Assessing the Feasibility and the Potential of Implementing Solar Water Heaters in Dimbaza, a Township in Eastern Cape, South Africa

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Abstract: The level of income of the inhabitants in a township has an impact on the potential to have adequate access to electricity. The bulk of the domestic energy sources needed in the residential buildings is derived from electrical energy. In South Africa, the base load electricity is derived from coal thermal power plants. However, the environmental impact associated with the combustion of coal in the thermal power plants is a cause for concern. This study was designed to identify the common mode of sanitary hot-water heating in Dimbaza and the potential economic and environmental advantages of replacing the electric water heaters with solar water heaters (SWH) coupled with auxiliary electric heaters. The secondary data on the weather conditions, walk-through audits of selected buildings, and the energy consumption of a residence were analysed. The results depicted that the average annual day temperature and the global solar radiations of Dimbaza were 25 °C and 4.95 kWh/m²/day, respectively. The qualitative data recovered from the survey questionnaires of the sample household representatives revealed the level of awareness of the impact of climate change owing to the electricity generated from the Eskom national grid as 69%. The simple payback period of the projected SWH based on energy consumed by an electric water heater in a specific residence was 5.02 years using the energy analysis method. The implementation of SWHs in the households of Dimbaza would be techno-economically and environmentally viable due to the potential energy savings and the greenhouse gas reduction.

Keywords: solar water heater; techno-economic viability; simple payback period; walk-through energy audits; secondary and historical data; energy saving

1. Introduction

In South Africa, the greatest energy consumption occurs in the industrial sector (mainly mining and manufacturing activities) and is driven by energy derived from fossil fuels, e.g., coal. Coal is the primary energy supply source (70%) and accounts for 85% of electricity generation [1], making South Africa one of the top twenty greenhouse gas (GHG) producers in the world [1]. To change this figure, the South African government opted for more renewable energy sources. For example, the government drafted a National Solar Water Framework in 2009, with the intention to accelerate the rollout of solar water heaters (SWHs) and to achieve the target of one million installed SWHs in households by 2015 [2]. There are a total of 17 million houses in South Africa and 84% of these are electrified, while 16% are unelectrified [3]. The main energy sources used for cooking in these households include electricity followed by paraffin and wood [3]. Specifically for sanitary water heating, the main energy source used is electricity, paraffin, and wood [4]. Nevertheless, electricity, candles, and paraffin are the energy sources commonly used by households for lighting [5]. A study conducted in 2004 in a low-income urban community in South Africa revealed that...
only 55% of households utilised electricity for cooking, while 38% of the households used paraffin and 6% used liquid petroleum gas (LPG) [6]. In addition, it was also discovered that the cooking appliances primarily used by the households were electric and paraffin stoves [7].

In this context, the priority of the South African government was to increase the access to an affordable and clean energy source to address the energy-related environmental and health effects [8]. Pending this achievement, the government has implemented a free basic electricity policy (50 kWh) for low-income households. However, some studies have criticised the amount of the free basic electricity of 50 kWh per month [9], although other reports have confirmed that the 50 kWh per month is insufficient for most of the households with a low income [10]. Nevertheless, the Free Basic Alternative Energy Policy (FBAE policy) adopted in 2007 was implemented in order to help poor households where electricity was not available, with a basic amount of free energy required to meet their basic energy needs [10].

Interestingly, the National Department of Energy has introduced a draft National Solar Water Heater Framework with the aim of increasing the initial one million SWHs target to 5.6 million installations by 2020 [11]. This will go a long way to increasing the uptake of SWHs in the residential sector and the utilization of solar energy, which is a renewable and clean source of energy. The residential sector in South Africa consumes more than 17% of the country’s electricity [12]. The installation of a solar water heater in a residence can reduce the electricity consumption because of water heating for low-income households by about 60% [12]. This may lead to about 25–30% savings on an average monthly electricity bill. A study by Mjuru et al. proved that SWHs are efficient at generating hot water for consumption with a potential of 49% energy savings and thus 49% of greenhouse gas saving [13]. In 2017, Eskom reported that the introduction of SWHs has significantly reduced the electricity demand in the residential sector, leading to a stable power supply [14]. Additionally, solar water heating reduces households’ CO₂ emissions by about 2.6 tons per year, and this depends on the technology and the size of the system [15].

A study by Naidoo [16] examined the socioeconomic impact associated with the use of solar water heaters in low-income households of Cator Manor in KwaZulu Natal, as well as their perception towards using solar water heaters. This study found that SWHs have a variety of socioeconomic impacts such as providing additional monetary saving that could be used towards livelihood strategies and benefits, allowing households to spend more time on productive activities. Additionally, this study provided evidence that residents approve of the SWH technology [16].

Beyond the energy and cost savings associated with the implementation of SWHs as a replacement for conventional electric water heaters, it is important to ascertain the level of awareness of the impact of the electricity that is generated from coal-powered plants with reference to climate change within low-income communities [17]. The rationale is based on evaluating the household representative’s knowledge of the adverse impact on the combustion of coal in the process of electricity generation with special emphasis on climate change [17,18].

Nonetheless, the advantages of the utilization of SWHs for sanitary hot-water heating overshadows the minor challenges, and it is encouraged to be exploited by countries with high global solar radiation such as South Africa. Overall, solar water-heating systems have provided opportunities of hot water to be consumed by people who had never used hot water for sanitary activities [19]. South Africa is situated between latitude 22° S and 34° N and has one of the highest solar radiation rates in the world (the annual solar radiation is between 3.5 kWh/m²/day and 6.5 kWh/m²/day). The high level of isolation has allowed solar water heating to become the most cost-effective means of reaching the national target of increased use of renewable energy sources. A similar study of audits was conducted on installed SWHs in Brazil to determine the economic and environmental benefits of the SWH technology in low-income housing [19].
It was established from the literature that the cost of hot-water heating is contributing more than 50% of the monthly electricity bill [20]. This high electricity bill compromises the quality of life for the low-income households [21]. To the best of the author’s knowledge, from the available literature [22], no study has been conducted on the feasibility of SWHs in Dimbaza. The feasibility study was executed to give an insight on whether there is a need for the rollout of SWHs in Dimbaza. The feasibility study is necessary to provide an informed decision on whether SWHs are a viable option for sanitary hot-water heating in Dimbaza. The incurred cost in a scenario where the SWH technologies proved not to be a viable option for sanitary hot-water heating is much lower through the feasibility study as opposed to the wasteful huge upfront cost associated with the implementation of SWHs without a feasibility study, in which case, the technology proves to be underperforming. This study aims to guarantee that the technology will perform best in this location by considering studies that have been conducted in similar weather conditions that are conducive for the system. Therefore, the study will be beneficial for the towns around South Africa and beyond with a similar weather condition.

This study contributes to the body of scientific knowledge by providing a sound recommendation of the potential economic and environmental benefits of replacing the existing electric water heaters with solar water heaters with the auxiliary electric heaters in Dimbaza based on assessing the solar energy resources in the location through quantitative data and energy consumption audits in selected buildings from qualitative data collected through walk-through audits. Therefore, this study will also be relevant and beneficial to towns around South Africa and beyond with a similar weather condition.

2. Objectives

The objective of this study is:

- To analyse the responses from the questionnaires on the section of environmental impact by the representatives of the selected households to categorise the level of awareness of the adverse consequences due to the consumption of electricity from the Eskom national grid.
- To determine the simple payback period potential for an installed solar water heater with an auxiliary electric heater as a replacement for an existing electric water heater in a house in Dimbaza based on the energy consumption and cost of electricity.
- To conduct walk-through energy audits with emphasis on the sources of energy used and types of electric water heaters in the sample households.
- To quantitatively analyse the ambient temperature, solar irradiation, and sunshine hours to justify the efficiency and better performance of solar water heaters that are installed in Dimbaza.

3. Methodology
3.1. Study Area

The study was conducted in a township called Dimbaza. Figure 1 shows the geographical position of Dimbaza on a satellite Earth map. Dimbaza is a small town in the Eastern Cape province of South Africa located in the Buffalo City Metropolitan Municipality (BCMM), which is about 11 km northwest of King William’s Town. It is along the R63 road, leading to Alice and Fort Beaufort. More elaborately, Dimbaza had a total population of 21,788 people as of 2019 and is comprised of 53% female and 47% male. The total population in the Buffalo City Metropolitan Municipality is 785,755 people, and Dimbaza contributes 2.8% to the total population [23]. The race groups in Dimbaza are categorised into Black, Coloured, Indian, Asian, and White in the proportions of 21,665 (99%), 37 (0.2%), 13 (0.06%), 9 (0.04%), and 64 (0.3%), respectively [23].
According to Census (2011), the age profile in Dimbaza is dominated by the youth, in the age groups between 18 and 25 years and 26 and 35 years. The age group consisting of 45–60 years and above is the second largest age group. Most of the population is educated with individuals from grade 1 to 11 [21,22]. A total of 6650 of the people have acquired an education from grade 1 to grade 7, while 6623 of the population have attained an educational level from grade 8 to 11. Approximately, over 1000 adults have never received any form of formal schooling [23]. According to a study conducted by Gantsho [24], most of the households are on a monthly income ranging from ZAR 1 to ZAR 400, resulting in an annual income of ZAR 12 to ZAR 4800 [23]. Several authors [21] further highlighted that only 14% of the inhabitants are employed, while 8% of the population are discouraged jobseekers. However, the economically inactive fraction of the population makes up 25%. The unemployment rate stands at 16%, and it is the portion of the population that is not employed but is actively seeking employment. The average annual temperature of Dimbaza is 25 °C, and it is dry for about 215 days a year with an average humidity of 52% and a UV index of 5 [23].

3.2. Design of the Study

The research design included the following:

i. Design of the survey questionnaires that were administered to the sample population residing in Ward 36 in Dimbaza. In South Africa, wards are geographical subdivisions of a municipality used for electoral purposes.

ii. Use of analytic analysis to interpret the secondary data retrieved from the literature of published articles based on the performance of solar water heaters in the townships of South Africa.

iii. Design of a systematical method to analyse the historical data on the electrical energy consumption for whole buildings and the hot-water heating devices in Dimbaza.

iv. Design of a method to perform walk-through energy audits for the sample homes in Dimbaza.
3.3. Methods of the Study

The study utilised a mixed-method approach whereby both the problems of subjective qualitative methods tamper with the objectivity of quantitative research methods [23]. Qualitative research was adopted because it enables the study to unearth, for comprehension, the phenomena in the respondents’ own setting [23]. The study methodology involved the analyses of the secondary data collected from the literature of published articles [23]. It also included the historical data on the electrical energy consumption in a home in Dimbaza, the relative humidity, the ambient temperature, and the solar radiation of Dimbaza, which were obtained from the South African Weather Service database [24]. The methodology included the analyses of both the quantitative and qualitative data on the sources of energy consumed in the 73 sample houses via questionnaires (see Appendix A) and walk-through energy audits. The primary criteria for the selection of the 73 houses were on the consideration of houses with installed electric water heaters, number of occupants in the buildings, and categorization of the selected houses into grouping intervals of three occupants.

3.4. Data Collection

The energy and electricity billed data were collected from each of the sample houses from 2018 to 2020. There are different categories of electric water heaters available in the houses of Dimbaza. There are 300 houses in Ward 36. So, out of the 73 houses of the sample size that were surveyed, 50 were considered in the analysis and 1 household that met the criteria (low-income household with a 200 L electric water heater) was identified as a representative of the monthly energy consumption [24]. Hence, the residence was used in the determination of the projected simple payback period of a SWH.

To evaluate the awareness of the adverse impact due to the source of energy from which the electricity is generated, the data were collected from the responses of the household representatives based on the designed questionnaires that tested their knowledge on the adverse impact due to the utilization of the Eskom grid electricity.

To evaluate the awareness of impact of climate change from generating electricity, the data required were collected through survey questionnaires and walk-through energy audits for 73 sampling houses. These data were collected from the 15th of January to the 31st of January 2021. The energy utilities in the sampling homes were light bulbs, electric or gas stoves, electric heaters, electric water heaters, paraffin stoves, and small energy consuming appliances (e.g., refrigerators, radio, television, electric iron, etc.). The energy sources used by these devices included electricity, LPG, paraffin, and firewood.

To assess the feasibility of the potential implementation of SWH as a replacement for the existing electric water heaters in the homes situated in Dimbaza, based on the ambient weather conditions. The data were collected from the historical database of the South Africa weather station and included the ambient temperature, relative humidity, and global solar radiation from the period 2018 to 2020.

To assess the feasibility of the potential implementation of SWH, the required data were extracted from the South African Weather Service database (www.weathersa.co.za, accessed on 1 July 2022). Factors that determine the feasibility of SWHs are ambient temperature, relative humidity, and sunshine hours [22]. So, the data collected were average daily sunrise and sunset hours in Dimbaza from January 2018 to December 2020 and were extracted from the database. Additionally, the data on the average month–day ambient temperature and relative humidity of Dimbaza were extracted from the South African Weather Service Database.

3.5. Data Analysis

After the data were collected, it was analysed in accordance with the study objectives listed below.

To evaluate the potential economic and environmental benefits of installing SWHs and to conduct a simple payback analysis in a home in Dimbaza based on historical energy consumed in the building,
Natural resources can be tangible or intangible and include land, water, biological diversity, forests, marine/wild resources, air quality, erosion protection, hydrological cycle, pollution sinks, and waste assimilation [25,26]. These two case studies, Kuyasa CDM Project and the Nelson Mandela Bay Municipality SWH project (Zanemvula project), have been able to reduce greenhouse gas emissions (improving indoor air quality as well) and deforestation as the SWHs meant households did not need to burn wood or other fossil fuels for hot water [26]. Natural resources have improved physical health, increased wellbeing through a more comfortable life, saved time, and saved energy costs. This demonstrates the interdependence of natural, human, and financial capital [26,27]. The data to evaluate the potential economic and environmental benefits were determined and analysed below:

For economic benefits:
The electrical energy consumed is the product of the electrical power and the time taken during the heating of hot water due to the heating element and is given by Equation (1).

\[ E = Pt \]  

where \( E \) = electrical energy consumed in kWh, \( P \) = electrical power consumed in kW, and \( t \) = time taken in h.

The electrical energy savings achieved by replacing the electric water heater with a solar water heater harbouring an auxiliary water heater are the difference between the electrical energy consumed by the electric water heater and the electrical energy consumed by the auxiliary water heater of the solar water heater over the same period, and this is presented in Equation (2).

\[ ES = EG - E_{SWH} \]  

For environmental and benefits:
The reduction in greenhouse gases (\( \text{CO}_2 \), \( \text{SO}_2 \), and \( \text{NO}_X \)) and water due to the energy savings occurring because of the replacement of the electric water heater with a solar water heater is the product of the electricity savings in kWh [28] and the appropriate conversion factor in SI units (kg/kWh) and is given by Equation (3).

\[ RS = ES \times CFx \]  

where \( RS \) = savings owing to the reduction in the emission of greenhouse gases or water consumed, \( ES \) = electricity savings in kWh, and \( CFx \) = conversion factor in kg/kWh.

For the simple payback period:
The simple payback period of a technology is the ratio of the capital cost and the product of the annual energy saved and tariff as shown in Equation (4).

\[ SPB = \frac{\text{Capital cost}}{\text{Annual energy saving} \times \text{tariff}} \]  

where \( SPB \) = simple payback period in years, capital cost = principal cost of the SWH and the installation cost, annual electricity savings = electricity saving (ES) in kWh for a year, and tariff = ZAR 1.20 per kWh of electricity consumed.

To evaluate the awareness of impact of climate change due to the source of energy from which the electricity is generated.

Previous research efforts and surveys point out the lack of awareness of the negative environmental impacts of electrical water heating and of the benefits of utilizing the potential of SWHs to reduce electricity bills and promote the sustainable and efficient usage of energy and water in South Africa [1,12,21]. So, in this study, the rating of the participants’ knowledge of the adverse impact due to electricity generated from the Eskom grid was tested on a level scale from 1 to 5. The primary energy source (coal) used for the generation of the Eskom baseload electricity is associated with adverse environmental and health impact such as air pollution, human health illnesses, human life expectancy, global warming potential, and depletion of the ozone layer. The level of awareness in this study
was ranked from level 1 to level 5 which was based on the number of correct answers to the questions. The level of awareness of the environmental impact for each representative of the selected households was assigned in five major questions in the designed questionnaires, which were: (i) The correct identification of the primary source of electricity utilized by Eskom for generation of baseload from the list of provided answers? E.g., (a) Hydro energy (b) Solar PV (c) Coal thermal energy (d) nuclear energy (e) wind energy. (ii) The baseload electricity from Eskom national grid can be classified as: (a) Eco-friendly energy (b) clean energy (c) renewable energy (d) nuclear energy (d) conventional energy (e) none of the above. (iii) The lifespan of human beings can be shortened significantly because of exposure to greenhouse gases emitted from coal thermal plants: (a) True or (b) False. (iv) Coal as a source of energy is a major contributor of greenhouse gases emission: (a) True (b) False. (v) The bulk of electricity generated by Eskom is from: (a) Coal thermal power plant (b) Nuclear power plants (c) Solar power plants (d) Hydro-power plants (e) Tidal waves power plants. The level 1 rating indicates that the participants have no knowledge about the adverse impact that generating electricity from coal has on climate change. The level 2 rating implied the participants had low knowledge or small understanding about the adverse impact from the grid electricity, and the awareness was 2 of 5 on the rating indicators. The level 3 and 4 ratings were attributed to the participants with average, and good knowledge of the adverse impact from the grid electricity and the awareness was 3 of 5 and 4 of 5 rating indicators, respectively. The level 5 rating showed that the participants had excellent knowledge and the awareness of the of the adverse impact from the grid electricity was 5 of 5, rating indicators.

To assess the feasibility of the potential implementation of SWH as a replacement for the existing electric water heaters in the homes situated in Dimbaza, based on the ambient weather conditions.

It is worth mentioning that the feasibility and performance of a SWH depends on the ambient temperature, relative humidity, sunshine hours of the location where the system is being installed, and the efficiency of installation [22]. The data (i.e., average daily sunrise and sunsets, average ambient temperature, and average ambient temperature) from the database were processed at every 5 min interval and was recorded for every hour of the day for the whole month. So, this was conducted for all the parameters (i.e., ambient temperature and relative humidity). Then, the data were averaged to obtain an average month–day ambient temperature and average month–day relative-humidity value. The value for each parameter determines whether the installation of a solar water heater is viable or not. SWHs can perform all year round if the ambient temperature is above zero degrees Celsius. So, if the values of the average month–day ambient temperature are above zero degrees Celsius, the SWH technology is considered feasible. South Africa is situated between latitude 22° S and 34° N and has one of the highest solar radiation rates in the world (3.5 kWh/m²/day and 6.5 kWh/m²/day) [20]. Additionally, the average annual temperature of Dimbaza is 25 °C and the solar radiation in Dimbaza is 4.95 kWh/m² [20].

4. Results and Discussion

The subtitles below seek to explain and discuss the findings of this study, and they are systematically written according to the objectives of this paper.

So, for evaluating the potential economic and environmental benefits of installing SWHs and conducting a simple payback analysis, the results are discussed henceforth.

4.1. Sample Population and the Sources of Income

Table 1 reveals that from the sample population, 34.24% of the household representatives derived their income from full-time employment. The remaining 65.76% of the sample population had diverse sources of income, including 29.92% through pension, 19.18% from child grants, and 9.59% linked to disability grants, as shown in Table 1. A very small number (6.85%) depended on small businesses while 8.22% of the household
representatives claimed their source of income was from casual informal jobs (classified as other sources of income).

Table 1. Distribution of the source of income of the sample population.

| Source of Income       | Number of Household Representatives | Household Representatives (%) |
|------------------------|-------------------------------------|--------------------------------|
| Employment             | 25                                  | 34.24                          |
| Pension                | 16                                  | 29.92                          |
| Child grant            | 14                                  | 19.18                          |
| Disability grant       | 07                                  | 9.59                           |
| Small business         | 05                                  | 6.85                           |
| Others                 | 06                                  | 8.22                           |

Francioli, in a study in 2018, found that in households that used electric water heaters, other energy sources such as paraffin and gas were used to boil water when electricity was running low. Similarly, a study by Uhunamure et al. in 2017 [27] indicated that when households had low to zero monthly income, they opted to collect firewood to heat water for household activities. Furthermore, Statistics South Africa [29] asserted that low-income electrified households used solid fuels such as wood and coal (25.3%), paraffin (9.2%), and gas (1%) to heat water. Thus, the SWHs in Dimbaza will allow residents to save money while also serving as an alternative to other nonrenewable energy sources. These findings are similar to the results of the study conducted by Naidoo (2019) [16] that concluded that using SWHs provided additional monetary saving that could be used for other household activities.

4.2. Monthly Electricity Consumption in a Residence

Figure 2 below shows the profiles of the monthly electricity consumption of a home in Dimbaza, where the entire energy consumed was provided by the Eskom national grid from 2018 to 2020. The energy data were obtained from the head of the household, who was a full-time employee (a teacher in a lay private primary school) earning a monthly salary of ZAR 7000.00. The house comprised of a family of six (four adults and two children). The hot-water heating in the home was produced by a 200 L, 4.0 kW high-pressure electric water heater. The average monthly electricity consumed by the whole building in the years 2018, 2019, and 2020 was 994.17, 1475, and 1245 kWh, respectively. The average monthly electricity consumed over the audited period was 1245.56 kWh. The average monthly electricity consumed over the three-year auditing period highlighted that there was higher electricity consumption during the winter period (May–August) as opposed to the summer period (September–April). The average monthly electricity consumed during the winter period in 2018, 2019, and 2020 was 1277.50, 1762.50, and 1465.00 kWh, respectively. The average monthly electricity consumed during the summer period in the years 2018, 2019, and 2020 was 852.50, 1331.25, and 1168.75 kWh and the average was 1117.50 kWh. A calculation of the percentage of electricity consumed by hot-water heating from a conservative analysis method showed that 15.96% of the income of the head of the household was spent on electricity. Additionally, Uhunamure et al. in 2017 [27], from a study on low-income households in Thulamela municipality, Limpopo, found that as income increases in a household, so does that household’s electricity consumption, as more expendable income is available which improves the lifestyle (for example, buying more appliances) of that household.
was 6726.00 kWh, as shown in Table 2. The average electricity savings from replacing (about 46%) of the whole-building electricity consumption. Therefore, the average annual electricity consumed by the electric water heater due to hot-water heating was 560.50 kWh

harbouring an auxiliary water heater were between 40 and 50% [31]. The average monthly electricity savings by retrofitting an electric water heater with a SWH resulted in electricity savings of about 40–50% monthly [16]. These findings are in agreement with the findings of a study by Bessa and Prado (2015) which was conducted in different regions in Brazil that are predominantly tropical in climate [30]. Additionally, a study by Adams (2012) concluded that electric water heaters account for between 40 and 50% of the overall energy consumption in a residential household. This study proved that average monthly electricity savings by retrofitting an electric water heater with a SWH harbouring an auxiliary water heater were between 40 and 50% [31]. The average monthly electricity consumed by the electric water heater due to hot-water heating was 560.50 kWh (about 46%) of the whole-building electricity consumption. Therefore, the average annual electricity consumed by the electric water heater for the purpose of sanitary water heating was 6726.00 kWh, as shown in Table 2. The average electricity savings from replacing the electric water heater with a SWH with an auxiliary electric heater were considered as 46% [31], and the electricity consumed was 4035.60 kWh. The electricity savings (46%) are the difference in electricity consumed from the electric water heater and the solar water heater with an auxiliary electric heater (see Appendix B). The annual electricity savings due to the potential implementation of the SWH will be 2690.4 kWh. The annual reduction in CO₂, SO₂, and NOₓ emissions from the application of the appropriate conversion factors

Figure 2. Annual monthly energy consumption profiles from 2018 to 2020.

4.3. Computing the Economic and Environmental Benefits of Retrofitting Electric Water Heaters with SWHs

The South African government has proactively launched initiatives to reduce residential energy demand but also improve their socioeconomic and environmental standing. One such initiative is the retrofitting of Reconstruction and Development Programme (RDP) houses with solar water heaters (SWHs) at no charge [20]. SWHs were chosen to be installed in these low-income houses for multiple reasons: to reduce dependency on the national grid, mitigate climate change, and most importantly, to aid the poverty alleviation of vulnerable communities [22]. Table 2 shows the projection of the electricity savings and the environmental impact of replacing a 200 L, 4.0 kW electric water heater with a 200 L, 2.0 kW solar water heater. According to Naidoo (2019), an average monthly electric bill that is attributed to water heating for an average household is between 40 and 50% of the total energy consumption [16]. So, replacing an electric water heater with a solar water heater resulted in electricity savings of about 40–50% monthly [16]. These findings are in agreement with the findings of a study by Bessa and Prado (2015) which was conducted in different regions in Brazil that are predominantly tropical in climate [30]. Additionally, a study by Adams (2012) concluded that electric water heaters account for between 40 and 50% of the overall energy consumption in a residential household. This study proved that average monthly electricity savings by retrofitting an electric water heater with a SWH harbouring an auxiliary water heater were between 40 and 50% [31]. The average monthly electricity consumed by the electric water heater due to hot-water heating was 560.50 kWh (about 46%) of the whole-building electricity consumption. Therefore, the average annual electricity consumed by the electric water heater for the purpose of sanitary water heating was 6726.00 kWh, as shown in Table 2. The average electricity savings from replacing the electric water heater with a SWH with an auxiliary electric heater were considered as 46% [31], and the electricity consumed was 4035.60 kWh. The electricity savings (46%) are the difference in electricity consumed from the electric water heater and the solar water heater with an auxiliary electric heater (see Appendix B). The annual electricity savings due to the potential implementation of the SWH will be 2690.4 kWh. The annual reduction in CO₂, SO₂, and NOₓ emissions from the application of the appropriate conversion factors
(Eskom (2019)) shown in Table 2 would be $2663.5$, $19,720.63$, and $11,272.78$ kg, respectively. The annual water, ash, and coal savings would be $3605.14$ L, $430.46$ kg, and $1345.20$ kg, respectively. In addition, the annual electricity cost savings would be ZAR $3228.48$. The capital and installation cost of the 200 L, 2 kW flat-plate SWH was considered as ZAR $16,200.00$, as provided in Table 6. The simple payback period would be 5.02 years. The average lifespan of a SWH is 20 years and, thus, the analysis confirms that a SWH would have a favourable payback period. If the payback period was less than the lifespan of the system, then it would be considered unfavourable. This payback period would be even lower had it been calculated based on the net present value for money, which considers both annual internal rate and the electricity tariff rate. This initiative is in line with the government’s long-term mitigation strategies for climate change to meet the renewable energy target of 10,000 GWh (gigawatt hour) [25]. SWHs can be a good recommendation for hot-water heating in the houses in Dimbaza.

Table 2. Projection of the economic and environmental benefits by replacing electric water heaters with SWHs over one year.

| Energy (kWh) | H$_2$O (L) | CO$_2$ (kg) | SO$_2$ (kg) | NO$_X$ (kg) | Ash (kg) | Coal (kg) |
|--------------|-------------|-------------|-------------|-------------|----------|-----------|
| Conversion Factors for: | Energy (kWh) | H$_2$O Savings (1.34 L) | CO$_2$ (0.99 kg/kWh) | SO$_2$ (7.33 kg/kWh) | NO$_X$ (4.19 kg/kWh) | Ash (0.16 kg/kWh) | Coal (0.5 kg/kWh) |
| Electric water (Baseline) SWH with auxiliary (Assessed scenario) | 6726.00 | 9012.84 | 6658.74 | 49,301.58 | 28,181.94 | 1076.16 | 3363.00 |
| | 4035.60 | 5407.70 | 3995.24 | 29,580.95 | 16,909.16 | 645.69 | 2017.80 |
| | 2690.40 | 3605.14 | 2663.5 | 19,720.63 | 11,272.78 | 430.46 | 1345.20 |

The next objective was to evaluate the awareness the adverse impact due to the source of energy from which the electricity is generated.

4.4. Walk-Through Energy Audits of the Sample Residences

A walk-through energy audit was conducted in each of the 73 selected houses. The energy audits focused on the sources of energy consumed for the purpose of lighting, cooking, space heating, hot-water heating, and small appliances (such as television, radio, refrigerator, etc.). The analysis from the energy audits is presented in Table 3. It can be observed from Table 3 that 50 of the 73 sampling houses utilized electricity for the operations of all the investigated devices (lighting, cooking, space and hot-water heating, and entertainment). Furthermore, 23 of the sample houses used either one or more than one of the other energy sources (LPG, paraffin, and wood). In addition, 10 homes were found to be using LPG for cooking, and electricity only for sanitary hot-water heating. Previous studies have found that households which consist of 1–4 people (small households) use modern energy sources (electricity) compared to households with more than 5 people that tend to use traditional (biomass) energy sources [32,33]. A Study by Ozdemir et al. in 2012 [34] found that the more people that live in one house, the more energy that household will require to heat additional water, for instance. The Renewable Energy Policy Network for the 21st Century speaks about solar water heating as having the potential to ‘partially or wholly substitute the use of electricity, LPG, and oil for water heating in areas with sufficient solar radiation’ (REN21 Renewable Energy Policy Network, 2005). Hence, the potential installation of SWHs in Dimbaza will allow residents to save money while also utilizing an alternative source of energy to other nonrenewable energy sources.
Table 3. Sample population and the sources of energy used by the households.

| Number of Households | Source of Energy Use for Lighting | Source of Energy Use for Cooking | Source of Energy Use for Space Heating | Source of Energy Use for Hot-Water Heating | Source of Energy use for Small Appliances (Radio, TV Set, and Refrigerator) |
|----------------------|----------------------------------|----------------------------------|----------------------------------------|------------------------------------------|-------------------------------------------------------------------------|
| 50                   | Electricity                       | Electricity                       | Electricity                             | Electricity                              | Electricity                                                              |
| 10                   | Electricity                       | LPG                               | Electricity                             | Electricity                              | Electricity                                                              |
| 3                    | Electricity                       | Paraffin                          | Paraffin                               | Paraffin                                 | Electricity                                                              |
| 10                   | Electricity                       | Wood                              | None                                   | Wood                                     | electricity                                                              |

4.5. Grouping of the Sample Houses with Electricity as the Only Energy Source

According to the analysis from the walk-through energy audits, 50 of the residences were using electricity from the Eskom national grid to operate all the household utilities. Figure 3 shows the bar chart for the grouping of the sampling houses and the number of representatives. The grouping was conducted with a family size of three, except for the fourth group. The first group included households with 1 to 3 occupants (01–03 occupants), the second group consisted of households with 4 to 6 occupants (04–06 occupants), the third class involved households with 7 to 9 occupants (07–09 occupants), and the fourth class harboured households with 10 or more occupants (10–more occupants). The distribution displayed in Figure 3 shows that the number of household representatives (people interviewed) for group 1, group 2, group 3, and group 4 was 13, 20, 12, and 5, respectively. More elaborately, in group 1 (01–03 occupants), the number of people interviewed consisted of six females and seven males. There were 12 female and 8 male household representatives that were interviewed in group 2 (04–06 occupants), while in group 3 (07–09 occupants), the female household representatives numbered 7 and their male counterparts numbered 5 that were interviewed. Lastly, group 4 (09–more occupants) had the lowest number of household representatives interviewed and comprised of three females and two males. Overall, of the considered 50 household representatives interviewed, 28 were females while 22 were men.

Figure 3. Distribution of the household occupant grouping and number of representatives.
4.6. Electric Water Heater Sizes within the Household Grouping

Table 4 provides the number of 100 L, 150 L, and 200 L electric water heaters installed in the four household groups. It can be found from Table 4 that in the total number of the sampling houses (50), there were three (3) categories of electric water heaters (2 kW, 100 L electric water heaters; 3 kW, 150 L electric water heaters; and 4 kW, 200 L electric water heaters). There were 13 installed electric water heaters under group 1 (01–03 occupants): 10 were 2.0 kW, 100 L electric water heaters; and 3 were 3.0 kW, 150 L electric water heaters. In group 2 (04–06 occupants), there were 18 installed electric water heaters composed of 15, 2, and 1 of the 2 kW, 100 L; 3 kW, 150 L; and 4 kW, 200 L electric water heaters, respectively. Table 4 further reveals that the 3.0 kW, 150 L electric water heaters had the highest frequency of installations (25); followed by the 2.0 kW, 100 L electric water heaters (14); and the lowest occurrence was the 4.0 kW, 200 L electric water heaters (11).

Table 4. Categorisation of the number of household occupants and electric water heater sizes used in the analysis.

| Household Occupants’ Groups | No. High-Pressure 2.0 kW, 100 L Electric Water Heaters | No. High-Pressure 3.0 kW, 150 L Electric Water Heaters | No. High-Pressure 4.0 kW, 200 L Electric Water Heaters |
|-----------------------------|--------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------|
| 01–03 occupants             | 10                                                     | 03                                                     | 00                                                     |
| 04–06 occupants             | 03                                                     | 15                                                     | 02                                                     |
| 07–09 occupants             | 01                                                     | 05                                                     | 06                                                     |
| 10–more occupants           | 00                                                     | 02                                                     | 03                                                     |

4.7. Cost on Monthly Electricity and Income Scale

Table 5 shows the estimated average monthly cost of electricity, the number of household representatives, and their estimated monthly salary ranges with respect to the size of the electric water heaters installed. It has been demonstrated that in the homes harbouring 2 kW, 100 L electric water heaters, the estimated average monthly cost of electricity consumption in the entire building was ZAR 650.00. The estimated average monthly income for the 14 heads of the homes with the installed 2 kW, 100 L electric water heaters was between ZAR 2600.00 and ZAR 4300.00. The estimated average monthly electricity cost of the homes installed with the 3 kW, 150 L electric water heaters was ZAR 900.00 and comprised of 25 household heads, with their estimated monthly income ranging from ZAR 3000.00 to ZAR 7000.00. The estimated average monthly electricity cost of the homes having the 4 kW, 200 L electric water heaters was ZAR 1200. The estimated monthly income was between ZAR 4400.00 and ZAR 12,000.00 and the number of household heads linked to the said electric water heater size was 11.

Table 5. Categorisation of the heads of the sample and analysed households with respect to electric water heater sizes, incomes, and energy expenditure.

| Electric Water Heater Sizes (L) | No. of Household Heads | Estimated Average Monthly Cost on Electricity (ZAR) | No. of Households with Males as Household Heads | No. of Households with Females as Household Heads | Estimated Range of Average Monthly Income for the Overall Households (ZAR) |
|---------------------------------|------------------------|-----------------------------------------------------|-------------------------------------------------|-------------------------------------------------|---------------------------------------------------------------------|
| 100 L                           | 14                     | 650.00                                              | 6                                               | 8                                               | 2600.00–4300.00                                                    |
| 150 L                           | 25                     | 900.00                                              | 11                                              | 14                                              | 3000.00–7000.00                                                   |
| 200 L                           | 11                     | 1200.00                                             | 5                                               | 6                                               | 4400.0–12,000.00                                                  |

A study by Uhunamure et al. in 2017 [25] on low-income households in Thulamela municipality, Limpopo found that as income increases in a household, so does that house-
hold’s energy consumption, as more expendable income is available which improves the lifestyle (for example, buying more appliances) of that household.

4.8. Estimated Monthly Electricity Consumption for Hot-Water Heating and the Whole Building

Table 6 shows the estimated monthly electricity consumed by and the electricity cost of the 2 kW, 100 L; 3 kW, 150 L; and 4 kW, 200 L electric water heaters installed in the 50 sampling houses that were considered for the analysis. The estimated monthly electricity cost of each of the electric water heater sizes was derived from the historical electricity bills obtained from the household heads. The estimated average monthly electricity cost of the whole building with a 2 kW, 100 L electric water heater was ZAR 650.00. The estimated monthly electricity consumed by the entire building was 541.66 kWh, with the flat tariff at ZAR 1.20/kWh. According to the literature [30], the share of electricity consumption for water heating in the overall electricity consumption is between 35 and 50%. So, the average monthly cost of electricity due to hot-water heating was assumed to be 46% [30] (for calculations, see: Appendix B) and the electricity cost of the electric water heater was ZAR 299.00. The average monthly electricity consumed by the 2 kW, 100 L electric water heater was 249.17 kWh. The average capital cost and installation cost of the 2.0 kW, 100 L high-pressure SWH was ZAR 9100.00. The estimated electricity cost of the whole building and the 3 kW, 150 L electric water heater were ZAR 900.00 and ZAR 477.00, while the electricity consumed were 750 and 345 kWh, respectively. The average capital and installed cost of the 3 kW, 150 L electric water heater was ZAR 13,300.00. The estimated electricity costs of the entire building and the 4 kW, 200 L electric water heater were ZAR 1200.00 and ZAR 540.00, respectively. The corresponding energy consumed by the whole building and the electric water heater were 1000 and 450 kWh, respectively. The average capital and installed cost of the 4 kW, 200 L electric water heater was ZAR 16,200.00.

Table 6. Categorisation of the heads of the sample and analysed households with respect to electric water heater sizes, cost of total electricity for the building, and electricity consumed by the electric water heater.

| Electric Water Heater (L) | No. of Household Heads | Estimated Average Monthly Cost of Electricity (ZAR) | Estimated Average Monthly Energy Consumed (kWh) | Estimated Average Monthly Cost of Water Heating (ZAR) | Estimated Average Monthly Energy Consumed by Electric Water Heater (kWh) | Estimated Capital and Installation Cost (ZAR) |
|---------------------------|------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| 100 L                     | 14                     | 650.00                                        | 541.66                                        | 299.00                                        | 249.17                                        | 9100.00                                       |
| 150 L                     | 25                     | 900.00                                        | 750.00                                        | 477.00                                        | 345.00                                        | 13,300.00                                     |
| 200 L                     | 11                     | 1200.00                                       | 1000.00                                       | 540.00                                        | 450.00                                        | 16,200.00                                     |

4.9. Qualitative Rating of the Awareness of the Impact of Climate Change

Table 7 shows that of the sample size of 50, the proportion of participants ascribed to levels 1, 2, 3, 4, and 5 was 4%, 20%, 42%, 28%, and 6%, respectively. Therefore, 76% (38 of the 50) participants in the survey questionnaires were grouped between level 3 and level 5. This also confirmed that the community was not ignorant of the importance of rolling out renewable energy sources and the need for energy efficiency initiatives, as depicted in Table 7. This was based on the responses on the adverse impact of electricity used in their homes that was derived from the Eskom national grid. These findings are in line with the results of Cawood [35] from doing a study about the social contribution of 100 solar water heaters installed in low-income households in Durban which was researched with a baseline and a follow-up household survey.
Table 7. Categorization of the heads of households according to tank sizes of the electric water heaters and the level of environmental awareness to the utilization of electricity from the national grid (2021).

| Response from Household Heads with the Electric Water Heater Sizes | Rating of Knowledge of the Impact of Climate Change by Household Representatives |
|---------------------------------------------------------------|------------------------------------------------------------------|
| 100 L                                                         | Level 1 (No Knowledge)    | Level 2 (Low Knowledge)    | Level 3 (Average Knowledge)    | Level 4 (Good Knowledge)    | Level 5 (Excellent Knowledge)    |
|                                                               | 0   | 1   | 5   | 6   | 1   |
| 150 L                                                         | 0   | 7   | 11  | 5   | 2   |
| 200 L                                                         | 2   | 2   | 5   | 3   | 0   |

The results were:

- Most households stated that they used less fuel in general than before the installation.
- Fewer households used wood and LPG and more households used electricity and paraffin for water heating.
- The financial savings due to the SWH were estimated by 70% of the respondents to be between ZAR 50 and ZAR 100 per month.
- Most of the household indicated that they were aware of the negative impacts of generating electricity from fossils fuel and, thus, they were advocating for SWHs for heating water.
- Almost every respondent of the follow up survey would recommend the installation to friends [35].

These findings were also in agreement with the findings of the study in Cato Manor in 2019 [16], where residents had an overall positive attitude and perception since receiving SWHs.

The next objective was to assess the feasibility of the potential implementation of SWH as a replacement for the existing electric water heaters in the homes situated in Dimbaza, based on the ambient weather conditions.

4.10. Ambient Temperature and Relative Humidity

It is well-documented that the performance and viability of a SWH is influenced by the ambient weather conditions [22]. Table 8 shows data on the average month–day ambient temperature and relative humidity of Dimbaza. The average month–day ambient temperature and relative humidity of Dimbaza range from 12.88 to 20.39 °C and 56.75 to 88.86%, over a period of 1 year (January to December 2021). The maximum month–day ambient temperature was 33.97 °C, which occurred in December (summer month), whereas the minimum was 1.33 °C and was recorded in July (winter month). The average month–day winter ambient temperature and relative humidity were 14.29 °C and 64.33%, while those of the summer were 18.05 °C and 83.57%, respectively. The average annual month–day ambient temperature and relative humidity were 16.80 °C and 77.16%. These results and findings from ambient temperature and relative humidity of Dimbaza confirm that SWHs are able to operate all year round in Dimbaza. Similar results were obtained in 2022 by Tang et al. [36], which confirm the efficiency of SWHs in summer ambient temperature using climatic information of 21 cities around South Africa.

4.11. Sunshine Hours and Global Solar Radiation

It is worth mentioning that the performance of a SWH depends on its design, the installation, and the location where the system is being installed [26]. The geographical location plays a significant role in the enhancement of the performance of the SWHs. The data extracted from the South African weather database on the average daily sunrise and sunset hours through the months of January to December 2018–2020 of the location (Dimbaza) [25] were analysed and are presented in Table 9. The average month–day sunrise over a yearly cycle (January to December) varied between 5:00 and 7:00 AM while the average month–day sunset ranged from 5:00 to 7:00 PM. It was depicted that the duration
of solar availability ranged from 10.06 to 14.23 h while the average month–day global solar radiation fluctuated between 3.20 and 6.90 kWh/m²/day. The mean of the average month–day solar availability for the winter period (May, June, July, and August) was 10.48 h while the corresponding mean of the average global radiation was 3.40 kWh/m²/day. The mean of the average month–day solar availability and global solar radiation for the summer period (January, February, March, April, September, October, November, and December) was 12.96 h and 5.74 kWh/m²/day, respectively. The mean annual duration of sunshine and global solar radiation was 12.13 h and 4.96 kWh/m²/day, respectively. The values representing the solar availability and global solar radiations indicate that a properly installed SWH in this location will exhibit a better technical and economic performance.

### Table 8. Annual average month–day solar availability (Weather SA, 2021).

| Months  | Average Month–Day Ambient Temperature (°C) | Maximum Month–Day Ambient Temperature (°C) | Minimum Month–Day Ambient Temperature (°C) | Average Month–Day Relative Humidity (%) |
|---------|------------------------------------------|------------------------------------------|------------------------------------------|----------------------------------------|
| January | 20.39                                    | 33.97                                    | 10.35                                    | 87.97                                  |
| February| 20.10                                    | 33.55                                    | 9.72                                     | 87.03                                  |
| March   | 19.42                                    | 32.45                                    | 9.32                                     | 84.94                                  |
| April   | 16.63                                    | 28.97                                    | 6.53                                     | 79.87                                  |
| May     | 15.42                                    | 26.88                                    | 5.63                                     | 70.42                                  |
| June    | 15.42                                    | 26.88                                    | 5.63                                     | 70.42                                  |
| July    | 12.88                                    | 24.71                                    | 1.33                                     | 56.75                                  |
| August  | 13.42                                    | 26.63                                    | 3.67                                     | 59.71                                  |
| September | 15.73                                  | 30.73                                    | 4.80                                     | 75.13                                  |
| October | 16.55                                    | 32.16                                    | 5.00                                     | 78.58                                  |
| November| 16.79                                    | 31.46                                    | 5.79                                     | 86.58                                  |
| December| 18.79                                    | 33.13                                    | 8.17                                     | 88.46                                  |

### Table 9. Annual average month–day weather condition and radiation of Dimbaza (Weather SA, 2021).

| Months  | Average Month–Day Sunrise Time | Average Month–Day Sunset Time | Average Month–Day Duration of Solar Availability (h) | Average Month–Day Global Solar Radiation (kWh/m²/day) |
|---------|--------------------------------|------------------------------|------------------------------------------------------|------------------------------------------------------|
| January | 5:18:00 AM                     | 7:22:00 PM                   | 14.17                                                | 6.90                                                 |
| February| 5:47:00 AM                     | 7:02:00 PM                   | 13.46                                                | 5.80                                                 |
| March   | 6:10:00 AM                     | 6:29:00 PM                   | 12.56                                                | 5.00                                                 |
| April   | 6:32:00 AM                     | 5:47:00 PM                   | 11.50                                                | 3.80                                                 |
| May     | 6:54:00 AM                     | 5:20:00 PM                   | 11.02                                                | 3.60                                                 |
| June    | 7:11:00 AM                     | 5:11:00 PM                   | 10.06                                                | 3.20                                                 |
| July    | 7:11:00 AM                     | 5:22:00 PM                   | 10.10                                                | 3.30                                                 |
| August  | 6:48:00 AM                     | 5:44:00 PM                   | 10.73                                                | 3.50                                                 |
| September | 6:10:00 AM                   | 6:02:00 PM                   | 11.64                                                | 5.30                                                 |
| October | 5:30:00 AM                     | 6:23:00 PM                   | 12.65                                                | 5.75                                                 |
| November| 5:01:00 AM                     | 6:49:00 PM                   | 13.44                                                | 6.70                                                 |
| December| 4:57:00 AM                     | 7:15:00 PM                   | 14.23                                                | 6.65                                                 |

### 5. Conclusions

Dimbaza has a favourable ambient temperature and global solar radiation that are suitable for the installing of SWHs in residences. It was determined that the annual average month–day ambient temperature was about 18 °C and the annual average global solar radiation was 4.96 kWh/m²/day. The annual average month–day duration of sunshine in Dimbaza was 12.3 h and the dominant energy source used in the residences was electricity from the Eskom grid. Despite the significant level of awareness (60%) of the adverse impact due to electricity from the Eskom national grid that was utilized in the homes, the uptake of the installation of the SWHs was low due to the low-income level of the people. The electricity consumed by the household for the purpose of sanitary hot-water heating
contributed to 46% of the monthly electricity bill. The simple payback period from the case study, from the potential replacement of a 200 L, 4 kW high-pressure electric water heater with a 200 L high-pressure SWH combined with a 2 kW auxiliary water heater, was 5.02 years. The payback period would be lower when calculated based on net present value of money. The net present value considers both the annual internal rate and the electricity tariff hike. The electricity savings are likely to increase when the volume of hot-water consumption increases and the period of hot water used coincides with available solar irradiance. Finally, the SWH technology would be economically and environmentally viable upon rollout in the households in Dimbaza.

The findings of this study must be seen in the light of some limitations. This study was not experimental, and, therefore, the 46% energy saving was a theoretical assumption, but it was supported by the literature with the reference cited in this paper. The assumption may affect the results in the study if the actual experimental results, upon implementation of the solar water heater, produce electricity savings different from the assumed figure. The difference will be of no significance that will nullify the articulated economic and environmental benefits of solar water heaters due to the findings obtained from the feasibility study of the solar resource assessment in Dimbaza.

Additionally, since Dimbaza has not yet rolled out solar water heaters, not being able to choose a household where the researchers could conduct an experiment and collect raw data from a SWH system was a major limitation.

So, this study recommends that more households are to be included in the survey and the walk-through energy audits to obtain a fair representation of the entire population and to cover a wide range of the entire population. Hence, conducting more surveys in other wards is imperative but was limited in this study due to a lack of funds. Additionally, going forward, an actual experiment will be conducted to monitor the performance of both electric water heaters (before the installation of a SWH) and solar water heaters (after installation) in one of the sampling houses.

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**Appendix A. A Template of a Questionnaire Used to Collect Data in Low Income Residences in Dimbaza**

The following interview questions will be aimed at low-income households in Dimbaza that already have electric water heaters with the potential to use a SHW (it is assumed that all participants are connected to the national electricity grid). The questions in the questionnaire focused on background, electricity consumption, knowledge on SWHs, etc.

| Date | Interviewee |
|------|-------------|

**Appendix A.1. Questions for the Questionnaire**

The questionnaire structured to produce information on patterns of energy consumption was designed to be administered to low-income households with electric water heaters in the area. The questionnaire and interview questions were subdivided into structured questions, and open-ended with unstructured responses where results would be inter-
interpreted and described in a participant’s point of view with contextual descriptions and direct quotations from research participants.

- What is the mode of hot water heating (electricity, LPG, Biodigester, wood etc)
- Number of inhabitants per household?
- Is the household employed, self-employed, unemployed, kids grant or old age grant?
- Total monthly income?
- Amount of money spent on electricity monthly
- Source of energy for lighting, cooking and heating water?
- Does the house have an installed and operating electric water heater (yes or no)
- What is the size of the electric water heater (50, 100, 150, 200 l)
- How many periods of a day, hot water is likely to be used (1, 2, 3)
- Does your house have installed SWH?
- Benefits of using SWH?
- Do you think it installation of SWH would reduce your monthly electric cost?
- Do you think the use of SWH would have a positive impact on you economically, environmentally and socially?
- What time is SWH most efficient to provide hot water?
- What time do SWH reach maximum hot water temperature?
- Volume of Hot water used daily?
- What is the household’s alternative method to heat water?
- What time of the day do the households use hot water mostly?
- Best months for SWH efficiency?
- Percentage of hot water availability from the winter months?

Appendix A.2. Awareness of Environmental Impact

(i) The correct identification of the primary source of electricity utilized by Eskom for the generation of baseload from the list of provided answers? (a) Hydro energy (b) Solar PV energy (c) Coal thermal energy (d) Nuclear energy (c) Wind energy

(ii) The baseload electricity from Eskom national grid can be classified as (a) Eco-friendly energy (b) Clean energy (c) Renewable energy (d) Conventional energy (e) None of the above

(iii) Pick the correct answer, Eskom’s baseload electricity is a major contributor to the factors responsible to climate change in South Africa (a) True (b) False (c) Neither a or b is correct (d) a and b are correct

(iv) A main environmental impact due to generation of the Eskom’s base load electricity (a) emission of greenhouse gasses (b) emission of oxygen (c) emission of hydrocarbon (d) emission of background radiation (e) None are correct

(v) The lifespan of human beings can be shortening significantly as result of exposure to the greenhouse gasses emitted from coal thermal power plants (a) True (b) False

Appendix B. Theoretical and Simplified Equation

The theoretical and simplified equation of the electricity saving (based on the 46% of electricity saved due to hot-water heating by replacing the existing electric water heater with a solar water heater with an auxiliary electric heater) is the difference in electricity consumed from the electric water heater and the solar water heater with an auxiliary electric heater when both are of the same tank size, and is given by the Equation

\[ E_{\text{save}} = E_{\text{EWH}} - E_{\text{SWH}} \]

and

\[ E_{\text{SWH}} = E_{\text{ESWH}} = 0.54 \times E_{\text{EWH}} \]

where \( E_{\text{save}} \) = electricity saved, \( E_{\text{EWH}} \) = electricity consumed by the electric water heater, \( E_{\text{SWH}} \) = electricity consumed by the solar water heater with an auxiliary electric heater,
and $E_{SWH}$ = electricity consumed by the auxiliary electric heater contained in the solar water heater.

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