



## Research Article

# Feasibility Study on Assessment of the Effects on Consumers and the Environment of a Multi-Fueled Solid Biomass Cookstove that Runs Continuously

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## ABSTRACT

In developed countries, cooking technologies rely on fuels such as electricity, geothermal energy, and liquefied petroleum gas (LPG), whereas in developing regions, particularly rural communities in Sub-Saharan Africa, solid biomass fuels are still predominantly used. These traditional cookstoves are inefficient and emit pollutants that are harmful to both health and the environment. Although several studies have improved stove efficiency through design modifications, limited attention has been given to scientific and technical approaches that enhance the efficient use of different biomass fuels, as well as improvements in combustion chamber design, ignition time, and cooking duration. This study investigates the factors required for designing and fabricating an efficient biomass cookstove and examines its implications for users and the environment. A feasibility study was conducted to obtain input from stakeholders, including investors and potential users. Seven research hypotheses guided the collection of quantitative primary data through 1,128 structured questionnaires using Likert-scale responses. Data were analysed using SPSS (version 27) and AMOS (version 24). The findings indicate that stakeholder involvement is essential for identifying factors related to environmental sustainability, health improvement, and user acceptance. The results also show that improved stove designs should focus on faster ignition, reduced cooking time, and lower fuel consumption. Furthermore, the design and fabrication of improved biomass cookstoves demonstrate potential to attract investment. The study concludes that feasibility study outcomes can be applied to strengthen design processes and support the development of more efficient biomass cookstoves..

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## INTRODUCTION

Current manufacturing industries have built-in sustainability criteria into their business operations as strategy to achieve a competitive advantage that is sustainable (Mensah et al., 2023). Addressing environmental sustainability issues are crucial for future generations (Syropoulos and Markowitz, 2024). The results from studies reveal that a well-designed and executed feasibility studies, involving key stakeholders and potential users, is fundamentally important not only for uptake of the intended product, but also essential to map out elements that are crucial for environmental sustainability and social health (Ng et al., 2010; Turyasingura and Agaba, 2023). However, limited involvement of beneficiaries in the feasibility of a projects can lead to unsustainability of the project (Ahmadabadi and Heravi, 2019). SEM was developed to address limitations of previous statistical techniques that were widely used (Schumacker and Lomax, 2010). A combination of path analysis, multiple regression and confirmatory factor analysis result in the formation of SEM, thereby making the model easier to understand. Villalva et al. (2021) applied structural equation models and partial least square method in engineering science in which their finding reveal that partial least square SEM technique constitutes an excellent support tool for research in the field of engineering sciences. SEM technique was used by Olanrewaju (2024) to evaluate modifications in sustainable buildings, wherein his study supports the improvement of viable practices in the construction industry.

According to, Ehrenspurger et al. (2024), a vast majority of rural and low-income dwellers still use wood and charcoal for cooking and heating. This cooking method has been connected to several health challenges like, respiratory and premature deaths (Shawatsu, 2019). These traditional stoves are inefficient in terms of fuel consumption and emits lots of pollutants which are harmful to the environment. Recently, improved cookstove, ICS, are increasingly been designed and produced to help provide solutions to the issues of traditional cook stove, as they are more efficient in burning fuel with less pollutants being produced (Negash et al., 2021; Neha and Joon, 2021). Mensah et al. (2023), point out that competitive edge can be achieved through including of environmental sustainability criteria throughout the design, manufacturing and marketing of products, which in essence are needed for business success, in this case, performance of a solid biomass cookstove. Several studies have been conducted to improve efficiency of

these cook stoves, leading to improvements in design parameters required to reduce fuel consumption. However, review show that very little has been done on solid biomass cookstove that runs continuously and consumes less fuel as compared to current biomass cookstoves in the market. It is against this background that the purpose of this study is predicated.

## 2.0 LITERATURE REVIEW

### 2.1 Feasibility Study

Feasibility assessment of the social and technical aspect of a project is an important step used to determine success factors of a public-private partnership (Ng et al., 2010). Feasibility assessment is considered as an important step for both investors and the project team to ensure that their mission is achievable with positive effects on the society (Rumane, 2017; Bond et al., 2023). The results from studies reveal that a well-designed and executed feasibility studies, involving key stakeholders and potential users, is fundamentally important not only for acceptance of product, but also essential trace out key elements which are essential for improving both environmental and social healthiness (Turyasingura and Agaba, 2023). Making assumptions on wrong premises about proposed product and its social and environmental outcomes stand the risk of failure (Alhamami et al., 2023). Also, limited involvement of beneficiaries in the feasibility of a projects can lead to unsustainability of the project (Heravi and Ahmadabadi, 2019). According to Bamgbade and Kamaruddeen (2018), project achieve sustainability when beneficiaries participate in design, execution, monitoring, evaluation and decision-making processes. The purpose of feasibility study is not only to provide exact solution to existing problem, related to the design and practicability of an intended product, but to also provide environmental sustainability and societal acceptance (Ikpesu and Firima, 2025). A feasibility study, involving both technical and social aspects, was conducted to gauge responses from stakeholders and potential users of cookstoves with the aim of attracting investors. Therefore, feasibility assessments involving environmental sustainability and their outcomes on the communities and surroundings are crucial for the success of the study and future generations

### 2.2 Structural Equation Modeling Symbols

SEM is a multivariate statistical technique which includes path analyses, analyses of variance, multiple regression and Confirmatory Factor Analysis (CFA) (Fan et al., 2016; Gefen et al., 2000; Grace, 2006). This technique has been employed in management to study the relevance of collaborations between different

organization (Ajzen, 1991; Azevedo et al., 2020); relevance of project planning (46); satisfaction of participants in a construction project (Olanrewaju, 2024); in engineering science (Villalva et al., 2021), amongst others. Measured (observable) and latent (hypothetical or theoretical) constructs are the two main types of variables used in SEM (Awang, 2015). SEM process involves two main steps. The first step is to confirm the validity of the indicators used in measuring the latent constructs, whereas the second step deals with fitting indicators and factors into the structural model to establish the connection between variables through path analysis or regression (Bollen et al., 2017). According to table 1, a square or rectangle are the widely used symbols of path diagram of the observed variable, which is an Indicator that is directly measurable and represents a latent construct. Oval or

circular shape represents latent construct, which is indirectly measurable, while rectangular/square shape represents measured variables.

Arrows represent the causal flow of relationship and are used to connect variables. Relationship dealing with regression are represented by a single-headed arrow, in which the direction of the arrow indicates the path of influence. Whereas, inter-correlations between variables are represented by bi-directional arrows. Symbols number 4 represents error associated with measured variable, whereas symbol number 5 represents covariance or correlation. Path links construct to indicator or link between constructs. It is often measured through a path coefficient. See table 1 for a graphical representation of the just described elements of SEM.

**Table 1:** Common Path Diagram/Symbols

NO.	Symbol	Meaning
1		Factor, Unmeasured Variable, Latent Construct
2		Observed Variable, Measured Variable
3		Direct Relationship
4		Error Associated with Measured Variable
5		Covariance or Correlation

Source: Grace (2006)

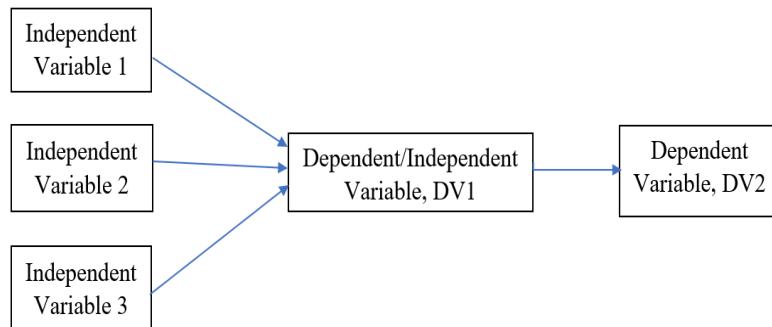
### 2.3 Dependent and Independent variables in SEM

Straight line equation is widely used in SEM to explain the relationship between the dependent and independent variables. Consider the equation of a straight line.

$$Y = aX + b \quad \text{Equation 1}$$

According to equation 1,  $Y$  is the dependent/endogenous/outcome variable, on which the study is focused. It is the problem of the study; that needs to be solved. Whereas,  $X$  is the independent/exogenous/predictor variable, wherein  $X$  tends to change  $Y$ , thus creating an effect on  $Y$  (Awang, 2015). The gradient is 'a', which is indication of the angle made by the line with the x-axis, whereas,  $b$  represents the point at which the line intersects the x-

axis. Multiple regression is a statistical study used to understand the relationship between one dependent variable on one or more independent variable/s. Arrows used on Structural Equation Modelling (SEM) diagrams point from independent variable to dependent variable/s. In SEM, a dependent variable can also be an independent variable. For instance, in figure 1, DV1 is a dependent variable for Independent variables 1, 2 and 3. It is also an independent variable for dependent variable DV2. Whereas the dependent variables are termed endogenous in at least one equation of the model, which leads to a causal relationship.



**Figure 1:** Dependent and Independent Variables in SEM    Source: Awang (2015).

## 2.4 Mediation and Moderation in SEM

The mediator variable explains the relationship between the independent/predictor variable and the dependent/outcome variable. Mediation is important as it provides a more accurate explanation of the causal effect on the dependent variable due to the change of the independent variable (Barron and Kenny, 1986). AMOS is used to analyse the effect of mediation analysis through observation of the indirect effects and their significance. Whereas, moderation is the impact of the independent variable on the dependent variable in the presence of the moderation variable (Hair et al., 2021). In other words, a moderator, which is an independent variable, alters or changes the direction or strength of the relationship between an independent variable and a dependent variable. Moderation effects are the joint effect of two predictor variables in addition to the individual main effects.

## 2.5 Factor Analysis

Information about construct validity, reliability and item quality are provided by factor analysis. Knowledge about hypothetical construct or factors, of an item from a scale is an important element of factor analysis. It also provides understanding of the extent to which items from a scale reflect proposed constructs. Covariation among items in a measure is broken down to meaningful components through the use of factor analysis method. The higher the correlations between items, the greater the overlap in what the items are meant to measure. Thus, higher internal reliability is achieved due to higher inter-item correlations (Mueller and Hancock, 2018). In practice, a factor should not be estimated with one item, rather, it should be estimated with a minimum of three (3) or more items. This is because, items that correlate higher with factor lead to higher contribution to the measure (Kline, 2023). Items are referred to as indicators, and loadings are slopes of regression between indicator and factor.

## 2.6 Structural and Measurement errors

### 2.6.1 Structural Error

The theory of SEM adds a structural error component to the model so that prediction of the dependent variable can be done by the independent variable. This error component is assumed to be uncorrelated with the exogenous variables of the model. This is done to achieve a consistent estimate of parameter (Joreskog, 1994).

### 2.6.2 Measurement Error or Disturbance

The observed variables or indicators cannot measure the related latent variables perfectly, therefore, this imperfection is modelled by a component representing measurement error, is added to the SEM. A disturbance exists in every dependent variable, which is referred to as noise. Additionally, a disturbance represents all variance that the dependent variable did not predict.

## 2.7 Measurement and Structural Models

### 2.7.1 Measurement Models

Measurement and Structural (path) models are evaluated with SEM. These models are described hereunder. Measurement model provides an explanation on how theoretical structures or implicit variables are reliant on observed variables (Fan et al., 2016). That is, latent variables not observed directly, but are inferred from other observed variables. Measurement model consists of Exploratory Factor and Confirmatory Factor Analyses. Firstly, detection of relationships and potential patterns between the fundamental structure of a set of variables can be determined through EFA. This technique is employed by researcher who intend to find out probable relationship between variables, but with minimal previous knowledge. EFA is one of the sets of multivariate statistical methods that attempts to identify the least number of hypothetical constructs (latent variables) that explains the covariance detected among a set of observed variables. (Kline, 2023; Hair et al., 2021). Secondly, Confirmatory Factor Analysis

(CFA) is used to confirm whether the relationship between variables is in alignment with existing theory. In essence, it is employed to test a model built on specific theory and to confirm if the data runs parallel with the theory. CFA models, which are special cases of SEM, are broadly employed in applications of measurement for numerous purposes. (Kline, 2023). In CFA, errors or residuals are allowed to correlate, and indicators are allowed to load on multiple factors. CFA tests whether the latent construct can be measured by existing indicator variables. Alternatively, CFA is a measurement model that shows whether a latent variable is measured by one or more indicator variables (Collier, 2020). Both EFA and CFA are statistical techniques used to examine the number of latent constructs that are fundamental to the observed responses. These analyses also evaluate how adequate individual items or variables are with respect to the latent constructs they are meant to measure.

### 2.7.2 Structural Model (Path Model)

Structural model stems from multiple regression, given that, multiple regression equations or models are involved in structural model. Also, structural relations among observed variables against latent variable are modelled. Thus, it can be thought of as a special case of SEM (Pearl, 2012).

### 2.7.3 Path Analysis

A fundamental element to SEM is path diagram, given that the researcher is allowed to use diagram to hypothesized set of relations on the model. The diagrams assist the researcher to provide clarification about the relationship among variable. Causal modelling, which is a theoretical relationship, is tested through path analysis (Schumacker and Lomax, 2010). Depending on the relationship between the variables that are specified in the path model, one or more multiple regressions analyses can be performed (Pearl, 2014).

### 2.8 SEM analyses procedures

The objectives of SEM are geared towards understanding patterns of covariance/correlation among a set of variables and to provide explanations of their variance with the specified model. There are five main procedures/steps involved in SEM analyses, which are outlined here after.

### 2.8.1 Model Specification

Model specification marks the first step of SEM, which is the mathematical specification of the links that are contained in the model. This step confirms the model, given that SEM is a confirmatory technique. Therefore, determination of the best possible model that generates the sample covariance matrix is essential (Schumacker and Lomax, 2010; Kumar, 2012). In this study, a systematic literature review was undertaken to determine the relationship between variables designed for the study (Malkanthie, 2019). For this study, independent and dependent variables were identified and resulting relationship established between them.

### 2.8.2 Model Identification

The observed data serves as a source for specifying every free parameter in the model. In this sense, model identification involves the study of conditions to obtain a unique solution, which constitutes the most difficult aspect of SEM. The identified model has a unique solution for every parameter of the model (Shaheen et al., 2017; Malkanthie, 2019). The parameter estimations can be trusted if a model is identified.

### 2.8.3 Model Estimation

Fixed and some free parameters, which are to be estimated from collected data, are contained in structural equation model that is accurately specified (Pearl, 2012). Model specification must be estimated by the researcher through the use of values obtained from sample statistics. Examples of these statistical metrics include: Generalised Least Squares (GLS), Maximum Likelihood (ML), Partial Least Squares and Weighted Least Squares (WLS) (Voth-Gaedderta and Oerther, 2014; Shaheen et al., 2017).

### 2.8.4 Model Fitness

Evaluation of the structural model are carried out to find out whether the hypothesized structural model fits the sample data (Hair et al., 2016). Fitness of model is a tool used to examine the efficiency of the model, it is done in conjunction with available trusted fitness indices, most of which are shown in table 2 (Malkanthie, 2015). Constructs with low correlations are removed from the model to improve fitness (Barrett (2007)

**Table 2:** Model Fitness Indices

Measure	Name	Threshold
CMIN/DF	Chi-square fit statistics/degree of freedom	CMIN/DF $\geq 3$
$\chi^2$	Model Chi-Square	P-value $>0.05$
GFI	Goodness of Fit	GFI $\geq 0.95$
NFI	Normed-Fit Index	NFI $\geq 0.95$
CFI	Comparative Fit Index	CFI $\geq 0.90$
RMSEA	Root mean Square Error of Approximation	RMSEA $< 0.08$
RMR	Root Mean Square Residual	SRMR $< 0.08$
AVE	Average Value Explained	AVE $> 0.5$

Source: (Malkanthie, 2015)

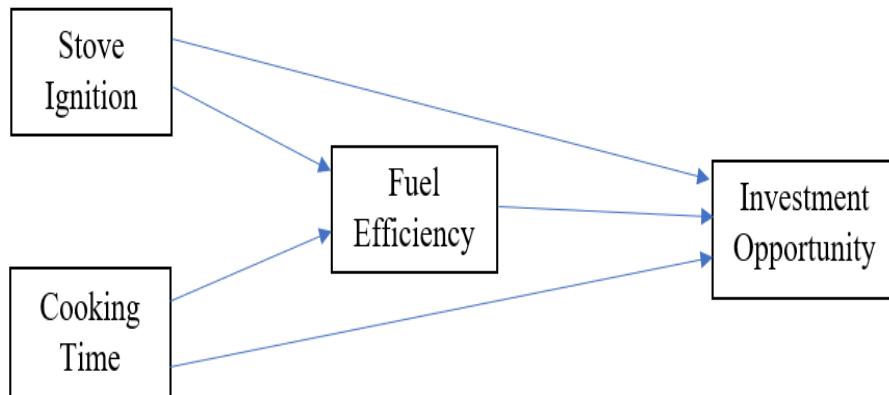
### 2.8.5 Model Modification

If fitness of model does not meet expectations, some actions can be taken to enhance it, such as; addition of new or elimination of some parameters, or alteration of the model and construction of new covariances (Hair et al., 2021). These steps are taken to improve effectiveness of the model. The observed data can be recreated through the theoretical model, leading overall model fitness. Reviewed literatures reveal an increase in the interest and application of SEM throughout multiple disciplines (Grace, 2006). Vothgaeddert and Oerther (2014) find out that SEM has the capabilities to be adapted in different field of studies with exceptional outcomes. SEM has the potential to be used as a platform for analysing quantitative primary data collected from respondents through survey.

## 3 METHODS

### 3.1 Conceptual Model

A conceptual research model, created for this study, is shown in figure 2. A unified conceptual model consisting of four stages was developed. These stages include the observed variables, which indicate the relationship that exists between; stove ignition, cooking time, fuel efficiency and investment opportunity. Both direct and indirect relationships exist between the variables. Direct relationship exists between: stove ignition and investment opportunity; Cooking time and investment; Fuel efficiency and investment opportunity. Whereas, indirect relationship exists between stove ignition and investment opportunity through fuel efficiency and; Cooking time and investment opportunity through fuel efficiency. It is important to note that these factors, including the acceptance of the product by users, are included in the questionnaire as observed variables, which are represented by rectangles, involving the four categories used to measure the latent factors in the SEM.

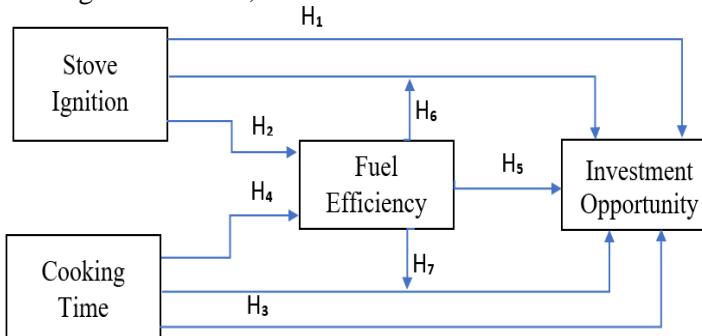
**Figure 2:** Baseline Research Model

Source: Researchers' Model

**3.1.2 Research Model Developed**

Single-headed arrows were used to connect each of the four observed variables including their factors, which

represents direction of hypothesized influence as shown in figure 3.

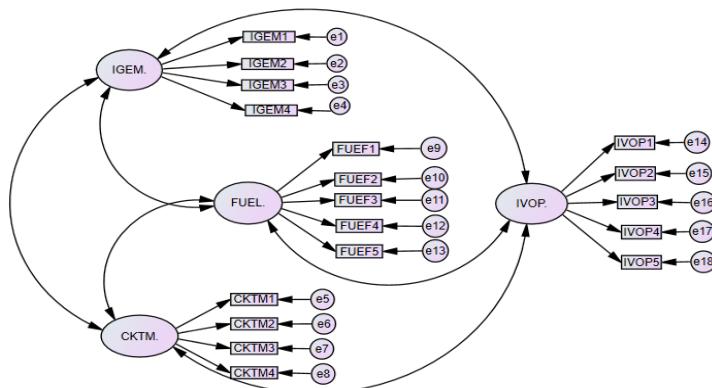
**Figure 3:** Conceptual Hypothesised Model

Source: Researchers' Model

**3.1.2 Measurement Model**

The SEM measurement model, shown in figure 4, deals with the variables that in rectangular shapes. There are five evaluation factors in the fuel efficiency

category (FUEF1 to FUEF5). The arrow heads emanate from the oval shape, containing the observed fuel efficiency category, to the latent fuel efficiency category housed in rectangles, as shown in figure 4.

**Figure 4:** SEM measurement model Source: Researchers'**3.2 Hypothetical SEM**

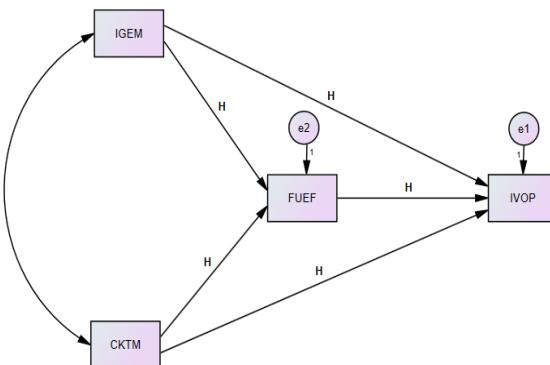
From the hypothetical SEM research model in figure 5, seven hypotheses were developed, which are presented hereunder.

H1: stove ignition has positive and significant effects on investment opportunities

H2: stove ignition has positive and significant effect on fuel efficiency

H3: cooking time has positive and significant effect on investment opportunity  
 H4: cooking time has positive and significant effect on fuel efficiency  
 H5: fuel efficiency has positive and significant effect on investment opportunity

H6: fuel efficiency mediates the relationship between stove ignition and investment opportunity  
 H7: fuel efficiency mediates the relationship between cooking time and investment opportunity

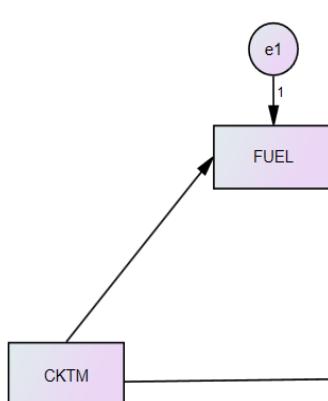


**Figure 5:** Hypothetical SEM Structural model Source: Researchers'

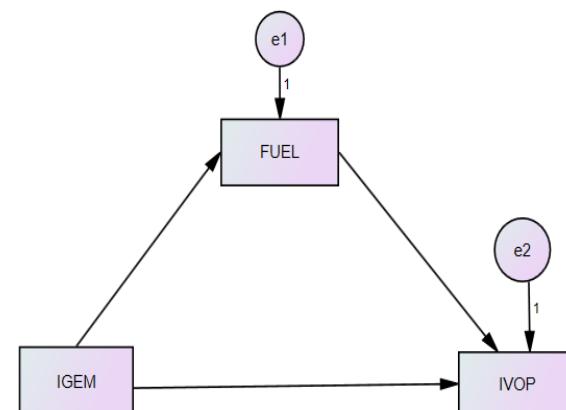
### 3.3 Mediation Testing

Baron and Kenny (1986) approach is used as guideline analyse for the indirect effect of mediation. In this study, mediation analysis for H6 is carried out by treating Ignition and Extinguishing Method (IGEM) as independent variable and Investment Opportunity (IVOP) as dependent variables, while taking Fuel

efficiency (FUEF) as mediating variable. See figure 6a. For H7, Cooking Time (CKTM) is treated as independent variable and investment opportunity as dependent variable whilst Fuel efficiency (FUEF) represent the mediating variable, as shown in figure 6b.



**Figure 6a:** FUEL between CKTM and IVOP



**Figure 6b:** FUEL between IGEM and IVOP

Covariance must exist between all independent variables that covaried between themselves. There should be a path from independent variables to dependent variable/s. Model fit, CFA, is then tested at the measurement model, thereafter it is taken to the SEM, structural model. Assessment of the feasibility study was carried out with four categories of evaluation factors. Therefore, addressing these factors contributes to achievement of the aim of the feasibility study and the success of the project.

### 3.4 Questionnaire Administration and Data Collection

Secondary data were obtained from internet data bases, research journals, dissertations, theses and books. Structured questionnaire was designed to collect quantitative primary survey data from respondents in the field. As a result, closed-ended questions with Likert scale options were used in its design (Adams et al., 2007; Sekaran and Bougie,

2016). The entire questionnaire consists of five sections. Section 1 deals with questions concerning demographic features of respondents, including some questions pertaining to the feasibility study, whilst the remaining four sections deals with statements regarding constructs dealing with five observed variables. Each of these observed variables contains five Likert scale options: strongly agree, agree, neutral, disagree, and strongly disagree (Likert, 1932). There were 1,128 structured questionnaires divided amongst fifteen (15) questionnaire administrators that were trained to collect primary data from participants using the questionnaires.

### 3.5 Pilot Testing, Reliability and Validity

Pilot testing of the questionnaire was done in two stages. In the first stage, the questionnaires were administered to twenty-six participants, which were selected from a population with similar features as the one to which the final survey questionnaire was administered. The time they took to complete the questionnaire was recorded. In the second stage, six experts in the field of heat transfer, statistical methods and research methodology were involved. These experts read through the instrument with the aim of providing suggestions to improve effectiveness of the instrument, especially its face, content and construct validities (Taherdoost, 2018; Sekaran and Bougie, 2016). The completed questionnaires were collected and concerns raised by participants were addressed, in which some items were modified whiles some were removed. The modified questionnaire was used in the final survey. Suggestions and opinions of the experts provided content validity of the questionnaire. Internal consistency, measuring the scale it was designed to measure, was addressed through the use of Cronbach's alpha, in which a measure of more than 0.7 is considered reliable (Cronbach, 1957).

### 3.6 Sampling Method

The primary data were collected through convenience sampling method, this is due to tight time schedule of the project. The country, Sierra Leone, was divided into four zones: North, East, West and South. From each zone, the most densely populated district head quarter towns were identified, which are, Makeni in the North, Kono in the East, Bo in the South and Waterloo in the West. This decision is guided by the fact that majority of the dwellers use solid biomass as fuel for cooking and heating. Central Freetown was not included in the frame, this is because, vast majority of its inhabitants do not use wood as fuel, but charcoal. The final stove design is meant to use different types

of solid biomass fuel, including charcoal. In essence, the sampling frame covers some communities in rural settlements of the selected towns. There have been debates on the sample size for acceptable SEM analysis with no agreement on what is regarded as a reasonable sample size. Nevertheless, a sample size that is less than 100 is considered small (Kline, 2023), between 100 and 200 is considered as medium, while a sample size of over 200 is seen as large. For this study, a sample size of 1128 is considered adequate to support a stable SEM model. As an exploratory study, convenience sampling was adopted as methods to collect primary data from respondents (Saunders et al., 2016)

### 3.7 Data Analyses

Statistical Package for Social Science (SPSS) version 27 and Analysis of Methods and Structures (AMOS) version 24 were the two software packages used to provide calculation and analyses of collected primary data. AMOS is used to perform hypotheses testing, CFA and causal model. Whereas, SPSS was used to provided descriptive statistics, such as means, median, variance and standard deviation (Field, 2000). It was also used to provide inferential statistical results, such as Pearson's Correlation Analysis, multiple regression analysis.

## 4 Analyses Results and Discussion

### 4.1 RESPONSE RATE

From the administered 1,128 questionnaires, 998 were collected and returned to the project office. Thus, the response rate =  $(998/1128) * 100\% = 88.47\%$ . Creswell (2019) suggests that a response rate of above 60% is considered adequate for a quantitative survey study, which means that the response rate achieved for this study is appropriate for such a study. Prior to entering the collected primary data into SPSS version 27 software, every questionnaire was thoroughly checked to find out whether it was correctly filled and does not contain missing data. It was found out that 27 of them were missing data or were not properly done, therefore, they were excluded from the batch of questionnaire collected. Ultimately, 971 questionnaires were used in the data analyses process. Analyses of results were carried out according to how items were presented on the questionnaire. Descriptive statistics obtained from general information of respondents were firstly analysed and presented hereunder.

### 4.2 Results from section 1 of the questionnaire

Results from section 1 are shown in table 2. Result from gender variable shows that percentage of female

participants was 67%, which is close to two-third of the total respondents. These results reflect the gender involved in cooking and heating in the country. Level of education construct revealed that 84.7% of the respondents are literate, which is vital a metric for completing the questionnaire. Employment construct registered a score of 44.6% of responses, this result reflects the employment status of the nation, in the sense that both private and public sectors accounts for

less than 35% of national employment. Single and married couples together made up of 81.6%, with married couples pulled 42.4% of all responses. National census results show that youth population in the country is highest. This is reflected in the results of this study in which a total of 63.3% of the total participants are within the age group of 18 and 37 years.

**Table 2: Demographic Results**

N	Variable	Option	Percent	N	Variable	Option	Percent
1	Gender	Male	33	4	Marital Status	Single	39.2
		Female	67			Married	42.4
2	Education	Junior Secondary	16.1			Fiancé	4.4
		Senior Secondary	29.8			Divorced	4.6
3	Employment	OND	9.0			Co-habiting	2.4
		HND	10.2			Widow	4.4
		First Degree	12.5			Widower	2.3
		Master's Degree	6.1			Others	.2
		Doctorate	1.1			5	Age Group
		Others	15.3			18 - 27	35.3
		Private Sector	13.8			28 – 37	28.0
		Public Sector	15.4			38 – 47	22.6
		NGO	9.8			48 – 57	10.1
		Self-Employed	44.6			58 - 67	3.0
		Others	16.4			68 & above	1.0

Note: OND = Ordinary National Diploma; HND = Higher National Diploma

From table 3, 39% of respondents used stoves made from metal and clay. This is an interesting result given that vast majority of the population use the popular wonder stove, which is made out of clay and metal. Traditional three-stove fire place is still being used in the country, as 24% of respondents admitted using it,

especially in rural communities. The result also reveals that wood and charcoal constitute 90.1% of fuel used, with charcoal being the higher. Cooking gas accounts for 6.1% of the responses. This might be due to cost and the fear of explosion of the gas canister, as it is widely believed.

**Table 3: Results from variables 6 to 9**

N	Variable	Options	Percent
6	Design of Cooking stove	Made from three stones	24.0
		Made from metal and clay	39.0
		Made from bricks	4.9
		Made entirely from metal	23.3
		Made from cement and sand	1.2
		Made from concrete	1.3
		Others	6.2
7	Type of Fuel Used	Wood; Charcoal	31.9; 58.2
		Cooking Gas; Kerosene	6.1; 1.0
		Ethanol; Briquettes	0.1; 0.3
		Coconut shells	1.0
		Palm Kernel Shells; Fruit nuts	0.8; 0.2
		Rice stalks; Cow dung	0.1; 0.2
8	How fuel was obtained	Bought with money	77.1
		Obtained from trees	22.9
9	Involved in fetching wood	Boy child; Girl child	20.3; 17.7
		Boy and girl	43.6
		Wife; Husband	7.8; 10.6

In table 4, 86.7% of participants stated that they were not comfortable with their current method of cooking. This can be interpreted to mean that, if a better alternative is available, they would prefer it. Therefore, they are ready to make a change, hence a response rate of 92.7% as regards the agreement for variable 12. Results from variable 13 highlight three reasons why respondents are not comfortable with their stoves; difficult to ignite, slow to perform task and emits lots of smoke. These metrics are vital for better performance of a cookstove and will be

considered in the design of the proposed stove. Result on ignition time shows that, 27.2% of respondents take over 11 minutes to ignite their stoves, which is a too long. Accordingly, ignition time is an important metric to be considered in the design of a cookstove. With reference to variable 15, 46.2% of participants use plastic, followed by gas lighter, 40.6%, as ignition materials to start a fire. This study aims to come up with better alternative to replace plastic as ignition material, as plastic is polluting and can affect health of users.

**Table 4: Results from variables 10 to 15**

No.	Statements	Options	Percent
10	Involved in forms of cooking	Yes; No	42.1; 57.9
11	Comfortable with current form of cooking	Yes; No	13.3; 86.7
12	Want to change current cooking method	Yes; No	92.7; 7.3
13	Not comfortable with form of cooking	Difficult to ignite	39.2
		Burns lots of fuel	9.6
		Emits lots of smoke	21.4
		Slow to cook	27.0
		Difficult to extinguish	2.8
14	Time taken to ignite	1 – 2 minutes; 3 – 4 minutes	13.8; 19.8
		5 – 6 minutes; 7 – 8 minutes	12.8; 11.3
		9 – 10 minutes	15.1
		11 minutes and above	27.2
15	Ignition liquid/material	Plastic; Paper; Gas lighter	46.2; 5.9; 40.3
		Sawdust; Grass; Coconut fibre	2.5; 0.8; 1.3
		Palm kernel fibre; Liquid fuel	2.1; 0.9

#### 4.3 Survey Reliability and Validity Analysis

In table 5, reliability results of the four constructs show values that are higher than 0.7, indicating acceptable internal consistency among the constructs. The results also show that IGEM, containing four

variables, registered the highest Cronbach's Alpha of 0.96, while CKTM, IVOP and FUEF give scores of 0.826, 0.822 and 0.755 respectively. These results provide a fit for further analyses.

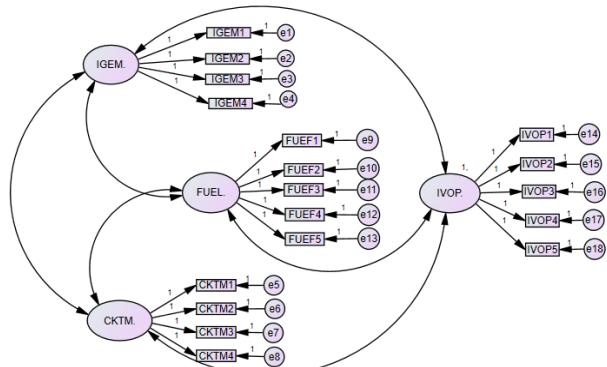
**Table 5: The internal consistency analysis**

Constructs	Number of Items	Cronbach's Alpha
Ignition and Extinguishing Method (IGEM)	4	0.960
Cooking Time (CKTM)	4	0.826
Investment Opportunity (IVOP)	5	0.822
Fuel Efficiency (FUEF)	5	0.755

#### 4.4 Measurement Using SPSS AMOS

Every statement, which is an observed variable, is assigned to square or rectangle boxes, as shown in figure 7. Owing to the length of these statements, shorter codes are assigned to each of the 18 observed variables. For instance, ignition and extinguishing method was coded as IGEM, while investment

opportunity was coded as IVOP. Errors terms of these observed variables are also coded. Initial measurement model of the analysis, obtained from AMOS version 23 software, is shown in figure 7. The relationships among the four latent variables are depicted in the overall measurement model.



**Figure 7: Analysis for Initial Measurement Model**

**Table 6: Model Fit Summary**

<b>CMIN</b>					
Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	46	707.999	143	.000	4.951
Saturated model	189	.000	0		
Independence model	36	6380.145	153	.000	41.700
<b>Baseline Comparison</b>					
Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.889	.881	.909	.903	.909
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000
<b>Parsimony-Adjusted Measures</b>					
Model	PRATIO	PNFI	PCFI		
Default model	.935	.831	.850		
Saturated model	.000	.000	.000		
Independence model	1.000	.000	.000		
<b>RMSEA</b>					
Model	RMSEA	LO 90	HI 90	PCLOS E	
Default model	.064	.059	.069	.000	
Independence model	.205	.201	.209	.000	

Using SPSS AMOS, Confirmatory Factor Analysis (CFA) were obtained and used to assess the measurement model, which was then checked for fitness. Several statistical metrics, which are fit indices, are used to assess validity of the model. The degree to which a hypothesized data “fits” or adequately describes the sample data is the key interest in SEM. Table 6 presents the model fit indices. The Chi-square fit, CMIN, indicates that the existing model is significant. Furthermore, Chi-square fit statistics/degree of freedom (CMIN/DF) provides an indication that sample data and conceptual model are in reasonably good fit. According to Hair et al. (2021) and Barrett (2007), Values greater than 3 are considered favorable for Chi-square fit statistics/degree of freedom (CMIN/DF). Table 6 shows the model fit summary for this study. The CMIN/DF is 4.951, which indicates that the hypothetical conceptual model fits well, and the number confirms that the model speculated is in consonance with the data collected. A comparison between the baseline model, figure 2, and hypothetical conceptual model, figure 3, is carried out by using the

Comparative Fit Index (CFI), which is an incremental fit index with a value greater than 0.9 is considered good fit (Kocakaya and Kocakaya, 2014; Malkanthie, 2015). CFI obtained for this study is 0.909, with a parsimony adjusted measure (PCFI) of 0.85. this shows that sample data and conceptual model are in a good fit.

Another fit metric that evaluates the amount of errors preventing the conceptual model from achieving perfection is the Root Mean Square of Error Approximation (RMSEA). An RMSEA score of less than 0.5 is considered favourable fit between the model and sample data (Kline, 2023). The RMSEA value obtained for this study is 0.064 (less than 0.5), which is a good fit and also indicates that the model is close to perfection. The SEM model in figure 8, depicts a reflection of dependent interaction among all the exogenous/independent constructs (IGEM, CKTM and FUEL) and endogenous/dependent variables (FUEL and IVOP). Correlational relationship among all the exogenous construct was done to improve Model fit.

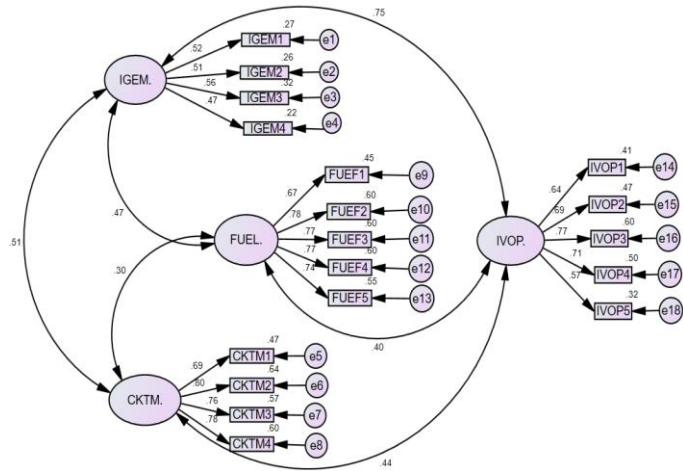


Figure 8: Standardised regression weights of final SEM

#### 4.4 Results from Structural Model

A depiction of the interaction amid the latent and observed constructs were portrayed through regression weights as shown in the model, see table 7, which also provide results of the relationship between the constructs. Regression analyses run standardised and unstandardized beta weights followed by standard errors, which are equivalent to standardised and unstandardized output in SEM. Standard estimates are usually presented by researchers; however, significance is determined by examination of the unstandardized portion of the output. Critical ratios and p-values determine how latent variables are affected by observed constructs, wherein

the p-values (which should be closer to 0) are used to make decisions on the significance of the observed variables. Critical ratios values that are above 3 are considered significant, which means that the observed variables have significant effect on the latent constructs. From table 7, significant relationship is denoted by (\*\*\*), on the column of p-value. CFA used shows correlations between the observed and latent variables are significant, as indicated by three asterisks for the p-values. Also, all the critical ratios (CRs) for the 18 observed variables, are above 3, which is the threshold for significance to be ascertained.

Table 7: Regression Weights

Parameter		Estimate	S.E.	C.R.	P	Label
IGEM1	<---	IGEM.	.801	.032	25.255	*** par_7
IGEM2	<---	IGEM.	1.004	.032	31.360	*** par_8
IGEM3	<---	IGEM.	.882	.029	30.376	*** par_9
IGEM4	<---	IGEM.	1.033	.035	29.372	*** par_10
CKTM1	<---	CKTM.	.913	.035	26.103	*** par_11
CKTM2	<---	CKTM.	1.199	.030	39.699	*** par_12
CKTM3	<---	CKTM.	1.226	.032	38.484	*** par_13
CKTM4	<---	CKTM.	1.108	.031	35.800	*** par_14
FUEF1	<---	FUEL.	1.099	.037	29.495	*** par_15
FUEF2	<---	FUEL.	1.147	.032	35.547	*** par_16
FUEF3	<---	FUEL.	1.187	.033	36.523	*** par_17
FUEF4	<---	FUEL.	1.204	.032	37.195	*** par_18
FUEF5	<---	FUEL.	1.117	.034	32.896	*** par_19
IVOP1	<---	IVOP.	1.028	.032	31.816	*** par_20
IVOP2	<---	IVOP.	1.071	.030	35.439	*** par_21
IVOP3	<---	IVOP.	1.001	.027	37.185	*** par_22
IVOP4	<---	IVOP.	1.055	.029	35.778	*** par_23
IVOP5	<---	IVOP.	1.056	.037	28.777	*** par_24

#### 4.5 Results from Hypothesised paths

##### 4.5.1 Hypotheses testing for H1 to H5

SEM was employed to generate path relationship among the constructs investigated. Table 8 show the following results. The estimate represents the beta value. All critical ratios are above the recommended value of 3 (Hair et al., 2021). Also:

- I. Stove ignition is positively and significantly associated with Investment Opportunity ( $b = 0.248$ ,  $p > 0.5$ ).
- II. Stove ignition is positively and significantly associated with fuel efficiency ( $b = 0.186$ ,  $p > 0.5$ ).

**Table 8: Hypotheses Testing, H1 to H5**

No.	Paths	Estimate	S. E	C. R	P	Comments
H1	Stove Ignition>Investment Opportunity	.248	.017	14.471	***	Accepted
H2	Stove Ignition>Fuel Efficiency	.186	.019	9.884	***	Accepted
H3	Cooking Time>Investment Opportunity	.212	.020	10.659	***	Accepted
H4	Cooking Time>Fuel Efficiency	.174	.023	7.686	***	Accepted
H5	Fuel Efficiency>Investment Opportunity	.202	.020	9.953	***	Accepted

##### 4.5.2 Mediation Analysis for H6 and H7

###### 4.5.2.1 Mediation Analysis for H6

In Figure 9a, a regression weight of 0.53 was achieved with the mediating variable, FUEL, in place. With the

- III. Cooking time is positively and significantly associated with investment opportunity ( $b = 0.212$ ,  $p > 0.5$ ).
- IV. Cooking time is positively and significantly associated with Fuel Efficiency ( $b = 0.174$ ,  $p > 0.5$ ).
- V. Fuel Efficiency is positively and significantly associated with investment opportunity ( $b = 0.202$ ,  $p > 0.5$ ).

Given that a statistically significant relationship exists in the direction of hypotheses, the five Null hypotheses are rejected. The results further reveal that the variables used to construct hypotheses H1, H2, H3, H4 and H5 are positively significant, therefore, they are accepted.

removal of the mediating variable, regression weight increased to 0.88, which shows that FUEL variable mediates the relationship between IGEM and IVOP.

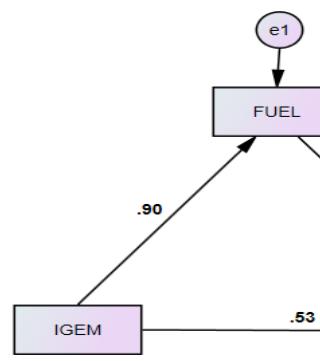


Figure 9a: Mediation Path

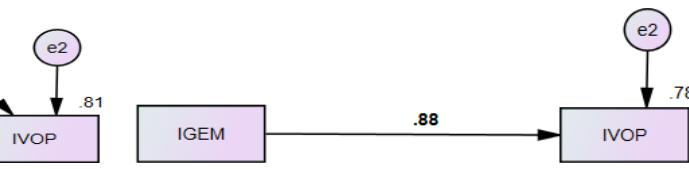


Figure 9b: Removal of Mediating Variable

**Table 9: Regression Weights for H6**

		Estimate	S.E.	C.R.	P
FUEL	<--- IGEM	.614	.010	62.984	***
IVOP	<--- FUEL	.351	.028	12.394	***
IVOP	<--- IGEM	.323	.019	16.646	***

Table 9 shows that all critical ratios are above the recommended value of 3 (Hair et al., 2021). Also, the all P-values are statistically significant with positive

beta values. Total effect is the sum of Direct and indirect effects for hypothesis H6, as shown in table 11 (Kenny and Baron, 1986). Hypothesized path for H6

shows a total effect of 0.539. Therefore, considering the results from tables 9 and 11, H6 is accepted.

#### 4.5.2.2 Mediation Analysis for H7

A regression weight of 0.69 was achieved when FUEL is the mediating variable, see figure 10a. Regression

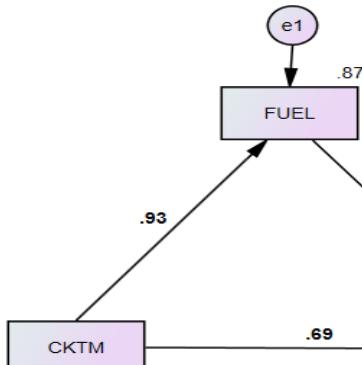


Figure 10a: Mediation Path

weight increased to 0.93 when FUEL was removed, Figure 10b, which shows that FUEL is a mediating variable between CKTM and IVOP.

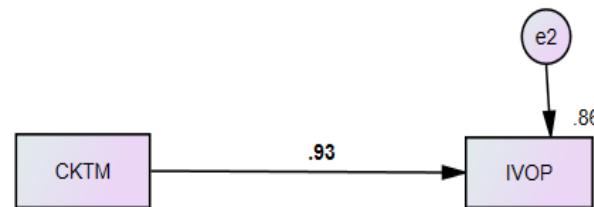


Figure 10b: Removal of Mediating Variable

Table 10: Regression Weights for H7

		Estimate	S.E.	C.R.	P
	FUEL <--- CKTM	.700	.009	81.652	***
	IVOP <--- FUEL	.229	.030	7.773	***
	IVOP <--- CKTM	.469	.022	21.190	***

Table 11: Mediation Path Analysis for H6 and H7

H	Path	Direct Effects	Indirect Effects	Total Effects	Comments
H6	IGEM>FUEF>IO	0.323	0.216	0.539	H6 is accepted, while the Null hypothesis is rejected given that indirect effect is statistically significant
H7	CKTM>FUEF>IO	0.469	0.161	0.629	H7 is accepted, given that indirect effect is statistically significant

Source: Kenny and Baron (1986) Approach

Table 10 shows that all critical ratios are above the recommended value of 3 (Hair et al., 2021). Also, the all P-values are statistically significant with positive beta values. According to Baron and Kenny (1986), Total effect is the sum of Direct and indirect effects for each hypothesis. Hypothesized path for H7 shows a total effect of 0.629. Therefore, considering the results from tables 10 and 11, H7 is accepted. Ultimately, results from tables 9, 10 and 11 show that H6 and H7 can be accepted.

#### 4.6 CONCLUSION

Relevant information about factors that should be considered during the design and production of cookstove leading to a viable business venture were

obtained during engagement with relevant stakeholders. Project achieve sustainability when beneficiaries participate in design, execution, monitoring, evaluation and decision-making processes. Thus, feasibility studies in which stakeholders are involved, together with potential users, is important for better planning of the design and fabrication of the intended product. The framework developed through SEM was used to assess the relationship between factors that are pertinent to the feasibility study and success of the project, it further shows the causal relationship existing between latent and observed variables and their resulting dependent and independent variables. This was done with the aim of

providing a model required to provide ultimate results through developing and statistically testing of hypotheses.

Studies have proposed that a stove that burns less fuel, for comparable task, than other stoves, is more efficient and can attract more user uptake. Accordingly, laying premium on design of the combustion chamber and grate can lead to improved heat transfer, which correlates to improved thermal efficiency. A stove with better ignition method, can reduce cooking time, therefore, enhanced extinguishing method can save fuel for future cooking and heating tasks. Consequently, premium will be applied on producing an upgraded cookstoves with higher thermal efficiency. Fuel Efficiency has a significant effect on Investment Opportunity, according to the result. This can be interpreted as, the more efficient a cookstove becomes, the greater are the investment opportunities. In this regard, more attention will be paid on efficiency improvement with the intention to attract more customers leading to increased profitability.

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