# Comparative Study on Energy Consumption at the University of Johannesburg Residences

Olusola O. Ayeleru, Joshua A. Adeniran, Sula Ntsaluba and J. J. de Koker

**Abstract—**This study evaluates the pattern of energy usage at the twenty-eight residences of the University of Johannesburg during the 2016 academic year. The study investigates the trend of energy consumption based on total energy usage per residence in terms of the number of students at each of the residences on a monthly and daily basis. The data employed in this study were collected over a period of eleven months which is the overall effective academic calendar. The results obtained showed a contrast between the total energy usage per residence and energy usage per student. Sophia town residence recorded the highest total annual energy usage of 149286 kWh while Takalani residence recorded the least which was 97093 kWh of all the residences considered in this study. However, when energy consumption was measured as a function of number of students in each residence, Goudstad residence recorded the highest monthly energy usage per student (450.69 kWh), followed by YMCA (389.09 kWh) while the least monthly energy usage of 51.30 kWh was recorded in Maqhawe residence. Similarly, results obtained from the study on daily energy usage per student in the last five months of the 2016 academic year showed Goudstad residence (23.32 kWh) and YMCA (20.34) as the two residences with the highest daily energy usage per student respectively. However, the energy usage does not follow a regular pattern within the period under consideration.

***Index Terms*—Energy usage, University of Johannesburg, Residences, South Africa**

## 1 INTRODUCTION

The increasing pressure on energy has become an issue of global concern [1]. This necessitates a reduction in energy consumption from all sectors of the economy, if sustainability would be achieved [2]. A sustainable energy system is that in which energy needs is provided for the present generation without compromising the ability of future generations to satisfy their own energy needs [3]. The sectors of the economy where reduction in energy consumption become very paramount include the residential, commercial, industrial, electric power and transportation [4],[5]. A study has shown that buildings contribute about 33% of GHG emissions across the globe when fossil fuels are used [6]. Recent study has also shown that the residential and commercial sectors which comprise of homes and buildings accounted for about 12% of the energy consumption somewhere around the world [5]. Energy consumption at the residential sector is grouped into four and this comprises of lighting, heating, cooling and other household appliances [7]. The crucial parameters that are needed to evaluate the changes in electricity consumption are the economic drivers, demand side management and technologies [8].

In many nations of the world, governments are continuously aware of the need to utilize energy efficiently. Energy efficiency is the amount of useful energy obtained from a system [9]. It is also the most cost-effective means to improve energy security and reduce emission of greenhouse gases (GHGs) to the environment [10],[11]. Energy efficiency is a core of a low-carbon economy [12]. When energy usage is reduced, energy bills also reduce, thus making energy system more sustainable and emission of GHGs reduce drastically [13],[14]. High energy usage poses environmental challenge which results to emission of gases which comprise of carbon dioxide ($CO_2$), methane ($CH_4$) and nitrogen oxide (NO) [15]. Emissions of carbon dioxide ($CO_2$) to the environment contribute greatly to global climate change [16]. Climate change reduces the quality of air in the urban areas and it also impact the marine environment negatively [17],[18]. Climate change and global warming are interdependent [19]. Global warming is the rise in the average temperature on the surface of the earth. As the temperature of the earth increases, various disasters also increase. Global warming is the cause of these disasters and climate change is the effect it poses on the earth surface [20]. Global warming may also aggravate the negative impacts on the growth of plants through the spreading of pests and diseases [21].

All over the world, energy is crucial to economic development [22],[23]. Energy is taken for granted in South Africa. The reason for this is because people are not educated on the impacts that result from the misused of energy resources and also the benefits that ensue from energy efficiency. Energy efficiency can only be achieved when people are properly educated [24]. Oftentimes, energy usage is not visible to the user, hence people do not

O.O. Ayeleru, Department of Chemical Engineering, Doornfontein Campus, University of Johannesburg, P O Box 254, Johannesburg 2094, South Africa (e-mail: olusolaolt@gmail.com).

J. A. Adeniran is with Department of Mechanical Engineering Science, University of Johannesburg, Auckland Park Campus 2006, South Africa (e-mail: nikjocrown2000@yahoo.com).

N. Sula, Project Manager (University of Johannesburg Sustainability Program), Faculty of Engineering and Built Environment (e-mail: sulan@uj.ac.za).

J.J. de Koker, Director Sustainable Energy Technology and Research Centre (SeTAR), Faculty of Engineering and the Built Environment University of Johannesburg, South Africa (e-mail:johandk@uj.ac.za).

really realize the impact that their actions are making on the environment and how their activities can affect the future generation from meeting their own energy needs. Therefore, it becomes very imperative that energy usage be made visible to users so that there can be attitudinal changes [25].

A detailed study on the pattern of energy consumption is very crucial in order to assist the policy makers and other stakeholders in the energy sectors on how to devise various intervention mechanisms to ensure responsible usage of energy resources. Energy consumption data may be available on a broader scale, for example; in the municipalities, cities or counties. It is also very pertinent to make energy consumption data available at the institutional levels. A careful study on energy usage pattern on a smaller or fragmented scale will provide better insights on the trend of energy consumption within an institution. Also, this will provide a sustainable approach to energy reduction plans. Additionally, this will ensure that energy efficiency is achieved at both the residential and commercial sectors [26],[27].

Furthermore, in South Africa, the bulk of the energy generation is obtained from coal fire power plants , which is known to be a high emitter of greenhouse gases [28].

This paper aims to compare the amount of energy consumptions among the University of Johannesburg Students' Residences.

## 2 DESCRIPTION OF THE STUDY AREA

Johannesburg is one of the cities across the globe that is not situated on coast and not on any major river. It is often referred to as the City of Johannesburg (CoJ). It is located in Gauteng province (GP) in the eastern plateau of South Africa (SA). It occupied a height of approximately 1,753 m. Johannesburg was formerly decentralized into 11 regions but currently, it has been merged and the results of the merger has reduced it into 7 regions. The regions consist of Regions A to G.

The current population of Johannesburg is about 4.4 million which is about 36% of the population of Gauteng and approximately about 8% of the total population of SA. The University of Johannesburg is located in Johannesburg and it is one of the residential universities in SA. It was founded in 2005 following the merger that took place among the Rand Afrikaans University (RAU), the Technikon Witwatersrand (TWR) and the Soweto and East Rand campuses of Vista University. It comprises of four campuses. All of these four campuses are widely spread across the city. The campuses are Auckland Park Kingsway which is the main campus followed by Auckland Park Bunting Road, Doornfontein and Soweto. The staff and students of the university came from more than 50 nations of the African continent and also from other nations across the globe [29], [30], [31].

## 3 METHODOLOGY

Remote data loggers (RDLs) were connected to the meters situated at the student residences. The RDL records data of energy usage at each of these residences. Data were collected and uploaded into software known as Metering Online. With the aid of the Metering Online, data for the energy consumptions were generated for each of the residences. The name of the company that owns the software is known as Power Meter Technique. The data for the number of the students who resided at each of the residences were obtained from the management of the University of Johannesburg Student Accommodation and Residence Life. These data were analysed and the results obtained were represented both in tabular forms and graphically.

## 4 RESULTS AND DISCUSSIONS

The results of the data obtained from the analysis carried out using Metering Online are represented in tabular and graphical forms as follows;

### 4.1 Daily energy usage per student

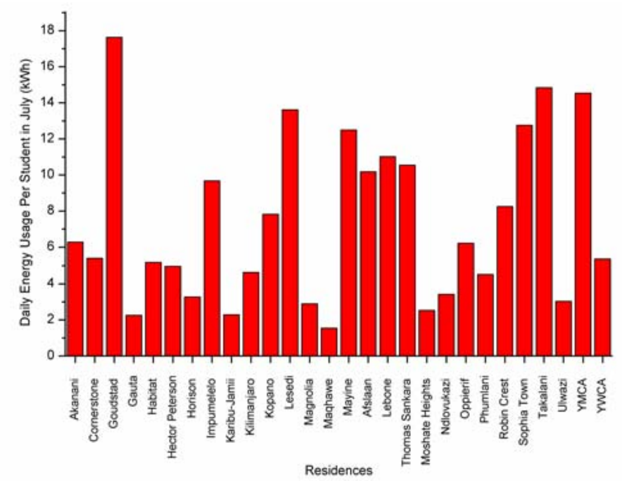


Fig. 1. Daily energy usage per student in July (kWh)

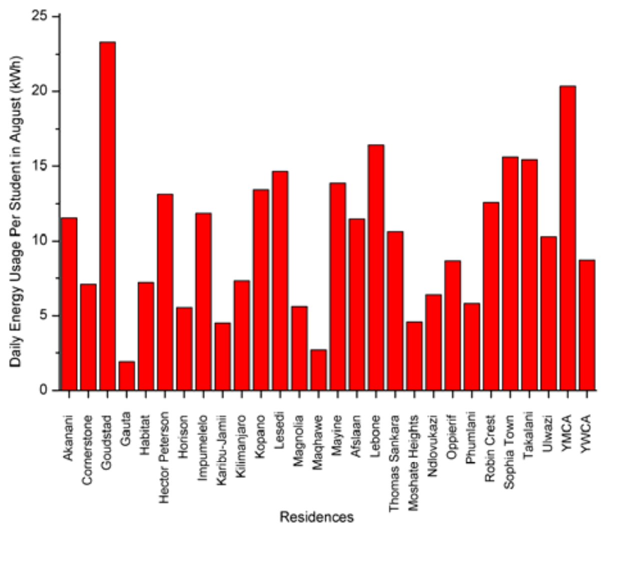

Fig. 2. Daily energy usage per student in August (kWh)

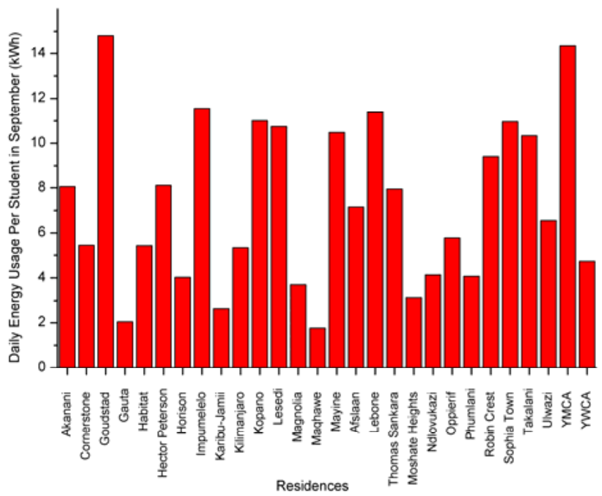


Fig. 3. Daily energy usage per student in September (kWh)

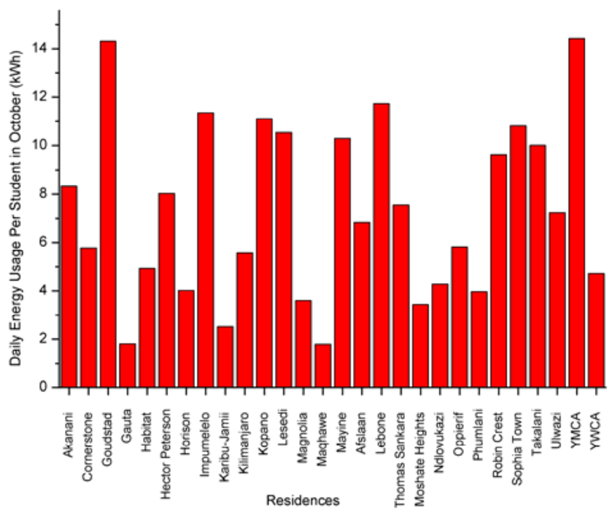


Fig. 4. Daily energy usage per student in October (kWh)

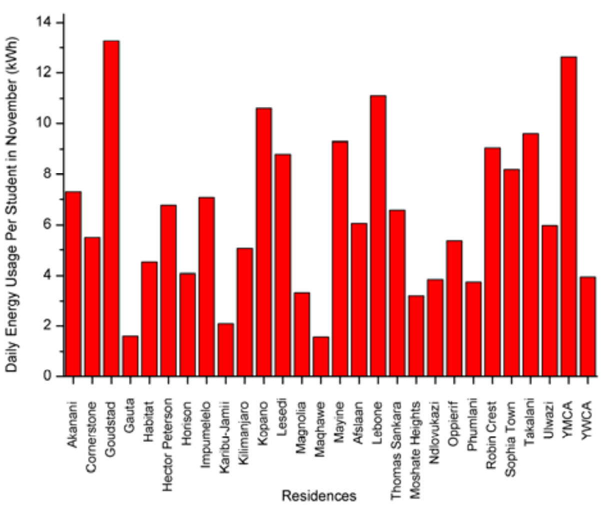


Fig. 5. Daily energy usage per student in November (kWh)

The last five months of the academic session were chosen being the winter period. Winter season normally starts around June every year but it is always at the peak around July and some periods in August. Additionally, it is also the second semester period of an academic calendar when students will be very busy period with various activities. Thus, energy consumptions by the students will be very high at this period since more electricity will be consumed.

Figure 1 to Figure 5 showed the daily energy usage per student in the month of July to November 2016 from all the residences. During the month of July (Figure 1), it was observed that Goudstad accounted for the highest energy consumption of 17.63 kWh while Maqhawe occupied the least energy consumption of 1.54 kWh. Furthermore, during the month of August (Figure 2), Goudstad occupied the highest energy consumption of 23.32 kWh while Gauta accounted for the least energy consumption of 1.90 kWh. Figure 3 showed the energy consumption during the month of September. It was observed that Goudstad maintained the highest energy consumption of 14.82 kWh while Maqhawe also occupied the least energy consumption of 1.76 kWh. During the month of October (Figure 4), Goudstad still maintained the highest position in the amount of energy consumption of 14.32 kWh and Maqhawe accounted for the least with 1.79 kWh. Finally, for the month of November (Figure 5), Goudstad accounted for the energy usage of 13.28 kWh while Maqhawe maintained the lowest energy usage of 1.56 kWh.

It was observed that the total number of 62 students who resided at Goudstad did not correspond to the amount of energy usage at that residence since Maqhawe where 244 students resided used less energy. Gauta accommodated 233 students and less energy was used compared to Goudstad. This clearly shows that there was energy wastage in Goudstad and some other residences. It therefore calls for proper educating the students on the need to reduce their energy consumptions.

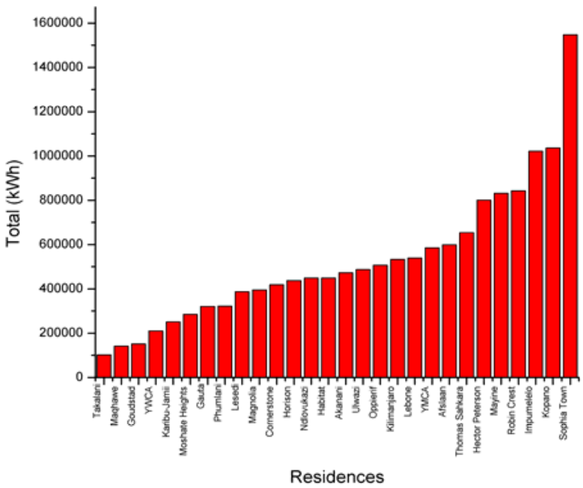


Fig. 6. Year to date residences energy usage (kWh)

Figure 6 showed the overall energy usage for the whole year. Sophia Town occupied the highest with 149286 kWh while Takalani residence recorded the least of 97093 kWh.

## 4.2 Energy Usage Per Quarter

Table I. Energy Usage in First Quarter of 2016

| Residences | Energy Usage (1st Quarter), kwh | | | Quarterly Average |
|---|---|---|---|---|
| | January | February | March | |
| Akanani | 11 855.000 | 26 814.000 | 34 359.000 | 24342.67 |
| Cornerstone | 12 983.000 | 25 199.000 | 31 378.000 | 23186.67 |
| Goudstad | 7 793.000 | 16 807.000 | 22 649.000 | 15749.67 |
| Gauta | 6 458.000 | 7 705.000 | 10 534.000 | 8232.33 |
| Habitat | 4 773.000 | 4 741.000 | 19 115.000 | 9543.00 |
| Hector Peterson | 11 044.000 | 47 366.000 | 57 143.000 | 38517.67 |
| Horison | 12 504.000 | 26 052.000 | 32 690.000 | 23748.67 |
| Impumelelo | 51 509.000 | 72 648.000 | 85 394.000 | 69850.33 |
| Karibu-Jamii | 1 686.000 | 12 326.000 | 16 817.000 | 10276.33 |
| Kilimanjaro Transformer | 17 576.000 | 35 126.000 | 41 351.000 | 31351.00 |
| Kopano | 31 591.000 | 59 505.000 | 82 063.000 | 57719.67 |
| Lesedi | 12 707.000 | 22 093.000 | 27 206.000 | 20668.67 |
| Magnolia | 6 986.000 | 30 347.000 | 40 872.000 | 26068.33 |
| Maqhawe | 1 843.000 | 7 985.000 | 10 451.000 | 6759.67 |
| Mayine | 31 507.000 | 49 933.000 | 62 289.000 | 47909.67 |
| Afslaan | 12 826.000 | 30 514.000 | 39 442.000 | 27594.00 |
| Lebone | 17 739.000 | 32 835.000 | 42 627.000 | 31067.00 |
| Thomas Sankara | 28 802.000 | 38 995.000 | 49 066.000 | 38954.33 |
| Moshate Heights | 6 354.000 | 16 312.000 | 22 540.000 | 15068.67 |
| Ndlovukazi | 10 059.000 | 27 135.000 | 33 462.000 | 23552.00 |
| Oppierif | 20 396.000 | 33 868.000 | 41 704.000 | 31989.33 |
| Phumlani | 13 816.000 | 20 463.000 | 24 581.000 | 19620.00 |
| Robin Crest | 23 214.000 | 48 557.000 | 60 784.000 | 44185.00 |
| Sophia Town | 57 793.000 | 95 805.000 | 119 528.000 | 91042.00 |
| Takalani | 3 204.000 | 4 831.000 | 6 972.030 | 5002.34 |
| Ulwazi Residence | 35 370.000 | 35 370.000 | 35 370.000 | 35370.00 |
| YMCA | 16 561.000 | 28 038.000 | 43 458.000 | 29352.33 |
| YWCA | 6 733.000 | 11 519.000 | 13 471.000 | 10574.33 |

Table II. Energy Usage in Second Quarter of 2016

| Residences | Energy Usage (2nd Quarter), kwh | | | Quarterly Average |
|---|---|---|---|---|
| | April | May | June | |
| Akanani | 42 451.000 | 65 819.000 | 49 371.000 | 52547.00 |
| Cornerstone | 36 370.000 | 56 669.000 | 40 280.000 | 44439.67 |
| Goudstad | 26 529.000 | 42 028.000 | 36 511.000 | 35022.67 |
| Gauta | 12 917.000 | 19 432.000 | 22 095.000 | 18148.00 |
| Habitat | 18 948.000 | 52 406.000 | 55 123.000 | 42159.00 |
| Hector Peterson | 74 107.000 | 123 331.000 | 77 590.000 | 91676.00 |
| Horison | 38 673.000 | 62 101.000 | 43 570.000 | 48114.67 |
| Impumelelo | 96 298.000 | 134 055.000 | 110 601.000 | 113651.33 |
| Karibu-Jamii | 23 541.000 | 42 179.000 | 25 398.000 | 30372.67 |
| Kilimanjaro Transformer 1 | 44 645.000 | 64 903.000 | 49 529.000 | 53025.67 |
| Kopano | 93 414.000 | 123 603.000 | 96 566.000 | 104527.67 |
| Lesedi | 31 168.000 | 45 224.000 | 43 960.000 | 40117.33 |
| Magnolia | 48 452.000 | 74 326.000 | 29 545.000 | 50774.33 |
| Maqhawe | 12 810.000 | 21 938.000 | 14 261.000 | 16336.33 |
| Mayine | 69 903.000 | 97 698.000 | 88 342.000 | 85314.33 |
| Afslaan | 46 224.000 | 81 111.000 | 76 945.000 | 68093.33 |
| Lebone | 48 072.000 | 66 505.000 | 51 991.000 | 55522.67 |
| Thomas Sankara | 52 420.000 | 76 250.000 | 74 775.000 | 67815.00 |
| Moshate Heights | 24 653.000 | 42 662.000 | 25 707.000 | 31007.33 |
| Ndlovukazi | 39 212.000 | 64 981.000 | 41 104.000 | 48432.33 |
| Oppierif | 47 591.000 | 70 893.000 | 50 711.000 | 56398.33 |
| Phumlani | 27 870.000 | 39 728.000 | 34 179.000 | 33925.67 |
| Robin Crest | 71 969.000 | 104 460.000 | 90 246.000 | 88891.67 |
| Sophia Town | 140 550.000 | 196 967.000 | 153 669.000 | 163728.67 |
| Takalani | 8 109.000 | 12 182.000 | 11 199.000 | 10496.67 |
| Ulwazi Residence | 35 370.000 | 35 370.000 | 545.000 | 23761.67 |
| YMCA | 50 193.000 | 70 311.000 | 62 438.000 | 60980.67 |
| YWCA | 17 246.000 | 31 405.000 | 25 256.000 | 24635.67 |

Table III. Energy Usage in Third Quarter of 2016

| Residences | Energy Usage (3rd Quarter), kwh | | | Quarterly Average |
|---|---|---|---|---|
| | July | August | September | |
| Akanani | 34 648.000 | 63 651.000 | 44 467.320 | 142 766.320 |
| Cornerstone | 37 056.000 | 48 446.000 | 37 204.250 | 122 706.250 |
| Goudstad | 32 791.000 | 43 368.000 | 27 554.100 | 103 713.100 |
| Gauta | 15 781.000 | 13 279.000 | 14 229.620 | 43 289.620 |
| Habitat | 51 720.000 | 71 673.000 | 53 976.000 | 177 369.000 |
| Hector Peterson | 46 699.000 | 123 402.000 | 76 230.300 | 246 331.300 |
| Horison | 32 386.000 | 54 943.000 | 39 895.120 | 127 224.120 |
| Impumelelo | 82 070.000 | 100 656.000 | 98 058.040 | 280 784.040 |
| Karibu-Jamii | 20 226.000 | 39 766.000 | 23 110.750 | 83 102.750 |
| Kilimanjaro Transformer 1 | 43 104.000 | 68 032.000 | 49 551.520 | 160 687.520 |
| Kopano | 73 390.000 | 126 296.000 | 103 413.900 | 303 099.900 |
| Lesedi | 42 862.000 | 46 258.000 | 33 824.880 | 122 944.880 |
| Magnolia | 23 792.000 | 46 275.000 | 30 432.730 | 100 499.730 |
| Maqhawe | 11 281.000 | 19 753.000 | 12 898.280 | 43 932.280 |
| Mayine | 89 175.000 | 97 777.000 | 74 857.950 | 261 809.950 |
| Afslaan | 72 368.000 | 81 572.000 | 50 844.160 | 204 784.160 |
| Lebone | 47 592.000 | 70 953.000 | 49 159.360 | 167 704.360 |
| Thomas Sankara | 75 859.000 | 76 365.000 | 57 211.200 | 209 435.200 |
| Moshate Heights | 20 715.000 | 37 470.000 | 25 613.040 | 83 798.040 |
| Ndlovukazi | 33 905.000 | 63 071.000 | 40 976.720 | 137 952.720 |
| Oppierif | 42 187.000 | 58 689.000 | 39 318.000 | 140 194.000 |
| Phumlani | 31 181.000 | 40 205.000 | 28 158.700 | 99 544.700 |
| Robin Crest | 70 801.000 | 108 009.000 | 80 766.600 | 259 576.600 |
| Sophia Town | 159 247.000 | 194 898.000 | 136 770.240 | 490 915.240 |
| Takalani | 12 468.000 | 12 972.000 | 8 688.930 | 34 128.930 |
| Ulwazi Residence | 26 383.000 | 89 650.000 | 56 993.420 | 173 026.420 |
| YMCA | 54 962.000 | 76 883.000 | 54 263.880 | 186 108.880 |
| YWCA | 18 714.000 | 30 354.000 | 16 473.360 | 65 541.360 |

Table IV. Energy Usage in Fourth Quarter of 2016

| Residences | Energy Usage (4th Quarter), kwh | | Quarterly Average |
|---|---|---|---|
| | October | November | |
| Akanani | 45 965.000 | 40 302.000 | 43133.5 |
| Cornerstone | 39 537.000 | 37 589.000 | 38563 |
| Goudstad | 26 635.000 | 24 704.000 | 25669.5 |
| Gauta | 12 623.000 | 11 123.000 | 11873 |
| Habitat | 49 151.000 | 45 030.000 | 47090.5 |
| Hector Peterson | 75 378.000 | 63 575.000 | 69476.5 |
| Horison | 39 835.000 | 40 440.000 | 40137.5 |
| Impumelelo | 96 394.000 | 60 065.000 | 78229.5 |
| Karibu-Jamii | 22 262.000 | 18 442.000 | 20352 |
| Kilimanjaro Transformer 1 | 51 804.000 | 47 033.000 | 49418.5 |
| Kopano | 104 204.000 | 99 482.000 | 101843 |
| Lesedi | 33 204.000 | 27 733.000 | 30468.5 |
| Magnolia | 29 602.000 | 27 341.000 | 28471.5 |
| Maqhawe | 13 078.000 | 11 389.000 | 12233.5 |
| Mayine | 73 476.000 | 66 339.000 | 69907.5 |
| Afslaan | 48 647.000 | 43 061.000 | 45854 |
| Lebone | 50 683.000 | 47 974.000 | 49328.5 |
| Thomas Sankara | 54 337.000 | 47 438.000 | 50887.5 |
| Moshate Heights | 28 243.000 | 26 274.000 | 27258.5 |
| Ndlovukazi | 42 421.000 | 38 157.000 | 40289 |
| Oppierif | 39 489.000 | 36 367.000 | 37928 |
| Phumlani | 27 420.000 | 25 871.000 | 26645.5 |
| Robin Crest | 82 597.000 | 77 651.000 | 80124 |
| Sophia Town | 134 896.000 | 102 361.000 | 118628.5 |
| Takalani | 8 411.000 | 8 055.000 | 8233 |
| Ulwazi Residence | 62 972.000 | 51 991.000 | 57481.5 |
| YMCA | 54 548.000 | 47 742.000 | 51145 |
| YWCA | 16 437.000 | 13 745.000 | 15091 |

Table I to Table IV presented the amount of energy consumptions per quarter at each of the residences during the entire academic year of eleven months. The quarterly average for each residence was computed. During the first quarter (Table I), Sophia Town accounted for the highest energy usage of 91,042 kWh followed by Impumelelo with 69,850.33 kWh while Takalani occupied the least energy consumption 5,002.34 kWh. Table II showed the data for the energy consumption during the second quarter. From Table II, it was observed that Sophia Town maintained the highest of 163,728.67 kWh followed by Impumelelo with 113,651.33 kWh while Takalani occupied the least of 10,496.67 kWh. Furthermore, Table III showed the energy usage for the third quarter. Here, Sophia Town still maintained the highest energy usage with 490,915.24 kWh followed by Kopano which accounted for 303,099.90 kWh while Takalani maintained the least energy consumption of 34,128.93 kWh. Finally, during the fourth quarter which comprised of only October and November (Table IV), Sophia Town was still the highest in terms of energy consumption with 118,628.50 kWh followed by Impumelelo with 78,229.50 kWh while Gauta accounted for the least energy usage with 11,873.00 kWh.

Table V. Total Number of Students in each Residence

| Residences | Number of students |
|---|---|
| Akanani | 184 |
| Cornerstone | 228 |
| Goudstad | 62 |
| Gauta | 233 |
| Habitat | 332 |
| Hector Peterson | 313 |
| Horison | 330 |
| Impumelelo | 283 |
| Karibu-Jamii | 294 |
| Kilimanjaro Transformer 1 | 310 |
| Kopano | 313 |
| Lesedi | 105 |
| Magnolia | 274 |
| Maqhawe | 244 |
| Mayine | 238 |
| Afslaan | 237 |
| Lebone | 144 |
| Thomas Sankara | 240 |
| Moshate Heights | 273 |
| Ndlovukazi | 330 |
| Oppierif | 226 |
| Phumlani | 230 |
| Robin Crest | 286 |
| Sophia Town | 416 |
| Takalani | 28 |
| Ulwazi | 290 |
| YMCA | 126 |
| YWCA | 116 |

Table V showed the total number of students who resided in each of the twenty-eight residences owned by the University of Johannesburg.

It was observed that throughout the four quarters of 2016, Sophia Town accounted for the highest energy usage, followed by Impumelelo while Takalani occupied the least. However, it was observed that it was not all the residences that their patterns of energy consumption are directly proportional to the number of student occupants in those residences. For instance, Goudstad had only 62 student occupants but it energy usage was always high.

## 5 CONCLUSION

It was concluded that cases of ineffective energy usage might have taken place in some of the residences. A number factors could be responsible for these; among which might be education. The University needs to increase its ongoing education on energy usage by the students in the residences and the effect that high energy usage poses on the environment. It was also observed that the buildings of the residences are different in design and construction. This can also contribute to high energy consumption. When efficient building is taken into consideration during the design and construction of a building, the amount of energy consumption would be reduced, thus, cost would be saved and emissions to the environment would also be minimized. It was also discovered that the residents of the various UJ residences studied different subjects. This may also serve as contributing factors to energy consumption since those who are running programs like Somatology, Sport and Movement Studies, Law etc. spent more time in their residences than those who are studying engineering and sciences. The science and engineering students often spend most of their time in the laboratory conducting experiments. Finally, there are also socio-economic differences among the students who resided at the different residences since these students came from differences places. Hence, it is possible that some came from hot regions, therefore during winter they may not be able to cope with too much cold and this can also contribute to more energy usage.

## 6 RECOMMENDATION

It is recommended that the University of Johannesburg put an incentive model in place in such a way that any residence that uses less energy will be rewarded. Also, the actual energy consumption data for all the residences can be presented to students through a web (U-link) as this will be go a long way to bring about changes in attitudes most especially when students from one residence notice their counterparts from other residences are consuming less energy and they are being rewarded for it. Additionally, an energy representative can be appointed in each of the hall of residences who will be educating and motivating students on the need to achieve energy efficiency so as to have a sustainable university.

## ACKNOWLEDGEMENTS

The authors wish to appreciate the Sustainable Energy Technology and Research Centre (SeTAR) of the University of Johannesburg for the resources provided to complete this project.

## REFERENCES

[1] L. Pérez-Lombard, J. Ortiz, and C. Pout, "A review on buildings energy consumption information," *Energy and buildings,* vol. 40, pp. 394-398, 2008.

[2] S. Sorrell, "Reducing energy demand: A review of issues, challenges and approaches," *Renewable and Sustainable Energy Reviews,* vol. 47, pp. 74-82, 2015.

[3] O. D., H. W., A. K., G. P., J. N., D. S., *et al.*, "Energy policies for sustainable development in South Africa: Options for the future," South Africa2006.

[4] The NEED Project, "Introduction to Energy," ed. Manassas: The NEED Project 2011.

[5] The NEED Project, "Energy Consumption," ed. Manassas: The NEED Project 2016.

[6] UNEP SBCI, "Buildings and climate change: Summary for decision-makers," France2009.

[7] E. Hittinger, K. A. Mullins, and I. L. Azevedo, "Electricity consumption and energy savings potential of video game consoles in the United States," *Energy Efficiency,* vol. 5, pp. 531-545, 2012.

[8] L. M. Platchkov and M. G. Pollitt, "The economics of energy (and electricity) demand," *The Future of Electricity Demand: Customers, Citizens and Loads,* vol. 69, p. 17, 2011.
[9] Kentucky Department of Education College and Career Readiness, Frankfort, KY2011.
[10] The International Energy Agency (IEA), "Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis," France2008.
[11] L. Ryan, S. Moarif, E. Levina, and R. Baron, "Energy Efficiency Policy and Carbon Pricing ", France2011.
[12] W. Prindle, "Energy efficiency as a low-cost resource for achieving carbon emissions reductions," *National Action Plan for Energy Efficiency,* 2009.
[13] Department of Energy and Climate Change, "The energy efficiency strategy: the energy effciency opportunity in the UK," London 2012.
[14] S. Fankhauser, "A practitioner's guide to a low-carbon economy: lessons from the UK," *Climate Policy,* vol. 13, pp. 345-362, 2013.
[15] J. Di Stefano, "Energy efficiency and the environment: the potential for energy efficient lighting to save energy and reduce carbon dioxide emissions at Melbourne University, Australia," *Energy,* vol. 25, pp. 823-839, 2000.
[16] N. J. Pedersen, S. Rosenbloom, and R. E. Skinner, "Policy options for reducing energy use and greenhouse gas emissions from US transportation," *Transportation Research Board Special Report, Transportation Research Board,* vol. 307, 2011.
[17] D. J. Jacob and D. A. Winner, "Effect of climate change on air quality," *Atmospheric environment,* vol. 43, pp. 51-63, 2009.
[18] A. S. Brierley and M. J. Kingsford, "Impacts of climate change on marine organisms and ecosystems," *Current biology,* vol. 19, pp. R602-R614, 2009.
[19] T. P. Hughes, A. H. Baird, D. R. Bellwood, M. Card, S. R. Connolly, C. Folke, *et al.*, "Climate change, human impacts, and the resilience of coral reefs," *science,* vol. 301, pp. 929-933, 2003.
[20] M. Venkataramanan, "Causes and effects of global warming," *Indian Journal of Science and Technology,* vol. 4, pp. 226-229, 2011.
[21] United Nations Environment Programme, "How will global warming affect my world? A simplified guide to the IPCC's "Climate Change 2001: Impacts, Adaptation and Vulnerability"," Switzerland 2003.
[22] S. Ghosh, "Electricity consumption and economic growth in India," *Energy policy,* vol. 30, pp. 125-129, 2002.
[23] World Energy Council, "World Energy Resources: 2013 Survey," London2013.
[24] P. Mlambo-Ngcuka, "Energy Efficiency Strategy of the Republic of South Africa," *Department of Minerals and Energy, South Africa,* p. 1, 2005.
[25] S. Darby, "The effectiveness of feedback on energy consumption," *A Review for DEFRA of the Literature on Metering, Billing and direct Displays,* vol. 486, p. 2006, 2006.
[26] N. Elsawaf, T. Abdel-Salam, and H. Abaza, "Economic evaluation and calculations of energy savings by upgrading the heating systems in pre manufactured homes," *Energy and Buildings,* vol. 59, pp. 187-193, 2013.
[27] A. Al-Ghandoor, J. Jaber, I. Al-Hinti, and I. Mansour, "Residential past and future energy consumption: potential savings and environmental impact," *Renewable and Sustainable Energy Reviews,* vol. 13, pp. 1262-1274, 2009.
[28] K. Menyah and Y. Wolde-Rufael, "Energy consumption, pollutant emissions and economic growth in South Africa," *Energy Economics,* vol. 32, pp. 1374-1382, 2010.
[29] O. O. Ayeleru, F. Ntuli, and C. Mbohwa, "Municipal Solid Waste Composition Determination in the City of Johannesburg," in *Proceedings of the World Congress on Engineering and Computer Science,* 2016.
[30] University of Johannesburg, "I care for my community, therefore I choose the University of Johannesburg: 2011 Community Engagement Report," Johannesburg2011.
[31] O. O. Ayeleru, F. Ntuli, and C. Mbohwa, "Characterisation of Fruits and Vegetables Wastes in the City of Johannesburg," in *Proceedings of the World Congress on Engineering and Computer Science*, 2016.

## AUTHORS BIOS AND PHOTOGRAPHS

**Olusola O. Ayeleru** received BEng (Hons) in Chemical Engineering from the Federal University of Technology, Yola, Adamawa State, Nigeria in 2007 and completed MTech Chemical Engineering from the University of Johannesburg, South Africa in 2017. He worked as a Research Assistant at the University of Johannesburg in the last two years. His research areas include waste sociology, process economics, plastic waste management, municipal solid waste management, zero waste and waste to energy, nanotechnology and self-healing properties of asphalt pavement. He is a member of Nigeria Institute of Management (NIM), South African Institute of Safety and Health (Saiosh) and International Association of Engineers (IAENG).

**Joshua A. Adeniran** obtained the degree of BTech (Hons) in Agricultural Engineering from Ladoke Akintola University of Technology, Nigeria in 2008 and Master's degree in Civil Engineering in 2015 from the University of Johannesburg. Currently, he is a doctoral candidate in the department of Mechanical Engineering Science at the University of Johannesburg. His research focuses on hydrogen generation, microbial fuel cells and bioenergy generation, water and wastewater engineering. Joshua is a member of the Young Water Professional (YWP), Water Institute of South Africa (WISA) and International Association of Engineers (IAENG).

**Sula B. K. Ntsaluba** obtained B.Eng (Electronic), B.Eng (Hons) Electrical, M.Eng (Electrical) at the University of Pretoria, South Africa. He is currently a lecturer at the Department of Electrical and Electronic Engineering Technology at the University of Johannesburg. He also manages the Sustainability Project at the University of Johannesburg, South Africa. He is a Certified Energy Manager (Association of Energy Engineers).

**Johan de Koker** had a successful career in railway research and development. He became Head of Department of Civil Engineering Technology at the University of Johannesburg in 2007. He was the Director of the Sustainable Energy Technology and Research Centre from 2015 to 2016. He has presented more than fifty papers at local and International conferences and he specializes in various aspects of railway rails like wear, profiles, lubrication, corrosion, rail joints and rail maintenance. He holds a Masters in Civil Engineering (Structural) from the University of Johannesburg awarded in 1991 (then Witwatersrand Technikon). He is an honorary fellow and past president of both the South African Institution of Civil Engineering and the Institute of Professional Engineering Technologists

**Presenting author**: The paper will be presented by Sula B.K. Ntsaluba