# DOMESTIC HOT WATER REQUIREMENT PROFILE IN NIGERIA

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**Abstract**

*A study of the domestic hot water requirement profile in Nigeria necessary for design of appropriate domestic solar water heaters is presented. The study is a combination of survey and evaluation research using the stratified random sampling with optimum allocation using an effective sample size of 200. Hence, 200 questionnaires were administered into domestic homes; hotels and hospitals across urban, semi-urban and rural areas of Nigeria. Several key variables such as the quantity of hot water needs, the period of the day hot water are most needed and main source of heating for the household in addition to the cost involved were studied. Other concomitant variables such as type of accommodation, income category, literacy level and family size were also considered. The study revealed that that 84% of homes consume about 100Litres, while 93% of hotels and 60% of hospitals need about 2000Litres of hot water daily. The study further revealed that firewood, kerosene and gas in that order are the major energy sources for producing hot water in homes. However, hotels and hospitals depend more on electricity and gas to produce hot water. Again, the study revealed that 50% of the homes recurrent expenditure on energy is used for heating water; while hotels and hospitals spend about 32% and 21% respectively of their energy recurrent expenditure for the same purpose. Further analysis showed that the utilization of solar water heaters could significantly reduce the cost of domestic water heating. There is a significant gain for using solar water heaters over existing methods. Generally, the cost of producing hot water was considered high; justifying the need for cheaper and sustainable energy devices such as solar water heaters.*

## 1. Introduction

In many rural locations in Nigeria and indeed most developing countries, grid-connected electricity and supplies of other non-renewable sources of energy are either unavailable, unreliable or, for most of the rural dwellers, too expensive. Over 70% of Nigerians live in semi-urban and rural areas; they face serious challenges to produce hot water in their homes. Healthcare in Nigeria is considered to be amongst the poorest in the world, thus maintaining good hygiene is a challenge in the country. The main use of domestic hot water in Nigeria is for hygiene purposes such as bathing, washing and cooking. In most of the rural homes and many urban homes in Nigeria, the traditional and most popular source of energy for water heating and indeed all cooking in Nigeria is firewood. The projected wood consumption in Nigeria for the year 2000 was 23.6 million tonnes of oil equivalent (Enibe & Odukwe, 1990). The attendant ecological hazards associated with deforestation due to the constant felling of trees (for the procurement of firewood) are obvious. Erosion and desert encroachment are particularly devastating in Nigeria. The rate of deforestation is about 350,000 hectares per year, which is equivalent to 3.6% of the present area of forests and woodlands, whereas reforestation is only at about 10% of the deforestation rate (Sambo, 2009). Coal, which is abundantly available in Nigeria, has, like firewood, associated with it during incomplete combustion, the emission of toxic gases like carbon monoxide which are suspected to be the main cause of respiratory diseases and conjunctivitis amongst women that cook daily with these fuels (World Energy Council, 1993). The cost of alternative fossil-fuel based cooking stoves and the unreliability of supply of such cooking fuels as kerosene and liquefied natural gas present such barriers that they are rarely adopted in most of the households. Consequently, a large proportion of the family income and/or enormous man-hours that could have been utilised in more productive services are expended regularly in the procurement of energy for such a basic activity as cooking. Under these conditions, solar-energy water heaters appear increasingly attractive as viable alternatives.

The absence of reliable energy supply has not only left the rural populace socially backward but has left their economic potentials untapped. Fortunately, Nigeria is blessed with abundant renewable energy resources such as solar, wind, biomass and small hydropower potentials. The logical solution is increased penetration

of renewable sources into the energy supply mix (Sambo, 2009). Nigeria is located between longitude 3° and 14° East of Greenwich and latitude 4° and 14° north of equator and has about 150 million people and a total land area of 923,768 km$^2$. Thus, Nigeria lies within a high sunshine belt and has enormous solar energy potentials. The mean annual average of total solar radiation varies from about 3.5 kWhm$^{-2}$day$^{-1}$ in the coastal latitudes to about 7 kWhm$^{-2}$day$^{-1}$ along the semi arid areas in the far Northern part of the country. On the average, the country receives solar radiation at the level of about 19.8 MJm $^{-2}$ day$^{-1}$. Average sunshine hours are estimated at 6hrs per day. Solar radiation is fairly well distributed. The minimum average is about 3.55 kWhm$^{-2}$day$^{-1}$ in Katsina in January and 3.4 kWhm$^{-2}$day$^{-1}$ for Calabar in August and the maximum average is 8.0 kWhm$^{-2}$day$^{-1}$ for Nguru in May; among others.

This research seeks to consider the possibility of utilizing environmentally friendly and abundant energy of the sun to address one of man's routine but essential needs for hygiene; hot water for domestic use. Although, the science and technology of solar hot water heater is well known, the pattern of the consumption in households, hotels and hospitals for Nigeria is relatively unknown. Consequently, a study of the trajectory or pattern of domestic hot water requirement profile in Nigeria necessary for the design of appropriate domestic solar water heaters for Nigeria was undertaken.

### *1.1 Objectives*

The primary objective of this study is to appraise the domestic requirement for hot water in Nigeria. Other specific objectives include:

1. To assess the demands of hot water in residential homes, hotels and hospitals.
2. To appraise the possibility of introducing the solar system as an alternative energy source in Nigeria.
3. To investigate whether the solar system could be a cheaper source of energy in Nigeria.

## 2. Methodology

This study is concerned with the evaluation and assessment of the needs for hot water in homes, hotels and hospitals in Nigeria in an objective and factual manner. Moreover, it is concerned with the comparison, by means of some parameters, the implications of the solar energy system for the provision of hot water. Consequently, the research is a combination, both in purpose and in design, of evaluation research and causal comparative (*ex post factor*) for tracking the trajectory of domestic demands for hot water. It is against this backdrop that the questionnaire method was adopted for data collection. The stratified random sampling with optimal allocation was the chosen sampling design. The survey objectives included specification of the information to be gathered and the population to which the findings of the survey will be extrapolated (Levy & Lemeshow, 2008). The Cochran (1977) method of planning and execution of a survey were adopted. Finally, the computations that lead to the actual data presentation and analysis were performed using the Statistical Package for the Social Sciences (SPSS) Version 17.0.

The population of this study consists of the number of domestic households, hotels and hospitals in Kaduna Metropolis and the environs, North-West Nigeria. They form the target population capable of providing the necessary information for the assessment and evaluation. Random Sample was drawn from the target population based on a statistically determined, efficient sample size so as to estimate some key parameters of the population. In order to obtain the most efficient, representative sample, for our research, based on a level of significance and a set margin of error, we used the following Cochran (1977) formula for sample size determination:

$$n = \left( \frac{Z_{\alpha/2}\sqrt{\hat{p}\hat{q}}}{\delta} \right)^2 = \frac{Z_{\alpha/2}^2 \hat{p}\hat{q}}{\delta^2} = \frac{1.96^2 \times 0.63 \times 0.37}{0.067^2} \approx 200 \qquad \text{(eq. 1)}$$

Where; $n =$ sample size required

$Z_{\alpha/2} = Z_{0.025} = 1.96$ (the value of the standard normal ordinate at 5% level of significance)

$\delta = 0.067$ ( the chosen margin of error)

$\hat{p} = 0.63$ (the estimated rural households, hotels and hospitals)

$\hat{q} = 1 - \hat{p} = 0.37$

That is, we need a sample size of at least 200 to arrive at a sample with a margin of error of at most 6.7%. Hence, we shall adopt a sample size of 200 to be spread optimally across the three strata. The following table 1 summarizes the effective sample size allocation in this stratified random sampling with optimum allocation and the reliability statistics:

**Table 1: Stratified Random Sampling and Reliability Statistics**

| Survey Areas | Sample size | Cronbach's Alpha | Cronbach's Alpha Based on Standardized Items |
|---|---|---|---|
| Domestic homes | 150 | 0.941 | 0.932 |
| Hotels | 30 | 0.907 | 0.895 |
| Hospitals | 20 | 0.899 | 0.898 |
| | 200 | | |

The reliability of the research questionnaire was measured by the Cronbach's alpha statistic. The formula that determines Cronbach's alpha makes use of the number of variables or question items in the scale ($k$) and the average correlation between pairs of items ($r$):

$$\alpha = \frac{kr}{1+(k-1)r} \quad \text{(eq. 2)}$$

Based on the formula of Cronbach's alpha, a rule of thumb that applies to most situations for the interpretation of reliability coefficient is mostly acceptable (Parimal, 2005). There is excellent reliability if $\alpha \geq 0.9$ and there is unacceptable reliability if $\alpha < 0.5$ (Mill, 1999). The reliability coefficients for the three questionnaires used are given in Table 1 above. Hence, from the table, the Cronbach's alpha of 0.941 for the instrument used for domestic homes implies that the domestic homes' instrument is reliable. Similarly, the respective Cronbach's alpha of 0.907 and 0.899 for hotels and hospitals implies that both the hotels' and hospitals' instrument are reliable. Hence, all instruments have excellent reliability as far as internal consistency is concerned. The content of the questionnaire, after scrutiny by relevant experts, was validated by the researcher through a pilot survey. Hence, the questionnaire has both the desired face and content validity.

## 3. Analysis and Results

General information on the respondents for domestic homes revealed that only adults were administered with the questionnaire; 70 % of respondents were males. The work status of the respondents cuts across the private and public sector workers in Nigeria as well as the unemployed. Sixty-five per cent of the respondents earn less than N60,000. (US$375) monthly (the minimum monthly wage in Nigeria is N18,000.00; approximately US$112.50). The respondents have varied academic qualifications. Furthermore, Tables 2, 3 and 4 below show the frequency distribution of the respondent's residential area, size of families and type of accommodation respectively.

It can thus be inferred that most respondents live in the urban part of Kaduna town and the average size of family consists of a man, wife and 4 children who reside in a multi-tenant, non-self contained compound. The questionnaire for hotels included information on the size of clientele, average monthly income of the hotel and portion of the hotel's income spent on provision of hot water.

**Table 2: Residential Area of Domestic Respondents**

| Residential Area | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| Urban/City | 115 | 76.7 | 76.7 |
| Semi-urban/Town | 9 | 6.0 | 82.7 |
| Rural/Village | 14 | 9.3 | 92.0 |
| Others | 12 | 8.0 | 100.0 |
| Total | 150 | 100.0 | |

**Table 3: Family Size of Domestic Respondents**

| Family Size | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| 1-3 members | 21 | 14.0 | 14.0 |
| 4-6 members | 64 | 42.7 | 56.7 |
| 7-10 members | 36 | 24.0 | 80.7 |
| More than10 members | 29 | 19.3 | 100.0 |
| Total | 150 | 100.0 | |

**Table 4: House Type of Domestic Respondents**

| House Type | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| One room or more in a compound | 78 | 52.0 | 52.0 |
| One bedroom self-contained flat | 22 | 14.7 | 66.7 |
| Two/Three bedroom flat | 39 | 26.0 | 92.7 |
| Four/Five bedroom flat | 11 | 7.3 | 100.0 |
| Total | 150 | 100.0 | |

It was discovered that 45% and 30% of the hospitals sampled are situated in urban and semi-urban areas respectively, while, the rest 25.0% are situated in rural areas. The major uses of hot water in homes are for cooking and bathing. Similarly hotels and hospitals need hot water for the same purposes. In addition the hospitals need hot water for the treatment of their patients. The proportion of usages for these purposes is shown in Figure 1. This agrees with the Review of Solar Heating systems done by Ogueke, N.V, et al (2009). The period of day when hot water is frequently used in homes, hotels and hospitals are depicted in Figure 2.

Tables 5-7 show the quantity of hot water required daily at homes, hotels and hospitals. From these, we deduce that 84% of homes consume about 100Litres, while 93% of hotels and 60% of hospitals need about 2000Litres of hot water daily.

**Table 5: Number of buckets (20 litres) of hot water utilized per day**

| Number of Buckets | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| Less than or about three buckets per day | 81 | 54.0 | 54.0 |
| 4-6 buckets per day | 45 | 30.0 | 84.0 |
| 7-10 buckets per day | 12 | 8.0 | 92.0 |
| 11-15 buckets per day | 12 | 8.0 | 100.0 |
| Total | 150 | 100.0 | |

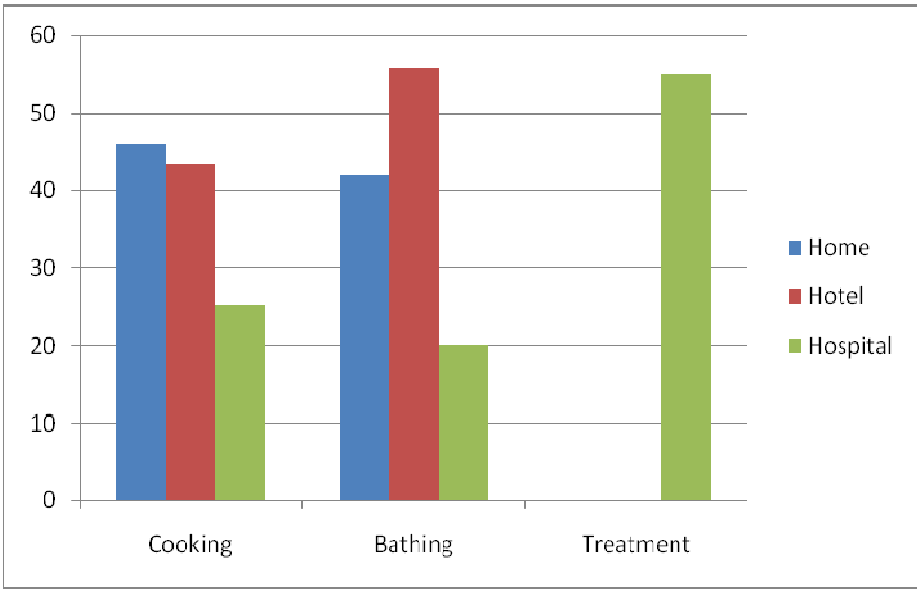


**Figure 1: Major Use of Hot Water**

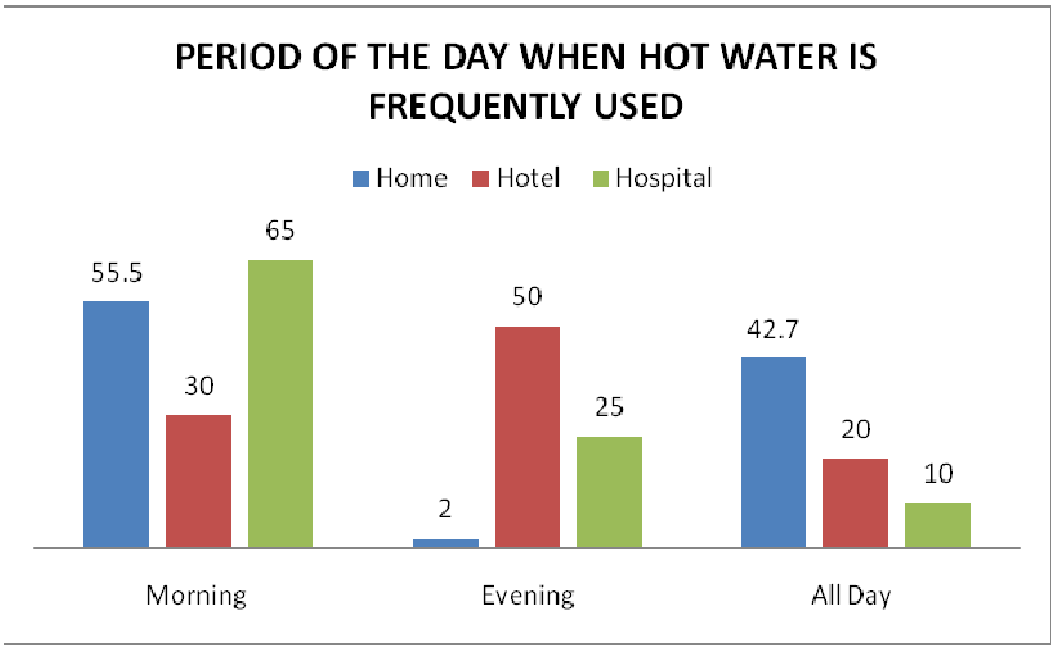


**Figure 2: Diurnal hot water utilization frequently for homes, hotels and hospitals.**

**Table 6: Number of buckets (20 litres) of hot water utilized per day in the Hotel**

| Number of Buckets | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| Less than 50 buckets per day | 10 | 33.3 | 33.3 |
| 50-100 buckets per day | 18 | 60.0 | 93.3 |
| More than 500 buckets per day | 2 | 6.7 | 100.0 |
| Total | 30 | 100.0 | |

**Table 7: Number of buckets (20 litres) of hot water utilized per day in the hospital**

| Number of Buckets | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| Less than 50 buckets per day | 5 | 25.0 | 25.0 |
| 50-100 buckets per day | 7 | 35.0 | 60.0 |
| 101-200 buckets per day | 6 | 30.0 | 90.0 |
| 201-300 buckets per day | 2 | 10.0 | 100.0 |
| Total | 20 | 100.0 | |

Figure 3 below, revealed that firewood, kerosene and gas in that order are the major energy sources for producing hot water in homes. However, hotels and hospitals depend more on electricity and gas to produce hot water.

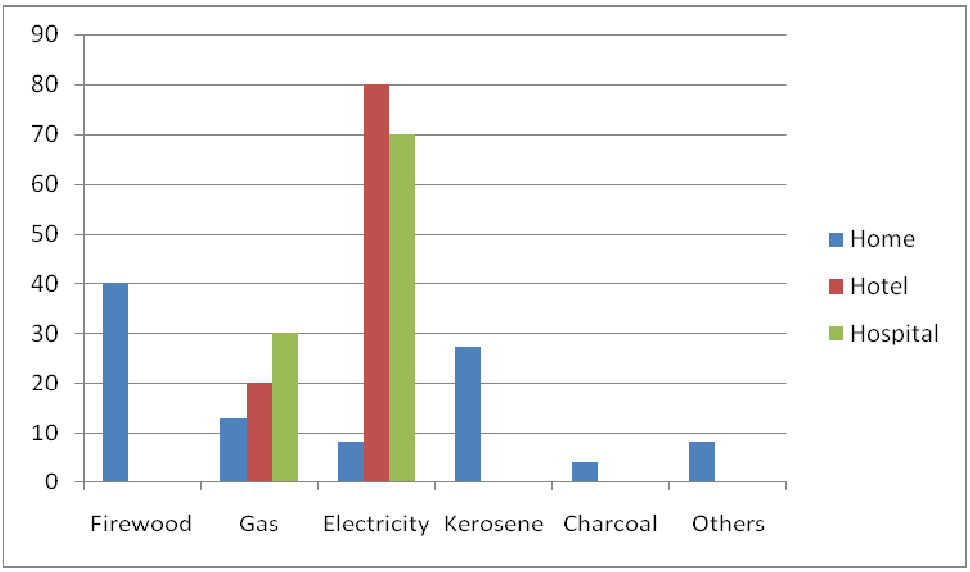


**Figure 3: Major energy sources for producing hot water**

The opinion of respondents on the cost of producing hot water is depicted in Figure 4 above. The survey revealed that 50% of the homes recurrent expenditure on energy is used for heating water; while hotels and hospitals spend about 32% and 21% respectively of their recurrent expenditure on energy for the same purpose as depicted in Table 8 below.

Respondents of the 3 domains, i.e. homes, hotels and hospitals were made to respond to 14 construct designed on the 5-Likert scale. The desired analytical tables were extracted for the proper data analysis and hypothesis testing. Since the responses were similar, this report presents only that for homes.

**Table 8: Descriptive Statistics**

| Average percentage of monthly recurrent expenditure on energy used for heating water | N | Mean | Std. Deviation |
|---|---|---|---|
| Domestic homes | 150 | 49.96 | 11.022 |
| Hotels | 30 | 32.17 | 9.621 |
| Hospitals | 20 | 20.75 | 6.129 |
| Total | 200 | 44.37 | 10.447 |

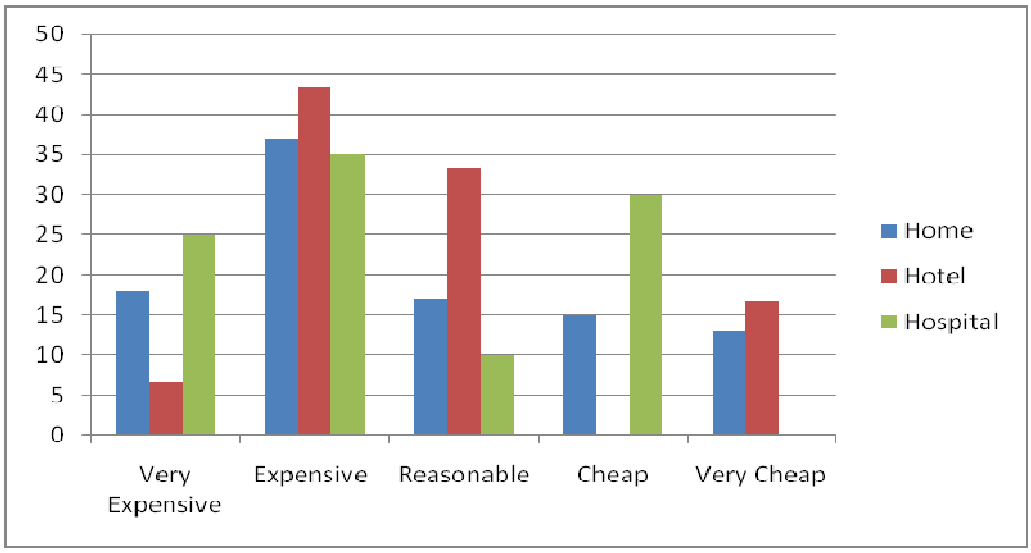


**Figure 4: Cost of heating water**

**Table 9: Descriptive Statistics for Domestic Hot Water Needs**

| Responses | N | Mean | Std. Deviation | Remark |
|---|---|---|---|---|
| Hot water is always needed on daily basis for domestic uses | 150 | 3.79 | 0.914 | Agreed |
| The home cannot do without hot water | 150 | 3.59 | 1.335 | Agreed |
| Most of the hot water used at home is diluted with cold water before use | 150 | 3.87 | 1.019 | Agreed |
| Most of the times, warm water is required more than hot water for home use | 150 | 3.53 | 1.481 | Agreed |
| Any cheaper technology than can provide warm water (say at 65$^{o}$C), can adequately meet the domestic demand of hot water | 150 | 3.92 | 0.832 | Agreed |
| With enough warm water, the home can generally do without hot water | 150 | 3.42 | 1.222 | Undecided |
| Most of the times, there is no need to boil water up to 100$^{o}$C before using | 150 | 4.50 | 0.653 | Strongly Agreed |
| The quantity of warm water needed for domestic use is more than that of hot water | 150 | 3.78 | 0.818 | Agreed |
| The solar system is the cheapest source of energy for domestic use | 150 | 3.57 | 1.207 | Agreed |
| A solar heater which can boil water up to 65$^{o}$C can adequately address the domestic demands for hot water | 150 | 3.79 | 0.658 | Agreed |
| The solar system is an environmentally safer source of energy compared to gas and kerosene | 150 | 3.52 | 1.104 | Agreed |
| For efficiency the solar water heater is preferred for domestic use. | 150 | 3.67 | 0.739 | Agreed |
| With adequate warm water at home, the demand for hot water is no longer necessary | 150 | 3.26 | 1.402 | Undecided |
| An alternative method of boiling water is highly needed for domestic use | 150 | 4.11 | 0.860 | Agreed |

### *3.1 Solar Heaters and Cost Reduction*

The aim of this hypothesis is to investigate whether there is any underlying relationship between the provision of solar heater for domestic, hotel and hospital purposes and cost reduction of heating hot water; the Chi-square test of homogeneity and independence is hereby applied to test this hypothesis. The results obtained for domestic homes, hotels and hospital are identical, thus, the procedure used to arrive at the result for domestic homes only is presented in this report:

Hypothesis 1: Chi-square Test

**$H_0$:** The provision of solar heater for domestic home purposes does not have any significant relationship with cost reduction of heating water

**$H_1$:** The provision of solar heater for domestic home purposes has a significant relationship with cost reduction of heating water

Level of Significance:

$\alpha = 0.05$

Test statistic:

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{\left(O_{ij} - e_{ij}\right)^2}{e_{ij}} \qquad \text{(eq. 3)}$$

Decision Criterion:

Reject $H_0$ if $p < 0.05$ otherwise accept $H_0$

Computations:

The computations are summarized on the SPSS Chi-square table:

Chi-square table for the provision of solar heater for domestic purposes and cost reduction of heating hot water.

**Table 10: Chi-Square and Related Statistics**

| Test Statistics | Value | Df | Asymp. Sig. (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 14.481 | 4 | 0.002 |
| Likelihood Ratio | 14.484 | 4 | 0.004 |
| Linear-by-Linear Association | 0.515 | 1 | 0.003 |
| Contingency Coefficient | 0.571 | | 0.002 |
| N of Valid Cases | 150 | | |

The chi-square test statistic is in Table 10 above. Since $p = 0.002 < 0.05$ we therefore conclude that the provision of solar heater for domestic purposes has a significant relationship with cost reduction of heating water. Furthermore, the contingency coefficient which measures the degree of such relationship is 0.571; which is moderately strong. Hence, solar heater can drastically reduce the cost of heating water in domestic homes.

### *3.2 Advantages of Solar Heaters over Other Methods*

The aim is to investigate whether there is significant advantage for using solar heater over the existing methods of heating water in our homes, hotels and hospitals. Hence, the independent sample t-test is hereby applied to test this hypothesis. Again, the results obtained for domestic homes, hotels and hospital are identical, and the procedure used to arrive at the result for domestic homes only is presented in this report:

Hypothesis 2: Independent Sample t-Test

**$H_0$:** There is no significant gain for using solar heater over the existing methods

**$H_1$:** There is significant gain for using solar heater over the existing methods

Level of Significance:

$\alpha = 0.05$

Test statistic:

$$t^* = \frac{\overline{X}_1 - \overline{X}_2}{sp\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad \text{(eq. 4)}$$

Decision Criterion:

Reject $H_0$ if $p < 0.05$ otherwise accept $H_0$

Computations:

The computations are summarized on the SPSS Descriptive and t- tables:

**Table 11: Group Statistics for using solar heater in domestic homes**

| Use of solar heater | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|
| There is gain using solar | 108 | 3.64 | 0.749 | 0.116 |
| There is no gain using solar | 42 | 3.01 | 0.609 | 0.059 |

**Table 12: Independent Samples for using solar heater**

| T-test statistics | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|
| | T | Df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| | 2.336 | 148 | 0.004 | 0.63 | 0.118 |

The descriptive statistics for the two groups of responses on the gain of using solar are vividly displayed in Table 11 above while the t-test is in Table 12. From Table 12 above, since $p = 0.004 < 0.05$ we therefore conclude there is significant gain for using solar heater over the existing methods. Hence, solar heater can guarantee cost reduction of heating water at home.

### *3.3 Level of Agreement by the Three Categories of Respondents*

Three categories of respondents were covered to assess and evaluate the use of hot water in Nigeria. In order to ascertain the extent to which the domestic homes, hotels and hospitals concur in their responses on the various items in the instrument with regards to the utilization of hot water we apply the Kendall's coefficient of concordance. The Kendall's coefficient of concordance takes on values between zero and one inclusive ($0 \le W \le 1$). The closer the value of $W$ is to one, the stronger the degree of agreement or association. It is distributed approximately chi-square with $k-1$ degrees of freedom. Hence, the test procedures for the Kendall's coefficient of concordance are applied as follows:

Hypothesis 3: Kendall's Test

**$H_0$:** There is no agreement between the responses for homes, hotels and hospitals

**$H_1$:** There is agreement between the responses for homes, hotels and hospitals

Level of Significance:

$\alpha = 0.05$

Test statistic:

$$\chi^2 = k(n-1)W \quad \text{(eq. 5)}$$

Where;

$$W = \frac{12}{k^2 n(n^2-1)} \sum_{i=1}^{n} \left[ R_i - \frac{k(n+1)}{2} \right]^2 \quad \text{(eq. 6)}$$

Decision Criterion:

Reject $H_0$ if $p < 0.05$

Computations:

The computations are obtained using the SPSS in the following tables:

**Table 13: Descriptive Statistics for Kendall's Test**

| Status of Respondents | N | Mean | Mean Ranks | Std. Deviation |
|---|---|---|---|---|
| Domestic homes | 150 | 4.17 | 1.96 | 1.116 |
| Hotels | 30 | 4.28 | 2.02 | 0.863 |
| Hospitals | 20 | 4.11 | 2.04 | 0.718 |

**Table 14: Kendall's Test Statistic**

| Test statistic | Test values |
|---|---|
| Kendall's Coefficient of Concordance | 0.675 |
| Chi-Square | 8.326 |
| Degrees of freedom | 2 |
| Asymptotic Sig. | 0.016 |

The descriptive statistics for domestic homes, hotels and hospitals are vividly displayed in Table 13 above while the inferential statistics are in Table 14. From Table 14 above, since $p = 0.016 < 0.05$ we therefore conclude that there is a strong agreement between the responses from domestic homes, hotels and hospitals. Again from Table 14, the value of the Kendall's coefficient of concordance of *0.675* has signified a strong agreement on the use of hot water in Nigeria across domestic homes, hotels and hospitals. This implies that the stratification into the three subpopulations of respondents is very vital to acquiring more information in the research.

## 4. Summary and Conclusion

A comprehensive, objective and factual study of the domestic hot water requirement profile in Nigeria necessary for the design of appropriate domestic solar water heaters for Nigeria was undertaken. Hence, this study was concerned with the evaluation and assessment of the needs of hot water at homes, in hotels and in hospitals; in Nigeria. The questionnaire survey method was adopted for data collection. The study revealed that the major uses of hot water in homes are for cooking and bathing. Similarly hotels and hospitals need

hot water for the same purposes. Eighty-four per cent of homes need about 100Litres, while 93% of hotels and 60% of hospitals need about 2000Litres of hot water daily. Firewood, kerosene and gas in that order are the major energy sources for producing hot water in homes. However, hotels and hospitals depend more on electricity and gas to produce hot water. Furthermore, the survey revealed that 50% of the homes recurrent expenditure on energy is used for heating water; while hotels and hospitals spend about 32% and 21% respectively of their energy recurrent expenditure for the same purpose. Analysis of the descriptive statistics on the5-Likert scale concluded that provision of solar heater for domestic purposes has a significant relationship with cost reduction of heating water and that solar heater can drastically reduce the cost of heating water in our domestic homes, hotels and hospitals. In addition to that, it was discovered that there is significant gain for using solar heater over the existing methods. The increasing rise in cost of non-renewable energy sources creates more burdens on citizens. Generally, the cost of producing the hot water was considered high, prompting the need for cheaper and sustainable energy devices such as solar water heaters. Nigeria has abundant solar energy potentials, perhaps more than Israel, which could be adequately utilized. Indeed, Israel is now the world leader in the use of solar energy *per capita* with 85% of the households today using solar thermal systems (3% of the primary national energy consumption). It is therefore recommended that Nigeria should consider the utilization of solar energy at least for domestic purposes because of its cost advantage control and relative flexibility in domestic usage i.e. the solar energy is relatively more comfortable to use when compared to firewood and kerosene.

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