Market Research Studies (Kenya)

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Low Cost Technologies ("The next generation of low-cost energy-efficient appliances and devices to benefit the bottom of the pyramid" (LCT))

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The project team is led by the Open University (UK) and the consortium includes the following partners:-

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Executive Summary

This document is an output of the project entitled "The Next Generation of Low-cost Energy-efficient Products for the Bottom of the Pyramid" (known as the LCT project). It presents the findings of a key activity of the project; a survey of respondents using a discrete choice modelling methodology to assess their response to technological ideas. The purpose of this output is to inform the research team of the findings as they plan the next steps of the research, to provide a summary for interested stakeholders and to provide data and analysis as an input to wider communication instruments.

This research is funded under the Understanding Sustainable Energy Solutions (USES) in Developing Countries Programme, which draws support from The Engineering and Physical Sciences Research Council (EPSRC) , The Department for International Development (DFID) and The Department of Energy & Climate Change (DECC) working with The Low Carbon Energy for Development Network (LCEDN) and The UK Collaborative on Development Sciences (UKCDS). The research is led by the Open University (UK) and carried out by a consortium including:- The Institute for Globally Transformative Technologies (USA), Gamos Ltd. (UK), United International University, Dhaka (Bangladesh), Africa Centre for Technology Studies, Nairobi (Kenya), and Nairobi Women's Hospital, Nairobi (Kenya).

Having used expert opinion to identify top- priority low-energy devices that have the potential to improve lives at the bottom of the pyramid (BoP), this report specifically addresses a key research question: What are context and culture-specific design and operational parameters that will govern levels of low-energy consumption? What are acceptable price points and how will the devices be constructed and commercialized at those levels?

Expert discussion identified 4 medical and 3 domestic technologies: -

- Measurement of vital signs
- Diagnosis of diseases from Urine and Blood analysis
- Diagnostic support
- Ultrasound

- Solar Pumping (in a specific set of conditions found commonly in Central Kenya)
- Domestic refrigeration
- Clean cooking with modern energy[1].

Discrete choice modelling was proposed as the theoretical construct to be used in consumer surveys, to identify the key characteristics (or parameters) that each product should have to find a ready acceptance with consumers. 413 interviews were conducted with staff from a range of medical facilities across the country of Kenya, and 780 household interviews were conducted in 5 regions across Kenya.

Medical Technologies

For the medical technologies, the choice modelling was predicated on the idea that a 'clinic in a box' or a 500W clinic might be viable by bringing together technologies into an integrated suite. The choice modelling differentiated some of the key components involved in medical diagnostics,

[1] This could be LPG or electricity.

clustering the choice pairs into the measurement of vital signs, the taking and analysis of blood and urine samples, providing diagnostic support, and the use of ultrasound.

Respondents assigned values to the various options, and confirmed that 'integration' and 'automation' were indeed important. There was a very strong preference for all medical devices to include rechargeable batteries (as opposed to non rechargeable). Most respondents worked in clinics connected to the grid, however the responses were interpreted as reflecting a frustration with unreliable electricity and the importance of introducing improved availability by having stand-alone battery powered equipment.

The use of solar energy for powering rechargeable batteries was valued although in most cases not as much as having rechargeable batteries alone. The unexpected relationship between the options regarding rechargeable batteries and solar should not be interpreted to mean that solar is not valued by the respondents. It is, and therefore it would be good to incorporate it into the 'clinic in a box' where possible, especially as this would enable it to operate in locations with no grid connection.

It should be noted that those who already have experience of equipment i.e. those in urban settings, in higher level medical institutions, and well resourced facilities, tend to be willing to pay slightly more than their counterparts. The original concept of a clinic in a box was that a medical practitioner, such as a nurse working in a remote location, would be able to set up a clinic and access technical support. While this may remain a primary market, enabling professional medical care where previously there was none, the 'enthusiasm' (shown through the slightly higher willingness to pay (WTP)) from professionals who currently have equipment suggest that there is a considerable market among existing institutions. Any design should not limit the improvements and benefits of the 500W clinic to remote locations only.

The ultrasound model documented the importance of robustness – represented by frequency of servicing requirements and promptness of repair. While this was only explicit in the ultrasound model (in order to keep the models manageable), it is reasonable to say that the principles would apply to any clinic in a box. Low service requirements and ease of repair will be important design considerations.

Finally, there was substantial value attributed to computerised advice and remote consultation in the context of a diagnostic support device. Computerised advice actually gained a higher assigned value than remote consultation with a real doctor. It was surmised that this might be because current experience of consulting real colleagues is a bit hit and miss. Colleagues may not be available 24 hours a day, and a consultation may often take time to arrange. If remote consultations via a device proved to be more planned and more reliable, it is possible that one might extract a higher value to this potential design feature. However, based on the survey results alone, the higher value is attributed to having computerised advice – something available 24 hours a day and known to be available when required.

Domestic Technologies

Regarding domestic technologies, some details on preferences were gained from the choice modelling of fridges, which could inform the design of a low powered domestic fridge. The key preference is for a medium sized fridge, and one that should hold its cool without power for at least 24 hours. This unfortunately is not helped by the preference for front door opening – top loading fridges more easily hold their cool. A freezing compartment would command value, but if its sufficient to freeze some ice this is good enough, as there is no strong preference for a compartment suitable for freezing food. There is some value assigned to being silent, and to being robust to work in heat and dust.

The survey may have given significant insight into the challenges of clean and cleaner stove commercialisation. There seems to be a lack of awareness of the health implications of charcoal stoves, as no premium value was assigned in the model to an absence of smoke from a charcoal stove. That said, when it comes to the proposed appliance, the most highly valued design feature was the absence of wood smoke. The debate over 'smoky flavour' in food was finally informed by robust data – with a preference for no smoky flavour. Other cultural features were revealed in the responses to parameters regarding the ability to cook more meals in a day, and to cook for larger households.

Similarly, there was a preference within the solar pump model for one that could irrigate larger pieces of land. Value was also assigned to the ability to have the solar panels next to (or on) the house, and to being sold a complete package (with sprinkler or drip irrigation equipment).

The fridge modelling showed that respondents put some value on being able to buy through monthly instalments. Interestingly, the choice model for the solar pump, based on responses from farmers, showed no preference for monthly instalments as opposed to paying for the system as a whole upfront. The cook stove modelling took monthly instalments as standard.

Summary

In summary then, the research confirms that an integrated unit that combines the ability to take readings of vital signs, to test blood and urine, and to give diagnostic support would find considerable value among medical professionals in Kenya. The inclusion of ultrasound in the package would also be highly valued. The team therefore need to consider the next steps to outworking such a package.

The survey gives no particular insights into ranking the market demand (or potential sizes) for each of the technologies. Rather it gives an indication of the premium added value each potential design feature may command within each technology. Therefore the choice of which technology to take forward is more dependent on innovator interest and the ability to design technologies that include such features within the price ranges indicated. The team therefore need to share the findings with a wider group of entrepreneurs and see where the interest lies.

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Although Gamos are presented as the primary authors of this report, we would like to emphasise that the design and implementation of the market surveys has been a collaborative effort between all members of the research consortium. Special thanks go to all of the team at ACTS who made field arrangements for the training and piloting exercise (especially Ann Kingiri), and who recruited and managed the teams of enumerators (especially Mourine Cheruiyot, who acted as team manager). We would also like to thank Becky Hanlin and Aschalew Tigabu for all their work to support the field work.

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1 Introduction

This document is an output of the project entitled "The Next Generation of Low-cost Energy-efficient Products for the Bottom of the Pyramid" (known as the LCT project). It presents the findings of a key activity of the project; a survey of respondents using a discrete choice modelling methodology to assess their response to technological ideas. The purpose of this output is to inform the research team of the findings as they plan the next steps of the research, to provide a summary for interested stakeholders and to provide data and analysis as an input to wider communication instruments.

1.1 The wider research programme

This research is funded under the Understanding Sustainable Energy Solutions (USES) in Developing Countries Programme, which draws support from The Engineering and Physical Sciences Research Council (EPSRC) , The Department for International Development (DFID) and The Department of Energy & Climate Change (DECC) working with The Low Carbon Energy for Development Network (LCEDN) and The UK Collaborative on Development Sciences (UKCDS). The research is led by the Open University (UK) and carried out by a consortium including :- The Institute for Globally Transformative Technologies (USA), Gamos Ltd. (UK), United International University (Bangladesh), Africa Centre for Technology Studies (Kenya), and Nairobi Women's Hospital (Kenya).

In recent years, we have seen an increase in activity to provide energy to low-income households and communities in developing countries, through micro-grids and other methods of distributed energy resources. While studies have shown some improvement in people's lives as a result of the incremental increase in access to lighting, there have been few studies evidencing broader improvement due to energy access. However, access to energy itself cannot change people's lives; rather, it is what people use the energy for that changes lives: appliance loads such as household devices, workplace machines, clinical/medical devices, etc. These appliances can enhance quality of life, generate incomes and provide huge health benefits. Currently, the limited understanding and attention provided to the many market segments represented by the global poor, and of what types of powered appliances and products might change the quality of their lives (and, ideally, their economic condition) is extremely scarce.

The research will use energy as the central theme to increase global understanding of the demand from various bottom of the pyramid segments with respect to low-cost energy-efficient technologies, and how such products can be sustainably developed and deployed in developing countries to have large-scale impact. Specifically, the project asks the following research questions:

1. What are the top- priority low-energy devices that have the potential to improve lives at the bottom of the pyramid? What are context and culture-specific design and operational parameters that will govern levels of low-energy consumption? What are acceptable price points and how will the devices be constructed and commercialized at those levels?
2. How can an effective innovation system be created to develop a continuous pipeline of pro-poor energy-related technologies?
3. What types of new partnerships and business models will lead to the uptake of innovative low-carbon clean energy and energy-efficient technologies at required speed and scale?

This report focuses on research question 1, seeking to identify the priority design parameters that will govern the means of energy provision and in particular the market acceptability of devices among potential consumers.

1.2 Technologies identified

The project as a whole is informed by the study "50 Breakthroughs" (Buluswar, Friedman, Mehta, Mitra, & Sathre, 2014) developed by LIGTT (pronounced 'light'), the Institute for Globally Transformative Technologies at the Lawrence Berkeley National Lab (LBNL). The main purpose of the study was to identify where paradigm-shaping breakthroughs are most required and in so doing launch a thought-provoking conversation among practitioners in the technology-for-development ecosystem in order to focus collective effort on the breakthroughs that really matter.

Market scans were also conducted by ACTS, including technologies in Kenya and wider Africa (Tigabu, 2016, Cheruiyot, 2016).

1.2.1 Medical technologies

As a part of the "50 Breakthroughs" study, the chapter on global health pointed to possibilities of enhancing health services in low resource settings by the strategic use of new technologies. It illustrated that by taking a view on low cost and low power technologies it may be possible to significantly change the mortality and morbidity statistics of health care in rural Africa.

Accordingly, the research programme team chose to explore the needs of health professionals in Kenya, particularly those working in remote clinics with limited equipment. The concept for discussion was a 'clinic in a box', targeting a peak power consumption of 500W. Drawing its energy from renewable sources, the 'clinic' would be a suite of technologies that would enhance the everyday processes of a rural clinic. Furthermore, low power consumption provided by renewable sources would enable clinics to be set up in remote areas where it is not currently possible to do so because there is no electricity infrastructure. A core concept would be that the equipment could be used by someone of basic medical training (such as a nurse) and might include remote support.

Further expert discussion of the key processes at a clinic identified 4 'technologies':-

- Measurement of vital signs.
- Diagnosis of diseases from Urine and Blood analysis.
- Diagnostic support.
- Ultrasound.

1.2.2 Domestic appliances

The chapter (in 50 Breakthroughs) on electrification identified a wide range of consumer products that might be suitable for investigation. While lighting is of strong interest to the development community and consumers, the team felt that it was being adequately researched and that little added value would be achieved by focusing on it. Many of these agencies are 'moving on' to consider refrigeration which they see as the next step in the consumption of modern energy from solar photovoltaic panels.

Similarly pumping by solar was also felt to be a strong productive possibility but was being explored in the wider setting by various public and private agencies. However, specific local expertise to Kenya suggested that there may be a large group of farmers whose needs are not currently being met. These farmers in Central District tend to have their house on top of a hill and have access to an open source of water at the base of the hill. Solar pumps designed to pump small amounts of water for high value cropping are not readily available on the market. This concept is illustrated in Figure 1.

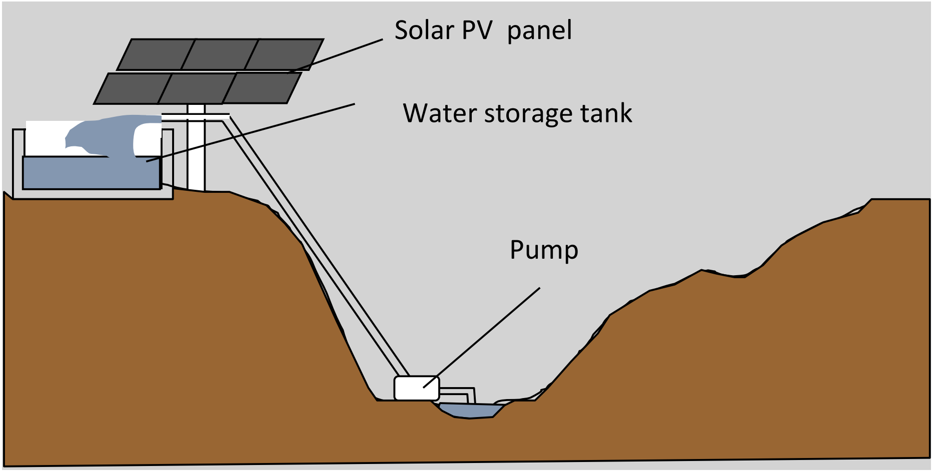

Figure 1 Solar pumping solution

While the '50 Breakthroughs' does not mention cooking on electricity as a potential new breakthrough use of energy, the recent Sustainable Development Goals, and particularly SDG 7, call for access to affordable, reliable, sustainable and modern energy for all. To date, discussion of SDG7 has tended to avoid discussing cooking with electricity as it has been thought that it would require significant energy provision, which was either too much for most African grids, and/or was not affordable. LPG (also considered 'clean) is used in some markets, but generally depends on whether government policies introduce a subsidy. Recent work by members of the team suggested that there are emerging opportunities for clean cooking, and hence they decided to investigate it further.

Accordingly after drawing on the market scans and the known consumer needs, the team settled on investigating consumer preferences for three technologies:

- Solar Pumping (in a specific set of conditions).
- Domestic refrigeration.
- Clean cooking with modern energy (implicitly LPG or electricity).

2 Methodology

2.1 Choice modelling

A series of market research studies were scheduled as one of the preliminary activities in the product development timeline. Discrete choice modelling was proposed as the theoretical construct to be used in these surveys, to identify the key characteristics (or parameters) that each product should have in order to find ready acceptance with consumers. Choice models are set up using choice cards, based on the key parameters identified, each of which has a limited number of 'levels'. The respondent must then choose one of the two cards presented. Discrete choice models predict the probability that an individual will choose an option, based on the levels of each parameter given in the option.

In the research, each technology was assigned between 4 to 7 parameters, each parameter having between 2 and 4 levels. Each technology included a cost parameter, which was considered to be a continuous variable – in most cases this was a capital cost for the device, but in clean stoves it represented an amortised monthly cost (i.e. covering both capital cost and operational fuel costs).

Fractional orthogonal design[2] was used to limit the number of choices to 16 choice cards per technology (Mangham, Hanson, & McPake, 2009). A simple constant comparator approach was used (De Bekker-Grob et al., 2010), in which one of the 16 choice cards was used as a 'reference'[3], and the 15 resulting pairs presented respondents with a choice between this comparator and each of the other choice cards. The literature suggests that respondents get fatigued when presented with too many choices, and a review suggested studies rarely used more than 16 choices (De Bekker-Grob, Ryan, & Gerard, 2012). For each technology the choice cards were therefore split in two sets (with 7 & 8 pairs in each), included in a Questionnaire A and Questionnaire B. We then hypothesised that, moving on to another technology within the same questionnaire, the respondent would be prepared to answer another 7 or 8 pairs. The field surveys employed four questionnaires - Questionnaire A and Questionnaire B for the medical technologies, and Questionnaire A and Questionnaire B for the domestic appliances. Piloting of the survey instrument confirmed that respondents could indeed respond to 4 technologies within a given questionnaire, with a maximum of 8 choice pairs per technology.

Data sets derived from choice modelling are quite different to those from other types of surveys. Firstly, each respondent is asked 7 or 8 questions relating to each appliance, resulting in multiple responses per individual. Secondly, each choice comprises a pair of choice cards i.e. two records are generated for each of the questions. The data is, therefore, 'expanded' into a matrix of continuous and categorical dummy variables that represent the characteristics of each choice (the level for each parameter), along with a categorical 'choice' variable – the dependent variable indicating whether the respondent chose or rejected the choice card in the pair presented (World Health Organisation, 2012).

The analysis used binary logistic regression to fit predictive models to the data for each technology because the dependent variable was a dichotomous categorical variable (representing whether the choice card was chosen or not). All of the parameters were entered into the model, which calculated regression coefficients for each, along with p values indicating whether the parameter was significant in the model. The modelling was done using SPSS, and the output tables are presented in Section 3 and Section 4. The two main figures to look for in these tables are the beta coefficients (B), which reflect the strength of preference for each attribute, and whether each coefficient is significant in the model (Sig). If a variable is significant (Sig<0.05), then the larger the B value (positive or negative), the more important it is in the making a choice. Other statistics presented include the stander error (S.E.), which is a measure of how precise the beta value is likely to be – a large standard error means that that the actual beta value may lie within a wider range. The odds ratio (Exp(B)) is the change in odds resulting from a unit change in the predictor variable, and is another measure of the influence the variable has on people's choice, as is the Wald statistic. As all

[2] Using SPSS software.

[3] The constant comparator choice card was selected on the basis that the mix of levels represented a mid-level of attractiveness, so one would expect the number of times the comparator was chosen and reject to be roughly balanced.

variables have been separated out into dichotomous dummy variables, the degrees of freedom (df) for all variables is 1.

Where the cost variable is significant in a model, a measure of willingness to pay (also known as implicit price) can be derived for each attribute from the ratio of the coefficients (Hanley, Mourato, & Wright, 2001):

$$WTP = \frac{-\beta_x}{\beta_c}$$

where:

β_x = coefficient of any parameter

β_c = coefficient of cost parameter

2.2 Sampling design

According to Rose & Bliemer "*an archetypal SCE [stated choice experiment] might require choice data be collected on 200 respondents, each of whom are observed to make eight choices, thus producing a total of 1600 choice observations*" (Rose & Bliemer, 2009). The literature goes on to point out that if the survey design is to include other questions that can be used to disaggregate the data, larger samples are required (Orme, 2010) . However the literature also states that to a large extent, sample size is determined by budgetary constraints. Work by the Consortium for Research on Equitable Health Systems (CREHS) confirms that sample sizes for discrete choice experiments have generally been based on experience rather than mathematical calculation (Wafula et al., 2011), and propose 100 – 150 respondents per sub-group. When considering the acceptable range of sample sizes, the WHO guidelines suggest the sample size must be more than 30 (World Health Organisation, 2012), and at the upper end a review of studies suggests that precision improves only marginally for sample sizes over 300 (Johnson et al., 2013). One of the leading experts in choice modelling states:- "*For robust quantitative research where one does not intend to compare subgroups, I would recommend at least 300 respondents.* ***For investigational work and developing hypotheses about a market, between thirty and sixty respondents may do****.*" (Orme, 2010) (Our emphasis).

Through discussion, the team examined the purposes of the survey. It was agreed that as the survey exercise was not the primary focus of the LCT research project, it was not necessary to aim for the upper end of recommended sample sizes, giving research standard precision. While disaggregation by sub-groups may give insights into the nuances of the market, it was not our primary purpose to define the market so precisely, so it was not necessary to aim for multiples of recommended sample sizes. Rather, the research question (RQ1) simply refers to "What are acceptable price points and how will the devices be constructed and commercialized at those levels?", so the intention of the sampling design was to have robust statistical power for the overall model, and to facilitate some 'indications' of preferences within some market segments.

For the medical technologies, the target respondents were health professionals working in Kenya, with a bias towards the less qualified grades such as nurses. Given that each respondent would be working with one half of each set of choice pairs, the target sample was 400 (giving 200 complete choice pairs).

For the domestic technologies, the central district was highlighted as the only area where the solar pump options would be relevant, so only respondents in central district would be offered the choice pairs for this technology. The target sample for the solar pumping was 300 (150 complete choice pairs). For the clean cooking and the refrigeration technologies choice pairs, the team thought that the different geographical regions of Kenya might yield slightly different responses. Therefore the sample was drawn from an additional four zones, each with a target of 100 respondents (50 complete choice pairs), giving a total of 350 complete choice pairs.

2.3 Computer assisted personal interviewing (CAPI)

Surveys were conducted on (PC) tablets with an Android operating system. Compared with paper collection, the reliability of the data is greatly improved and there are savings on digitising the data (transcription from paper to computer).

While the team has extensive experience of collecting data on tablets, it was not immediately clear whether CAPI systems could use graphics, and whether respondents would be able to browse options for themselves before making a choice. The first issue of concern was whether respondents would be comfortable with handling the tablet (recent experience of self-administration in rural areas of DRC was mixed), and secondly, the particular software needed to include graphics (for non-literate respondents).

The Poimapper Plus digital survey tool was selected because it offered the ability for enumerators to show respondents graphics representing the choice cards – see Figure 2.

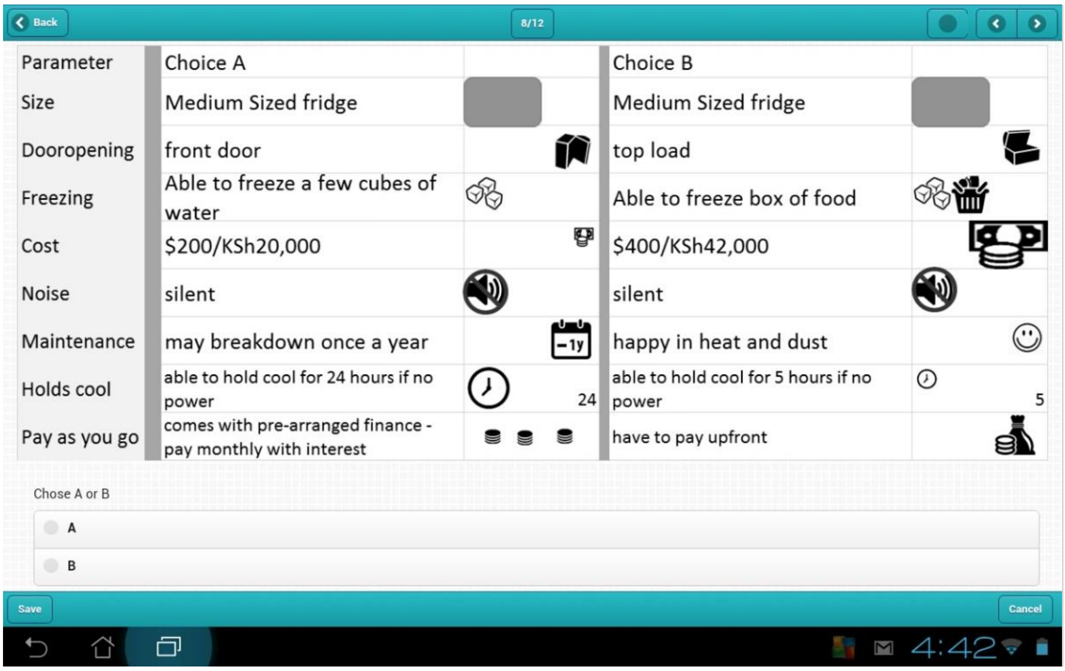

Figure 2 Screenshot of choice card with graphics

One disadvantage to CAPI is that it is difficult to create a word document for inclusion as an annex in reports such as this. Annex 1 and Annex 2 present lists of variables collected using the Health Workers and the Domestic questionnaires respectively.

2.4 Training and piloting

ACTS recruited a team of enumerators from Nairobi based universities (Bachelors and Masters students). 7 students (4 Female and 3 Male) where finally selected for training and employment. A recruitment requirement – checked during an interview – was the need to have experience of conducting surveys using a tablet. However, none of the applicants had this but all had good knowledge of smart phones and android devices which proved sufficient during training.

The training was conducted at CHAKS Guest house in Nairobi during the week commencing 5th October 2015. The training was conducted by trainers from Gamos, UK. The ACTS supervisory team (Mourine Cheruiyot, Ann Kingiri and Aschalew Tigabu) were trained alongside the enumerators. The field training also acted as pilot testing of the survey itself. The team split into two groups to conduct the pilot testing at two locations:

(i) Kawangware open air market which involved 6 enumerators and one supervisor. Pilot 17 respondents with very useful feedback.

(ii) Health survey done in Kisumu where 2 enumerators, supervisor, undertook the survey at the Kenya National Nurses Association annual general meeting. Pilot 34 respondents with very useful feedback.

Debriefing from the piloting identified edits to be made to the questionnaires, and adjustments on ways of clarifying and how to explain some of the questions that came up during the pilot survey. Pilot survey responses were **not** included in the analysis because changes to the questionnaires, and the format of the choice modelling design in particular, meant that the two sets of data were not compatible.

The field survey teams identified some of the challenges they faced, and how they addressed them:

- Time - the time taken to interview one respondent was about 30 minutes. It is normal to see surveys moving faster once the enumerators have got used to the questioning, however in this case the timing seemed to depend on the time taken by respondents to understand the choices presented.
- Survey permits - each region required separate permissions to conduct the survey, which took time; sometimes they would get to regions where the relevant departments were not aware that a survey was being done.
- Market days - market days are too busy for respondents to take 30 minutes on an interview hence the team offered a modest cash incentive.
- Incentive - when some respondents knew that an incentive was being given after the interview then occasionally it became the main motivation for completing the interview, in which case some respondents gave less well considered responses.
- Technology – they developed strategies to enable enumerators to continue working just in case someone's tablet crashed.
- Security - enumerators were not confident to visit rural clinics in Marsabit due to security issues in the area.
- Distance - distance between respondents (health survey) made the survey move slowly and with considerable expense.
- Questions from respondents – the training was helpful because of the time taken to go through the questionnaire and ask questions as a team, because the questions that came up in the training were also raised by respondents.

Evening meetings held at the end of the day were key to identifying issues, and thinking of ways to mitigate challenges arising (Figure 3).

Figure 3 Team debriefing at end of the day (Isiolo)

2.5 Creating Proxy Indicators

Respondents to the medical survey represent a range of different institutions. Principal component analysis has been used to create an index that accommodates different characteristics of the facilities that respondents represent:

- Medical care –
  - Type of services (inpatient / outpatient)
  - Size of facility (Number of beds, number of patients seen, number of medical staff)
  - Availability of doctors
- Physical assets – backup generators (almost all facilities have grid electricity), internet, landline

There is a good degree of intercorrelation between all of these variables (Cronbach alpha = 0.615), so it is reasonable to draw out a single factor. A dichotomous index representing poorly resourced, and well resourced facilities has been based on the first factor extracted from a factor analysis of these indicators.

Similarly, respondents themselves have different characteristics that may influence their aptitude to new technology. An aptitude variable has been created on the basis of the following personal characteristics:

- Experience – age, length of time in health service, length of time at current facility
- Medical responsibilities – medical training, conducting medical tests (observations, diagnostics, microscope, lab equipment, immunoassay, ultrasound, x-ray).
- ICT literacy – use computers, use internet, facebook.

There is a good deal of intercorrelation between variables, confirming that they can be considered together and used to create a single factor (Cronbach alpha = 0.613). The first factor extracted from a factor analysis of these indicators been used to create a dichotomous variable of two equal categories (representing higher or lower professional status). 85% of all respondents have been classified in this way.

With any household study such as the domestic appliances survey, it is assumed that poverty will be a key determinant of adoption behaviour and preferences. It can also be asserted that early adopters of new technologies will tend to be those who have already adopted other technologies and are intensive users of other technologies. Where a device meets a need, it is more likely to be adopted by people who are aware of those needs. For example, respiratory infections associated with traditional cooking methods are a major cause of deaths, yet demand for improved cookstoves will only be stimulated when people become aware of the consequences of traditional cooking methods. Some of the supporting questions in the domestic appliances questionnaire were designed to explore these issues of poverty, adoption of technology, and general level of understanding (or awareness). Given that level of education and ownership of assets are commonly used as determinants of wealth, a high degree of interconnectedness is to be expected between these three issues.

Principal component analysis has been used to create a combined 'wealth' index that accommodates various characteristics of the respondents:

- household characteristics,
- asset ownership,
- cooking fuels and expenditure,
- use of technology.

A proxy wealth indicator was calculated on the basis of the first factor extracted from a factor analysis of these supporting indicators, and households were divided into wealth quintiles.

3 Medical Technologies - Findings

3.1 Overview of respondents

3.1.1 Description of sample

413 interviews were conducted with staff from a range of medical facilities across the country. The distribution of interviews was divided into four health zones[4] as indicated in Figure 4 and summarized in Table 1. Enumerators tended to use the B questionnaires – 162 Questionnaire A and 251 Questionnaire B. Most respondents were from rural areas – the ratio was 82:18 (rural:urban). Only facilities in the Drylands zone were drawn almost exclusively from rural areas. There was a modest female bias among the sample; the balance was 46:54 (male:female). Whilst respondents from urban areas were mostly female, the gender of health workers from rural areas was quite equally balanced. The mean age of respondents was 34.7 years; ages of respondents from rural and urban areas were similar.

Most respondents had attended college. The sample included respondents with a good mix of types of medical training. Nearly one half of respondents were nurses; the remainder were split between specialist medical professionals (35% - doctors and specialists such as laboratory and pharmacy staff), and support staff (17%), both medical (e.g. counselling) and administrative.

The mean length of service in the health sector was 9.2 years (median 6 years). The mean time respondents had been employed at their current facility was 4.5 years (median 2 years). There

[4] These zones were devised on inspection of the geographical characteristics of facility locations. N.B. they do not correspond to any official typology of health risks.

seems to be quite a rapid turnover, as 53% of respondents had been at their current facility for only 2 years or less. Staff turnover was higher among rural facilities, where the mean time at the current facility was 3.6 years, compared with 8.8 years among respondents from urban areas.

Almost all respondents were willing to give their names to enumerators (98.5%), and 77% gave their phone number to enumerators, indicating that they would be willing to be contacted again in connection with the survey.

Table 1 Distribution of health worker interviews by Health Zone

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Lake Victoria	18	4.4	4.4	4.4
	Coastal	73	17.7	17.8	22.2
	Drylands	92	22.3	22.4	44.6
	Central	227	55.0	55.4	100.0
	Total	410	99.3	100.0	
Missing	System	3	.7		
Total		413	100.0		

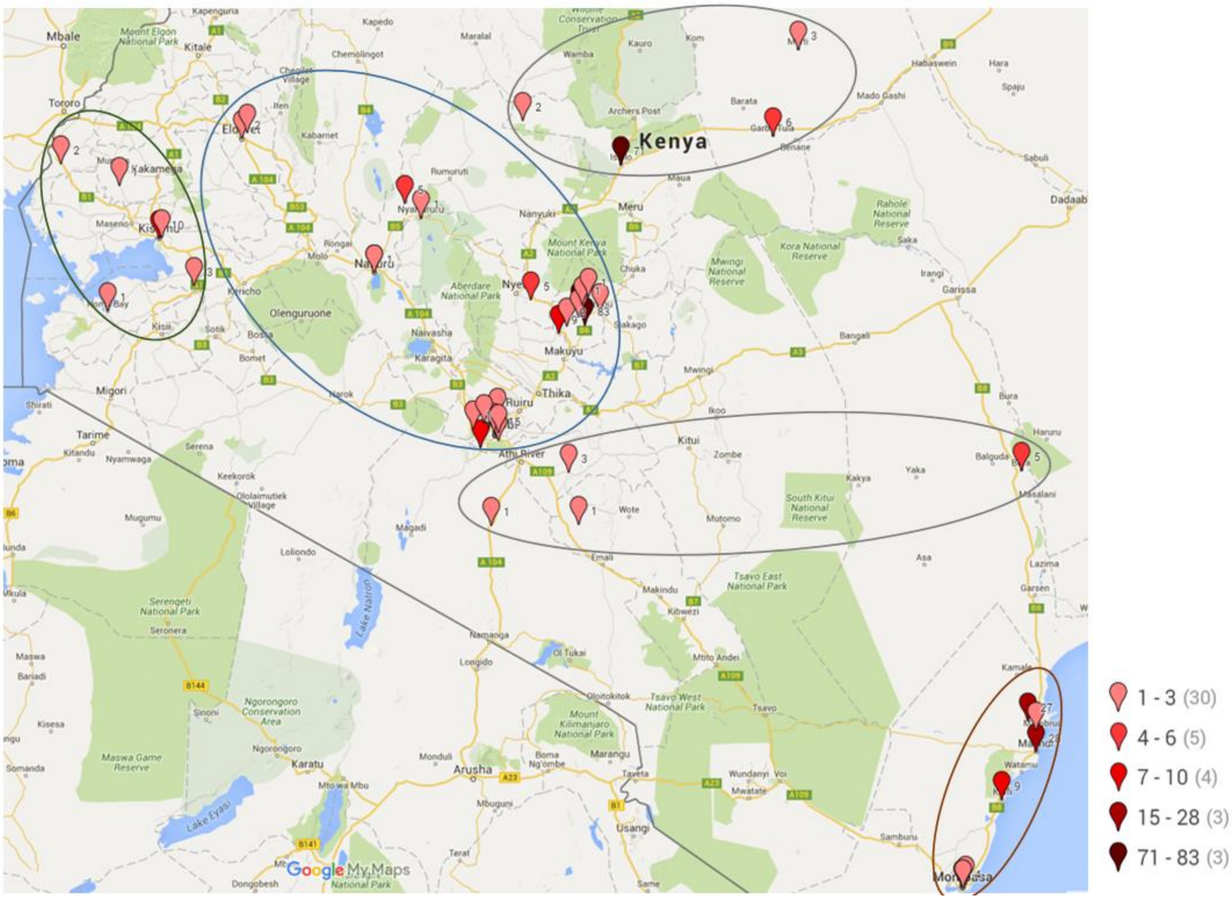

Figure 4 Distribution of surveys (by Sub-County)

3.1.2 Respondents' Medical Facilities

Most respondents worked in government health facilities (see Table 2). Figures suggest that government run facilities account for 51% of all health facilities, the private sector 29%, and NGOs 20%, but this is based on 1998 data (Kenya National Health Sector Service Providers, 2010). Nevertheless, it appears that NGO facilities may be somewhat underrepresented in the sample.

Table 2 Affiliation of health facilities

		Frequency	Percent
Valid	Government	225	54.5
	Private (commercial)	146	35.4
	NGO (e.g. Church)	39	9.4
	Total	410	99.3
Missing	System	3	.7
Total		413	100.0

Some types of facility also have a Community Unit attached to them; in these instances, the facility has been classified according to the 'highest' function of the facility – see Table 3[5]. Most hospitals were government run, whereas health centres and dispensaries were largely split between the government and private sector. The small number of NGO run facilities were mostly dispensaries.

Table 3 Type of facility (highest function)

		Frequency	Percent
Valid	Community Unit	14	3.4
	Dispensary	154	37.3
	Health Centre	120	29.1
	District Hospital	63	15.3
	Higher hospital	16	3.9
	Other	45	10.9
	Total	412	99.8
Missing	System	1	.2
Total		413	100.0

Many facilities (48%) provided inpatient services, and 51% provided only outpatient services. The number of beds in facilities providing inpatient services ranges from just a few (mainly in dispensaries) to up to 2,000 in the Kenyatta National Hospital. Overall, the mean number of beds was 151 (median 60). It is mostly dispensaries that have either no doctors or only part time doctors.

[5] N.B. some facilities originally coded as 'other' were in fact higher level hospitals e,g. teaching & referral, provincial hospitals, Kenyatta National hospital; these have been classified as 'higher hospitals'.

Table 4 Availability of doctors in different types of facility

Is there a doctor at the clinic?	TYPE OF HEALTH FACILITY (MAIN) Community Unit	Dispensary	Health Centre	District Hospital	Higher hospital	Other	Total
Several full time	4	0	5	46	16	13	84
One full time	9	2	29	15	0	17	72
Part time (including 'on call')	0	6	15	0	0	5	26
No doctor	1	144	70	0	0	11	226
Total	14	152	119	61	16	46	408

The number of medical staff in facilities ranges widely from 1 or 2 up to thousands. The mean number of medical staff is 100 (median 7). The number of patients seen in a day varies in the same way – the mean number of patients seen is 110 per day (median 58).

Most clinics (86%) have either piped water or borehole water. Most facilities treat their drinking water (72%), and most facilities using piped and borehole water still treat it.

Availability within health facilities of a range of appliances and services is presented in Table 5.

Table 5 Ownership of assets within facility

	Proportion of health facilities with appliances and services(%)
Energy assets	
Grid electricity	91.3
Backup generator	37.3
Solar power	11.1
Solar water heater	6.1
Fridge	83.8
ICT	
Internet access	30.8
landline	13.6
Communal mobile	30.8

In addition to these assets, respondents were asked if their facility has any solar powered assets – see Table 6. Ownership of solar appliances (lights, and chargers) is mostly complementary to ownership of solar cells (on a roof). Nearly one half of facilities with cells on the roof also have solar electricity, so it must be assumed that this is used to power a miscellaneous range of low powered equipment such as computers and lighting. It is not clear what the other half of facilities that have cells on the roof are using them for.

Table 6 Health facility ownership of solar powered assets

	Proportion of health facilities with solar powered assets (%)
Solar light (e.g. torch; lantern; D-light)	9.9
Cells on roof	13.6
Radio charger	0.0
Phone charger	2.9
other	1.5

Regarding how the facilities gain these assets, During the pilot phase it was determined that there are two stages to making a decision to purchase new equipment – firstly, somebody has to make a request for a new item of equipment, and then another party makes the decision whether to purchase it or not. Clinic managers are most commonly responsible for making requests for new equipment, followed by medical staff. The 'other' category included officer in charge, committees and teams, and administrators.

When it comes to making purchasing decisions, these are most commonly made by Clinic managers and facility management teams.

3.1.3 Respondents' use of technology

The frequency with which respondents carry out common tests, and their use of medical equipment is presented in Figure 5.

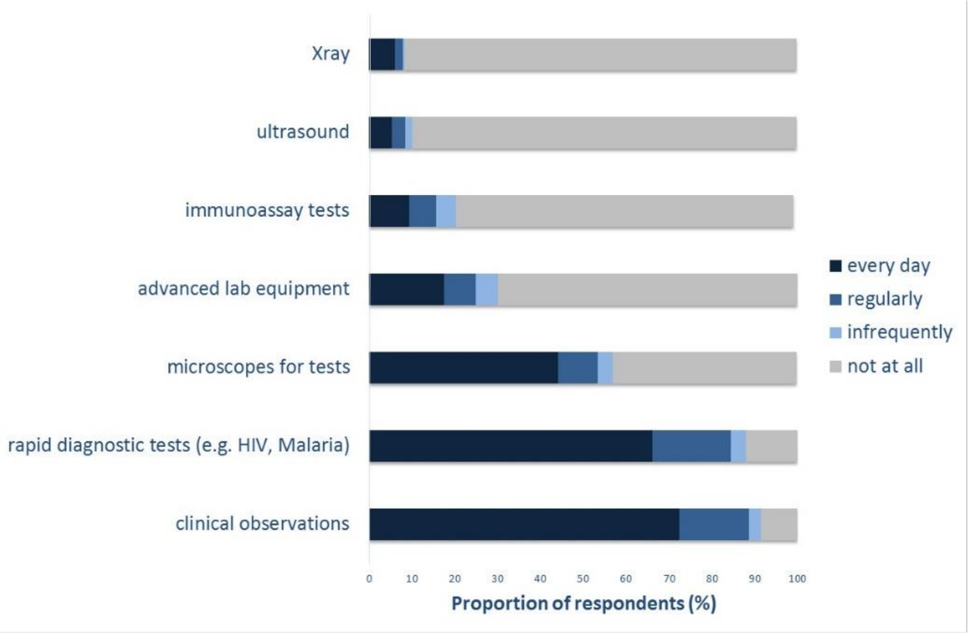

Figure 5 Respondents' use of medical equipment

51% of respondents used computers at work. The data shows that computers are most commonly used for managing patient information, and this is true for all types of professionals. It also shows that nurses are the ones who make greatest use of the internet to research diseases.

91% of respondents have used a private mobile phone in the last month, 99% are able to send texts, and 99% use mPesa or other mobile payment service (Table 8). Smart phones are the dominant type of phone (Table 7), and this is true for all the main groups of health professionals.

Table 7 Type of mobile phone most commonly used (Health Workers)

		Frequency	Percent
Valid	Smart phone	269	65.1
	Feature phone	77	18.6
	Basic phone	35	8.5
	Total	381	92.3
Missing	System	32	7.7
Total		413	100.0

Table 8 Use of Mpesa (or other mobile money platform) (Health Workers)

		Frequency	Percent
Valid	not used	2	.5
	1 or 2 times a month	108	26.2
	3 - 10 times a month	282	68.3
	Daily	19	4.6
	Total	411	99.5
Missing	System	2	.5
Total		413	100.0

87% of all respondents made some use of the internet and 76% had used Facebook. The data shows there is a small proportion of Facebook users who have stopped using the service (2.4%); this suggests that a finding from the pilot exercise that nurses got overwhelmed with information and quit the service was not in fact widespread.

3.2 Choice modelling - Vital Signs Measurement

The following parameters were explored (see Figure 6):

1. 'Number of devices' – there were 2 options:
    - 1 device – it may be possible to combine all the instruments (blood pressure, heart rate, etc) into a single integrated device. (VSint=1)
    - Many devices - a different instrument is required to measure each of the vital signs (VSint=0).

2. The level of automated analysis. This is whether you just connect something to the patient and the device automatically gives you the readings, or whether you have to conduct manual tasks, such as pumping up a blood pressure cuff then carefully listening through a stethoscope, or trying (several times) to get a temperature thermometer to give a successful reading. There were 2 options:
   - Device(s) are manual (VSauto=0)
   - Devices(s) are automatic, and can be used with minimal training (VSauto=1).

3. The power source that can be used by the equipment – there were 3 options:
   - Batteries – replaceable batteries e.g. Everready (VSPowerRech=0, VSPowerSolar=0)
   - Rechargeable - devices have rechargeable batteries and can be plugged into power sockets (like a phone) (VSPowerRech=1)
   - Rechargeable with solar - devices have rechargeable batteries and can be plugged into power sockets and come with a solar charging station (VSPowerSolar=1).

4. Cost – this is the total cost of the kit, which may include only 1 device, or many devices. Options offered were:
   - 50,000 KSH
   - 100,000 KSH
   - 150,000 KSH
   - 200,000 KSH

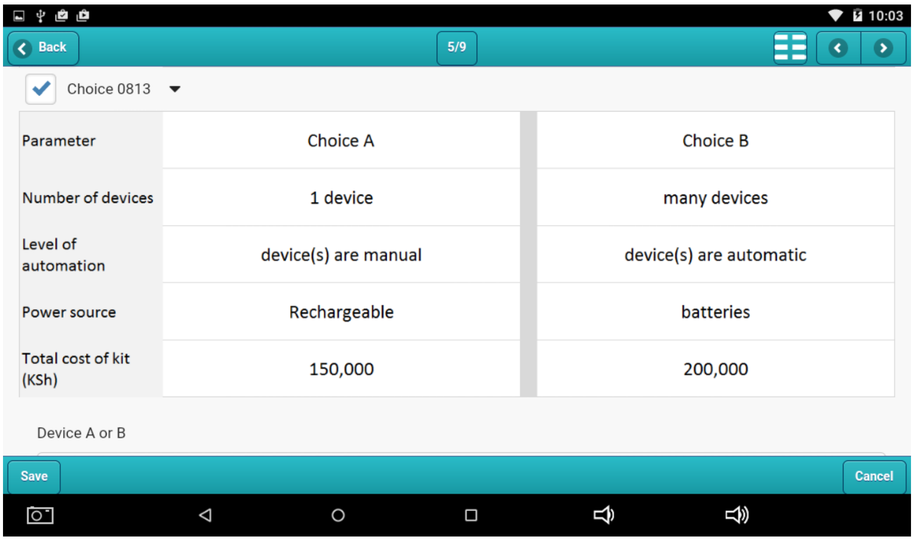

Figure 6 Example of choice pair from Medical survey - Vital signs device

Results from the binary logistic regression are presented in Table 9.

Table 9 Binary logistic regression – vital signs

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	VSint(1)	.355	.068	26.976	1	.000	1.426
	VSauto(1)	1.005	.074	182.661	1	.000	2.731
	VSPowerRech(1)	1.461	.079	338.097	1	.000	4.310
	VSPowerSolar(1)	1.485	.099	225.411	1	.000	4.415
	VSCOSTC[b]	-.585	.070	69.755	1	.000	.557
	Constant	-.810	.113	51.172	1	.000	.445

a. Variable(s) entered on step 1: VSint, VSauto, VSPowerRech, VSPowerSolar, VSCOSTC.

b. Costs have been divided by 100,000 in order to create a unit of increment compatible with other variables.

Note: Compared against a constant only model, the model was significant ($\chi^2 = 623$, p = 0.000, with df = 5); Nagelkerke $R^2 = 0.130$. Prediction success = 59.7%.

Those design features that appear to be most important to consumers are (in descending order of importance) presented in Table 10 along with estimates of willingness to pay for each attribute, which can be used to weigh up trade-offs between different design features.

Table 10 Key design characteristics – vital signs

Design feature	Willingness to pay (KSH)
People have a strong preference for a device that does not use disposable batteries – people are not really willing to pay more to be able to charge the device using solar, over normal rechargeable batteries	354,000 (solar) 250,000 (rechargeable)
People are willing to pay for an automatic device	172,000
Not surprisingly, people preferred an integrated device that could be used for multiple observations, but they were willing to pay less for this facility	61,000

3.3 Choice modelling – Blood and Urine testing

The following parameters were explored:

1. 'Number of devices'. Although it is a little unlikely we can develop a single device for all possibilities, for the sake of simplicity, we asked respondents to choose between a single device, and multiple devices – there were 2 options:
   - 1 device – that can test for a range of diseases (Utint=1).
   - Many devices - a separate instrument is required to test for each disease (Utint-0).

2. The amount of preparation needed before samples can be analysed by the devices(s). There were 2 options:
   - Needs preparation (Utprep=0)
   - Does not need preparation (Utprep=1)

3. The power source that can be used by the equipment – there were 3 options:
   - Batteries – replaceable batteries e.g. Everready (UTPowerRech=0, UTPowerSolar=0)
   - Rechargeable - devices have rechargeable batteries and can be plugged into power sockets (like a phone) (UTPowerRech=1)
   - Rechargeable with solar - devices have rechargeable batteries and can be plugged into power sockets and come with a solar charging station (UTPowerSolar=1).

4. Cost – this is the total cost of the kit, which may include only 1 device, or many devices – options were:
   - 50,000 KSH
   - 100,000 KSH
   - 150,000 KSH
   - 200,000 KSH

5. An additional charge that needs to be paid each time a test is done; this may, for example, reflect the cost of reagents. There were 2 options:
   - No charge (UTUseFee=1)
   - 50 KSH per test (UTUseFee=0)

Results from the binary logistic regression are presented in Table 11.

Table 11 Binary logistic regression – urine testing

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Utint(1)	.361	.070	26.421	1	.000	1.434
	Utprep(1)	.792	.076	109.074	1	.000	2.208
	UTPowerRech(1)	1.397	.079	315.557	1	.000	4.043
	UTPowerSolar(1)	1.388	.098	202.629	1	.000	4.008
	UTUseFee(1)	-.159	.076	4.414	1	.036	.853
	UTCOSTC[b]	-.275	.067	16.698	1	.000	.760
	Constant	-1.171	.121	94.061	1	.000	.310

a. Variable(s) entered on step 1: Utint, Utprep, UTPowerRech, UTPowerSolar, UTUseFee, UTCOSTC.
b. Costs have been divided by 100,000 in order to create a unit of increment compatible with other variables.

Note: Compared against a constant only model, the model was significant (χ^2 = 566, p = 0.000, with df = 6); Nagelkerke R^2 = 0.119. Prediction success = 63.4%.

Those design features that appear to be most important to consumers are (in descending order of importance) presented in Table 12.

Table 12 Key design characteristics – urine testing

Design feature	Willingness to pay (KSH)
People have a strong preference for a device that does not use disposable batteries – people are not really willing to pay more to be able to charge the device using solar, over normal rechargeable batteries	508,000 (rechargeable) 505,000 (solar)
People are willing to pay for a device that eliminates the need to prepare samples	288,000
People preferred an integrated device that could be used for multiple observations,	131,000
People preferred to pay a usage fee	58,000

3.4 Choice modelling - Diagnostic Support Device

The devices described above may feed into a further device (computer) that could do several things that might help nurses to work more effectively. The following parameters have been explored:

1. The level of support that the device could provide in making a clinical diagnosis (on the basis of readings taken). There were 3 options:
    - No support (DSSupportComp=0, DSSupportDoct=0)
    - Computerised advice on screen to help the clinician make a diagnosis based on the results (DSSupportComp=1)
    - Support from a doctor - the device feeds information from the test results to an expert/doctor in real time, who offers clinical advice (some kind of telemedicine solution) (DSSupportDoct=1).

2. How many devices are connected to this computer? There were 2 options:
    - Vitals only (DSDevices=0)
    - Vitals + urine/blood tests (DSDevices=1)

3. The power consumption. There were 3 options, as above:
    - Batteries – replaceable batteries e.g. Everready (DSPowerRech=0, DSPowerSolar=0)
    - Rechargeable - devices have rechargeable batteries and can be plugged into power sockets (like a phone) (DSPowerRech=1,
    - Rechargeable with solar - devices have rechargeable batteries and can be plugged into power sockets and come with a solar charging station (DSPowerSolar=1).

Two further characteristics explore how helpful it would be for the computer device to provide a nurse with easy access to different types of information.

4. The patient's history including clinical records – there were 2 options:
    - None – no information available on the device (DSPatient=0)
    - Patient history – device can provide information on the Patient's clinical history e.g. admissions, attendance at clinic, diagnosis, what action was taken (DSPatient=1).

5. Financial information relating to managing clients e.g. whether the patient will be paying for themselves or whether the clinic will need to claim from an insurance company, that sort of thing. There were 2 options:
    - None – no information available on the device (DSFinancial=0)

- Business information – e.g. patient billing, accounts, insurance and inventory can be managed through a hand held device (DSFinancial=1)

6. Cost of the device – there were 3 options:
   - 50,000 KSH
   - 100,000 KSH
   - 150,000 KSH
   - 200,000 KSH

Results from the binary logistic regression are presented in Table 13.

Table 13 Binary logistic regression – diagnostic support device

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	DSSupportComp(1)	1.295	.090	208.539	1	.000	3.650
	DSSupportDoct(1)	.759	.105	51.922	1	.000	2.137
	DSDevices(1)	.985	.081	149.150	1	.000	2.677
	DSPowerRech(1)	1.140	.097	137.319	1	.000	3.127
	DSPowerSolar(1)	.930	.096	94.215	1	.000	2.534
	DSPatient(1)	.708	.079	80.982	1	.000	2.031
	DSFinancial(1)	-.158	.084	3.575	1	.059	.854
	DSCOSTC[b]	-.366	.076	23.130	1	.000	.694
	Constant	-2.241	.174	166.036	1	.000	.106

a. Variable(s) entered on step 1: DSSupportComp, DSSupportDoct, DSDevices, DSPowerRech, DSPowerSolar, DSPatient, DSFinancial, DSCOSTC.

b. Costs have been divided by 100,000 in order to create a unit of increment compatible with other variables.

Note: Compared against a constant only model, the model was significant (χ^2 = 1458, p = 0.000, with df = 8); Nagelkerke R^2 = 0.277. Prediction success = 71.6%.

Those design features that appear to be most important to consumers are (in descending order of importance) presented in Table 14 along with estimates of willingness to pay for each attribute, which can be used to weigh up trade-offs between different design features. Note that the strength of willingness to pay for diagnostic advice and for rechargeable batteries were similar.

Table 14 Key design characteristics – diagnostic support device

Design feature	Willingness to pay (KSH)
People have a strong willingness to pay for some kind of diagnostic advice, and quite a strong preference for computerised advice rather than a remote doctor.	354,000 (computerised) 207,000 (remote doctor)
People have a strong willingness to pay for a device that does not use disposable batteries, and there is a modest preference for normal rechargeable batteries rather than the option for solar recharging.	311,000 (rechargeable) 254,000 (solar)
People are willing to pay for a device that would connect to, and process data from, multiple devices	269,000
People were willing to pay for a device that could handle clinical information on patient histories	193,000

3.5 Choice modelling – Ultrasound

The following parameters have been explored:

1. Ultrasound has different levels of penetration and therefore is useful in different situations. The first characteristic addresses whether the device can only be used for pregnancy related applications, or has wider uses. There were 2 options:
   - Pregnancy only – can be used for most common conditions related to pregnancy e.g. placenta previa, gestational age, breech (USGScope=0);
   - Many services (USGScope=1)

2. Power source that can be used by the equipment – there were 3 options:
   - Batteries – replaceable batteries e.g. Everready (USGPowerRech=0, USGPowerSolar=0)
   - Rechargeable - devices have rechargeable batteries and can be plugged into power sockets (like a phone) (USGPowerRech=1)
   - Rechargeable with solar - devices have rechargeable batteries and can be plugged into power sockets and come with a solar charging station (USGPowerSolar=1).

3. Cost of the device – options were:
   - 100,000 KSH
   - 300,000 KSH
   - 600,000 KSH
   - 1,000,000 KSH

4. The ability of the device to store a digital image. During the piloting exercise we found that some people would like the ability to store an image so that they can share it with their colleagues and get a second opinion. There were 2 options:
   - Not possible (USGImage=0)
   - Can store image (USGImage=1)

Medical ultrasonography appliances (USGs) are notoriously difficult to maintain so there are two parameters that explore the two types of maintenance – breakdowns and servicing.

5. Breakdown response – the time taken for an engineer to get to you to get a machine repaired once it has broken down. There were 2 options:
   - Delay of 2-6 weeks (USGRepair=0)
   - Repaired within 2 weeks (USGRepair=1)

6. How often it needs servicing, as there is effort and expense involved in arranging for service visits. (Note that we did not give respondents any idea what the cost of servicing might be). There were 2 options:
   - Frequent (e.g. every 3 months) (USGService=0)
   - Rarely (e.g. every 18 months) (USGService=1)

Results from the binary logistic regression are presented in Table 15.

Table 15 Binary logistic regression – ultrasound device

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	USGScope(1)	.579	.072	63.844	1	.000	1.784
	USGPowerRech(1)	1.354	.085	251.838	1	.000	3.873
	USGPowerSolar(1)	1.166	.091	165.678	1	.000	3.211
	USGImage(1)	.912	.077	139.002	1	.000	2.490
	USGRepair(1)	.554	.070	63.059	1	.000	1.741
	USGService(1)	.522	.078	45.094	1	.000	1.686
	USGCOSTC[b]	-.043	.011	14.216	1	.000	.958
	Constant	-1.972	.135	214.451	1	.000	.139

a. Variable(s) entered on step 1: USGScope, USGPowerRech, USGPowerSolar, USGImage, USGRepair, USGService, USGCOSTC.

b. Costs have been divided by 100,000 in order to create a unit of increment compatible with other variables.

Note: Compared against a constant only model, the model was significant (χ^2 = 585, p = 0.000, with df = 7); Nagelkerke R^2 = 0.119. Prediction success = 60.7%.

Those design features that appear to be most important to consumers are (in descending order of importance) presented in Table 16 along with estimates of willingness to pay for each attribute, which can be used to weigh up trade-offs between different design features. Note that strength of willingness to pay for the two aspects of reliability explored (time to repair and servicing frequency) were similar.

Table 16 Key design characteristics – ultrasound device

Design feature	Willingness to pay (KSH)
People have a strong willingness to pay for a device that does not use disposable batteries, and there is a strong preference for normal rechargeable batteries rather than the option for solar recharging.	3,149,000 (rechargeable) 2,712,000 (solar)
People have a strong willingness to pay to store a digital image	2,121,000
People are willing to pay for a device that would perform multiple functions	1,347,000
People were willing to pay for a device that could be repaired promptly	1,288,000
People were willing to pay for a device that required less frequent servicing	1,214,000

4 Domestic Appliances

4.1 Overview of respondents

4.1.1 Description of sample

A total of 780 interviews were conducted in 5 regions across Kenya (see Table 17). The A and B questionnaires were administered fairly equally – 367 Questionnaire A and 413 Questionnaire B. The sample contained a balance of respondents from rural and urban areas (49:51 rural:urban), although almost all respondents from Nairobi were urban. Overall, the sample was equally balanced by gender - 50:50 (male:female). The age profile of the sample is presented in Table 18, and shows an excellent match with the national average age distribution (Kenya National Bureau of Statistics (KNBS) & ICF Macro, 2010), even though the sample was not intended to be representative in any way.

Table 17 Geographical distribution of sample (Domestic)

		Frequency	Percent
Valid	Central Kenya	332	42.6
	Western Kenya (Kisumu region)	98	12.6
	North Kenya (Marsabit region)	106	13.6
	Coastal Kenya	108	13.8
	Nairobi	136	17.4
	Total	780	100.0

Table 18 Age profile of sample, compared with national averages (Domestic)

	National (DHS)	Sample
less than 30	31.0%	30.6%
30-39	37.9%	38.9%
40-49	21.8%	19.8%
50 and over	9.1%	10.7%

A comparison of the highest level of education attained by respondents with average data from the latest DHS survey (*ibid*) (adjusted for adults only) indicates that the sample was of higher educational status than the population as a whole. The majority of respondents (89%) were either head of household or the spouse of the head of household. This is consistent with the sampling approach, as it is heads of household and spouses that will most commonly be involved in decisions concerning the purchase of household appliances. 63% of all respondents were a member of at least one community group – community groups suggest that a product that enhances livelihoods would find a ready pathway for word of mouth marketing. Among these respondents, 62% were members of only one group and the remainder were members of 2 or more groups.

Almost all respondents were willing to give their names to enumerators (99.6%), even if some people only gave their first name, which suggests that people had confidence in the survey and the enumerators. Of those respondents who had a mobile phone in the household, 75% also gave their phone number to enumerators, indicating that they would be willing to be contacted again in connection with the survey.

4.1.2 Respondents' households

The mean household size was 4.7 members, which is a bit higher than a mean of 4.2 members per household based on national data from 2008-09 (*ibid*). Household sizes were larger in rural areas – a mean of 5.3 compared with 4.1 in urban areas.

Respondents lived a mean of 3.8 km from their nearest market. As expected, rural households were more remote – a mean of 4.5 km compared to a mean of 3.1 km for urban households.

Main sources of drinking water have been classified as clean or not as follows:

- Safe – piped into premises, public tap, borehole, protected well/spring, rainwater, bottled water;
- Unsafe – unprotect well / spring, surface water, tanker/cart, sachet.

On this basis, 15% of households had unsafe sources of drinking water. The Multidimensional Poverty Index methodology (Alkire & Santos, 2010) uses characteristics of drinking water supplies as one component of the overall poverty index. The indicator is defined as follows:

> *"Drinking Water: deprived if the household does not have access to clean drinking water or clean water is more than 30 minutes' walk from home (round trip)".*

When combined with the times taken to collect drinking water, 20% of households were classified as deprived. The principal flooring material is also used by the MPI methodology as a component of the poverty index; households are classified as deprived if they have an earth floor. On this basis, 25% of households would have been classified as deprived. The principal cooking fuels used are presented in Table 19. Cooking fuels are used as one component of the MPI poverty index, based on the following definition:

> *"Cooking Fuel: deprived if the household cooks with wood, charcoal or dung"*[6].

On this basis, 53% of households were classified as deprived.

[6] The definition has been amended to include coal / lignite.

Table 19 Type of fuel mainly used for cooking (Domestic)

		Frequency	Percent
Valid	Electricity	12	1.5
	Cylinder gas	216	27.7
	Biogas	1	.1
	Kerosene	129	16.5
	Coal; lignite	11	1.4
	Charcoal	208	26.7
	Wood	195	25.0
	Other	3	.4
	Total	775	99.4
Missing	System	5	.6
Total		780	100.0

66% of all respondents had an electricity supply. Ownership of a range of electrical and transport assets was documented. Household ownership of some of these assets is used by the MPI methodology as a component of the poverty index as follows:

Indicator 6:

> *"Assets: deprived if the household does not own more than one of: radio, TV, telephone, bike, motorbike, or refrigerator and does not own a car or tractor".*

Based on the definition, 6.8% of households were classified as deprived.

Table 20 Household ownership of assets

	Proportion of households owning item (%)
Electrical assets	
Radio	90.0
Mobile phone	94.5
Non-mobile phone	0.8
TV	61.9
Fridge	14.2
Transport assets	
Animal drawn cart	12.1
Bicycle	26.0
Motorbike	21.3
Car / truck	5.9

In addition to these assets, respondents were asked if their household have any solar powered assets – see Table 21. Note that only around one half of households with a radio charger or a phone charger also had cells on their roof, so chargers are not necessarily linked to ownership of PV panels.

Table 21 Household ownership of solar powered assets

	Proportion of households owning item (%)
Solar light (e.g. torch; lantern; D-light)	36.0
Cells on roof	9.0
Radio charger	7.4
Phone charger	7.3
Other	2.2

When it comes to broadcast media, radio clearly has the greatest reach, with 94% of respondents listening to the radio, and 79% listening daily. There is a quite a usage gap between radio and television, as only 70% watch television at all. 86% of respondents have used a private mobile phone in the last month. Among these users, basic handsets remain most commonly used, but only just, and it is interesting to note that the number of smartphones has already overtaken the number of feature phones. Although only 86% of respondents had used a mobile in the last month, 95% of respondents owned a mobile handset (or SIM card), showing that there was a sizable minority of respondents who owned a phone yet did not use it (at least not within the last month). 91% of all respondents were able to read SMS texts themselves. There was a small minority (6%) of phone owners who were unable to read SMS messages. There was almost universal use of mobile money systems (see Table 22).

Table 22 Use of Mpesa (or other mobile money platform) (Domestic)

		Frequency	Percent
Valid	not used	34	4.4
	1 or 2 times a month	248	31.8
	3 - 10 times a month	445	57.1
	daily	52	6.7
	Total	779	99.9
Missing	System	1	.1
Total		780	100.0

39% of all respondents made some use of the internet and 34% had used Facebook. Facebook users were largely a sub-set of internet users, although there was a small number of facebook users who did not use the internet, who most likely accessed facebook exclusively via an app on their mobile phones.

4.1.3 Current stove use data

Just over one half of respondents use either wood or charcoal (split almost equally) as their main cooking fuel, and nearly a third used bottled gas. Only a small minority (1.5%) used electricity. Among respondents mainly using wood or charcoal, 7% used an improved stove (N=30); this proportion was similar among wood users and charcoal users.

The median amount of money saved by improved cookstoves was 580 KSH/month, and the saving was similar between wood users and charcoal users. Despite a substantial number of people using wood, almost all respondents paid something for their cooking fuel. Only 5.4% of all respondents paid nothing, and these were mostly but not entirely wood users.

The median amount spent on fuel (most recent purchase) was 1,000 KSH, and the median time that this lasted for was 30 days. However, this is not very interesting, as it conceals different characteristics of how people purchase different fuels. When these are separated out, it can be seen that wood and kerosene are bought most frequently, whereas cylinder gas lasts longest. The ranking of fuel costs, in terms of per capita daily cost of cooking fuel, corresponds to fuel quality[7] (i.e. cost of LPG is highest), although people appear to spend more on wood than they do on charcoal (bear in mind that these figures relate to 'main' cooking fuel, and in practice people will use multiple fuels).

Separating out energy used for cooking and heating water

Although the data on cooking fuel costs above were given in response to a question specifically about the cost of cooking fuels, it is possible that these fuels were used not only for cooking, but also for heating water. 48% of all respondents heated water for bathing.

Does heating water for bathing really make a difference to the amount of energy used? It is easiest to explore this question by considering respondents who use cylinder gas, as the energy and costs are relatively clearly defined. The refill price point of 1000-1300 KSH corresponds to a 6kg cylinder, and 2500-2800 KSH corresponds to a 13 kg cylinder*. Recent figures indicate there is no cost saving to be had by using larger cylinders[1] i.e. the cost per kg of LPG is constant. When comparing people who did and did not heat water for bathing, there was no difference in the mean amounts they spent when they last bought a cylinder (around 1,600 KSH); this indicates that the ratio of large to small cylinders purchased was similar. However, the cylinders purchased lasted longer among households that did not heat water for bathing (a mean of 62 days compared with 49 days). Unfortunately, this cannot be attributed solely to heating water because households that heated water were larger – a mean of 3.7 people compared with 3.2 among households that did not heat water. Using a cost of 200 KSH/kg, and a calorific value of 49.6 MJ/kg[1], the per capita energy consumption among households that heat water is 2.28 MJ/person/day, compared with 2.01 MJ/person/day among those who do not i.e. 14% higher. The difference in energy (0.27 MJ/person/day) is enough to heat 2 litres of water to 50°C (from 20°C).

In a South African study, Cowan (Cowan, 2008) measured the energy need to cook various types of meal. Using his figures, we can estimate the LPG energy required to cook a meal for four of ugali and chicken stew to be 1.5 kWh, which equates to 1.4 MJ/person/meal. On this basis, the specific cooking energy consumption figures calculated above are sufficient to cook around one and a half meals per day, which is more or less what one might expect, even though households will actually use multiple fuels (questions concern the *main* cooking fuel only).

A similar analysis of kerosene users also confirms that the amount of energy used for heating water is small in comparison with cooking energy requirements. Using a cost of 55 KSH/ltr, a density of 0.8 kh/ltr, and a calorific value of 46.2 MJ/kg[1], the per capita energy consumption among households that heat water is 5.4 MJ/person/day, compared with 4.2 MJ/person/day among those who do not i.e. 28% higher. The difference in energy (1.2 MJ/person/day) is enough to heat 9 litres of water to 50°C (from 20°C).

* http://allafrica.com/stories/201502100664.html (accessed 21/12/2015)

[7] Only those fuels used by more than 20 respondents.

Overall, over one third of all respondents felt that the decision to purchase a cookstove would be made by the female head of household; only 15% felt that this would be a man's decision. Again, there is a clear gender divide here, with men more likely to feel that they would be involved in decision making (either solely or jointly), and women more likely to feel that they would make the decision (χ^2 (4) = 50.3, p = 0.000).

There was a consensus that people would adopt modern cooking fuels if the cost was the same as their current expenditure on charcoal and wood[8]. There was also a consensus that any new device would need to accommodate very large pots (93% of all respondents agreed), and this feeling was stronger among women (χ^2 (1) = 8.9, p = 0.003).

4.1.4 Current fridge use data

14% of all respondents had a domestic fridge. There was a small discrepancy in fridge ownership, as some respondents who did not have a fridge in the household went on to describe the size of their fridge, and others who had a fridge in the household went on to say they did not have a fridge. Among fridge owners, two thirds had a medium sized fridge. Of those respondents who did not have a fridge, only 3.1% used someone else's fridge (N = 21). The distribution of sizes of these fridges was similar to that of fridges owned by respondents themselves.

When asked what they used a fridge for, 17% of respondents gave a valid answer. Keeping food for the household is the most common use of fridges, followed by keeping drinks (it is not clear if these are for selling) – see Table 23.

Table 23 Use of fridges (Domestic)

Use of fridge	Proportion of valid responses (%)
Keep food for the household to eat	83.6
Keep food for selling	17.9
Store medical things for selling	6.0
Mainly drinks	39.6
Mainly local brew	0.0
Other	0.7

Overall, roughly half of respondents felt that the decision to purchase a fridge would be made jointly (between male and female head of household). The remainder were split between those who felt that the male head of household would make the decision, and those who felt that the female would make the decision. However, there is a clear gender divide here, with men more likely to feel that they would make the decision (although 55% still felt the decision would be made jointly), and women more likely to feel that they would make the decision (although 59% still felt the decision would be made jointly) (χ^2 (4) = 74.7, p = 0.000). There was no evidence that patterns of decision making were any different among people who had already made this decision i.e. who had a fridge in the household.

[8] N.B. respondents were not asked if they would use modern fuels themselves, but about other 'people' in a generic, third party sense. This is the acceptable way of asking about difficult subjects.

4.1.5 Farming practice – Central Kenya only

Farming practices of respondents based only in Central Region of Kenya were explored using the questionnaire. All respondents (except 1) grew at least one type of crop; the distribution of crop types grown is presented in Table 24.

Table 24 Proportion of households growing crop types (Central Kenya only)

Crop type	Proportion of respondents (%)
Cereals	90
Legumes	58
Vegetables	56
Fruits	34
Roots/tubers	25
Cash crops	10
Spices	3
Ornamentals	2

Most people grow for domestic use (88%) or for markets (87%), and there is a large overlap between these. Only 6% grow for a company. It is not clear that any particular type of crop is grown for a specific purpose.

The majority of farmers grow most of their produce in fields next to their house, or just a short walk away. Only 8% use fields next to a river.

In addition to the 29% who used a field next to their house, a further 21% had some kind of garden or field next to their house, making a total of 50% of farmers who had some kind of field next to their house. The selection of a solar pump as a potential device for the project was based on the assumption that there is significant potential demand from farmers to irrigate land next to their dwelling, so this finding tends to confirm the assumption.

The mean size of this piece of land was 1.4 acres (median is 1 acre) although 66% of respondents had only 1 acre or less.

At present, 60% (n=198) of farmers irrigate their crops, and half of these use a pump in an open river. N.B. most of the 'other' responses referred to channels using water diverted from a river. Respondents who said they did irrigate their crops were then asked how much land they irrigated – it can be seen from Table 25 that most of these farmers irrigate only small areas of land, less than one acre. It also shows that some farmers are currently using pumps to irrigate small areas (less than half an acre).

Table 25 Methods used to irrigate different amount of land (farmers who irrigate)

	Do you currently irrigate your crops?			Total
	A little by hand and bucket (n)	By pump from open river (n)	By pump from spring/borehole (n)	
less than 1/8th acre (500 square meters)	11	6	2	19
1/8th to less than 1/4 of an acre (500 to 1000 sq.m)	3	7	1	11
1/4 to less than 1/2 of acre (1000 to 2000 sq.m)	1	14	4	19
1/2 to less than 1 acre (2000 to 4000 sq.m)	1	17	7	25
1 acre or more	0	53	7	60
Total	16	97	21	134

Of the 118 respondents who were using a pump for irrigation, 62% used a pump with a motor.

Among the 228 respondents who do not irrigate from a river, 36% have a river near their house (N=83). Although they are not pumping from an open river, many are using some other means of irrigation. Most farmers that use channels diverted from a river (most of the 'Other' means of irrigation) did not answer the question on why they did not irrigate from the nearby river, because they have no need. However, among farmers who do not irrigate by any means, cost is the main single barrier preventing them from using a river. Most of the 'other' reasons given for not irrigating from a nearby river revolve around an absence of any need to irrigate e.g. there is enough rainwater, no problem.

Overall, nearly half of respondents from Central Kenya felt that the decision to purchase either a solar pump or a solar panel for the house would be made jointly (between male and female head of the household). Again, there is a clear gender divide here as almost all men felt they would be involved in making either of these decisions, whereas over one quarter of women felt that women could make a decision on their own (χ^2 (4) = 64.5, p = 0.000 for purchase of solar pump, and χ^2 (4) = 51.1, p = 0.000 for purchase of solar panel).

Do solar panels make you look poor?

Respondents were also asked if there were stigmatising attitudes associated with the use of solar panels (in general i.e. not necessarily as part of an irrigation package). Results in the table show that, overall, ownership of panels is associated with wealth, but only among one half of respondents. Respondents in rural areas are more likely to associate ownership of panels with wealth (χ^2 (2) = 7.7, p = 0.021).

Assumptions on wealth status associated with solar panels (Domestic)

		Frequency	Percent
Valid	household is poor	16	2.8
	doesnt suggest anything	246	43.0
	household is wealthy	307	53.7
	Total	569	99.5
Missing	System	3	.5
Total		572	100.0

4.2 Choice modelling – Clean cookstoves

The following parameters were explored:

1. Size of monthly payment – this is the size of the monthly payment in Kenya Shillings. It is important to note that this is a monthly cost that **includes** fuel. This covers everything – the purchase of the equipment (paid off over a number of years) and the fuel for each month.
   - have to pay KSh500 a month
   - have to pay KSh1,000 a month
   - have to pay KSh1,500 a month
   - have to pay KSh2,000 a month

2. Smokey flavour – Some people have told us that food just doesn't taste the same when cooked with LPG or electricity. Indeed, during the training, we had a long debate about how Ugali tastes when cooked with LPG. This parameter is designed to try to explore how important this taste is, as opposed to smoke that gets breathed in.
   - no smoky flavour (Smokey=0)
   - still gives a smoky flavour to the food (Smokey=1)

3. Number of people – this is simply how many people the system can cook for within that monthly cost.
   - can cook for 4 people (Cookfor8=0)
   - can cook for 8 people (Cookfor8=1)

4. Number of meals – this is simply the number of meals it can cook within that cost. We have talked about one hot meal and one warmed meal – i.e. reheating some food for breakfast perhaps. In contrast the alternative is two meals cooked from ingredients (i.e. not just reheated) and some water for tea.
   - can cook one meal and reheat old meal (2Meals=0)
   - can cook two meals a day and boil water for tea (2Meals=1)

5. Simmering – this is about how long the system can last when simmering. Does it have enough fuel for a long slow simmer.
   - Able to simmer for 30 mins (Simmer2hr=0, Simmer5hr=0)
   - Able to simmer for 2 hours (Simmer2hr=1)
   - Able to simmer for 5 hours (Simmer5hr=1)

6. Boiling – And this in contrast to simmering is about how quickly it can boil water, and cook food.
   - brings medium pot to boil in 20 mins (Boil20mins=1)
   - brings medium pot to boil in 40 mins (Boil40mins=1)
   - brings medium pot to boil in an hour (Boil40mins=0), Boil20mins=0)

7. Emissions – finally this is about how much smoke it generates. Even though this is presented as a modern energy stove, which may well not generate smoke, the purpose is to explore whether this parameter is important to them.

- does not generate any smoke in the air (SmokeWood=0, SmokeChar=0)
- generates same smoke into the air as charcoal stove (SmokeChar=1)
- generates same smoke into the air as a wood fire (SmokeWood=1)

Results from the binary logistic regression are presented in Table 26.

Table 26 Binary logistic regression - cookstoves

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Smokey(1)	-.586	.052	127.246	1	.000	.557
	Cookfor8(1)	.470	.056	69.958	1	.000	1.600
	@2Meals(1)	.183	.052	12.571	1	.000	1.201
	Simmer2hr(1)	-.064	.064	1.004	1	.316	.938
	Simmer5hr(1)	.102	.059	2.921	1	.087	1.107
	Boil40mins(1)	-.308	.072	18.268	1	.000	.735
	Boil20mins(1)	-.354	.042	71.579	1	.000	.702
	SmokeWood(1)	-.822	.064	163.292	1	.000	.440
	SmokeChar(1)	.114	.076	2.271	1	.132	1.121
	STOVECOSTC[b]	-.762	.050	231.070	1	.000	.467
	Constant	1.382	.102	184.028	1	.000	3.983

a. Variable(s) entered on step 1: Smokey, Cookfor8, @2Meals, Simmer2hr, Simmer5hr, Boil40mins, Boil20mins, SmokeWood, SmokeChar, STOVECOSTC.

b. Costs have been divided by 1,000 in order to create a unit of increment compatible with other variables.

Note: Compared against a constant only model, the model was significant (χ^2 = 739, p = 0.000, with df = 10); Nagelkerke R^2 = 0.083. Prediction success = 58.8%.

Those design features that appear to be most important to consumers are (in descending order of importance) presented in Table 27 along with estimates of willingness to pay for each attribute, which can be used to weigh up trade-offs between different design features. Discussion with the field survey team revealed that respondents misinterpreted the 'boiling' parameter as the duration after cooking that the stove would continue to deliver heat to a pan of water, as is current practice. This explains the counterintuitive finding that people appear prepared to pay more for a device that takes longer (60 minutes) to come to the boil.

Table 27 Key design characteristics – cookstove

Design feature	Willingness to pay (KSH)
People have a strong preference for a cookstove that does not generate smoke like a wood stove. N.B. there is no preference for a cookstove that does not generate smoke over a cookstove that generates smoke from a charcoal stove.	1,080
People prefer NOT to have smoky flavour to food cooked on the stove	770
Ability to cook a meal for 8 (as opposed to a meal for only 4)	620
It appears that people prefer a cookstove to take a long time to come to the boil (compared with 60 mins to boil)	-460 (20 mins) -400 (40 mins)
Ability to cook 2 meals a day (rather than cook just 1 meal and reheat 1 old meal)	240

4.3 Choice modelling – Refrigeration

The following parameters were explored:

1. Size – Based on the discussion during the training, we have made these sizes, small, medium and large. These sizes correspond with a 'mini fridge' that can be found in the market, an 'ordinary' 'waist high' fridge, and one of the bigger standing 'as tall as you' fridges.
   - Small mini fridge (SizeM=0, SizeL=0)
   - Medium Sized fridge (SizeM=1)
   - Large fridge (SizeL=1)

2. Door opening – Quite simply, the fridge is accessed by a top door that opens like a chest or box, or the fridge has a normal door that opens sideways.
   - front door (FrontOpen=1)
   - top load (FrontOpen=0)

3. Freezing – some fridges come with separate freezing compartments. The choice here is between no freezing, one that might freeze a few ice cubes, or one that is big enough to freeze a basket of food
   - Not able to freeze (FreezeIce=0, FreezeFood=0)
   - Able to freeze a few cubes of water (FreezeIce=1)
   - Able to freeze box of food (FreezeFood=1)

4. Cost – this is the cost of the whole fridge.
   - $100/KSh10,000
   - $200/KSh20,000
   - $300/KSH31,000
   - $400/KSh42,000

5. Noise – Some fridge's have a slight hum to them; this parameter investigates whether this is important to people.
   - Silent (Silent=1)
   - makes a hum (Silent=0)

6. Maintenance – testing whether reliability is an important factor in people's choices.
   - happy in heat and dust (Robust=1)
   - may breakdown once a year (Robust=0)

7. Holds cool – If the power goes off, how long can the fridge hold the cooling for?
   - able to hold cool for 5 hours if no power (Cool24hr=0)
   - able to hold cool for 24 hours if no power (Cool24hr=1)

8. Pay as you go – again, does the technology come with prearranged finance or does it require payment in full at the shop.
   - have to pay upfront (PayMonthly=0)
   - comes with pre-arranged finance - pay monthly with interest (PayMonthly=1)

Results from the binary logistic regression are presented in Table 28.

Table 28 Binary logistic regression - fridge

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1[a]	SizeM(1)	.886	.071	154.740	1	.000	2.426
	SizeL(1)	.517	.074	49.490	1	.000	1.677
	FrontOpen(1)	.332	.058	32.460	1	.000	1.394
	FreezeIce(1)	.574	.076	56.398	1	.000	1.775
	FreezeFood(1)	.265	.091	8.421	1	.004	1.303
	Silent(1)	.455	.059	60.134	1	.000	1.576
	Robust(1)	.138	.062	4.877	1	.027	1.148
	Cool24hr(1)	.713	.059	148.432	1	.000	2.040
	PayMonthly(1)	.249	.060	17.175	1	.000	1.283
	FCOSTC[b]	-.553	.026	437.164	1	.000	.575
	Constant	-1.174	.112	109.657	1	.000	.309

a. Variable(s) entered on step 1: SizeM, SizeL, FrontOpen, FreezeIce, FreezeFood, Silent, Robust, Cool24hr, PayMonthly, FCOSTC.

b. Costs have been divided by 10,000 in order to create a unit of increment compatible with other variables.

Note: Compared against a constant only model, the model was significant (χ^2 = 2930, p = 0.000, with df = 10); Nagelkerke R^2 = 0.299. Prediction success = 72.6%.

Those design features that appear to be most important to consumers are (in descending order of importance) presented in Table 29 along with estimates of willingness to pay for each attribute, which can be used to weigh up trade-offs between different design features.

Table 29 Key design characteristics – Fridge

Design feature	Willingness to pay (KSH)
People prefer medium and large fridges (over a small fridge), but preference is for medium	16,000 (medium) 9,000 (large)
The ability to keep cool for 24 hours when the power goes off (rather than keeping cool for only 5 hours)	13,000
People prefer a fridge with a freezing compartment; preference is only to make ice	10,000 (make ice) 5,000 (freeze food)
Silent (as opposed to makes a hum)	8,000
Front opening fridge (rather than top opening)	6,000
Monthly payments (rather than paying pump sum)	5,000
Robust enough to work in heat and dust	2,000

4.4 Choice modelling – Solar Pump

The following parameters were explored:

1. Cost – the cost is given in both dollars and Kenya shillings. Note that this is the price of the system and that because it is solar, there are no fuel costs i.e. no ongoing costs other than maintenance and repairs.
    - $700/KSh74,000
    - $1100/KSh110,000
    - $1600/KSh170,000
    - $2100/KSh220,000

2. Ability to lift (Head) – This is the ability of the pump to lift over a height. Existing pumps are set up to pump over small heads between 1 to 5m, so we want to explore whether a pump that can do 80m would be valued by farmers.
    - 1 metre (side of river) i.e. it can only just lift water out the river onto the nearby land (Head5=0, Head120=0)
    - 5 metres - 5 metres is quite high in terms of irrigation, it means the pump can draw from a river or shallow well and pump it onto land that is slightly raised (Head5=1)
    - 120 metres (top of a hill) – 120 metres is quite high, the top of a hill (Head120=1).

3. Drip irrigation included – This is whether the pump will be sold on its own, or whether within the price, the pump comes with a drip irrigation kit.
    - pump sold on own (Drip=0)
    - drip kit comes with pump (Drip=1)

4. Quantity of water – how much land could it irrigate? Irrigation depends on the weather, and changes over the season and year, so rather than give a quantity in litres that does not mean anything to anyone, options were based on how much land could be irrigated. We expressed the land area in both square metres and acres. Options also included an example of the possible use of the land –it might be for high value crops or just a household garden.
    - enough for 250 square metres (small high value veg) (1/16 acre) (Quant500=0, Quant1000=0)
    - enough for 500 square metres (household garden) (1/8 acre) (Quant500=1)
    - enough for 1000 square metres (1/4 acre) (Quant1000=1)

5. Location of Solar Panel – theft of panels could be a problem, and so we think that farmers may prefer to have the panels at their house where they can more easily keep an eye on them. At the training workshop some respondents asked whether the panels could be portable (enabling them to be located at the river during the day and packed away at night). It was decided that the panels should be regarded as fixed, so panels located at the river would have to stay there overnight.
   - next to or on roof of house (Location=1)
   - next to water source (and left there, not portable) (Location=0)

6. Can charge phone – a system could be designed to pump water directly without the use of a battery, or the design could incorporate some degree of energy storage. That would affect whether people could charge their phone, so the two options in this parameter investigate how important charging a phone is.
   - has socket for charging phone (Battery=1)
   - pumps water directly (no battery) (Battery=0)

7. Way to pay – whether the system could be bought by paying the whole amount 'up front' i.e. at the start, or with prearranged finance.
   - have to pay upfront (Payments=0)
   - comes with pre-arranged finance - pay monthly with interest (Payments=1)

This analysis is based on responses from the 332 respondents from Central Kenya (Table 17), all of whom answered most of the choice questions on solar pumps. Results from the binary logistic regression are presented in Table 30.

Table 30 Binary logistic regression - solar pumps

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1[a]	Head5(1)	.177	.108	2.661	1	.103	1.193
	Head120(1)	.145	.098	2.218	1	.136	1.156
	Drip(1)	.286	.083	11.878	1	.001	1.331
	Quant500(1)	.592	.101	34.256	1	.000	1.808
	Quant1000(1)	.975	.104	88.376	1	.000	2.651
	Location(1)	.430	.077	31.202	1	.000	1.537
	Battery(1)	.204	.083	6.092	1	.014	1.226
	Payments(1)	.121	.077	2.456	1	.117	1.129
	SPCOSTC[b]	-.761	.077	98.188	1	.000	.467
	Constant	-.015	.164	.009	1	.925	.985

a. Variable(s) entered on step 1: Head5, Head120, Drip, Quant500, Quant1000, Location, Battery, Payments, SPCOSTC.

b. Costs have been divided by 100,000 in order to create a unit of increment compatible with other variables.

Note: Compared against a constant only model, the model was significant (χ^2 = 297, p = 0.000, with df = 9); Nagelkerke R^2 = 0.078. Prediction success = 59.5%.

Those design features that appear to be most important to consumers are (in descending order of importance) presented in Table 31 along with estimates of willingness to pay for each attribute, which can be used to weigh up trade-offs between different design features.

Table 31 Key system characteristics – Solar pump

	Willingness to pay (KSH)
The ability to irrigate large areas of land (more than 250 sq. metres)	128,000 (1,000 sq. metres) 78,000 (500 sq. metres)
The ability to have the appliance (the solar panels) located next to the home;	57,000
Being able to buy a complete kit (as opposed to buying the pump on its own);	38,000
Incorporating a battery with a socket for charging a phone.	27,000

5 Discussion of survey insights and implications

5.1 Variables and proxy variables used for disaggregation

Section 2.2, on the design of the survey sampling, describes how the research team agreed that the purpose of the choice modelling survey was to generate some understanding of acceptable price points, and to provide some indications of preferences within some market segments. Each of the technology sections presents the willingness to pay as generated by the discrete choice modelling for that technology (Section 3 and Section 4). In this section we revisit each device in turn, drawing on disaggregated data to provide some insights into preferences within different market segments. We are not suggesting that products should be tailored to sub-sectors of each market, but comparing the strength of preferences between different groups may give marketing insights that might prove valuable when it comes to promoting the products. In the interest of simplicity, the plethora of supporting SPSS output tables generated in this exercise have not been presented in the report.

Models for medical technologies have been disaggregated according to the following:-

Affiliation of clinic	Government/Private/NGO
Type of clinic	Community Unit/Dispensary/Health Centre/District Hospital/Higher hospital
Region	Lake Victoria/Coastal/Drylands/Central
Rural/Urban	Rural/Urban
Gender	Male/Female
Age group	less than 30/ 30-39/ 40-49/ 50 and over
Resource 'richness' of clinic	poorly resourced/well resourced
Professional status	lower status/higher status

Models for each of the domestic technologies have been disaggregated according to the following:-

Region	Central Kenya/ Western Kenya (Kisumu region)/ North Kenya (Marsabit region)/ Coastal Kenya/ Nairobi
Rural/Urban	Rural/Urban
Gender	Male/Female
Age group	less than 30/ 30-39/ 40-49/ 50 and over
Education	None or incomplete primary/Primary or incomplete secondary/Completed secondary or higher
Household position	Head of household/spouse
Wealth quintiles	Lowest or low/high or top

5.2 Medical technologies

For the convenience of the Reader, the key Willingness to Pay tables for the whole sample are repeated here.

Table 32 Key design characteristics – vital signs

Design feature	Willingness to pay (KSH)
People have a strong preference for a device that does not use disposable batteries – people are not really willing to pay more to be able to charge the device using solar, over normal rechargeable batteries	354,000 (solar) 250,000 (rechargeable)
People are willing to pay for an automatic device	172,000
Not surprisingly, people preferred an integrated device that could be used for multiple observations, but they were willing to pay less for this facility	61,000

Table 33 Key design characteristics – Urine and Blood

Design feature	Willingness to pay (KSH)
People have a strong preference for a device that does not use disposable batteries – people are not really willing to pay more to be able to charge the device using solar, over normal rechargeable batteries	508,000 (rechargeable) 505,000 (solar)
People are willing to pay for a device that eliminates the need to prepare samples	288,000
People preferred an integrated device that could be used for multiple observations,	131,000
People preferred to pay a usage fee	58,000

Table 34 Key design characteristics – diagnostic support device

Design feature	Willingness to pay (KSH)
People have a strong willingness to pay for some kind of diagnostic advice, and quite a strong preference for computerised advice rather than a remote doctor.	354,000 (computerised) 207,000 (remote doctor)
People have a strong willingness to pay for a device that does not use disposable batteries, and there is a modest preference for normal rechargeable batteries rather than the option for solar recharging.	311,000 (rechargeable) 254,000 (solar)
People are willing to pay for a device that would connect to, and process data from, multiple devices	269,000
People were willing to pay for a device that could handle clinical information on patient histories	193,000

Table 35 Key design characteristics – ultrasound device

Design feature	Willingness to pay (KSH)
People have a strong willingness to pay for a device that does not use disposable batteries, and there is a strong preference for normal rechargeable batteries rather than the option for solar recharging.	3,149,000 (rechargeable) 2,712,000 (solar)
People have a strong willingness to pay to store a digital image	2,121,000
People are willing to pay for a device that would perform multiple functions	1,347,000
People were willing to pay for a device that could be repaired promptly	1,288,000
People were willing to pay for a device that required less frequent servicing	1,214,000

5.2.1 Energy storage and Reliability

Energy and the 'reliability' of energy supply as captured in rechargeable batteries is a very important feature of all the devices. It ranks highest in all the technologies, with the highest willingness to pay (with the exception of computerised diagnostic advice in the diagnostic support device). From qualitative data it is clear that it is the availability of the device that is important, that it not be susceptible to power outages. Rechargeable batteries are seen as the key to improved availability.

The high value placed on rechargeable batteries suggests that respondents have enough experience of non rechargeable batteries (known as 'everready' in Kenya), to know that while 'everready' can give on demand energy, their cost and expense is prohibitive.

One might expect that institutions with limited equipment such as community units or dispensaries might value energy storage (and reliability) more than the higher institutions. However, this is consistently not the case – across all technologies, a reliable energy source is the top priority among respondents from District and Higher hospitals. Similarly, one might expect rural respondents to value energy storage more highly than urban respondents. However, urban respondents consistently value the rechargeable batteries more highly than their rural counterparts. Qualitative data suggests that it is the presence of equipment, and the unreliability of energy supply, that create a higher value for the energy storage.

This idea that equipment itself then enhances the demand for energy storage is supported by the data comparing poorly resourced institutions with well resourced institutions. Respondents from well resourced institutions (i.e. those who have a more experience of equipment) place a significantly (at lower confidence levels) higher value on the energy storage.

Female respondents generally value energy storage more than males but the differences are relatively small (with ultrasound being an exception).

Conclusion:- The picture that emerges from the data and that is very strongly supported by qualitative data, is that health practitioners are frustrated by unreliable electricity supplies. Almost all the respondents attend institutions that are grid connected, and yet they very highly value energy storage in the form of rechargeable batteries. Those who already have experience of and access to equipment value this more highly than those who currently have limited access – experience heightens the frustration of an unreliable energy supply (and possibly the expense of non rechargeable batteries).

5.2.2 Solar charging

Most respondents are working in clinics that have grid electricity. This is not always reliable, and many have backup generators. It is interesting to note that rechargeable batteries augmented by solar, while still ranking high on the willingness to pay, does not necessarily rank higher than the core ability to 'hold' energy as discussed above. The idea of rechargeable batteries with solar charging, while hugely attractive compared to the use of 'everreadies', does not rank higher than rechargeable batteries on their own in three out of the four technologies (the exception being the vital signs device). This finding is surprising to the solar experts on the team, as one would imagine that the additional reliability of solar over and above rechargeable batteries would command a premium.

Consistent with the response for rechargeable batteries alone, District and higher hospitals have a higher WTP than community units and dispensaries across all the technologies. Urban respondents have higher WTP than rural, and respondents from well resourced facilities have a higher WTP than those from poorly resourced facilities (with the exception of the diagnostic support device). It is lower status individuals that tend to be more willing to pay for solar (in three out of four technologies). We hypothesised above that the strength of preference for rechargeable batteries in these situations is likely based on experience of technology and the frustration of not having a reliable supply. This is likely to be true also for rechargeable batteries with solar charging.

The gendered responses are not consistent, with males placing more value on solar combined with ultrasound, and females adding slightly more value to solar combined with the other technologies.

Further research is needed to explore of people's opinion of solar. For example, it could be that current experience of solar is for very low powered equipment only, and the respondents do not believe that solar can provide for all types of equipment.

Conclusions:- Solar may have an image problem among health workers. It may be that people cannot conceive that it can run a lot of equipment reliably, or recharge batteries. The respondents still value solar highly, but there is a near consistent higher valuing of simply 'rechargeable batteries'. Any 'clinic in a box' or 500W clinic will need to take into account current perceptions of solar and address the issue directly in its marketing.

5.2.3 Integration

For the basic core requirements of taking vital signs, and examining urine and blood samples, there was a considerable desire for a single device to take multiple observations. Similarly, a diagnostic support device with the ability to process data from multiple devices (vital signs, and/or reading the blood and urine tests) commanded a premium.

While females showed a higher preference for integration over their male colleagues, there was little in the disaggregated data of further note. There were no notable differences between those working in different types of institution, rural or urban areas, resource levels, etc.

Conclusion:- Integration of the instruments whether in the collection of data or the analysis of data is valued consistently by all.

5.2.4 Automation

Automation of the collecting of vital sign data was highly valued as was the elimination of the need to prepare samples when testing blood and urine samples.

The gendered response is not consistent with females valuing automation of vital signs more than their male counterparts, but males valuing more highly the lack of preparation for blood and urine sampling. Similarly the rural urban divide is not consistent, with rural respondents slightly valuing automation of vital signs over their urban counterparts, but urban respondents valuing lack of preparation of samples over the rural counterparts.

When comparing respondents from well resourced and poorly resourced facilities, those from poorly resourced facilities place a higher value on the automated preparation of samples for testing, while respondents from well resourced facilities place a higher value on the automation of vital signs devices. Those in lower status jobs value both more highly than their higher status counterparts.

Conclusion:- One might expect those who are less qualified to appreciate automation of processes, and whiles there is some evidence to support this from the data, differences are modest.

5.2.5 Diagnostic support

Each of the health technologies of 'vital signs', 'blood and urine diagnostics' and 'ultrasound' have the potential to be supported by a more senior professional. The diagnostic support device choice pairing offered a parameter differentiated by 'computerised advice' and support from a remote doctor. It is interesting that the computerised advice is valued more than the remote doctor – although it is important to note that the remote doctor is still highly valued.

Qualitative data suggests that the higher value for the computerised advice may be focused around availability. Nurses tend to request a consultation either with their on-site colleagues or a remote doctor by phone, only to be told to wait, or be called back. Their current experience is likely to be of a service from colleagues that cannot be relied on to be timely. There are two points to note. Firstly, while views on real time support from a doctor may be based on experience, most respondents will have little experience of computerised advice. Secondly, the actual utility of computerised advice will depend very much on the quality of the service, which has yet to be determined e.g. imprecise advice may run the danger of misdiagnosis on some less common conditions.

When considering the disaggregated data, it can be seen that respondents working in rural settings value computerised advice more highly than their counterparts in urban centres, as might be expected. Women also valued more highly the ability to get computerised advice than men. Those working in lower grade facilities such as Community units, Dispensaries and Health centres place a higher value on computerise advice than those from district hospitals, which supports the idea that the greater availability of doctors at district hospitals centres reduces the need for computerised and remote advice. Similarly, lower status individuals place a higher value on being able to get some kind of support (either computerised or from a doctor) than do higher status individuals.

Conclusion:- There is substantial demand for diagnostic support, resulting in relatively high willingness to pay. The data consistently indicates that low status practitioners and those without access to highly qualified medical personnel would most appreciate some form of computerised advice.

5.2.6 Ultrasound

The ultrasound responses show that respondents highly value the rechargeable batteries and solar charging as discussed above. They also value the ability to store an image. Storing an image would enable a consultation with either their on-site colleagues, or with a remote doctor (as suggested in the diagnostic support device choice pairing), although how this could be done was not specified e.g. staff could simply email the image to a doctor. One might expect rural, poorly resourced institutions to value the stored image more highly than their urban higher hospital counterparts but this is not the case. Similarly there is no notable gender difference.

Ultrasounds can be used for simple diagnosis of pregnancy concerns, or a wider range of conditions including bone fractures. It is not surprising that respondents were will to pay for a device that could perform multiple functions. Male respondents, those from well resourced, and urban respondents each gave slightly higher values than female, poorly resourced, and rural respondents. This suggests that those who have slightly more experience of equipment value an ultrasound that could do a wider range of activities.

Current experience of ultrasound is that they are difficult to maintain and keep in good repair. This was captured in the choice modelling, and respondents would be willing to pay for devices that could be repaired promptly and indeed that required less frequent servicing. Females placed higher value (over males) on promptness of repair, as do rural respondents (over urban). However respondents of higher status assigned extra value to promptness of repair and frequency of servicing than those with lower status. Comparing responses from respondents from poorly resourced and well resourced facilities showed mixed findings, as those from poorly resourced institutions placed less value on promptness of repair, although they do assign slightly higher value to servicing frequency.

The picture then is clear that prompt repair and less frequent servicing is valued by respondents, however there is no particular disaggregation that indicates any reasons behind this value. One might hypothesise that lower status respondents might want more 'help', or that rural institutions would be wary of distance and expense that repairs might encounter – and indeed there is some evidence that maintenance is more important to rural respondents. In an environment where maintenance and repair of complex equipment is generally difficult, it is reasonable for all the respondents to value prompt repairs and less frequent maintenance.

Conclusion:- Any design of an ultrasound device should attempt to maximise the use of the technology but minimise the maintenance and repair requirements. Modular construction, facilitating rapid replacement of frequently failing components could command higher values for the instrument as a whole. As with all the proposed technologies, they should contain rechargeable batteries where possible, and innovation with solar could be explored, but will require some awareness raising among health professionals. Storing images for asynchronous consultation is highly valued.

5.2.7 Diagnostic 'administration'

In the choice modelling for the diagnostic support device, two parameters explored the ability to provide logistical support to diagnosis. Being able to access a patient history was valued by the respondents, but providing access to financial information was not. It is well known that a clinician can be helped in their diagnosis by being able to see clinical history. To have this on hand is seen by respondents as suitable and appropriate diagnostic support. The availability of patient history was more valued by those working in hospitals, urban locations and in well resourced settings. This may reflect, as we have come to expect from the data, the fact that those who actually currently deal with equipment and have a more formalised setting to their diagnostics appreciate the value of on hand clinical notes (and diagnostic support in general). There was no notable difference in the gendered responses, nor in the status of the respondent.

Being able to access the financial records/history of the patients was not seen as bringing additional value to the proposed device. In the team discussion of this, many felt that finance, payment for treatment etc. was not a subject area for the practitioner but would be handled by a different department. However, while this is the current response, the introduction and growing presence of health insurance may change the landscape. It may become necessary for a diagnostic consultation to be informed by whether the patient has insurance in order to know how to refer the patient.

It is worth noting that the idea of a user fee was explored within the context of a urine and blood testing device. A modest value was attributed to having a user fee included in the business model, even though intuitively one might expect no fee to be the preferred option.

Conclusion:- access to clinical records from the device would be valued by all practitioners, and should be designed into the system. However access to financial records is not necessary.

5.2.8 System design

While these 'devices' were presented as four separate technologies, the responses indicate that the core suggestion of a clinic in a box, or the 500W clinic, would be appreciated by medical professionals. We have seen that integration and automation are valued to varying degrees and dependent on the connection into system, and we have noted that computerised diagnostic advice is highly valued. The idea of a clinic in a box is that of bringing together many devices and integrating their data outputs into a single device (screen). With the advent of tablet PCs this should not be difficult and the burgeoning number of smartphone based apps gathering health related data only supports this trend.

The high value placed on computerised advice is significant when thinking about the 'clinic in a box' design. It would seem best for it to explain the meanings of readings rather than just deliver them, having software that is sophisticated enough to give a meaningful diagnosis. While remote doctor advice was less valued than computerised advice, we have hypothesised that this is because of a lack of trust in doctors being available.

Conclusion:- Integration and automation are valued, and the bringing together of all these technologies into a single 'box' that can deliver computerised advice and link to remote doctors would be highly valued by all.

5.3 Domestic technologies - Cookstoves

Table 36 Key design characteristics – cookstove

Design feature	Willingness to pay (KSH)
People have a strong preference for a cookstove that does not generate smoke like a wood stove. N.B. there is no preference for a cookstove that does not generate smoke over a cookstove that generates smoke from a charcoal stove.	1,080
People prefer NOT to have smoky flavour to food cooked on the stove	770
Ability to cook a meal for 8 (as opposed to a meal for only 4)	620
It appears that people prefer a cookstove to take a long time to come to the boil (compared with 60 mins to boil)	-460 (20 mins) -400 (40 mins)
Ability to cook 2 meals a day (rather than cook just 1 meal and reheat 1 old meal)	240

5.3.1 Smoke gets in your lungs

The parameter assigned the highest value by respondents was the smokiness of the cooking process, but note that no value was placed on eliminating the smoke emitted by a charcoal stove. It has long been a known problem that kitchen emissions from woodfuels and charcoal are harmful to the household's health, particularly to women who make up the majority of cooks. There have been extensive educational campaigns, and much of the work on improved charcoal cookstoves aims to reduce this effect. Recently ESMAP and GACC acknowledged that unless an improved charcoal cookstove has forced gasification, the reduction in emissions in improved stoves do not cause a "significant health benefit" (Putti, Tsan, Mehta, & Kammila, 2015). Of course for woodfuel stoves the smoke is often visible, for charcoal stoves the emissions are barely visible.

The response to the smokiness parameter is very insightful. If respondents do not value the difference between a clean stove and a charcoal stove, we can reasonably state that the educational campaigns on the dangers of charcoal stoves in confined spaces are not penetrating the public's awareness. Biomass cooking is an important public health issue, and results in more deaths per year globally than malaria and tuberculosis combined (The World Bank, 2014). Uptake of improved stoves has been frustratingly slow, and these respondents may have illustrated why. Even though it has only recently been shown that the health benefits of improved stoves are limited, the dissemination of the improved stoves is often sold on the basis of health benefits. The data here is effectively saying that respondents do not acknowledge that charcoal stoves have a health implication.

If this is about messaging, and awareness of a public health risk, we might expect those better connected to wider society to be more aware. The disaggregated data shows that urban respondents value 'no smoke' (for wood fires) more highly than rural respondents, young people more than older respondents, the wealthier place higher value than the poorer households, and the strength of opinion is clearly liked to the level of education of the respondent. Interestingly gender differences in the data were small, with men and women placing similar values on the no wood smoke options, although head of household (which tends to be male) placed a greater value on this parameter than respondents who identified themselves as the spouse.

Eliminating smoke generated by a charcoal stove was not a significant component of models for any of the disaggregation options tested.

5.3.2 Smoke gets in your food

The above parameter attempted to include kitchen smoke emissions in the choice pairing. A different parameter with a picture of food next to it the choice pair graphics attempted to consider smoky flavour. This is an emotive parameter. In the literature, and particularly in focus group discussions, it is common to find a commentary on 'smoky flavour'. The lack of uptake of improved stoves is sometimes attributed to the idea that people like a smoky flavour in their food and that this desire for taste overrides the economic and health concerns of improved stoves.

In contrast to this often anecdotal data, the respondents have attributed an extra value to NOT having smoky flavour. This does not preclude enjoyment of the occasional barbecue – but for day to day cooking it would seem that smoky flavour is actually a negative rather than a positive feature. Urban dwellers, men, the young, the educated, head of households, and the wealthier all assigned stronger value to NOT having smoky flavour than their counterparts. The picture that emerges is that those who are 'less traditional' assign stronger value to the lack of smoke flavouring. This is consistent with focus group discussions where younger people state that 'their grandmother' doesn't like the taste of food cooked with LPG, and only when pressed will acknowledge that they themselves like non smoke flavoured food.

5.3.3 Bringing to the boil

The responses to whether the stove should bring water to the boil quickly (options 20, 40 and 60 minutes), are on the surface counter intuitive. The data suggests that respondents would rather have a stove that brings a pan of water to the boil in 60 minutes than one that takes only 40 or 20 minutes. This was not picked up during the pilot, but debriefing with the enumerators post survey suggested that many people were interpreting the parameter in a different way than the team intended. The parameter was intended to represent the power or capacity of the clean cookstove i.e. a higher capacity stove would bring water to the boil more quickly.

However, the respondents' habit when using a wood or charcoal stove is to complete the cooking, and then put a pan of water on the burning embers for washing. The times shown in the parameter may have been interpreted as the time that the stove gives residual heat, hence the longer time is the more 'helpful' stove.

5.3.4 More food please

The respondents assigned an added value to cooking for 8 people over cooking for 4 people, and a higher value to cooking 2 meals over one and a reheat. While one might expect this, it is interesting that the values assigned are not proportional to the added benefit. In naïve terms a meal for 8 people should cost significantly more than for 4 people (not quite double since there are economies of scale in cooking). And yet the added value assigned by the respondents is less than that assigned to the wood smoke and smoky flavour.

Males value the ability to cook for 8 more than females, rural respondents value it more than urban respondents, the older value it more than the young, and the lesser educated more than the educated. The picture that emerges is that 'traditional' households value the ability to cook for eight more than more sophisticated households. This is consistent with our understanding that 'traditional' households are larger than 'modern' ones.

When disaggregating the data, the number of meals parameter was often not significant in the models, making it difficult to make any comparisons, although there is some evidence that higher status individuals place a higher value on being able to cook 2 meals.

5.3.5 A Square Meal?

Choice questions on cookstoves were framed in terms of a cookstove using modern energy, which was carefully not specified. At the end of these questions, respondents were presented with three basic design ideas and asked which they preferred (see Figure 7). Results showed that the rectangular design was most popular, although preferences were split quite evenly (Table 37).

Table 37 Preferred cookstove design

		Frequency	Percent
Valid		4	.5
	A (rectangular)	302	38.7
	B (circular)	243	31.2
	C (triangular)	231	29.6
	Total	780	100.0

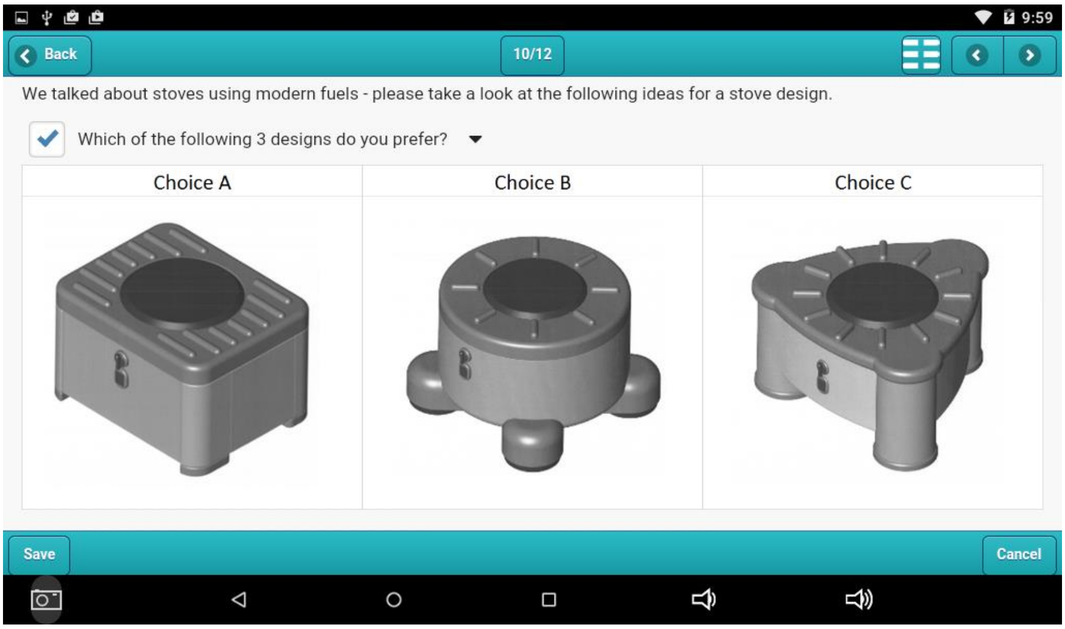

Figure 7 Basic cookstove design options

5.4 Domestic technologies – Fridge

Table 38 Key design characteristics – Fridge

Design feature	Willingness to pay (KSH)
People prefer medium and large fridges (over a small fridge), but preference is for medium	16,000 (medium) 9,000 (large)
The ability to keep cool for 24 hours when the power goes off (rather than keeping cool for only 5 hours)	13,000
People prefer a fridge with a freezing compartment; preference is only to make ice	10,000 (make ice) 5,000 (freeze food)
Silent (as opposed to makes a hum)	8,000
Front opening fridge (rather than top opening)	6,000
Monthly payments (rather than paying pump sum)	5,000
Robust enough to work in heat and dust	2,000

5.4.1 Holding your cool

The ability of a fridge to keep cool when the power goes off is a highly valued attribute according to the choice modelling. This is supported by anecdotal evidence from Kenya where fridges with the ability to hold their temperature for 24 hours are now featured in adverts. One might expect this feature to be most appreciated by respondents in rural areas, however this is not the case; urban dwellers value this more highly than rural respondents. Males value it slightly more than females, and this can also be seen in the preferences of heads of households who value it more than spouses. Wealthier households tend to value this too, more than poorer households.

It is likely that the value placed is being driven by current experience. Those who have some experience of fridges (i.e. the wealthier) and of power outages (urban dwellers), know how valuable keeping the cool for 24 hours could be. Further investigation is required to understand the gender differences.

5.4.2 Sizing the fridge

While a large fridge is valued over and above a small fridge, a medium sized fridge is the preferred option. Once again it is those who have experience (higher status urban dwellers) that express stronger opinions by assigning higher values - men more than women, wealthier households more than poorer households and urban more than rural. The gendered response is muted with females slightly valuing the larger fridge amore than males. The strength of preference for a medium sized fridge decreases with age, and preference for a large fridge increases with age over 40, so much so that among the over 40 age groups, there is a preference for a large fridge over a medium fridge.

5.4.3 Freezing ice

Exploring the capacity of a potential freezing compartment, it is interesting that the ability to freeze ice is valued more highly than the ability to freeze food. The team had considerable debate about whether this was a male preference (because they want iced drinks) or a lack of experience of freezing food. The gender disaggregation of data does indeed indicate that men place a higher value on ice making, and the disaggregation by head of household and spouse shows a similar pattern. However a difference can be seen in the rural - urban split where rural respondents place a higher value on ice making than urban respondents; also younger people assign a higher value than older age groups. Differences based on education and wealth indicators are small or inconsistent.

5.4.4 Silence is cool

A premium value was placed on a silent fridge. It was thought that perhaps people would not be that aware or interested in the hum of fridges because of the general noise of life in Kenya, however that did not prove to be the case. Young people (under 30) assigned the largest value to the silence, and urban dwellers assigned a higher value than rural people. The wealthier were also slightly more concerned with the noise, as were male respondents.

5.4.5 Front or top

The team were aware that top loading fridges can be more energy efficient than front loading ones, as front loaders loose much of the cool when the door is opened. However, the choice modelling showed that people valued the front loading option. This could be because they do not understand the efficiency implications, or perhaps they were thinking about form and function rather than energy efficiency. There were no particular gender differences in the data and limited differences across all the disaggregation criteria with the exception that younger people and rural respondents seem to have a stronger preference for the front loading option.

5.4.6 Robustness

While some extra value was assigned to the fridge being robust in heat and dust, the value was relatively small. When disaggregating the data, this parameter was often not significant in the models, making it difficult to make any comparisons.

5.4.7 Credit

Finally, value was given to the idea that one can purchase the fridge on credit, repaying monthly. This parameter is not so much one connected purely to fridges, but is indicative of how people seek to manage their purchases of major assets. Not surprisingly, cost is more important to lower status respondents (wealth index), so they are less willing to pay for all of the additional features explored, but they do value the ability to make payments monthly.

5.5 Domestic technologies - Solar pumping

Table 39 Key system characteristics – Solar pump

	Willingness to pay (KSH)
1. The ability to irrigate large areas of land (more than 250 sq. metres)	128,000 (1,000 sq. metres) 78,000 (500 sq. metres)
2. The ability to have the appliance (the solar panels) located next to the home;	57,000
3. Being able to buy a complete kit (as opposed to buying the pump on its own);	38,000
4. Incorporating a battery with a socket for charging a phone.	27,000

5.5.1 More is good

The data for solar pumping was collected from a purposive sub sample drawn from Central Kenya. Understandably these respondents assigned higher value to the ability to irrigate larger areas of land.

The disaggregation insights show that the value assigned is linked to the farmers' current practice and their specific situation. For instance, those with a river nearby assign a higher value than those without access to a river. Those who currently irrigate from the river (as opposed to irrigating from another water source) assign a much higher value to both the 1,000 sq.m option and the 500 sq.m option, and those who currently irrigate by any means assign a higher value than those who don't.

The situational effect is further nuanced by proximity of farming land, as those who have to farm away from the house (because they have no field next to their house) assign higher value to being able to irrigate a 1,000 sq.m piece of land than those who have a field next to their house.

Wealthier respondents assign a higher value, perhaps because they can perceive of farming more land, and the more educated also assign higher values.

The gender responses show similar coefficients (beta values), but women are more cost sensitive than men and therefore this translates into men assigning a higher financial value to the ability to irrigate a 1,000 sq.m piece of land.

5.5.2 Prevention of theft

The parameter regarding whether the solar panels were able to be placed on the house, or had to be located next to the river, was introduced because qualitative data suggested that people may be concerned about theft. It was thought that if the panels could be used next to the house, people would be able to keep an eye on them i.e. the risk of theft would be less.

As expected, respondents placed value on the ability to have the panels next to (or on) the house, as opposed to putting the panels next to the river. Older respondents, more educated respondents, and the wealthier all assign slightly more value to this feature than their counterparts. Similarly those with experience of irrigating i.e. those currently irrigating (from any source) and those currently irrigating from the river assign higher values than those who don't.

5.5.3 The whole package

A parameter was introduced offering a whole package, including the panels, the pump, and a distribution system, as opposed to the solar panels and pump alone. Respondents appreciated the idea of a complete package and assigned a value to this design option. Again it is those who have experience of irrigation who assign a slightly higher value to this feature. There are no notable differences across gender or other potential desegregation categories.

5.5.4 Incorporating a battery

A solar pumping device could be designed to have a direct connection between the pump and the panels with no significant energy storage. Since irrigation schedules tend to be during the day, the challenge of, say, lighting systems that must 'translate' daytime energy generation to night-time energy demand via a battery is not present. Since the battery is often a significant proportion of the capital cost the idea of direct linkage between pump and panels is attractive.

However, for the farmer, the team anticipated that having solar panels and not being able to charge other devices might be disappointing. The option was therefore included to charge a phone. In theory we continue to imagine a system without battery, but in this case we conceive of a power take off point which would have a controller circuit board to make it suitable for charging phones.

As expected, this option would indeed find favour with the farmers, and was assigned an added value. When disaggregating the data, this parameter was often not significant in the models, making it difficult to make any comparisons.

5.5.5 Pumping head

The parameter seeking to explore people's preferences on pumping head was not significant in the overall model. Neither was it significant in the disaggregated models, making it difficult to make any comparisons.

This is counter intuitive since one would expect that the ability to pump a higher head would have some extra value. Responses to the descriptor variable, "What is the head you pump (metres)?", asked of those who said they did some irrigation already, varied between 0 and 1,600 metres. Since 1600 m head is not realistic, this suggests that respondents were not able to state accurately 'head'. They may have been confusing it with 'distance', or they may not have understood the question. This lack of understanding concerning pumped head is likely to have confounded the choice modelling.

5.5.6 Business models

The choice pairing also included an option on payments schedule, whether respondents would choose to pay for the whole capital expenditure in one go or in instalments. Given that monthly payments were valued in the fridge choice modelling, it is perhaps surprising that they do not feature here. There was no added value attributed to the idea of monthly payments in the sample as a whole. Similarly, when disaggregating the data, this parameter was not significant in the models, making it difficult to make any comparisons.

6 Conclusion and next steps

The survey was designed to answer elements of research question 1:-

> *"What are the top- priority low-energy devices that have the potential to improve lives at the BoP? What are context and culture-specific design and operational parameters that will govern levels of low-energy consumption? What are acceptable price points and how will the devices be constructed and commercialized at those levels?"*

Having identified from the literature low energy devices that have such potential, the survey sought to clarify the context and culture specific operational parameters, and using discrete choice modelling to identify design priorities and to indicate acceptable price points.

The next steps are for the team to use this data and the associated insights in the process of design and innovation.

6.1 Medical technologies

The survey was able to reach a wide range of medical practitioners. As such it was able to gather data from four 'zones' within Kenya, each of which has slightly different prevalent diseases and different levels of health infrastructure. The respondents had a suitable range of medical experience and worked in a variety of health institutions. Respondents willingly gave their time to the choice modelling exercise, and the data has given some insight into the parameters important to the respondents.

The choice modelling was predicated on the idea that a 'clinic in a box' or a 500W clinic might be viable by bringing together technologies into an integrated suite. The choice modelling differentiated some of the key components involved in medical diagnostics, clustering the choice pairs into the measurement of vital signs, the taking and analysis of blood and urine samples, providing diagnostic support, and the use of ultrasound.

Respondents assigned values to the various options, and confirmed that 'integration' and 'automation' were indeed important. There was a very strong preference for all devices to include rechargeable batteries (as opposed to non rechargeable). Most respondents worked in clinics connected to the grid, however the responses were interpreted as reflecting a frustration with unreliable electricity and the importance of introducing improved availability by having stand-alone battery powered equipment.

The use of solar energy for powering rechargeable batteries was valued, although in most cases not as much as having rechargeable batteries alone. The unexpected relationship between the options regarding rechargeable batteries and solar should not be interpreted that solar is not valued by the respondents. It is, but the data simply suggests that people are not willing to pay an additional premium for solar charging, therefore it would be good to incorporate it into the 'clinic in a box' where possible, especially as this would enable it to operate in locations with no grid connection.

Part of the muted solar response was thought to be a perception problem – that solar is not thought to be able to run high powered equipment. These findings from the survey should be taken into consideration when the innovation reaches commercialisation – they inform the potential advertising campaign.

It should be noted that those who already have experience of equipment i.e. those in urban settings, in higher institutions, and well resourced facilities, tend to be willing to pay slightly more than their counterparts. The original concept of a clinic in a box was that a medical practitioner, such as a nurse working in a remote location, would be able to set up a clinic and access technical support. While this may remain a primary market, enabling professional medical care where previously there was none, the 'enthusiasm' (i.e. the slightly higher WTP) from professionals who currently have equipment suggest that there is a considerable market among existing institutions. Any design should not limit the improvements and benefits of the 500W clinic to remote locations only.

The ultrasound model documented the importance of robustness – represented by frequency of servicing requirements and promptness of repair. While this was only explicit in the ultrasound model (in order to keep the models manageable), it is reasonable to say that the principles would apply to any clinic in a box. Low service requirements and ease of repair will be important design considerations.

The values assigned to ultrasound seemed high to the team. There are two ways to interpret this. On the one hand trusting the modelling process, there is no particular reason to doubt them and therefore it seems that the inclusion of an ultrasound in the 'box' would hold considerable value to medical professionals. This should of course store images and be integrated with the diagnostic support. On the other hand the high monetary values could be seen as due to a very low beta value for cost. One could surmise that a high cost item bought infrequently and possibly from a different budget, resulted in respondents not focusing on cost, being cost insensitive as it is not their concern.

Finally there was substantial value attributed to computerised advice and remote consultation in the context of a diagnostic support device. Computerised advice actually gained a higher assigned value than remote consultation with a real doctor. It was surmised that this might be because current experience of consulting real colleagues is a bit hit and miss. Colleagues may not be available 24 hours a day, and a consultation may often take time to arrange. If remote consultations via a device proved to be more planned and more reliable, it is possible that one might extract a higher value to this potential design feature. However, based on the survey results alone, the higher value is attributed to having computerised advice – something available 24 hours a day and known to be available when required.

6.2 Domestic technologies

The survey was able to reach a wide range of households in several different geographical zones within Kenya. While not nationally representative, the sample covers an adequate range of key demographics. Respondents willingly gave their time to the choice modelling exercise, and the data has given some insight into the parameters important to the respondents.

Some details on preferences were gained from the choice modelling of fridges, which could inform the design of a low powered domestic fridge. The key preference is for a medium sized fridge, and then the fridge should hold its cool without power for at least 24 hours. This unfortunately is not helped by the preference for front door opening – top loading fridges more easily hold their cool. A freezing compartment would command value, but if it sufficient to freeze some ice this is good enough, as there is no strong preference for a compartment suitable for freezing food. There is some value assigned to being silent, and to being robust to work in heat and dust.

The survey may have given significant insight into the challenges of clean and cleaner stove commercialisation. There seems to be a lack of awareness of the health implications of charcoal stoves, as no premium value was assigned in the model to an absence of smoke from a charcoal stove. When it comes to the proposed appliance, the most highly valued design feature was the absence of wood smoke.

The debate over 'smoky flavour' in food was finally informed by robust data – with a preference for no smoky flavour. Other cultural features were revealed in the responses to parameters regarding the ability to cook more meals in a day, and to cook for larger households.

Similarly, there was a preference within the solar pump model for one that could irrigate larger pieces of land. Value was also assigned to the ability to have the solar panels next to (or on) the house, and to being sold a complete package (with sprinkler or drip irrigation equipment).

The fridge modelling showed that respondents put some value on being able to buy through monthly instalments. Interestingly, the choice model for the solar pump, based on responses from farmers, showed no preference for monthly instalments as opposed to paying for the system as a whole upfront. The cook stove modelling took monthly instalments as standard.

6.3 Next steps

The research team will now consider and share these findings to inform the next stages of innovation and development.

In summary then, the research confirms that an integrated unit that combines the ability to take readings of vital signs, to test blood and urine, and to give diagnostic support would find considerable value among medical professionals in Kenya. The inclusion of ultrasound in the package would be highly valued. The team therefore need to consider the next steps to outworking such a package.

The survey gives no particular insights into ranking the market demand (or potential sizes) for each of the (domestic) technologies. Rather it gives an indication of the premium added value each potential design feature may command within each technology. Therefore the choice of which technology to take forward is more dependent on innovator interest and the ability to design technologies that include such features within the price points indicated. The team therefore need to share the findings with a wider group of entrepreneurs and see where the interest lies.

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Annex 1

List of variables – Health Workers' Survey

Name	Variable label
Clinic	Name of Clinic/locality
Affiliation	Affiliation of health facility
m8wd5udx	What type of facility do you work at?
SubCounty	Name of Sub-county (clinic)
RurUrb	Type of area (rural / urban)
Gender	Gender of the Respondent (observe)
respage	Age
LvlTraining	What is the highest level of training you have had?
MedTraining	What medical training have you had?
clinrole	What is your role in the clinic?
yrs@clin	How long have you been at your current clinic? (years)
Yrsexper	How long have you been working in health? (years)
typeclin	What type of services does your clinic provide?
NumBeds	How many beds does it have?
drclinic	Is there a doctor at the clinic?
patient#	How many patients does the clinic see on an average day?
staff#	How many medical staff does the clinic have overall?
assets	Does your clinic have
Water	What is the main source of drinking water for the clinic?
sterile	What is the main way that the clinic sterilises its water?
Solardevices	Do you have any type of solar device in the clinic?
Bpplus	How often do you take clinical observations (BP, pulse oximeter, stethoscope, fetal doppler)?
diagnose	How often do you do Rapid diagnostic tests (e.g. for HIV, Malaria)
microsco	How often do you use microscopes for tests?
advanced	How often do you use advanced lab equipment (e.g. biochemistry machines, hematology machines, centrifuges)
immuno	How often do you use immunoassay tests?
ultrasou	How often do you use ultrasound?
ultrasoundtype	Is that Doppler or Basic Ultrasound
xray	How often do you use an Xray?
pcmanage	Do you use computers at work?
compUse	What do you use computers/applications for?
usedmobi	How often have you used a private mobile phone in the last month?
typeofmobi	What type of phone do you most commonly use?
SendSMS	Do you send SMS texts yourself?
internetUse	How often have you used the internet in the last month?
UsedFacebook	Have you used Facebook (any time in the past)?
facebookUse	How often do you currently use Facebook?
MpesaUse	Have you used Mpesa to send money (or another mobile money platform)
	Choice questions - vital signs device

Name	Variable label
	Choice questions - urine testing device
	Choice questions - diagnostic support device
	Choice questions - ultrasound device
decEquip	If your clinic were going to purchase equipment, who would make a request for new equipment?
DecPurch	If your clinic were going to purchase equipment, who would be the main decision maker?
decFunds	And once that decision had been made, who would need to raise the funds to pay for it?
FridgeSZ	You said you had a fridge at the clinic - what size is it?
FridgeOP	Would you be interested in a vaccine fridge that 'dispensed' individual phials of vaccines?
Name	Name
MobNumber	Mobile number

Annex 2

List of variables – Domestic Survey

Name	Variable label
Region	Region
Village	Name of Village/locality
SubCounty	Name of Sub-county
RurUrb	Is your household in an urban or rural area (Rural/Urban)
Gender	Gender of the Respondent (observe)
respagec	Age
respEducc	What is the highest level of school you have attended?
primyrs	If 'incomplete primary', how many years completed?
relation	What is your relationship to the head of the household?
House#	How many people are living in your household?
water	What is your main source of drinking water for members of your household?
Watertrp	How long does it take to collect water (round trip)
GrpMem	Please indicate if you are a member of any of the following community groups
LCTAsset	Household ownership of electrical devices
SolarDevice	Do you have any type of solar device in your house (list)?
SOLfuel	What type of fuel does your household mainly use for cooking?
LPG	Do you use LPG for all your cooking needs?
impstov2	If charcoal or wood - Is this an 'improved stove'
MoneySaved	how much fuel did the improved stove saved you over the old cooking stove (KSH/month)
elecexp	Have you ever in your life cooked with electricity?
FuelSpend	How much did you spend, the last time you bought cooking fuel? (KSH)
FuelLast	How long will that fuel last? (days)
Bathing	In addition to cooking food and boiling water for drinks, do you boil or heat water for bathing?
Floor	Can you describe the floor of the house you live in?
transprt	Household ownership of transport assets
Market	How far is it from your household to the nearest market place? (km)
Radio	How often do you listen to the radio?
TV	How often do you watch television?
usedmobi	How often have you used a private mobile phone in the last month?
phonetype	What type of phone do you most commonly use?
respMob	Do you own a mobile phone (or SIM card)?
readSMS	Are you able to read SMS texts yourself?
internet	How often have you used the internet in the last month?
UsedFacebook	Have you used Facebook (any time in the past)?
facebook	How often do you currently use Facebook?
Mpesa	Have you used Mpesa to send money (or another mobile money platform)
cropsgrown	What types of crops do you grow?
cropdestination	Are these for domestic, the market, or company
growhere	Where do you grow most of these crops?

Name	Variable label
nearhome	Do you have a garden or field next to your house?
landAvbyhouse	What size of land is available for crops next to your house. (acres)
pumpcrop	Do you currently irrigate your crops?
landirrigated	How much land do you irrigate (square metres)
headpump	What is the head you pump? (metres)
motorpump	Do you use a pump with a motor?
costfuelpump	How much do you spend in a year on fuel for the pump? (in KSH/year)
neariver	Is a river available near your house
whynoir	Why do you not irrigate from it
FridgeSize	If you have a fridge, what size is it?
UseNeighbFr	Do you ever use someone else's fridge?
NeighbFrSize	What size is their fridge?
UsesFridge	What do you use a fridge for?
	Choice questions - Solar pump
	Choice questions - Fridge
	Choice questions - Cookstove
STCh3style	Cookstove design choices
STChTriangle	Cookstove design choices
decpump	If you were going to purchase a pump, who in your household would be the main decision maker?
decfridg	If you were going to purchase a fridge, who in your household would be the main decision maker?
deccook	If you were going to purchase a new cooking device, who in your household would be the maker?
decSOL	If you were going to purchase a solar panel for the house, who in your household would be the main decision maker?
WealthStatus	If a household has solar panels, what does this suggest about the wealth status of the household?
ModernEnergySwitch	do you think many people would use modern fuels if the cost was the same?
NewDeviceLargePots	Would a new device need to take very large pots as well as medium sized ones?
RentingEquip	How would people in your neighbourhood feel about renting equipment?
RespName	Name
RespNumber	Mobile number