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# EXPLORING THE FEASIBILITY OF CLIMATE CONTROL IN BUILDING USING GEOTHERMAL ENERGY IN KADUNA, NIGERIA

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***Abstract:***

*Globally, climate control in buildings, both residential and commercial, represents a very significant percentage of total electricity consumption. Given that to date the bulk of this energy is from fossil fuels, any technology that is able to reduce this consumption will contribute in no small measure to the reduction of Green House Gases emission into the atmosphere which contributes to global warming. This research work seeks to determine the Geothermal temperature profile of Kaduna up to a depth of 10m to obtain the necessary data required to design climate control systems for residential and commercial buildings, that do not require phase change and use 80% less energy than conventional air-conditioning. In this work, the analyses of soil temperature at fifth depth (1m, 2m, 4m, 6m and 10m) for a well were simulated in MATLAB software. The work shows that the temperature at 7m above becomes constant, which means thermal heat can be harness for effective use in households and other buildings.*

***Keywords:*** *Climate control, Geothermal, Temperature, energy and utilization*

## Introduction

Utilization of Geothermal Energy systems nowadays has developed interest to the researchers as well as industrial used. A heat pump is a device which used to extract heat from the ground surface for the utilization of heat to the teeming population in the world. However, earth tube heat exchangers are used for space heating, space cooling and domestic hot water. Heat can also be transferred between and mediums that have temperature differences, in respective of how these differences were, but bigger ones allow higher performance of such process. Heat pump may be use in shallow ground of a source of heat transfer for both heating and cooling that flows in any underground either horizontally or vertically buried in a well or boreholes, which took advantage of seasonal temperature variations. Currently about 90% of the electrical energy generated and distributed in Nigeria is consumed in households, while Air-conditioning loads in residential and commercial buildings accounts for well over 70% of the overall energy consumption of such buildings with the conventional air conditioning equipment involving phase change. Currently, nearly 100% of buildings use this type of technology. The Geothermal properties of most locations on earth, within a few meters (>=10m) below the earth surface present a fairly constant temperature that could be utilized for climate control in buildings. The technology required to utilize this property uses about 70-80% less energy than conventional systems[1]. The aim of this Research and Development activity is to investigate the Geo-thermal characteristics of Kaduna to a depth of up to 10m depth.

## Ground Temperature

The properties of soil that determine its response to temperature changes at the surface are volumetric heat capacity, which is given as $C_v$, and thermal conductivity, **K** and water content [3]. Heat pump can be sized with the required knowledge of minimum and maximum ground temperature depth. The distributed ground temperature $T_g$, with its unit in $^0C$ can be evaluated using

$$T_g(z,t) = T_a + A_0 e^{-\frac{z}{d}} \sin\left[\frac{2\pi(t-t_0)}{365} - \frac{z}{d} - \frac{\pi}{2}\right] \quad (1)$$

Where, $T_g(z,t)$ is the soil temperature at **t** (day) with the depth of $z(m)$, $T_a$ is the average ambient temperature in degree centigrade $(^0C)$, and $A_0$ is the annual amplitude of the surface soil temperature $(^0C)$ that can be calculated as follows:

$$A_0 = \frac{1}{2}(T_{max} - T_{min}) \quad (2)$$

Here **d** is the damping depth (m) of the fluctuation annually and $t_0$ is the time lag (days) from the starting date of the research work (i. e. January 1, 2020) to the occurrence of the minimum temperature in a year. However, the damping depth is calculated as:

$$d = \left(\frac{2\alpha}{\gamma}\right)^{\frac{1}{2}} \quad (3)$$

Where $\alpha$ is the thermal diffusivity and $\gamma = \frac{2\pi}{365}\left(d^{-1}\right)$ so, thermal diffusivity is also computed as:

$$\alpha = \frac{K}{C_p \rho} \tag{4}$$

Here $\alpha$ is the thermal diffusivility ($m^2$/day), K is the thermal conductivity (W/m $^0$K), $C_p$ is the specific heat (J/Kg. $^0$K) and ρ is the density (Kg/$m^3$). Below equations is used to determine the thermal properties as shown in equation (5). Here, for silt and clay soils, the thermal conductivity is evaluated as:

$$K = 0.14423\left(0.9\log(w) - 0.2\right)10^{0.000642\rho d} \tag{5}$$

Where **w** is the water content (i.e moisture) in the soil, $\rho d$ is the dry density of the soil. Now, for a sand soil K is given by:

$$K = 0.14423\left(0.7\log(w) + 0.4\right)10^{0.000642\rho d} \tag{6}$$

The corrected specific heat of soil is given by:

$$C_p = \frac{\left[wC_{pw} + \left(100 - w\right)C_{pd}\right]}{100} \tag{7}$$

Where, $C_{pw}$ is the specific heat of water (4180J/Kg. $^0$K) and $C_{pd}$ is the soil dry specific heat (840J/Kg.$^0$K) and therefore, the corrected density of the soil is given as:

$$\rho = \frac{\left[w\rho_w + \left(100 - w\right)\right]\rho_d}{100} \tag{8}$$

Now, by using equation (4) and (8), the physical properties of the soil for the research well were computed as shown in Table 1 below:

**Table 1: Physical properties of the soil**

| | |
|---|---|
| **Water content (Moisture) (%)** | **44** |
| **Thermal Conductivity (W/m.K)** | **1.8** |
| **Dry Specific heat (J/Kg.K)** | **840** |
| **Specific Heat (J/Kg.K)** | **2209.6** |
| **Density (Kg/$m^3$)** | **1450** |
| **Thermal Diffusivity ($m^2$/day)** | **0.042** |

However, the Mean monthly maximum and minimum ambient temperature data which was taken for an average of one year is summarized in Table 2. (January – November, 2020).

**Table 2: Temperature in Kaduna for (January - December 2020)**

| Temperature °C | Jan | Feb | Mar | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. °C | 23.6 | 25 | 27.4 | 28.6 | 27 | 25.4 | 24.2 | 23.3 | 24.4 | 25.4 | 24.4 | 23.4 |
| Min. °C | 15.4 | 16.6 | 19.7 | 22.2 | 22.2 | 20.6 | 20.1 | 19.5 | 19.5 | 19 | 16.1 | 14.5 |
| Max. °C | 31.9 | 33.4 | 35.1 | 35.1 | 31.9 | 30.2 | 28.4 | 27.2 | 29.4 | 31.6 | 32.7 | 32.3 |
| Avg. °F | 74.5 | 77.0 | 81.3 | 83.5 | 80.6 | 77.7 | 75.6 | 73.9 | 75.9 | 77.7 | 75.9 | 74.1 |
| Min. °F | 59.7 | 61.9 | 67.5 | 72.0 | 72.0 | 69.1 | 68.2 | 67.1 | 67.1 | 66.2 | 61.0 | 58.1 |
| Max. °F | 89.4 | 92.1 | 95.2 | 95.2 | 89.4 | 86.4 | 83.1 | 81.0 | 84.9 | 89.2 | 90.9 | 90.1 |
| Precipitation/ Rainfall(mm) | 0 | 2 | 9 | 61 | 130 | 166 | 219 | 284 | 256 | 80 | 4 | 0 |

**Results:**

The various results obtained are:

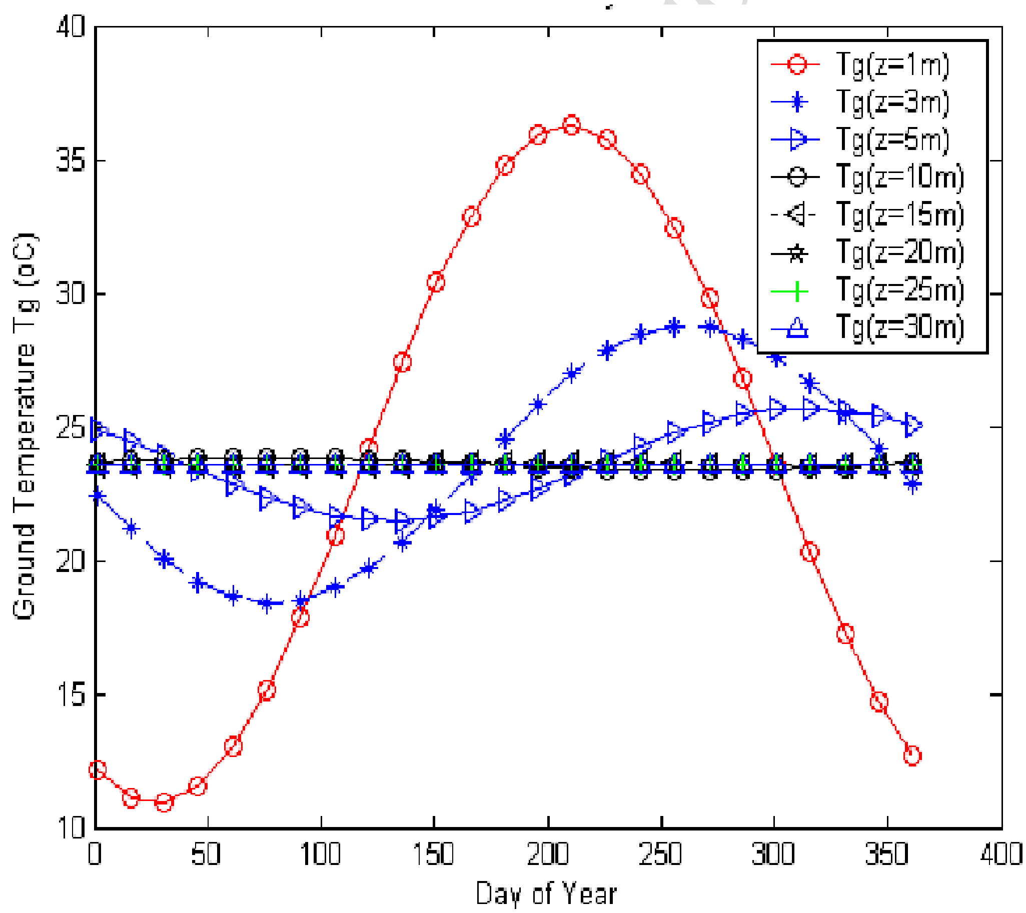


**Figure 1**: Distribution of Soil Temperature for one year for different depth level.

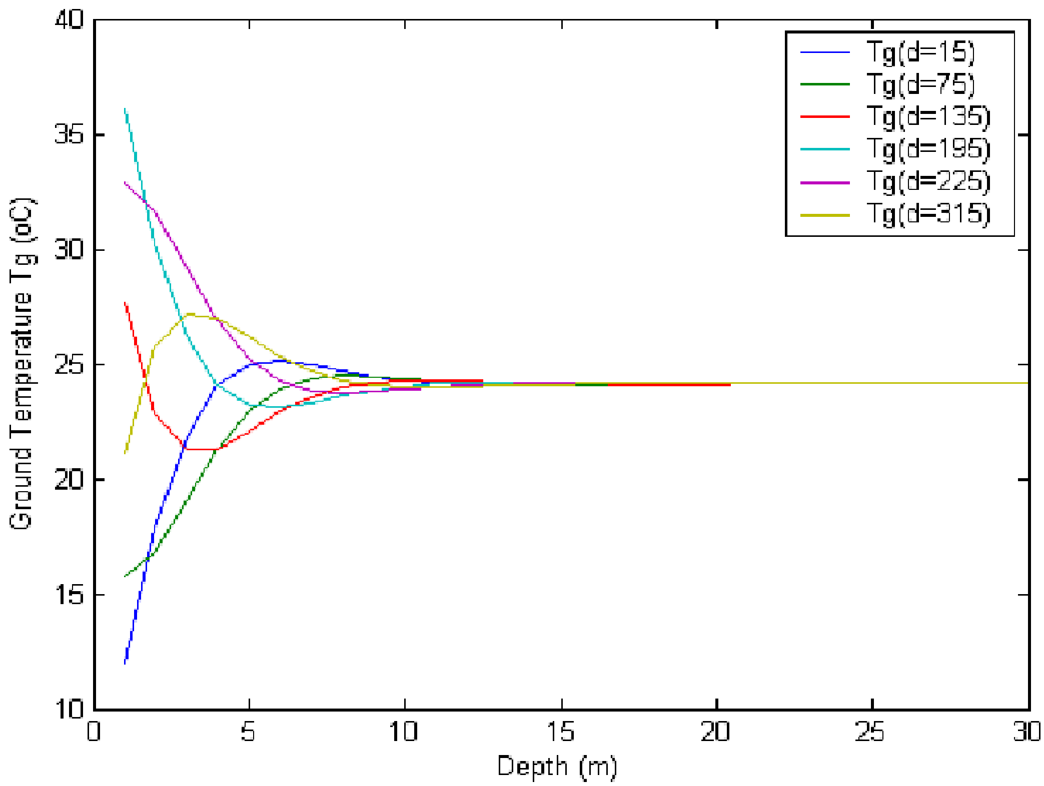


**Figure 2**: Soil Temperature distribution with the depth for days

**Discussions of Results**

Figure 1. Shows the temperature distribution for one year for five depths (1m, 2m, 4m, 6m, and 15m) respectively. Where the average temperature varies from 9 $^{0}$C minimum in the month of January to maximum of about 36 $^{0}$C in August 2020, therefore, an amplitude fluctuation of 14 $^{0}$C was observed which is half of the difference in temperature between maximum and minimum. So, at 1m depth the temperature varies from 12 $^{0}$C to about 36 $^{0}$C. This means the amplitude has reduced to 12 $^{0}$C. However, at 4m interval, the temperature reached almost to September. Also at 4m, later it shifted further to the right side of the temperature scale, which means fluctuations vanishes rapidly with the depth (i.e 6m beyond), such that the temperature above 10m seems to remains constant. In the same vein, the Amplitudes of annual wave also diminish with the variation of the depth. The average soil temperature is expected to be the same to the mean air temperature. Figure 2. Depicts the well soil temperature distribution as a function of depth for the selected days from year. From Figure 2, at the depth of 13m the temperature becomes constant to the beyond, which means heat can be harness for heating and cooling purposes.

## Conclusion

This paper presents exploring the Feasibility of Climate Control in Building using Geothermal Energy in Kaduna, Nigeria. The research work shows the importance of utilizing heat flow from the ground which can be harness for households' purposes. However, the research work has shown the feasibility of using heat pumps for cooling and heating both offices and other residential use. The temperature becomes constant along year at depth of 7m, 8m and 10m beyond. It can be concluded that heat at ground level of a boreholes or wells can be utilize for general heating and cooling purposes.

## Recommendations

The results of the research work had shown the viability of harnessing heat at some depth of a bore hall or wells for easy heating and cooling of household and commercials residences. The following are recommended for future work:

1. Heat pump can be design and utilize to extract heat flow for household heating and cooling purposes.
2. Apart from heat pump utilization, a geothermal heat exchanger (GHE) can also be use to extract or inject heat from/into the ground for considerate heating or cooling purposes.

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