Interventions for Mitigating Indoor-Air Pollution in Nigeria: A Cost-Benefit Analysis

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INTERVENTIONS FOR MITIGATING INDOOR-AIR POLLUTION IN NIGERIA: A COST-BENEFIT ANALYSIS

ABSTRACT

Purpose of this paper: This study evaluates the costs and benefits of interventions to reduce indoor-air pollution from the use of solid biomass for cooking and heating in Nigeria.
Design/methodology/approach: The study uses cost-benefit analysis and assesses two intervention scenarios: Providing access to improved stoves; and Providing access to cleaner fuels (LPG burners). Both intervention scenarios are compared with the current situation, i.e., the ''business as usual'' scenario where there is no attempt to reduce the present level of exposure to indoor-air pollution from solid fuel use.
Findings: The result shows that the cost-benefit ratio of the stove intervention is 0.388 while that of LPG is 0.371.
Practical implications: While providing access to cleaner fuels (LPG) has a larger health impact on the population than improved stoves, the low income level of the participants will favor the stove option because of the lower recurrent cost which is usually borne by the participants. From a public health point of view, there is need for a continued emphasis on the promotion of improved stoves to reduce exposure in households using solid-fuels until everyone can have access to cleaner fuels. Furthermore, since choice of cooking technologies is influenced by income level, the intervention policy should be implemented alongside other socio-economic development programmes.

What is original/value of paper: This study bridges the knowledge gap with respect to indoor-air pollution issue in Nigeria. It offers policy makers an insight into the potential net benefit of intervening to reduce indoor-air pollution through the use of solid biomass fuels in Nigeria.

KEYWORDS: Intervention, Indoor-air Pollution, Cost-benefit Analysis, Nigeria.

1.0 INTRODUCTION

Access to cleaner energy is necessary for economic growth, healthy living condition, and for meeting the basic energy needs of cooking, lighting and heating. About 40% of the global population rely on solid fuel such as wood, agricultural residues, animal dung, charcoal and coal for their energy needs (IEA, 2010). These solid fuels are the main sources of indoor-air pollution (IAP) in developing countries (Mehta & Shahpar, 2004). Other sources of IAP include smoke from nearby houses, deforestation, household waste burning, using kerosene lamps and indoor tobacco smoking (Bruce *et al.*, 2000; Fatmi *et al.*, 2010).

Exposure to indoor-air pollution results in health damages and economic losses. It is responsible for high risk of acute respiratory infections (ARI) in children, chronic obstructive pulmonary disease (COPD) in adults, lung cancer, asthma, low birth weight, tuberculosis, cataracts, perinatal deaths and heart disease (Fatmi *et al*., 2010). The health effect leads to loss of productivity and income. The reliance on solid fuels is linked to environmental problems such as deforestation, land degradation, acid rain and increased CO_2 emission (WHO, 2006; Hutton *et al.*, 2007). The exposure to indoor-air pollution accounts for almost two million deaths in developing countries (WHO, 2011a). Women and children are the most exposed to IAP due to their household responsibility, especially in biomass collection and cooking. Children are particularly more vulnerable because of the immaturity of their metabolic pathway organs to export the pollutant particle from their body, and the fact that they spend much time with their mothers around the cooking area, sometimes, at the back of the mothers (Smith *et al.*,2007; Hutton *et al*., 2007; Fatmi *et al*., 2010).

In Nigeria, about 79% of the population rely on solid fuel for their energy as shown in table 1.

Table 1: Percentage distribution of households by type of fuel for cooking in Nigeria, 2007[1].

	South- West	South-East	South-South	North Central	North-East	North-West
Electricity (%)	0.98	0.16	0.50	0.49	0.43	0.79
Gas (%)	0.92	0.92	0.97	0.60	0.00	0.38
Kerosene (%)	44.52	20.74	25.07	13.37	2.83	3.49
Wood (%)	49.88	77.96	73.12	81.46	96.54	95.22
Coal (%)	3.73	0.26	0.32	4.23	0.20	0.12

Source: NBS/CBN/NCC Social-Economic Survey on Nigeria, 2008.

Estimate from the United Nations shows that more than 66.4% of Nigerians live below one dollar per day (WHO, 2010). Nigeria is not also performing well in other indices of human development like rural literacy level, rural povery headcount etc. (World Bank, 2011). Given that the choice of cooking technology depends on the level of income, the low income of Nigerians poses a significant barrier to movement to the next rung of the energy ladder. Moreover, this low income, and the possibility of free collection of solid fuels in rural areas (i.e. solid fuel is not monetized) had resulted in an increased dependence on solid biomass despite its health, socio-economic and environmental consequences. WHO (2009) estimated that in 2004, 95300 deaths

[1] The composition of the zones is presented in appendix 1

in Nigeria were attributed to indoor air pollution. The slow pace of development in Nigeria suggests that the problem will persist since the poor will continue to rely on solid fuels for many years unless intervention measures are introduced.

Some studies on intervention options for mitigating indoor-air pollution have been carried out in some developing countries (WHO, 2005; Malla *et al*., 2011; Ezzati & Kammen, 2001; Ezzati & Kammen, 2002), however, there is a significant gap with respect to the Nigerian case. The issue has largely been neglected in the Nigerian policy-making circle and the academia. One of the challenges of policy-makers in allocating scarce resources to an investment project such as an intervention programme to reduce indoor air pollution is to determine the economic viability and efficacy of such investment. The objective of this study is to evaluate, in monetary terms, the costs and benefits of two intervention options: providing access to cleaner fuels, and providing access to improved stoves to reduce indoor-air pollution in Nigeria.

The paper is organized as follows: Section two provides a review of the existing literature on the subject, the third and the fourth sections discuss the methodology and present the results of our analysis, while the last section offers some concluding remarks.

2.0 LITERATURE REVIEW

Several studies have been carried out on the impact and mitigation options of indoor-air pollution in developing countries. Most studies have specifically evaluated the health benefits (Ezzati & Kammen, 2002; Hammitt & Zhou, 2006; Mehta & Shahpar, 2004; Fullerton *et al.*, 2008; Smith & Mehta, 2003), and have employed diverse methodologies including: benefits transfer, compensating wage differentials, human capital approach, utility approach, cost-benefit approach, cost-effectiveness approach, and value of a work day (Pearce, 1996; Larson & Rosen, 2002; WHO, 2006). Other benefits identified in the literature include: time-savings, increased convenience, and reduced damage to environment (Hutton *et al.*, 2007; Malla *et al*., 2011).

In a global study, Hutton *et al.* (2007) employed benefit-cost analysis in examining the effectiveness of switching to clean fuel (LPG) and efficient stove as intervention options. The result showed that annual economic benefits of halving the population without access to LPG amount to USD91 billion at a net cost of USD13 billion while the improved stove intervention generates USD105 billion in economic benefits at a negative net cost of USD34 billion. The benefit-cost ratios for LPG ranges from 1.5 to 21.2 in rural areas while that of improved stoves is negative, as fuel cost savings exceed intervention costs, thus giving net negative costs. The study finally concluded that investments in interventions to reduce indoor-air pollution are potentially cost-beneficial. In a similar study, Mehta & shahpar (2004) applied cost-effectiveness methodology to analyze the cost effectiveness of three intervention options of reducing indoor-air pollution in South and South-East Asia, Africa, and the Americas. The results show that intervening with improved stove is much cost effective, though access to clean fuel (LPG) has more health impacts. The study indicates that a well improved stove in a properly ventilated area could reduce the exposure of IAP by 75%, while switching to clean fuel reduces the exposure to natural level.

Furthermore, Malla *et al.* (2011) evaluated household-level impact of indoor-air pollution in Nepal, Sudan and Kenya using cost-benefit analysis. The results suggest that interventions are justified on economic grounds with estimated internal rates of return of 19%, 429% and 62% in Nepal, Kenya, and Sudan, respectively. The studies found that time savings constituted by far the most important benefit, followed by fuel cost savings, while direct health improvements were a small component of the overall benefit

In Kenya, Ezzati & kammen (2001) reported that adoption of improved stove is associated with up to 65% decrease in incidence of acute lower respiratory infections (ALRI) and lower chances of incidence is observed when shifting to improved ceramic woodstoves. In a related study, Ezzati & Kammen (2002) used longitudinal health data coupled with detailed monitoring of personal exposure from more than two years of field measurements in rural Kenya to examine the reductions in disease from a range of interventions, including changes in energy technology (stove or fuel) and cooking location. The result showed that from the set of interventions considered, on average, incidence of acute respiratory infection (ARI) and acute lower respiratory infections (ALRI) for infants and children below 5 years will reduce by 24–64% and 21–44% respectively. The range of reductions is larger for those above 5 yr, and is highly dependent on the time-activity and budget of individuals.

Larson & Rosen (2002) used utility function approach to develop a general household framework to identify in detail the determinants of household demand for indoor air pollution interventions, where demand for an intervention is expressed in terms of willingness to pay. The research revealed that household demand for intervention is strong for improved stoves, given that willingness to pay. In addition, Smith *et al*. (2007) evaluated the impact of improved cooking-stoves and reported that there are major and mostly statistically significant improvements in 48-hour indoor air pollution concentrations in those households using the stoves one year after introduction. Kitchen levels of carbon monoxide reduced 30-70% and concentrations of small particles reduced 25-65%.

In their part, Foell *et al*. (2011) examined household cooking fuels and technologies in developing countries in terms of their implications for sustainable development, health and climate issues; and the different action plans for a successful intervention to ensure access to clean cooking technologies. The study identified action areas to include societal awareness, government participation, and public-private partnership and noted that household energy policies should not be isolated from the larger socio-economic planning for broader issues such as education, health care, and economic development.

3.0 METHODOLOGY

This research employs cost-benefit analysis (CBA) recommended by WHO (2006) for evaluating the costs and benefit of reducing indoor air pollution following a similar work by Hutton *et al.* (2007) and Malla *et al.* (2011). The model is specified in equation 1:

$$\frac{C}{B} = \frac{\sum_{t=1}^{T} \frac{C^t}{(1+i)^t}}{\sum_{t=1}^{T} \frac{B^t}{(1+i)^t}} \qquad ...(1)$$

Where:

B^t = benefit in year t

C^t = cost in year t

i = discount rate

The research estimates the present value of the cost and benefits over a 10-year period using a discount rate of 10% for the base case. The choice of the discount rate reflects the present cost of funding in the country. The choice of the intervention period is informed by the intervention equipment life span of 10 years for both stove and LPG burner and cylinder. The analysis was carried out with the support of a simulation software developed by WHO called '**WHO-CHOICE Tools'**[†].

3.1 Modeling Intervention scenarios

The two intervention options analysed in this work take various factors into account, including the distinctive characteristic of Nigeria, availability of resources and manpower, cost, time expected to achieve the coverage, cultural need, policy consideration, and viability (WHO, 2006). The first option is to reduce exposure through switching from traditional biomass to efficient stoves (Stove Option) and the second option is to switch to cleaner fuel- Liquefied Petroleum Gas (LPG Option). The two intervention options are compared with the current situation, i.e. the "business as usual" case, where there is no attempt to reduce the present level of exposure to indoor-air pollution from solid fuel use.

3.2 Target population With respect to the target population, the research employs state-wide data for population and average household (HH) size for the 36 states and the Federal Capital Territory in Nigeria for 2008[2] obtained from National Bureau of Statistics, Nigeria. The states were grouped into the six geopolitical zones: South-West, South-East, South-South, North-Central, North-East, and North-West (see appendix 1). The household size of each zone is estimated using a weighted average of number of households, and population of the state within the zone. The number of households exposed to indoor air pollution in each zone is obtained by applying the percentage of the population exposed to indoor air pollution (as reported by National Bureau of Statistics) to the population of the zone.

Finally, to reflect a realistic policy option, win the support of the public, and attract support of non-governmental organizations, the study adopted intervention coverage of 20% of the population exposed which gives a total sample size of 4.37 million HH (see table 2 below)

[2] This is the most recent available state-wide data in Nigeria from National Bureau of Statistics, Nigeria.

Table 2: Zonal Exposure to indoor air pollution from solid fuels used in Nigeria (2008)

	South West	South East	South-South	North Central	North East	North West	TOTAL
Population (Million)	28	16	21	20	19	36	140
Average HH size	3.63	4.42	4.32	5.04	5.80	7.26	
Number of Households (Million)	8	4	5	4	3	5	
Number of HH currently exposed (%)	55.0	83.3	69.2	82.5	96.7	95.3	
Number of Households Exposed (Million)	4.20	3.09	3.37	3.33	3.17	4.71	
Sample HH for Intervention (Million) 20% of total HH exposed	**0.84**	**0.62**	**0.67**	**0.67**	**0.63**	**0.94**	**4.37**

Source: NBS/CBN/NCC Social-Economic Survey on Nigeria, 2008; and authors' calculations

3.3 Costs and Benefits analysed

The intervention costs considered are: *capital cost* (cost of efficient stove, or LPG burner and cylinder); *administrative cost* (staff/labour, planning and supervision, transportation, and training); and *recurrent cost* (annual operational and maintenance cost). The benefits considered are: *health benefits* (morbidity and mortality averted as a result of intervention, and reduction of health related expenditure); *productivity gains* (from working days recovered); *time savings* (from solid fuel collection and cooking); and *environmental* (aversion of deforestation and reductions of carbon emission).

3.3.1 Sources of cost data

Cost data are sourced from market survey, recent pilot intervention by ICEED[3] and Swiss Embassy in Bida, (Nigeria) and other published studies. Prices are adjusted to correct the existing market distortions and followed the principles of shadow pricing or opportunity cost (WHO, 2006; Bhattacharyya, 2011, pp. 165-169). The cost of improved stove used is USD14, cost of LPG burner and cylinder are USD60.0 and USD50.0 respectively (Hutton *et al.*,2007). The staff are categorized into permanent staff (for the duration of the intervention) and ad-hoc staff (for the initial year). The permanent staff salary is estimated using the professional and general levels of the International Civil Service Scale while the ad-hoc staff followed the Nigeria

[3] International Centre for Energy, Environment and Development, Nigeria

Civil Service Scale. Planning/supervision, and transportation cost of 20% and 10% of the staff cost are assumed respectively. Annual operational and maintenance cost of USD75 for stove and USD109.5 for LPG intervention is used[4]. The stove intervention assumes 50% of the solid fuel is purchased by the household and the rest are collected by the household at no cost. For the LPG fuel, free on board (FOB)[5] price is used to estimate the recurrent cost.

3.3.2 Sources of benefit data

Healthcare cost savings: Intervention reduces preventive and curative health care expenditure incurred by the government and the households themselves. Data on reported cases of illness associated with indoor pollution was not available directly but an estimate was made in consultation with medical staff of hospitals in Kebbi State Nigeria. We apply the rate of such diseases to our sample household size to come up with the number of illness reported and the cost savings are estimated on this basis. However, we assumed that only 40% of the exposed households will be affected and seek medical care. As there is significant difference on the cost of medication due to severity of the sickness, we assumed a moderate level of severity. Data on the cost of treatment was obtained from WHO international review of cost with adjustments and includes in-patient, out-patient, and hospitalization cost (WHO, 2011b). The unit cost of drugs, and transportation and treatment-related costs were also added to the unit cost per household to get the overall cost of treatment per household. Finally, average length of stay for hospital in-patients of 3-5 days for ALRI and 8-10 days for COPD was used (Hutton *et al.*, 2007).

Productivity gain: The productivity gain as a result of an intervention arises from illness-free days gained, which could be used for income generating activities (WHO, 2006). Illness-free days range from 7-10 days of sick period depending on the severity level (Hutton *et al.*, 2007). Due to data constraint, the research assumes seven (7) days gain, on average, for an averted sickness and values the economic benefits of reduced morbidity on this basis. For adults, the number of sickness-free days is monetized by multiplying the daily minimum wage in Nigeria by the days gained for the adult population. Following WHO (2006), and the procedure above, the

[4] This was estimated from a survey of average expenditure of 20 households in Nigeria
[5] FOB price represents the opportunity cost for Nigeria, being a major oil and gas producer.

study estimated gains for children by using half of minimum wage in Nigeria for the days gain from ALRI aversion as a result of the intervention.

Time saving: Intervention will help reduce the time spent by households in collecting solid fuels and for cooking. Hutton *et al*. (2007) reported that time spent for fuel collection is about 18minutes (0.3hrs) in Nigeria. In their study, Anozie *et al.* (2007) estimated the time taken to cook 270g of beans using different fuel types and reported a time-saving of 26 minutes (0.43hrs) using a clean stove and 49minutes (0.82hrs) using LPG relative to solid biomass usage. The research adopts a conservative time of 0.3hrs for fuel collection and 0.43hrs and 0.82hrs for time saved on cooking using improved stove and LPG per household respectively, converted the time-saving into daily working rate, and monetized it by multiplying by the daily minimum wage.

Environmental Benefits: Intervention reduces the number of trees cut down. This reduces the effects of deforestation and land degradation and its associated risk of disaster such as floods, loss of soil nutrient among others. Rather than placing value directly to the effects, the research employs an economic method of monetizing the benefits of intervention by estimating the cost of replacing the trees to avert environmental effects (Hutton *et al.*, 2007). The replacement cost comprises the labour cost, cost of tree sapling planted (adjusted by waste factors) and is estimated at USD0.75 per tree. The research assumes an annual reduction in cutting trees of five for stove and seven for LPG intervention[6].

Furthermore, the benefit of CO2 reduction is estimated based on the Nigerian Project of Global Alliance for Clean Cookstoves[7] which estimated that providing clean stove for 10 million households will save over 300,000 tonnes of carbon in ten years. Thus, the reduction in CO2 emission per household is estimated and monetized using clean development mechanism (CDM) certified emission reduction (CER) credit price of USD12 dollar per tonne of CO2 equivalent (Carbon Trust, 2011).

3.4 Sensitivity Analysis

This research employed some assumptions in the monetization of the cost and benefits. This makes the result of the study susceptible to some uncertainty. Sensitivity analysis was carried out

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[6] This is based on information gotten from Ministry of Environment, Kebbi State, Nigeria.
[7] http://www.nigeriacookstoves.org/ (Last visited on 13th March, 2012)

on some defined variables to examine the impact of optimistic and pessimistic assumptions on the cost-benefit ratios. Optimistic scenario assumes higher benefit than the base-case scenario while pessimistic assumes lower benefit compared to the base-case scenario. The values for the analysis were drawn based on the available literature and five sensitivities were examined: changes in the capital cost, recurrent cost, health benefit, time saving benefit, and environmental benefits.

4.0 RESULTS

4.1 Costs of the interventions

The annual intervention costs of the programme for the two options are presented in table 3 below. The total intervention cost for improved stove is distributed as follows: capital cost (1.66%), administrative cost (0.43%), and recurrent cost (97.91%). The annual cost per household ranges from USD84.05 in South-West to USD84.33 in North-West, with an average of USD84.16 for the six zones. At the zonal level, the South-East has the lowest overall cost of intervention mainly because of the small number of households that are exposed to indoor-air pollution as compared to other regions, while the North-West records the highest.

Table 3: Average Annual Cost of Intervention to Reduce Exposure to Indoor Air Pollution from Solid Fuel use in Nigeria (million USD)

ZONES	South West	South East	South-South	North Central	North East	North West	TOTAL
STOVE							
Capital	1.1740	0.8642	0.9435	0.9318	0.8856	1.3188	6.1180
Administrative	0.1906	0.1584	0.2160	0.2605	0.2718	0.4816	1.5788
Recurrent	69.1819	50.9270	55.6015	54.9092	52.1881	77.7172	360.5250
TOTAL	**70.5465**	**51.9496**	**56.7610**	**56.1016**	**53.3455**	**79.5177**	**368.2218**
LPG							
Capital	9.2243	6.7903	7.4135	7.3212	6.9584	10.3623	48.0700
Administrative	0.2382	0.1863	0.2273	0.2481	0.2471	0.4014	1.5484
Recurrent	101.0056	74.3535	81.1782	80.1675	76.1946	113.4671	526.3665
TOTAL	**110.4680**	**81.3300**	**88.8191**	**87.7369**	**83.4001**	**124.2308**	**575.9849**

Furthermore, compared to the cost of stove intervention, the annual intervention cost of LPG option is higher. The cost per household ranges from USD131.62 in South-West to USD131.76 in North-West. The major cost component is the recurrent cost which accounts for 91.39% while capital cost and administrative cost account for 8.35% and 0.29% respectively. At the regional level South-East requires USD81.11million investment per year to reduce the effect of the IAP for the selected sample while North-East will need USD124.23million. For the overall country-wide cost, a total of USD368.22million and USD575.98milllion is required for the improved stove and LPG options respectively.

4.2 Benefits of the interventions

The benefits of the two intervention options are presented in the table 4 below. For the improved stove intervention, the average annual economic benefit per household for the six zones is USD216.83. Time saving for collection of fuel and cooking constitutes the largest benefit, accounting for 57.99% of the total benefit, while environment benefit contributes the least with a share of 4.34%. At the regional level, the total benefit ranges USD133.97million in the South-East to USD204.44million in North-West

Table 4: Average Annual Benefit of Intervention to Reduce Exposure to Indoor Air Pollution from Solid Fuel use in Nigeria (USD)

ZONES	South West	South East	South-South	North Central	North East	North West	TOTAL
STOVE							
Health	56.9610	41.9308	45.7796	45.2096	42.9691	63.9885	296.8386
Productivity	11.5821	8.5259	9.3085	9.1926	8.7371	13.0110	60.3572
Time savings	105.5255	77.6807	84.8109	83.7549	79.6043	118.5446	549.9208
Environment	7.9175	5.8283	6.3633	6.2841	5.9726	8.8943	41.2601
TOTAL	**181.9860**	**133.9658**	**146.2622**	**144.4411**	**137.2831**	**204.4385**	**948.3767**
LPG							
Health	85.5158	62.9509	68.7291	67.8733	64.5097	96.0663	445.6451
Productivity	11.5821	8.5259	9.3085	9.1926	8.7371	13.0110	60.3572
Time savings	160.6865	118.2865	129.1438	127.5359	121.2156	180.5111	837.3794
Environment	40.3561	29.7074	32.4342	32.0304	30.4431	45.3350	210.3063
TOTAL	**298.1405**	**219.4708**	**239.6156**	**236.6322**	**224.9055**	**334.9234**	**1553.6880**

The LPG intervention records higher benefits compared to stove intervention having an average annual benefit per household for all the zone of USD355.22. In this option, time saving also constitutes the largest share of 53.90% followed by heath benefits that account for 28.68%. At the country-wide analysis, the improved stove will accrue a total benefit of USD948.38million while the LPG option will benefit the country by USD1553.69million respectively.

4.3 Cost Befit Ratio

The cost-benefit ratios of the two interventions are reported in the table 5.

Table 5: Benefit Cost Ratio For the six zones in the Country (Return per USD invested)

COST-BENEFIT RATIO	South West	South East	South-South	North Central	North East	North West
STOVE	0.38765	0.38778	0.38808	0.38840	0.38858	0.38896
LPG	0.37052	0.37057	0.37067	0.37077	0.37082	0.37092

For the stove options, the ratios for all the zones closely revolve around 0.388 which implies that a benefit of USD1 is received for every 39 cents spent. Thus, the result of our analysis shows that the stove intervention option is viable. The slight variations in the cost-benefit ratio among the zones are due to regional characteristics, administrative cost, and different assumptions such as the time taken to cook in each of the zone.

The LPG intervention reveals that the cost-benefit ratio among the zone is closely around 0.371 which implies that a benefit of USD1 is received for every 37 cents spent. The ratio among the zones is similar basically due to uniformity of the cost of input such as the LPG burner, cylinder and maintenance. Based on the cost-benefit ratio of the two intervention options, it is evident that the LPG intervention is more cost-effective in the case of Nigeria.

4.4 Sensitivity Analysis

Sensitivity analysis is carried out to examine the impact of changes in some of the underlying variables used in the analysis under low and high scenarios as compared to the base-case scenario. Keeping the benefits constant, the capital cost is increased by 20% relative to the base-case, and then reduced by 15% relative to the base-case, to examine the sensitivity on the cost-benefit ratio for both interventions. Similarly, the same procedure was followed for the recurrent cost. With respect to the benefits, keeping cost constant, the research increased time saving benefits by 10% and then reduced by 20% relative to the base-case. The same sensitivity is done for health benefit. On the other hand, environmental benefits were reduced by 25% and increased by 10% relative to the base-case scenarios.

From the result of our sensitivity analysis as presented in figures 1and 2, we observe that changes in some variables affects the cost-benefit ratios considerably while others do not. In particular, for both intervention options, changes in the recurrent cost and time savings benefit are more sensitive to the overall cost-benefit ratios. This is because the recurrent cost and time savings benefits constitute the largest share in both costs and benefits aspect respectively. The effect of changes in the capital cost and environmental benefits are less sensitive with corresponding changes in the cost-benefit ratio fairly stable compared to the base-case. Even at these pessimistic assumptions, the interventions are still justified as the rates are favourable under all the conditions.

Figure 1: Sensitivity analysis for stove

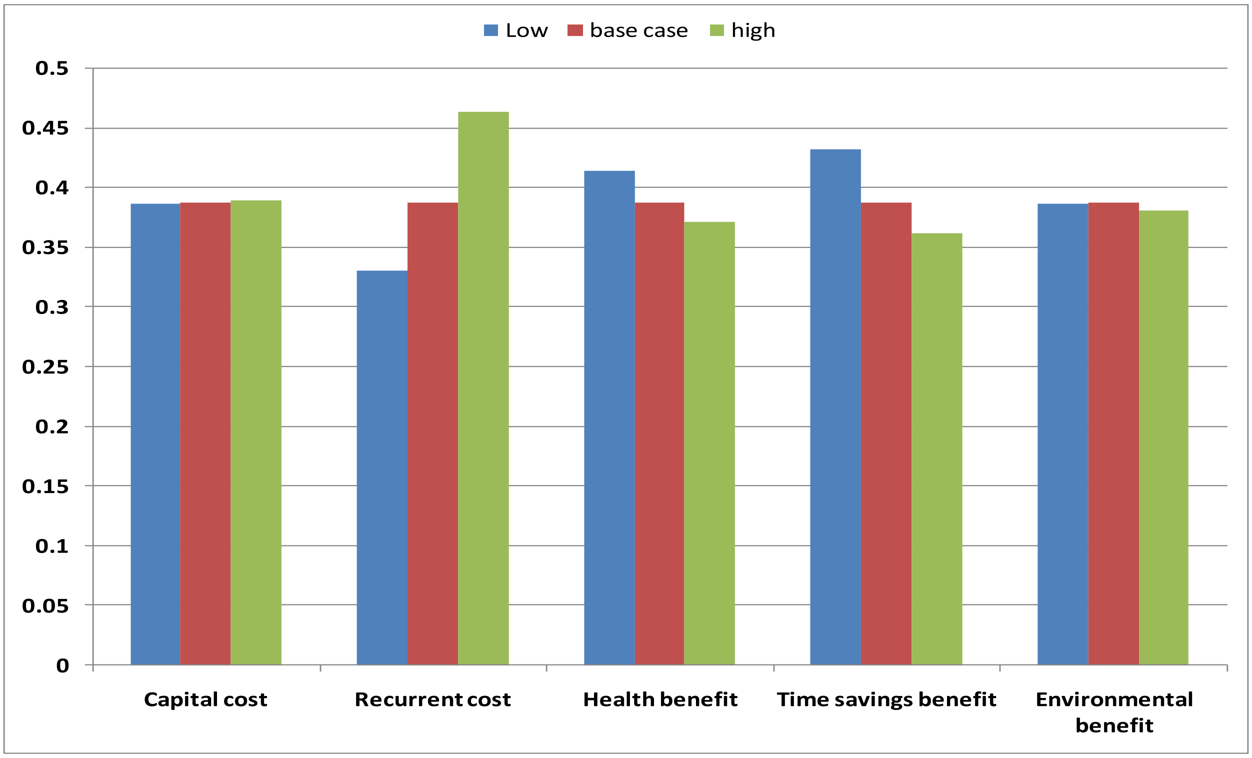
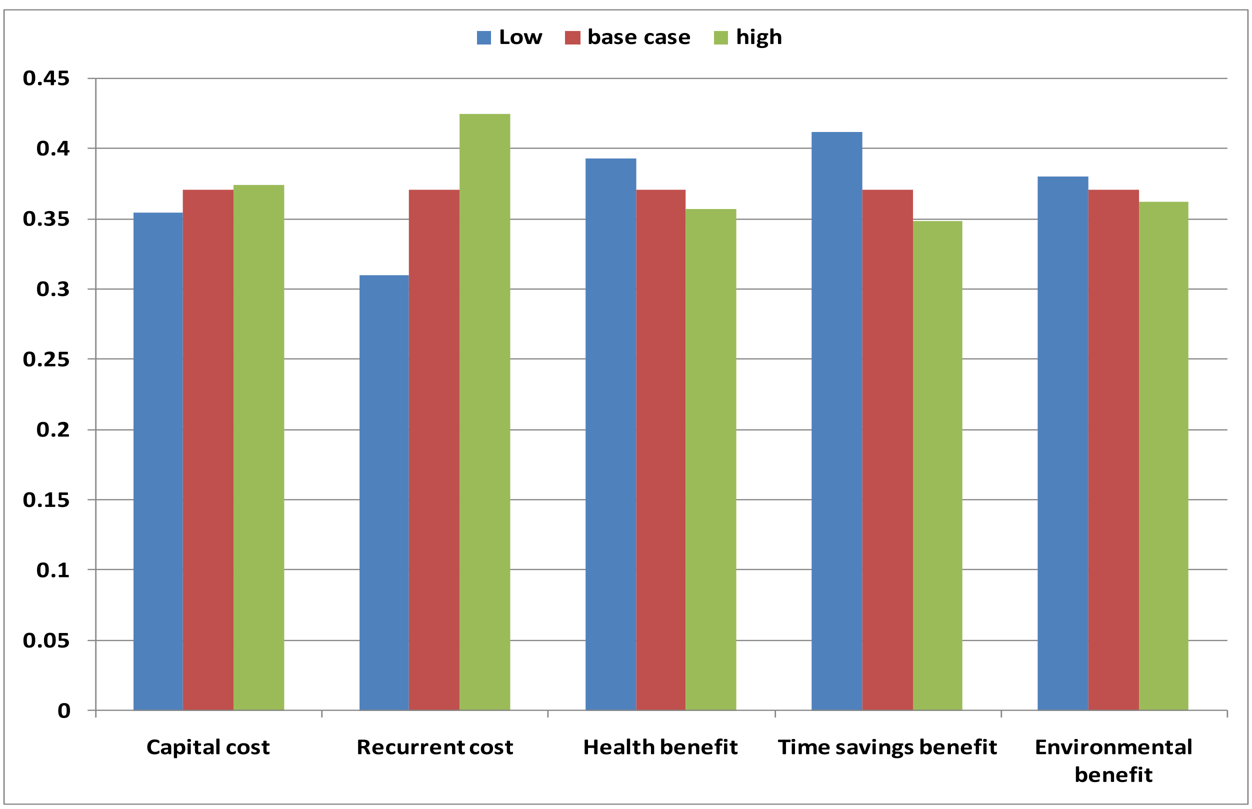


Figure 2: Sensitivity analysis for LPG



5.0 DISCUSSIONS AND CONCLUSION

The result of our study shows that the net benefits of the two intervention options to reduce indoor air pollution are positive. It is important to mention that the research did not consider all the potential benefits that will result from the intervention options. This is largely due to unavailability of data and scientific evidence linking some diseases to indoor-air pollution. The health impacts included only those that have strong evidence of association with indoor air pollution as identified in the literature (Smith *et al.*, 2004). Also socio-economic benefits like income generation activities, reduction of cost of building renovation, increased time for children education, higher standard of living, employment generation from investment, increased soil nutrients, number of averted deaths, and potential improvement in food safety and nutrition were not considered. The exclusion of some other greenhouse gases such as methane, SO2, NO2, and other gases that are linked to global warming in the analysis also underestimates the benefits.

In contrast, some assumptions in the study, for example, constant efficiency of stove and LPG burner throughout the lifespan of the intervention, complete switch to stove or LPG burner, immediate acceptance, may inflate the benefit. In reality, maintaining a high efficiency comes with additional maintenance cost, changes in cooking facilities are not easy as some households will prefer their present cooking method, and some households may combine the traditional biomass with the stove or LPG burner. Furthermore, the research has not considered the negative side of LPG as improper usage might result in fire that could cost the households their entire savings.

The analysis of the two interventions indicates that the annual average benefit per household is USD216.83 for stove and USD355.22 for LPG, while the annual average cost per household is USD84.16 for stove and USD131.69 for LPG. Clearly, the benefits of the LPG burner are higher than that of the stove option, so also the cost. Given that the average annual recurrent (operating and maintenance) cost per household for stove and LPG options are USD75 and USD109.5 respectively, and the fact that the recurrent cost is usually borne by the participants, the low income level of the participants will favour the stove option over the LPG option. Thus, we advocate for the stove option since it is easier and cheaper to operate and maintain. Moreover, the unavailability of facilities to refill LPG cylinders in rural areas makes the stove option more feasible.

As earlier mentioned, the choice of cooking technologies is influenced by income level. Thus, the intervention policy should be implemented alongside other socio-economic development programmes. Since most rural dwellers in Nigeria engage in subsistent agricultural activities, programmes that will increase their productivity, which will in-turn improve their income should be also be encouraged. Additionally, the National Poverty Eradication Programme (NAPEP) of government should be better implemented by adopting a bottom-up approach with zone-relevant policies accorded due priority. Community level participation should be encouraged especially in terms of co-operative societies to assist in making fuels readily available to the participants and in equipment maintenance.

Furthermore, we recommend government intervention by bearing the capital and administrative cost to reduce the barrier of affordability. In addition, since the intervention will reduce greenhouse gas emission, the cost of government intervention can be reaped through Clean Development Mechanism under the Kyoto Protocol. There are also opportunities to support the intervention programme through carbon finance (Simon *et al.*, 2012).

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APPENDIX 1

South West	Ekiti, Lagos, Osun, Ondo, Ogun, Oyo
South East	Abia, Adamawa, Anambra,Ebonyi, Enugu, Imo
South-South	Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Rivers
North Central	Benue, FCT, Kogi, Kwara, Nasarawa, Niger, Plateau
North East	Adamawa, Bauchi, Borno, Gombe, Taraba, Yobe
North West	Kaduna, Katsina, Kano, Kebbi, Sokoto, Jigawa, Zamfara