includes development of a 'logic model' (a framework for understanding the linkages and influences within the system, and in the case of the LPG market we describe this as a 'best practice model').

The fieldwork will be focussed in one study region (Limbe - a peri-urban English speaking area with an established LPG market). Towards the end of the evaluation period scoping and census work will be undertaken of a second study region (Mbalmayo - a peri-urban French speaking area with more limited LPG penetration) to lay the basis for additional fieldwork. This fieldwork will be undertaken following the 12-month initial evaluation phase, dependent on additional funding. The LACE study (in Limbe) will have three phases.

Phase 1: This **preparation and scoping** phase will obtain key information on fuel use, and current practice in LPG supply and distribution, as well as perceptions at the household level. In addition, interviews will be carried out with stakeholders throughout the value chain including GlocalGaz suppliers/distributors, retailers and micro-credit providers. The phase will also incorporate rapid census surveys to gather information on household structure and current fuel use: this will serve as a sampling frame for the main evaluation study.

Phase 2: The second main **evaluation phase** will conduct assessments of (i) uptake and impacts of LPG use at household and community level including the socio-behavioral context, and (ii) identify enabling and limiting factors for initial and sustained use of LPG across communities including both users and potential users of LPG. Among users of LPG, assessment of patterns of use over time, reasons for the observed patterns of use, and impacts on HAP (ambient, kitchen and personal $PM_{2.5}$ and CO), health risks (indirectly via exposure-response functions), household economics, household decision making, cooking preferences, gender roles and time allocation to household tasks, safety and perceptions of safety will be examined. Among potential users of LPG, this phase will assess the factors that would affect adoption and sustained use, including the impact of targeted financial incentives, and equipment. Methods will include standard methods for measuring air quality and exposure assessment and semi-structured interviews and focus groups to explore stakeholder perspectives.

Phase 3: The **final phase** will include integrated analysis of the quantitative and qualitative data, and synthesis of these results in the light of the national assessment work conducted by the GLPGP and the National LPG working group.

Summary of the applicant's capacity to conduct and manage the research

The proposed study benefits from a highly experienced multidisciplinary team. The PIs from the University of Liverpool (UoL) lead the Energy, Air Pollution and Health research group within the WHO Collaborating Centre for Policy Research on Social Determinants and Health at the Department of Public Health and Policy. The research group has made significant contributions into (i) establishing the evidence base for household air pollution (HAP) and health outcomes, (ii) evaluation of interventions (improved cookstoves and cleaner fuels) to reduce exposure to HAP and improve health and (iii) informing policy and programs to reduce HAP and improve health. This is evidenced through the research awards and peer reviewed publications of the group. The UoL is an International leading research centre (part of the Russell Group of the top

20 UK Universities) and has a comprehensive infrastructure and professional support services to support the proposed research and manage the financial award.

1. Background

1.1 Rationale for action on clean fuels

The burden of disease attributed to household air pollution (HAP) currently stands at around 4 million premature deaths per year (1, 2) and in addition there a large number of deaths and serious injuries from burns and poisoning through the use of solid fuels and kerosene in the home. New WHO indoor air quality guidelines have been developed to address this burden (2). Key evidence reviews carried out for these guidelines have shown that (i) there is a need to achieve low levels of $PM_{2.5}$ exposure to secure major health benefits at or close to guideline levels (i.e. 10-35 $\mu g/m^3$ $PM_{2.5}$), and (ii) in everyday use, the majority of solid fuel 'improved' cook stoves do not come close to reaching these levels. The WHO guidelines recommend greater emphasis on access to clean fuels, whilst recognizing the challenges in achieving this in lower income countries and settings, and the reality that most households use multiple fuels and technologies. The goal is therefore to identify policies, strategies and instruments to encourage progressively more exclusive use of clean fuel use over time, whilst ensuring – where still needed - the best possible solid fuel stoves are developed and promoted.

1.2 Evidence needs

In order to enhance political and donor commitment to these objectives, two critical areas of evidence require to be strengthened, namely demonstrating that:

- Transition to clean fuels such as LPG can be achieved and sustained among the lower income homes and communities currently reliant on solid fuels and kerosene, and;
- The use of clean fuels such as LPG in these settings will result in the substantial reductions in HAP required for preventing the disease burden, and that this transition will meet acceptable safety standards.

1.2.1 LPG markets are complex systems

A well-functioning and sustainable LPG market relies upon many components delivered by multiple actors, which can usefully be seen as a complex 'ecosystem.' These components include facilitative policy and regulatory frameworks, adequate supply and distribution, effective enforcement action on safety standards, potentially some form of targeted financial assistance, and ongoing private sector investments to operate in an economically sustainable manner (3). Only in functional and healthy LPG markets, where black markets[1] of domestic LPG cylinders are controlled, is there real potential for long-term LPG scalability – allowing LPG to be a substantive contributor to HAP reduction and other socio-environmental benefits. Research designed to address the evidence gaps identified in 1.2 above therefore needs to recognise this complexity through both the methods used, and in working alongside efforts being made by governments and their partners (such as the Global LPG Partnership (GLPGP)) to assess and enhance these key aspects of the LPG ecosystem.

In recognition of these points, the current study draws on the growing literature on methodology for the evaluation of complex interventions (see methods, Section 3.1). The research team will also work in close collaboration with the GLPGP over the course of the project as assessments of key policy and investments needs are made, and in due

[1] Black market refers to the introduction of second hand cylinders into the domestic market which can represent a significant safety risk due to lack of maintenance and periodic re-certification of cylinders.

course are addressed (see details in Section 1.3.1). The Global LPG Partnership was established in 2012 as a public-private partnership under the United Nations SE4All initiative to help developing countries plan, finance and implement comprehensive, economically sustainable, large-scale transitions to LPG from biomass for household cooking[2].

1.3. Rationale for country selection

1.3.1 Cameroon: a case study

We have selected Cameroon as the focus for the work given its strong commitment to expanding access to LPG as a household fuel. Cameroon is a lower middle-income coastal country of central Africa, with a population of 22.25 million in 2013 (4). Key economic and health indicators (2013) include a per capita GDP of US$ 1315, adult literacy rate of 71% (5), life expectancy of 55 years, and an infant mortality rate which is still high at 61/1000 live births (2012).

Cameroon is an early-stage LPG market with limited penetration over the national territory. LPG use in households stands at 6% (2014) [public statement by Minister of Water and Energy on 11 December 2014]. About 70% of the population relies on traditional biomass (mostly wood and agricultural residues for cooking and heating) (6). The government of Cameroon, which historically has paid little attention to the HAP problem, is now looking at addressing the issues of forest conservation, energy security, and air quality, and has expressed the desire to expand use of LPG to approximately 60% of the population by 2030, in accordance with the country *Vision 2035* (Cameroon being an emergent country by 2035).

The GLPGP and the Government of Cameroon have been collaborating since June 2012, when Cameroon became a pilot country of the GLPGP. In December 2014, the two parties signed a Memorandum of Understanding (MOU) that includes a joint commitment to develop a national LPG Master Plan overseen by a new LPG Working Group (LWG) [co-chaired by the Ministry of Water and Energy (MINEE)] and GLPGP senior advisors. Through funds from the European Union (EU), GLPGP commissioned consultants will support the work of the LWG and will (i) conduct preliminary analysis using existing sources, (ii) carry out a national market assessment and (iii) assess the whole LPG value chain, including LPG supply capabilities and potential for scale up and expanded distribution. This information will become publicly available in the form of a report expected to be published in the second quarter of 2016, and will be used to inform, shape and implement the necessary and sufficient market reforms, investment plans and promotion programmes to achieve the government's LPG goal on an accelerated basis.

1.3.2 Existing clean fuel intervention: the GlocalGaz commercial programme

Programme overview

GlocalGaz is a product of Kosan Crisplant Cameroon S.A (KCC), a subsidiary of Kosan Crisplant international - a Danish multinational corporation and a leading company in the LPG industry that operates in 110 countries. Cameroon is the first market where

[2] See http://www.se4all.org/commitment/global-lpg-partnership/

Kosan Crisplant both provides the filling equipment and also fills and distributes LPG to the domestic market. GlocalGaz began as a small-scale commercial operation in the South West region of Cameroon with a LPG filling station based in Limbe. Glocalgaz is now an established and trusted LPG company that serves end-users and distributors across the national territory, with more limited presence in the Northern Regions.

A key strategy adopted by GlocalGaz to enhance demand through its brand was the prioritisation of consumer-safety through unique technical safety-features of the supplied LPG cylinders including compact 21 mm centre valves and 'quick-on' regulators. The 21 mm compact valve regulates the flow of gas which is under high pressure in the cylinder, inhibiting the potential for explosion in the event of a release of high pressure gas especially if there is a fire. The 'quick-on' regulator has a plastic spindle that melts and shuts off the valve in the event of fire. In addition, the GlocalGaz filling plant includes a cylinder 'reconditioning' system ensuring cylinders are tested daily according to national safety standards. Reconditioning also serves to prolong the life and maintain the appearance of GlocalGaz branded cylinders. Finally, GlocalGaz uses a Check Weighing System (developed by Kosan Crisplant), to ensure accurate and quick control of the net content of LPG in cylinders. This system quickly identifies and addresses under or overfilled cylinders ensuring users get the LPG they pay for (the safety features and filling processes of the GlocalGaz operation are detailed in the site visit report – available on request).

Stakeholders' contribution to the planned national LGP expansion

The Cameroon Ministry of Water and Energy's (MINEE) policy target to increase LPG penetration from 6% to 60% by 2030 is being planned in close co-ordination with GLPGP and its affiliated partners, to promote the expansion of the LPG infrastructure (from storage through to the distribution network), improve the country's current regulatory regime and ensure optimal market conditions for LPG market scale-up on a financeable, safe and sustainable basis.

The LPG market in Cameroon has undergone substantial growth over the last three decades, but domestic consumption is uneven, with predominant penetration in the urban centres of Douala and Yaoundé. Governmental subsidies have contributed to the stimulation of domestic consumption, but subsidies are currently not targeted at the most vulnerable populations and insufficient coverage of LPG sales points is holding back access to LPG in more rural areas. The government also ensures that all cylinders carry the seal of the marketer (this is referred to as '*marketer-owned cylinder model*'[3]), in order to ensure that cylinders are not coming from the black market. However, there is sometimes a lack of necessary resources for monitoring and control of the activities of the downstream sector.

Current coverage of the programme, targeted population and scalability

GlocalGaz owns depots in Limbe, Douala and Yaoundé and currently partner with a number of distributors to ensure its products reach the consumer. The chain of sales between GlocalGaz and end-users includes both direct selling to consumers (11% of direct sales take place in Limbe) and through distributors and retailers, boosting geographical coverage. Consumers are responsible for picking up their cylinders from the distributor necessitating accessible retail sales points.

[3] Under the *marketer-owned cylinder model* it is the marketer that is solely entitled to fill the exchanged empty cylinders and is responsible for maintaining its cylinders under safe standards.

Prospective LPG users initially purchase the LPG burner, and then pay a deposit for the LPG cylinder before paying for the gas (‘*deposit scheme*’ model). With the deposit scheme the customer exchanges an empty branded cylinder for another full one of the same brand in any distribution outlet. Whilst the deposit is refundable, almost 93% of consumers do not get receipts for the purchased cylinders, required if the cylinders are returned to the marketer. GlocalGaz ensures that all users do get a receipt and this has contributed to the expansion of operations over the past 9 years.

Having explored the issues in LPG distribution across the country, GlocalGaz is now planning a further expansion in LPG supply (from 5% market share to 20% within the next five years), to serve peri-urban and rural areas more extensively. One issue in achieving this goal is the need for a sufficient number of cylinders to meet the domestic demand; these are currently imported in bulk and then filled at the main GlocalGaz filling station. GlocalGaz is now looking at market expansion by exploring new routes to market and new tools for customer acquisition in order to reach more vulnerable populations. The planned strategy will address last-mile distribution barriers, including lack of sales outlets in rural locations, inconsistent availability of LPG when a cylinder refill is required, and will explore which type of financial offers can best support and stimulate the switch to LPG, especially among poorer households. For example, there are current plans to pilot sales of a complete ‘start-up’ LPG kit (stove, plus LPG equipment and cylinder), which will be made available for purchase to the communities (through local or newly established retailers) and offered in combination with a loan scheme upon identification of micro-lending partners supporting this project.

Fuel and technology promoted

LPG is a naturally occurring by-product of oil and natural gas production and petroleum refining and has previously been disposed of through the production process (for example by ‘flaring’ from refineries). As a by-product of industry practices, LPG supply to the domestic energy markets represents an opportunity to utilise this fuel that would otherwise be wasted.

LPG (consisting of propane and/or butane) is a highly efficient and high energy-content cooking and heating gas at 45.5 MJ/Kg, surpassing other domestic fuels including charcoal (30 MJ/Kg), wood (16 MJ/Kg) and even biogas (22.8 MJ/m^3) [O’Sullivan and Barnes, 2007]. This efficiency is due to the high temperature of the LPG flame (530 °C). LPG can be easily burnt in simple cooking devices with very limited pollution formation meeting the IWA Tier 4 indoor emissions requirements (2).

GlocalGaz promotes three cylinders for domestic use; 3kg, 6kg and 12.5kg. The 3kg cylinder is most popular among the more vulnerable populations. All cylinders are filled at the central filling station and the practice of ‘decanting’[4] is not used.

Single, double and multiple LPG burners are widely available in the local market with single burner costs ranging from US$10-25 and double burners starting at US$25.

[4] Decanting of LPG is the process of transferring LPG from larger cylinders or tanks into smaller cylinders away from the normal cylinder filling equipment. This practice carries safety risks including fire and explosions because (i) cylinders can be over-filled, and (ii) damaged or corroded cylinders would not picked up by checking at the filling station.

Evidence of program progress and monitoring and evaluation

As part of its commercial operations, GlocalGaz monitors LPG sales on a regular basis in each channel, i.e. in the form of direct sales to end-users, or through distributors and retail points. User awareness is increased through word of mouth and door-to-door publicity campaigns.

GlocalGaz provides an example of an innovative and well-managed operation with a strong commitment to safety, service quality and meeting consumer needs, and thereby provides a valuable model for expansion of LPG supply in Cameroon and other countries. The proposed study will assess the GlocalGaz operation in the context of the national market and policy (by reference to the assessment and enhancement of that described above) in order to (i) identify enhancements required to current practice and (ii) inform other similar initiatives aimed at promoting LPG diffusion and sustainable scaling up in Cameroon and more widely. Other commercial LPG operations will, of course, be considered whilst evaluating user perspectives through the evaluation process.

2. Aim and Objectives

2.1 Aims

The overarching aims of this work are to:

1. Assess the factors that currently enable and constrain LPG use and its expansion in both established and potentially new markets across the national territory.
2. Assess the impacts of LPG adoption on HAP, health and safety risks and livelihoods.

This will be done in the context of (i) the activities of the GlocalGaz operations and (ii) government and industry commitment to expand the national LPG market, and external support by the GLPGP for planning and implementing enhanced policy and associated investment. As a result of this arrangement, the evaluation work will be able to draw on contemporaneous work led by LPG National Working Group and GLPGP commissioned consultants to (i) assess the national LPG market 'ecosystem' during the project, and (ii) plan practical strategies and investment to begin addressing system deficits.

2.2 Objectives

It is proposed to carry out the LACE study initially in one study region with an established and expanding LPG market (Limbe, an English speaking per-urban area). Towards the end of the evaluation period, scoping and census work will be undertaken in another study region with new rural LPG markets (Mbalmayo, a French speaking peri-urban area). This will be carried out to prepare for additional fieldwork after the established LPG market evaluation in Limbe has taken place (dependent on additional funding at a later stage) to provide additional perspectives from potential market evaluation in Cameroon.

1. To conduct an assessment (drawing on data from WHO, the IEA and national sources) of the national Cameroon household energy situation to help elucidate the potential role that LPG can play along with other clean fuel and improved solid fuel options.
2. To conduct an initial assessment of local LPG markets and current practice in (i) supply, (ii) distribution and (iii) adoption of LPG in a peri-urban setting, elucidating local barriers and facilitators.

3. To develop a best practice model ('logic model') informed by evidence from literature, the initial assessment of the GlocalGaz operations, and other sources (e.g. GLPGP the forthcoming national assessment report, industry and programme experience, etc.) for sustainable LPG scaling up in Cameroon, as a framework for interpreting evaluation findings.
4. Among users of LPG in an established and growing market setting, to assess patterns of use over time, reasons for the observed patterns of use, and impacts on HAP (ambient, kitchen and personal $PM_{2.5}$ and CO), health risks (indirectly via exposure-response functions), household economics, household decision making, cooking preferences, gender roles and time allocation to household tasks, safety and perceptions of safety.
5. Among current and potential users of LPG, to assess the factors that would affect adoption and sustained use, including targeted financial incentives, and equipment.
6. To assess the findings in the light of strengths and weaknesses identified across the entire LPG value chain (both fuel and equipment) by the national LPG Working Group.

3. Methods

3.1 Overview of approach and theoretical underpinning

The approach to this evaluation study draws on methods for evaluation of complex interventions, which include initial development of a 'logic model' (a framework for understanding the linkages and influences within the system, and in the case of the LPG market we describe this as a 'best practice model') and the application of mixed methods. This involves a mix of quantitative (surveys, air quality measurements, SUMs, etc.) and qualitative (in-depth interviews, focus groups, observation, etc.) methods, which together can provide an assessment of key aspects of the logic model. The methods will be informed by MRC guidance[5] and by approaches published by experts (7).

Development of a best-practice model will draw on recent systematic reviews (8, 9), and experience gained from other assessments and industry documents [(3, 10) and the forthcoming GLPGP-commissioned national evaluation].

Mixed methods approach

This project will use mixed methods taking a pragmatic epistemological approach matching appropriate qualitative and quantitative research methods to the specific research questions, whilst recognizing the different world views of these paradigms (11). This approach lends itself well to field research as the emphasis is on user / stakeholder experience and application in the field. Knowledge is seen as being relative as opposed to absolute and it is accepted that there can be singular or multiple realities (12). Further, in terms of understanding complex interventions, what is required is a means of integrating knowledge with practice in order to build a meaningful model. The acceptance of multiple realities is useful in this respect as different forms of knowledge (quantitative and qualitative) can be integrated in order to understand and describe practice in the field.

In terms of uptake of cleaner fuels and technologies, the project will draw on Roger's Diffusion of Innovations theory to inform the analysis of adoption and sustained use of LPG (13). The theory was identified as most appropriate in the systematic review of Puzzolo et al. of enablers and barriers to adoption and sustained use of improved

[5] See: www.mrc.ac.uk/complexinterventionsguidance

cooking solutions and clean fuels (8). It suggests that initially small numbers of individuals will adopt a new idea or technology and these early adopters will spread the word to others in the community increasing adoption. Others then disseminate the message to a wider community further increasing adoption until, over a period of time, the idea or product becomes diffused amongst the population reaching saturation. The theory stresses the importance of communication and the peer networking as being integral to the adoption process (13). Whilst this theory is helpful in the consideration of factors affecting adoption of LPG in terms of demand, attitudes to change and how these are diffused in the wider community, it is recognised that the situation is more complex and other factors of the LPG 'ecosystem' will also be important to consider including, for example, supply, pricing and safety.

The LACE study will be conducted over a 12-month period.

- Phase 1: The first **preparation and scoping** phase will develop the initial version of the best-practice model and obtain key information on fuel use, and current practice in LPG supply and distribution, as well as stakeholder perceptions at the level of household and community. The scope of this assessment will be determined in consultation with GLPGP regarding its assessment, in order to avoid undue gaps or overlap. The phase will also incorporate rapid census and scoping surveys of the main study region to gather information on household structure and current fuel use: this will serve as a sampling frame for the LACE study.

- Phase 2: The second main **evaluation phase** will conduct assessments of (i) uptake and impacts (HAP, costs, safety, etc.) of LPG use at household and community level including the socio-behavioral context, and (ii) identify enabling and limiting factors for initial and sustained use of LPG across study communities with an established and expanding LPG market (Table 1). In respect of LPG use, assessed outcomes will include: market penetration, characterization of LPG early- vs. late-adopters, LPG adoption rates and use over time (3-months) including displacement of traditional biomass cooking practices among others.

- Phase 3: The **final phase** will include analysis of quantitative and qualitative data, and synthesis of these results in the light of the national assessment work conducted by the GLPGP and for investment and other aspects of system enhancement. This will lead to recommendations for further development and future research, including further round(s) of evaluation.

3.2 Phase I: Planning, scoping assessment and census surveys

Best practice model

A model describing the components required for a successful LPG market at scale in Cameroon will be developed based on the evidence available from systematic reviews (8, 9), industry best-practice guidance documents (3) and experience as well as the National assessments carried out by GLPGP in collaboration with the National LPG Working Group (LWG) and consultants. An initial model will be developed based on these sources, with variants proposed for different social and geographic areas (e.g. urban, per-urban, rural), if required. The model(s) will evolve as evidence and experience is accrued over the course of the 12-month study period. After this time the model will be tested on a larger scale and used by GLPGP and the LWG to support

implementation and enforcement planning of LPG dissemination (beyond the scope of the current study).

Initial site visit

An initial visit was carried out by representatives of the research team (University of Liverpool and GLPGP) on April 26th to May 1st 2015 (report available upon request). During the visit the LACE study plans were reviewed with Cameroon project partners, potential study sites were visited, and meetings were held with key stakeholders (including community leaders, LPG stove suppliers and distributors). The visit also served to begin to plan a more detailed scoping assessment for the rest of Phase I, including the census survey.

Scoping assessment and rapid (census) survey

After ethical approvals have been secured, a scoping assessment will be conducted in months 1-2 in collaboration with the local Cameroon research partner, in order to obtain more information about the proposed study area, household fuel use (cooking, lighting, other uses), and key aspects regarding LPG supply, distribution, safety management, etc. Local staff will be hired to assist with interviews in the local language(s) and the work will include the following components:

- A rapid census-type survey will be carried out of approximately 1,500 homes across selected areas from the study region to identify a suitable sampling frame for the evaluation and to obtain basic information on fuel use and availability, household and family structure of the study area.
- Interviews will be conducted with key stakeholders, including GlocalGaz suppliers/distributors, retailers and local micro-credit providers
- Observation (including photographs) of local infrastructure for supply, distribution, storage and safety will be made, and relevant supporting documentation obtained.

Refinement of plans for evaluation study

Results of the scoping assessment will be used to plan for the evaluation study including preparing a sampling frame, and to put in place arrangements for managing and implementing the field evaluation. At this stage, the best-practice model(s) will be reviewed and revised in light of information obtained from the scoping study, and learning from the contemporaneous GLPGP/LWG assessment.

3.3 Phase II: evaluation

Study site and sample selection

The census survey will be used to select homes for the evaluation. Equal numbers of LPG and solid/mixed fuel users will be selected. Eligible homes will be those with families including at least one child under 5 years of age. The numbers of homes are considered under sample size, below.

Table 1: Proposed study region

ID	Proposed area	Region	Current status of LPG use	Plans for market development
A	Peri-urban area: *Limbe* outskirts	South-West region	Early stages, with potential for expansion; close to filling centre and long-term consumers	Strengthen promotion, access and potentially financial assistance

Sample size requirements

Two parameters have been used to determine the required sample size:

1. Survey-based household information assessed quantitatively. For the purpose of this calculation, aspects of fuel use for cooking are considered key, for which precision of estimates for important aspects such as % stacking LPG with solid fuels, and % of all cooking carried out with LPG, will determine sample size. Calculations for characteristics with a prevalence of 25% and 50% are shown in Table 2 below:

   Table 2: Sample size for precision of estimates

Prevalence of characteristic	Precision (at 95% level)	Total sample size required
25%	+/- 5%	290
50%	+/- 7%	200

   Based on these calculations, and allowing for around 10% refusals and lost information, a total of around 300 homes would be selected for survey-based data collection.

2. Demonstration (in cross-sectional baseline assessment) of differences (between predominant solid fuel and predominant LPG users) in ambient kitchen and personal exposure to $PM_{2.5}$ of at least 30%: For $PM_{2.5}$, we assume (based on work in similar settings) a mean in solid fuel-using homes of 250 $\mu g/m^3$ and SD of 125 $\mu g/m^3$, and (equivalent to a 30% reduction) a mean of 175 (SD = 87.5) $\mu g/m^3$ or lower, in clean fuel homes, with significance of 5% and power of 80%. This yields a sample size of 33 per group; allowing for around 20% refusals and lost data, a total of 40 per group (combined total 80) will be required. These calculations will be sufficient for demonstrating similar percentage differences in CO. While it might be anticipated that predominant LPG users would see larger reductions in HAP, the sample size has been designed to detect modest reductions (as a result of stacking, emissions from neighbours, and other ambient sources) with reasonable precision.

Summary of sample size requirements

In summary, a sample size of around 300 is required for adequate precision of quantitatively assessed characteristics. For measures of air pollution, random sub-samples of around 40 per group will be needed.

Survey

An interview-based survey will be conducted by trained local staff recruited for the study. The survey will cover household characteristics and family structure, all fuel use for cooking, lighting and other purposes (including multiple fuel/device use), fuel provision (purchase, collection), household economics relating to fuel use, safety (injuries, perceptions) and will explore parameters affecting LPG sustained/ exclusive use (among users) or aspiration (among non-users). Questionnaires will be prepared in English, translated and back-translated. Data will be entered directly into PDA devices.

Air quality and exposure assessment

Pollution assessment will include both $PM_{2.5}$ and CO, to align the findings with the new WHO Air Quality Guidelines on household fuel combustion. It is proposed to include assessment of exposure to $PM_{2.5}$ in young children (given the importance of this vulnerable group), but as the equipment required (the RTI-ECM) is still being field-tested, these plans can be considered provisional.

Methods for particulate ($PM_{2.5}$) measurement:

This will include measurements of average levels in the kitchen, and adult (woman) and child (<5 years) personal exposure, as follows:

- Kitchen: 48-hr $PM_{2.5}$ measured using the RTI MicroPEM, located at standard height and distance from the hearth.
- Personal: 48-hr $PM_{2.5}$ measured using MicroPEM for women, and the Enhanced Children MicroPEM (ECM) for children.

Field quality control will cover filter preparation, laboratory and field blanks, and instrument flow rate calibration using procedures agreed with RTI for the MicroPEM instruments. Real-time data will be downloaded at the end of each sampling period, and backed up. Analysis of filters will be carried out by RTI.

Carbon monoxide:

CO will be measured in tandem with $PM_{2.5}$ as described above, using Lascar electrochemical monitors for both area and personal assessment. Instruments will be calibrated before and after deployment in the study using CO spangas.

Outdoor air quality:

At each site, a Real Time Air Quality (RTAQ) monitoring system will be used to measure outdoor $PM_{2.5}$ and CO at a central location for a period of 2-4 weeks. The system placement will have no impact on human subjects.

Stove use:

The use of all cooking devices will be measured in the air quality monitoring sub-samples during a one-month period (for each home) that includes the 48-hr $PM_{2.5}$ and CO assessment days, using SUMs monitors. For LPG users, gas cylinders will be weighed before and after this period. The reason for conducting this assessment over a one month period, is that experience shows fuel and stove use often differs from routine practice when families know they are being observed more closely with air quality monitoring instruments and also stove use varies considerably on a day to day basis depending on the number of people cooked for, other responsibilities outside of the home etc.

Time activity diaries:

A time activity diary, including structured data and open questions, will collect information from households sampled to receive HAP monitoring. Households will be asked to record cooking episodes, start and end time for cooking, stove(s) used, type of meal cooked, and number of people cooked for during the monitoring period. This will allow for the comparison of patterns of cooking in relation to traditional stove use and LPG use and will also provide triangulation with HAP monitoring data. Women will be asked to record these data for themselves, and the diary will be designed to take into account levels of literacy.

Lamp use:

The methods for lighting will be assessed in the survey, and can be expected to include kerosene lamps (which are believed to be widely used), candles and electricity (grid and/or battery/solar, etc.). Multiple use and hours per day will be recorded. Emissions from kerosene lamps in particular will be assessed by reference to published studies, and (if possible) through analysis of MicroPEM data which recent work has shown can detect the impact of the high black carbon content on filter resistance.

Qualitative assessment:

This component of the study, conducted in parallel to the quantitative data collection, will provide more detailed information on and understanding of, perspectives of households on the use of/potential for use of LPG, and of key stakeholders involved in the promotion, distribution (including re-filling of cylinders) and financing of LPG stoves, cylinders' deposit and fuel.

Individual interviews (semi-structured) will be conducted with women in a purposively selected sub-set of homes (approximately 10 with a mix of LPG and solid fuel users) to obtain a more in-depth understanding of the reasons behind current fuel use patterns. This will include fuel stacking, views about increasing the use of LPG, safety, costs, household decision making on fuel use, reasons for stove choice and patterns of cooking, views on approaches to increasing uptake of LPG and maintaining sustained use and views on financing and credit options. Interviews will be conducted at the end of the one-month observation period and will be used to inform focus group discussions (FGDs).

Focus group discussions (FGDs) will follow the semi-structured interviews with separate FGDs for groups of men and women from the local community (3 FGDs with women as the main stove users (1 with LPG users, 1 with non-LPG users and 1 with a mixture of both LPG users and non-users) and one with men, for a total of 4 FGDs. FGDs will allow participants to share their views on enablers and barriers to LPG adoption, the functionality of LPG use and acceptability, as well as reasons for multiple fuel use and views on LPG promotion, household decision making on fuel use, views on approaches to increasing uptake of LPG and maintaining sustained use and views on financing and credit options. Since they can capitalize on group interaction, participants will be able to further explore and clarify their views in a way that is not possible during the interviews (14).

Interviews and FGDs will be audio-recorded, translated and transcribed. Data will be analysed by the qualitative researcher at the University of Liverpool using a thematic approach. Observation will also be used as relevant (including photographs) to assess LPG and other stove use patterns, distribution and refilling facilities, safety, road conditions, etc.

Scoping assessment and rapid (census) survey of additional study site

Towards the end of the evaluation period for Limbe (peri-urban, established and expanding LPG market), a scoping assessment of approximately 1,500 homes will be conducted in a second site, Mbalmayo (peri-urban, limited LPG market) (Table 3) with a view to conducting an additional identical evaluation exercise after the 12-month study period (pending funding).

Table 3: Proposed additional study region:

ID	Possible area	Region	Current status of LPG use	Plans for market development
B	Peri-urban area: *Mbalmayo*	Centre Region	Limited use, with potential for expansion;	Promotion, distribution assistance

The scoping exercise will obtain information about the proposed study area, household fuel use (cooking, lighting, other uses), and key aspects regarding LPG penetration, supply, distribution, safety management, etc. Local staff will be hired to assist with interviews in the local language(s) (French and French Pidgin), and the work will include the following components:

- A rapid census-type survey will be carried out to enumerate homes across selected areas from the study region, and to obtain basic information on fuel use and availability, household and family structure.
- Interviews will be conducted with key stakeholders, including LPG suppliers/distributors, retailers and local micro-credit providers
- Observation (including photographs) of local infrastructure for supply, distribution, storage and safety will be made, and relevant supporting documentation obtained.

3.4 Phase III: analysis and synthesis

Analysis of quantitative and qualitative data will be carried out using standard methods.

Quantitative methods –cross-sectional surveys:

Based on cross-sectional surveys, descriptive statistics will be presented to summarise household fuel use for cooking, lighting and other uses (e.g. % using LPG, solid fuel, mixed use etc.). Details about use of LPG (supply, accessibility, cost, perceived benefits/ limitations etc.) will be extracted from the surveys to reflect perspectives from communities in Limbe where the LPG market is currently established but is still developing.

To explore the association between household characteristics and LPG adoption and sustained/ exclusive use, cross-sectional comparisons will be made using appropriate hypothesis testing (Chi-squared tests for categorical comparisons (e.g. LPG use by asset index) and t-tests for continuous data (e.g. LPG use by monthly income)). Unconditional logistic regression will be used to summarise the associations between independent variables (household composition, assets, finances etc.) and dependent variables (LPG adoption, LPG exclusive use etc.) adjusting for potential confounders (including SES characteristics, environmental tobacco smoke, and household characteristics and composition etc).

Quantitative methods – Household Air Pollution measurements and respiratory health:

The impact of LPG use on $PM_{2.5}$ (ambient and personal exposure) will be summarized cross-sectionally by comparing geometric means from natural log transformed levels of $PM_{2.5}$ between (i) households adopting LPG relative to non-adopters and (ii) households exclusively using LPG relative to non-exclusive use. T-tests will be used to compare geometric means between the groups. Multivariable linear regression will be used to summarise differences in levels of $PM_{2.5}$ between (i) LPG users vs non-LPG users and (ii) exclusive LPG users vs non-exclusive LPG users) adjusting for potential confounders (including SES characteristics, environmental tobacco smoke, and household characteristics and composition etc.).

Potential impacts on health associated with reductions in HAP from LPG use (mixed use and exclusive) will be modeled using published integrated exposure-response (IER) curves for PM2.5 and childhood pneumonia, lung cancer and chronic obstructive pulmonary disease (COPD) (15).

Quantitative methods – Stove Use Monitors (SUMS):

The SUMS data will be analysed in relation to time-activity data collected from cooks within households selected for household air pollution measurement ($PM_{2.5}$ and CO). This will be compared over the 48-hr monitoring period to examine the discrepancy between the amount that cooks/ households report using their stoves and their actual

stove use. Correlation analysis will be performed summarising the relationship between SUMS reported time (in minutes) and time-activity recorded time. Mean differences in minutes (with confidence intervals) (SUMS recorded time minus time-activity reported time) will be presented. Results will be stratified by (i) LPG exclusive users, (ii) LPG and traditional stove users and (iii) exclusive traditional stove users.

For households using LPG, cylinder weights will be taken immediately before and after the 48-hr HAP monitoring period. The amount of gas used during the period will be estimated in grams from the difference in weights and compared to (i) time activity data reporting exclusive and non-exclusive use of LPG and (ii) SUMS data of LPG stove use. Correlation analysis will be used to summarise the relationship between LPG used (grams) and minutes spent cooking with LPG (time activity data and SUMs data).

Qualitative methods: Analytical approach

Interviews and FGDs will be audio-recorded, translated and transcribed verbatim by field staff. Data will then be analysed by a qualitative researcher at the University of Liverpool.

The qualitative data will be analysed using web based qualitative analysis software Dedoose (www.dedoose.com) allowing the sharing of the qualitative databases between researchers in different locations. A thematic approach will be taken to the analysis with six distinct phases of analysis being used as a framework for the process (16). In phase 1, transcripts will be read carefully to gain familiarity with the data. In phase 2, initial codes will be generated from the individual transcripts before comparing and agreeing codes within the research team. Phases 3 and 4 will involve broad themes being developed from the codes that will then be reviewed by the research team. Phase 5 will refine the themes using an analytical approach with phase 6 being the dissemination of findings in a final report.

Observation (including photographs) will be used to assess LPG and other stove use patterns, distribution and refilling facilities, safety, road conditions, etc.

Integration of quantitative and qualitative findings

Quantitative and qualitative findings will be given equal weighting, and integration of the findings will draw on the convergent design model. This approach initially analyses qualitative and quantitative data separately and then findings are merged in relation to the specific themes that have been identified. Some themes will be defined prior to analysis (e.g. stove stacking) whereas other themes will emerge during the qualitative thematic analysis.

3.4.1 Dissemination strategy

Publications and reports

The qualitative and quantitative findings will be synthesised in relation to the evidence base and the updated best-practice model to identify what is currently facilitating LPG uptake and sustained use and also those areas where further change is required.

A structured report will be produced at the end of the project evaluation summarising the collected information and detailing actable recommendations. The report will be shared with programme leads and project donors prior to public dissemination.

The LACE study findings will be published in peer-reviewed journals and will be presented at national and international conferences. One academic publication will present development of the best-practice logic models of the LPG 'eco-system' identified

for the different peri-urban and rural contexts. A further publication will summarise the findings from the mixed-method evaluation of LPG use (adoption and exclusive use), including barriers and facilitators, in the three study contexts.

Dissemination and Impact

There will be opportunities to disseminate the LACE study findings at local workshops that will be organised by the GLPGP in collaboration with Government of Cameroon in 2016.

The results and recommendations from the LACE study will be of high relevance for the Government of Cameroon and its associated local and international partners, and will be used to support the identification of measures collectively required to accelerate the large-scale adoption of LPG (and concurrent rejection of traditional biomass fuels) at the national level. It is possible that the emerging recommendations from the study will be formally integrated as part of the National LPG Master Plan for Cameroon, which will be developed over the course of the following 12 months by the National Working Group and GLPGP international experts and consulting partners.

Recommendations for further enhancement and evaluation will be also used as a foundation for a longer-term effort to evaluate LPG promotion efforts in Cameroon, across Sub-Saharan Africa and potentially more widely.

The potential of the evaluation methods and approach used in the study to serve as a template for similar work in other countries, and as part of the implementation of the WHO Guidelines for household fuel combustion, will be evaluated.

3.5 Strengths and Limitations

Strengths

National partnerships and political context

One important strength of this evaluation is the political context under which the research will be undertaken. The Cameroon government is committed to support LPG as a fuel for dissemination and adoption for the majority of the population by 2030. Our findings will therefore be of direct relevance to the National LPG Working Group (LWG) (co-chaired by the Ministry of Water and Energy and GLPGP international experts). Understanding factors that facilitate expansion of LPG markets to vulnerable and rural populations is essential to meet these political aspirations. An additional advantage of this relationship is the potential for this study to benefit from the work undertaken by the LWG and GLPGP commissioned consulting partners assessing the national LPG 'eco-system' in Cameroon. Through our close relationship with GLPGP, who have provided a research lead (Dr Elisa Puzzolo) to collaborate in this research, this study will be able to access results from the national market assessment, transition and scale up planning conducted by LWG and commissioned consultants assessing the whole LPG value chain, including the starting conditions, LPG supply capabilities and potential for scale up and expanded distribution and demand. This will provide invaluable information in developing our 'best-practice' model for adoption and sustained use of LPG.

The GlocalGaz LPG Operation

GlocalGaz is ideally placed to be evaluated as an expanding operation and popular LPG brand, with a stated goal to disseminate to wider markets in more vulnerable, rural populations. Advantages of working with GlocalGaz include:

(i) Their commitment to identifying best practice in reaching these vulnerable populations (they are providing support to the project through liaison and facilitation).

(ii) Their innovative LPG 'product' which has an emphasis on quality (ensuring consumers get what they pay for) and safety (unique features of their cylinders equipment limit the potential for accidents) with recognition of this in the market.

Research setting

Another strength of this study is the ability to evaluate the role of clean fuel (LPG) in communities resident in an established and expanding LPG market where there is currently a mix of fuels and technologies used. We additionally plan to evaluate communities from a rural context with a much less established LPG market provide to investigate barriers and facilitators to adoption and sustained use of LPG across heterogeneous market contexts (dependent on funding). The research is also conducted in the context of well-regulated LPG national market where the black market exerts little influence.

Research team

The proposed study benefits from a highly experienced multidisciplinary team and can draw from a diverse mix of skills and expertise. These include substantial research experience of HAP and health including evaluation of interventions (improved cookstoves and clean fuels), HAP exposure measurement using the latest technologies, economic evaluation and mixed-methods expertise. The team also has the advantage of prior experience of the literature on adoption and sustained use of improved cooking technologies and clean fuels, having been co-authors on an influential systematic review synthesizing the evidence on this topic (8, 17, 18). As authors of this review, the team is fully cognizant of the theoretical underpinning of theories of behavioural change central to understanding adoption and sustained use of these technologies/ clean fuels. They have also proven ability to work effectively together to deliver a high quality research outputs in a timely way.

Limitations

Whilst GlocalGaz is an innovative, dynamic and growing LPG operation we recognize that it is only one supplier within a complex system and there is a need to take this into account. We have therefore adopted methods to acknowledge this complexity in our appreciation of the 'best-practice' model of adoption and sustained use of LPG in the Cameroon context.

Ideally we would like also to test informed interventions to identify factors that facilitate adoption and sustained use in relation to expanding markets. Whilst this is not possible with the current proposal give limitations in time and scale, we feel this evaluation provides an excellent basis for an additional intervention-based phase at a later date.

4. Management Plan and Organizational Capacity

Organisational units and research tasks:

The University of Liverpool (UoL) will host this research project and provides the principal investigators (Dr Daniel Pope and Professor Nigel Bruce) as well as a co-investigator (Dr Debbi Stanistreet). The principal investigators (PIs) will be responsible for the coordination and management of the project and will organise subcontracting with other organisations including our local research partner (Dr Bertrand Mbatchou, Douala General Hospital), Columbia University (Dr Darby Jack) and the Research

Triangle Institute (RTI). The PIs will lead the project steering group and liaise directly with the National LPG Working Group and GLPGP (through our partner Dr Elisa Puzzolo) in the preparation for and conduct of the research project. Two researchers (Grade 6) will be managed by the PIs from UoL who, together with the co-investigator, will be responsible for organising qualitative, quantitative data collection, mixed-methods analysis and dissemination.

Douala General Hospital will form the local Cameroon organisational sub-awardee providing the local principal investigator (Dr Bertrand Mbatchou). The local PI will be responsible for the coordination and management of the project within the research location. The PI will be part of the project steering group and will report to the UoL PIs. A research assistant (field coordinator) and 3 fieldworkers will be employed and supervised by the local PI to (i) carry out the rapid census survey in Limbe, (ii) conduct the surveys, interviews and focus groups and (iii) assist with the HAP monitoring. They will also assist with the rapid census survey in Mbalmayo towards the end of the 12-month evaluation. A data manager will also be employed and supervised by the local PI to prepare the data for analysis and dissemination. The local PI will also be responsible for obtaining local ethical and administrative approvals and for organising the dissemination workshop hosted in Douala.

Columbia University will provide the services of Dr Darby Jack in an advisory capacity given his extensive research experience in HAP and health including exposure measurement of HAP, economic evaluation and management of large related research projects. Dr Jack will be on the project steering group and will support the HAP monitoring phase of the project. He will also contribute to the analysis and dissemination phase of the research.

The Research Triangle Institute (RTI) have worked with the UoL PIs previously, piloting the latest technology in personal exposure measure of HAP (MicroPEM) developed by RTI. They will provide the equipment for HAP monitoring for the project together with expertise and training in use, quality assurance and calibration, data collection, preparation and analysis.

Organisational, academic, partner and local/governmental relationships

The organisational relationships between research partners are shown in the diagram in Appendix 1. The UoL PIs will ultimately manage and supervise the research project, leading the project steering group and deciding on logistical issues. The local PI will provide day-to-day management of the field-work and implementation of the evaluation and will report to the UoL PIs. Collaboration between academic research partners, the National LPG Working Group and GlocalGaz will be facilitated through our GLPGP research partner (Dr Elisa Puzzolo) who is part of the project steering committee. Our official programme liaison representing KCC-GlocalGaz (Ms Bessem Enonchong) is also part of the steering committee and will work with Dr Elisa Puzzolo and the UoL PIs facilitating interaction between the researchers and the GlocalGaz programme. The UoL PIs will work directly with Columbia University (Dr Darby Jack) and RTI in relation to exposure monitoring for HAP. Dr Darby Jack will also sit on the project steering committee. The committee will meet once a month to discuss progress with the evaluation and to ensure project milestones are met.

Institutional management functions of applicant organisation to meet requirements of research

The University of Liverpool (UoL), as an international leading research centre, has a comprehensive infrastructure and professional support services, with the knowledge,

experience and resources to support academic research at the multi-national collaborative level. The functions of key support services are detailed below.

The central Finance Department and Institutional Finance and Research Team collect, interpret, monitor and present financial information to academic staff to contribute to planning, and budgeting resources and meeting statutory reporting requirements. They establish and maintain UoL financial policies and also ensure that UoL meets the requirements of UK government, funding bodies and any other external agencies.

The central Procurement Department and Institutional Finance and Research and Management Services Teams ensure that procurement of goods and services is timely and effective, provides excellent value for money, complies with all legislation effecting UoL's procurement activities, minimises commercial and contractual risk, is open and fair to the supplier community, gives due consideration to environmental impact and promotes high ethical standards and financial probity.

The central Human Resources Department and Institutional Management Services Team are responsible for providing advice and guidance on organisational development, recruitment and promotion of staff, payroll and pensions, and staff health and welfare. They establish and maintain UoL HR policies and also ensure that UoL is compliant with all aspects of UK employment law.

The central Computing Services Department (CSD) provides IT services to support UoL's research activities. CSD is governed by a set of IT regulations, policies and guidelines on digital communication and data management, security and storage.

Description of the depth and breadth of experience of the applicant

The Energy, Air Pollution and Health research theme: (https://www.liv.ac.uk/psychology-health-and-society/research/energy-air-pollution-health/) is located within the Department of Public Health and Policy, UoL and is part of the WHO Collaborating Centre for Policy Research on Social Determinants of Health. The applicants (Professor Nigel Bruce and Dr Daniel Pope) lead the research theme and have made substantial research contributions to the field of household air pollution (HAP, energy access and health in lower- and middle- income countries. These include:

(i) Establishing the evidence base for HAP and health outcomes

Our research group has made a key contribution to quantifying the global burden of disease (GBD) from household air pollution (HAP), with Bruce co-chairing the HAP expert group for the GBD 2010 study led by the Institute for Health Metric and Evaluation. Our team is contributing to the development by Public Health England (in partnership with IHME) of the 2013 disease burden study for England.

We have led on a number of systematic reviews and meta-analyses summarising the burden of exposure to household air pollution through biomass combustion in relation to a number of health outcomes including: childhood pneumonia, adult ALRI, adverse pregnancy outcomes, cataracts, cervical cancer, lung cancer and tuberculosis. As well as contributing to the comparative risk assessment for the 2010 Global Burden of Disease Study, the systematic reviews have provided intervention effect estimates for several important preventive strategies and tools. This includes the Global Action Plan for the Prevention and Control of Pneumonia & Diarrheoa [GAPPD] and the Lives-Saved Tool which is used to prioritise interventions for child and maternal survival and which we have been working on with the Child Health Epidemiology Reference Group (CHERG) since 2009.

Relevant Funding:
(1) Bill and Melinda Gates Foundation. Review of evidence for household air pollution as an intervention for child survival. US$ 10,000 (Dec 2011 – Sept 2012).
(2) Global Action Plan on Pneumonia: systematic review and meta-analysis of indoor air pollution, hand washing and childhood pneumonia. World Health Organisation/UNICEF: US$ 22,470 for 6 months.

(ii) Evaluating interventions (improved cookstoves and cleaner fuels) to reduce exposure to HAP and improve health

Professor Bruce was Co-PI for the first randomised controlled clinical trial to test the impact of an improved cookstove intervention on child pneumonia (RESPIRE-Guatemala). Professor Bruce and Dr Pope have also been co-investigators on a WorldBank funded intervention study assessing the HAP exposure and acute health impacts of fuel switching from biomass to ethanol in Madagascar. They are currently both co-investigators on the Cooking and Pneumonia Study (CAPS) - an advanced cookstove intervention to prevent pneumonia in children under 5 years old in Malawi, a cluster randomised controlled trial.

Relevant Funding:
(1) Ethanol as a Household Fuel in Madagascar: Health Benefits, Economic Assessment, and Review of African Lessons for Scaling-Up Funded by World Bank, December 2008 (14 months). Total project award US$ 400,000.
(2) World Health Organisation. Title: Comparative review of experiences with household energy interventions (Phase 2): US$ 13,700 from July 2007.
(3) Norwegian Research Council. Evaluation of impact of improved stove on adult respiratory health. With University of Bergen. US$ 140,000 for three years, from December 2002.
(4) NIEHS (US): Indoor air pollution and child ARI: a randomised trial, June 2001 (US$ 1,734,457 = £1,238,900 at 1.4 US$ to £).
(5) World Health Organisation. Title: Comparative review of experiences with household energy interventions: US$ 14,520 from March 2006.

(iii) Informing policy and programmes to reduce HAP and improve health

Professor Bruce recently led the development of the new WHO air quality guidelines (AQGs) for household fuel combustion which aim to help public health policy-makers, as well as specialists working on energy, environmental and other issues understand best the approaches to reducing the health burden from household air pollution. These were published in November 2014. Dr Pope and Professor Bruce have also led successful research projects (i) investigating enablers and barriers to adoption of improved cooking technologies and clean fuels and (ii) assessing access to healthcare for children and mothers in Guatemala.

Relevant funding:
(1) Systematic review of enabling or limiting factors influencing the large scale uptake by households of cleaner and more efficient household energy technologies, covering cleaner fuel and improved solid fuel cookstoves? £ 40,150 (August 2011 – May 2012).
(2) UBS Optimus Foundation: Improving child survival through enhanced understanding of barriers to health care access in rural Guatemala. Awarded CHF/- 450,000 (£ 204,500) for three years, from June 2007.
(3) DFID Knowledge and Research. Smoke health and household energy – scaling up. £250,000. Jointly with ITDG (International NGO) for period of 5 years from September 2003.
(4) World Health Organisation (Geneva): additional support for Guatemala study to include investigation of RSV infection in children, and respiratory health of women. US$ 71,000 (£46,000) for 3 years from January 2003.

Applicant's ability to ensure compliance with ethical standards for human subjects' research

Ethical approval for the evaluation will be required from Cameroon and the local PI will be responsible for securing this approval. The National ethics committee comprises a

Professor of medicine (Committee President), other clinicians and medical practitioners, biologists, lawyers and lay representatives representing civil society and the community. For research on humans, where samples will be collected from participants, insurance is required and a material transfer agreement is required for samples to be analysed abroad. The committee meets approximately every two months. The local PI is fully cognizant of these procedures and has costed the applications into the budget and incorporated them into the research timeline.

5. Personnel & Staffing

Details of the personnel involved in the proposed evaluation are shown in the tables below including (i) Key personnel, (ii) co-investigators and research partners and (iii) research staff to be employed for the project.

Key personnel			
Staff	**Experience/ qualifications**	**Project Role**	**% effort**
Prof. Nigel Bruce. University of Liverpool, UK.	Prof. of Public Health. WHO consultant. International recognition in field of HAP and Health. Experience leading a number of related population based studies as PI including RESPIRE trial. Experienced epidemiologist. BA, MBBS, MSc, PhD, FFPH	Co-PI. Co-leading management and supervision of research.	15%
Dr. Daniel Pope. University of Liverpool, UK.	Senior Lecturer in Epidemiology. Substantial experience in the conduct of research into HAP and health (evidence reviews and primary data including analysis of trials). Has managed a large EU funded project (3.6million Euros) of urban health as PI. Experienced epidemiologist. BSc(hons), MSc, PhD, MFPH	Co-PI. Co-leading management and supervision of research.	15%
Dr. Bertrand Mbatchou. Douala General Hospital, Cameroon.	Senior Lecturer. Clinical researcher in field of environment, air pollution and respiratory disease. Recent experience leading study of COPD in rural population. Research methods trained. Specialist training in respiratory medicine. MD	Local PI. Supervising fieldwork and local data management.	67%

The Study/Project Directors will be the research PIs, Professor Nigel Bruce and Dr Daniel Pope, equally responsible for overseeing the administrative direction and financial oversight of the award.

Research co-investigators and partners			
Staff	**Experience/ qualifications**	**Project Role**	**% effort**
Dr. Debbi Stanistreet University of Liverpool, UK.	Senior Lecturer. Experienced in mixed-methods research including qualitative work in HAP and improved cookstoves. Published in the field of mixed-methods analytical techniques. BA(hons), MPH, PhD	Co-I. Supervising and advising on qualitative methods and mixed-methods.	10%
Dr. Darby Jack Columbia University, US.	Assistant Professor. Substantial experience on health effects of environmental exposures including leading research on adoption of health-improving technologies. Co-led R01	Co-I. Adviser on HAP exposure measurement and economics.	5%

	funded RCT of improved cooking technology. Experienced epidemiologist and economist. BA, PhD.	Assisting with dissemination.	
Dr. Elisa Puzzolo GLPGP and University of Liverpool (hon), UK.	Director of Research (GLPGP) and Senior Research Fellow (UoL, hon). 5 years research experience of HAP and energy access. Recent experience working with clean energy stakeholders at regional and national levels. MSc, MPH, PhD.	Co-I. Liaising with GlocalGaz programme. Advising on LPG 'eco-system'.	12%
Ms Bessem Enonchong Kosan Crisplant, Cameroon/ GlocalGaz	Manager –Kosan Crisplant Cameroon / GlocalGaz. Experience in marketing and management. Represents the GlocalGaz programme.	Research partner. Advising on aspects of the LPG programme.	12%

Research Staff			
Staff	**Experience/ qualifications**	**Project Role**	**% effort**
Grade 6 University of Liverpool, UK.	Quantitative researcher with epidemiological experience. Environment and health research experience in LMICs preferred. Mid Grade. BSc/ MSc (potentially PhD)	Researcher (7 months). Supervising quantitative data collection and analysis.	100%
Grade 6 University of Liverpool, UK.	Qualitative researcher (ideally mixed-methods). Environment and health research experience in LMICs preferred. Experienced epidemiologist. BA/ MA (potentially PhD)	Researcher (5 months) Supervising qualitative data collection and analysis.	100%
Grade 6 equiv Douala General Hospital, Cameroon	Research associate. Quantitative/ qualitative research skills, ideally epidemiology. Environment and health research preferred. BSc/BA/MSc/MA	Local research coordinator. Supervising fieldwork and local data management.	54%
Grade 5 equiv Douala General Hospital, Cameroon	Data manager. Experience of managing research datasets (evidence of dissemination).	Data manager for data collected during project. QA assurance.	20%
Fieldworkers (3) Doula General Hospital, Cameroon	Fieldworkers familiar with the research settings and communities. Training will be given	Qualitative and quantitative data collection for the project.	54%

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Appendix 1 – Organizational chart