ENERGY CONSUMPTION AND ENERGY EFFICIENCY OF AIRPORTS: A CASE STUDY OF AIRPORTS IN SOUTH AFRICA

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ABSTRACT

Energy efficiency is vital as the first step in reducing carbon emissions and, in many cases, it is more cost effective to eliminate energy wastage prior to changing energy generation sources to less carbon intensive energy sources such as renewable energy to mitigate climate change. To achieve energy efficiency for a site, it is key to understand the energy consumption of the site. This study investigates the site energy consumption of nine airports in South Africa. The paper presents the typical facilities installed at the airports, seeks to establish the drivers of the energy consumption, quantifies the base load energy consumption and significant energy users constituting more than 70% of the site’s total energy consumption. From these parameters the technology focus of all energy efficiency initiatives can be identified.

KEYWORDS: Energy efficiency in developing countries, base load energy consumption, drivers of Energy Consumption & significant energy users

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1. INTRODUCTION

During the 20th century, the age when electricity became the preferred and popular choice for a source of energy for commercial, domestic and even industrial uses, whether derived from coal, oil or natural gas, not much consideration was given to energy efficiency. Energy efficiency is universally defined as getting the maximum output or benefit for a given energy input. Reducing energy wastage is often coupled with energy efficiency. Reducing energy wastage is not just about cost saving; in the bigger picture it allows for decreasing the rate of growth of energy demand considering the ever-growing human population and increase in urbanization in developing countries.

Three key factors point towards the potential for energy efficiency projects in the context of the Clean Development Mechanism:

- High growth in energy demand is forecast for developing countries, with electricity use expected to increase significantly in the future.
- The most cost-effective energy efficiency projects tend to be those implemented as part of new construction or major facility modification efforts and these types of projects are projected to be significant in developing countries.
- Most developing countries did not participate in the wave of energy efficiency investment that occurred (mostly in OECD countries) after the oil price shocks of the 1970s and 1980s. Consequently, there are still numerous opportunities to increase energy efficiency in developing countries (as well as in countries with economies in
transition) [1]

Only a few developing countries have undergone the end-use profiling of energy demand that allows for the successful planning of energy efficiency projects. Independent of the value this information might have for establishing baselines, national end-use energy analyses will be critical to the identification of cost effective, high-impact energy efficiency projects that might be implemented in developing countries[1].

Nearly all OECD countries have seen substantial improvements in the efficiency of their energy using equipment in the past two decades. As a result, they have established markets for energy-efficient products and services with personnel trained in the installation and maintenance of high-efficiency equipment [1]. The oil price shocks of the 1970s highlighted the economic benefits of energy efficiency and developed countries had the capital resources required to make energy efficiency investments. In contrast, the energy efficiency wave of the 1970s largely bypassed developing countries, where national governments lacked the institutional capabilities to implement and promote energy efficiency policies [1]. Today (and in the foreseeable future), new market drivers are expanding the energy efficiency sector in developing countries. Some key trends in the energy efficiency sector include:

- **Subsidy removal.** In recent years, many developing countries have begun to decrease or remove energy subsidies. This makes the true cost of energy more apparent to end-users and increases the incentives for efficiency.

- **Restructuring and privatisation.** Restructuring of the electricity sector is typically undertaken to open the power sector to competition and encourage outside investment. In the course of restructuring, many countries are privatising their state-owned utilities and major industries, which generally increases the pressure on companies to cut costs and increase efficiency.

- **Demand-side management (DSM).** Governments struggling with power supply problems, brown outs, black outs and increasing electricity demand, often encourage energy efficiency through DSM. DSM is viewed as a means of implementing load management and energy conservation initiatives to mitigate these problems.

- **Construction boom.** Economic growth in developing countries has led to a construction boom, expanding the demand for greenfield energy efficiency projects, specifically those related to building envelope and control technologies.

- **Environmental concerns.** A growing interest in energy efficiency is coming from the threat local and global environmental problems, including global climate change and concerns for resource scarcity [1].

Increased energy efficiency is one of the highlighted objectives in the European strategy for smart, sustainable, and inclusive growth. Improving energy efficiency in energy-intensive industry is thus becoming increasingly important. From an industrial perspective, improved energy efficiency is recognized as providing several direct economic benefits, apart from indirect benefits such as increased competitiveness and higher productivity. Energy costs for European energy-intensive foundry industries represent about 5% to 15% of the added value. Two main means of reducing energy costs can be identified. First, enterprises can apply supply side management, e.g. through investments in new electricity production or negotiating lower prices with their energy suppliers. Second, enterprises can apply demand side management, e.g. adopt energy management practices at plant level within four principal areas: energy-efficient technologies, load management, energy conversion, and encouraging more energy-efficient behaviour (energy conservation). Energy management has
received increased attention in regard to policy formulation, both in the form of Long-Term Agreements (LTA) and Voluntary Agreements (VA). Moreover, standards for energy management have been set internationally, e.g. the ISO 50001. Recent research shows that when adoption of energy saving technology goes hand-in-hand with energy management practices the energy efficiency potential is higher [2].

To establish the focus of technologies for energy efficiency initiatives and energy management programmes, it is important to know the site’s energy consumption in terms of its drivers, its base load and the significant energy users of the site up to at least 70%. These key factors were investigated and established for nine airports in South Africa, namely, OR Tambo International Airport in Gauteng, Cape Town International Airport in the Western Cape, King Shaka International Airport in Durban, Port Elizabeth International Airport, East London Airport, Bram Fischer International Airport in Bloemfontein, George Airport, Upington International Airport, Kimberley Airport. These nine airports are owned and operated by Airports Company South Africa.

2. INVESTIGATING THE ENERGY CONSUMPTION OF NINE AIRPORTS IN SOUTH AFRICA

2.1 Describing the nine airports in the case study

Airports Company South Africa (ACSA) was formed in 1993 as a public company under the Airports Act (No. 44 of 1993) and, although majority owned (74.6%) by the South African Government, is legally and financially autonomous and operates under commercial law. Over the years, the company has transformed a fragmented infrastructural parastatal into a focused, customer driven, efficient and commercially successful business, whose airports have become critical success factors in the Brand South Africa campaign. The company has the South African Government through the Department of Transport as a major shareholder and is thus regarded as a state-owned company (SOC) in terms of the Public Finance Management Act (PFMA). The company owns and manages a network of nine airports in South Africa, including the three main international gateways of O.R. Tambo International, Cape Town International and King Shaka International Airports. Other airports in the Airports Company South Africa network are Port Elizabeth International Airport, East London Airport, Bram Fischer International Airport in Bloemfontein, George Airport, Upington International Airport and Kimberley Airport. These nine airports operated and owned by ACSA facilitated the movement of 42 million passengers and about 380,208 tonnes of cargo between 1 April 2018 and 31 March 2019.

While the airports’ passenger numbers pre-COVID-19 pandemic (and global lockdown), have been steadily increasing, their energy consumption has been steadily decreasing. Even with construction activities over the years depicted in Figure 1, the electricity consumption of the airports has been decreasing. Figure 1 depicts actual electricity consumption numbers from the national electricity grid as well as the yield of solar photovoltaic (PV) plants as per their beneficial operation dates as outlined in Table 1. The reduction in grid electricity consumption can be seen in Figure 2.
Figure 1: 6-year view of ACSA’s Nine Airports Total Electricity Consumption

Figure 2: 6-Year View of ACSA’s Nine Airports Electricity Consumption from the National Electricity Grid
Table 1: Airports’ Solar Photovoltaic Plant Installations

<table>
<thead>
<tr>
<th>Airport</th>
<th>Solar Photovoltaic Plant Peak Capacity</th>
<th>Date of Beneficial Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>George Airport</td>
<td>750kWp</td>
<td>October 2015</td>
</tr>
<tr>
<td>Kimberley Airport</td>
<td>500kWp</td>
<td>May 2016</td>
</tr>
<tr>
<td>Upington International Airport</td>
<td>500kWp</td>
<td>May 2016</td>
</tr>
<tr>
<td>Bram Fischer International Airport</td>
<td>750kWp</td>
<td>December 2018</td>
</tr>
<tr>
<td>Port Elizabeth International Airport</td>
<td>1MWp</td>
<td>July 2019</td>
</tr>
</tbody>
</table>

The percentage contribution of each airport to the total energy consumption for the period 1 April 2019 to 31 March 2020 (FY2019/20) can be seen in Fig.3, the ratio of solar PV yield to electricity consumption from the grid is in Figure 4.

The energy reduction of the airports differs annually, this is due to project execution timing and organizational dynamics involved in the execution. Making a business case is key to ensuring that a project is approved for funding. To determine where energy efficiency efforts should be focussed, it is imperative to understand where most of the energy is consumed. Table 2 shows the typical facilities at the airports.
<table>
<thead>
<tr>
<th>Airport</th>
<th>Onsite facilities as at 2020</th>
<th>Average of annual maximum energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>O R Tambo International Airport</td>
<td>Passenger Terminal Buildings and passenger boarding bridges that include commercial and retail stores, restaurants, baggage handling facilities, waste sorting areas, sewage sumps, water storage tanks, HVAC plants. Aprons (parking bays for aircraft), air traffic control tower, radar towers, cargo terminal building, aircraft hangers with maintenance and repairs, fire fighting facilities, Jet A1 fuel storage and hydrant network, runways, taxiways. Three hotels, car rental facilities and wash bays, car parking lots, office buildings, warehouses, cold storage rooms, maintenance storage and stock rooms, bus staging areas, vehicle fuelling stations.</td>
<td>16 MVA</td>
</tr>
<tr>
<td>Cape Town International Airport</td>
<td>Passenger terminal buildings and passenger boarding bridges that include commercial and retail stores, restaurants, baggage handling facilities, waste sorting areas, sewage sumps, water storage tanks, HVAC plants. Aprons (parking bays for aircraft), air traffic control tower, radar towers, cargo terminal building, aircraft hangers with maintenance and repairs, fire fighting facilities, Jet A1 fuel storage and hydrant network, runways, taxiways. One hotel, car rental facilities and wash bays, car parking lots, office buildings, warehouses, cold storage rooms, maintenance storage and stock rooms, bus staging areas, vehicle fuelling stations.</td>
<td>10.5 MVA</td>
</tr>
<tr>
<td>King Shaka International Airport</td>
<td>Passenger terminal buildings and passenger boarding bridges that include commercial and retail stores, restaurants, baggage handling facilities, waste sorting areas, sewage sumps, water storage tanks, HVAC plants. Aprons (parking bays for aircraft), air traffic control tower, radar towers, cargo terminal building, aircraft hangers with maintenance and repairs, fire fighting facilities, Jet A1 fuel storage and hydrant network, runways, taxiways. Car rental facilities and wash bays, car parking lots, office buildings, cold storage rooms, maintenance storage rooms, bus staging areas, vehicle fuelling stations.</td>
<td>5.7 MVA</td>
</tr>
<tr>
<td>Port Elizabeth International Airport</td>
<td>Passenger terminal building that includes retail stores, restaurants, luggage conveyor belts, waste sorting area, water storage tanks, HVAC plant. Aprons (parking bays for aircraft), air traffic control tower, radar tower, fire fighting facilities, Jet A1 fuel storage and hydrant network, runways, taxiways, car rental facilities and wash bays, car parking lots, office buildings.</td>
<td>1.24 MVA</td>
</tr>
<tr>
<td>East London Airport</td>
<td>Passenger terminal building that includes restaurants, baggage conveyor belts, waste sorting area, office areas, HVAC plant. Aprons (parking bays for aircraft), air traffic control tower, radar tower, fire fighting facilities, Jet A1 fuel storage tank, runways, taxiways. Car rental facilities and wash bays, car parking lots, office building.</td>
<td>0.8 MVA</td>
</tr>
<tr>
<td>Bram Fischer International Airport</td>
<td>Passenger terminal buildings that include restaurants, baggage conveyor belts, waste sorting area, water storage tanks, HVAC plant. Aprons (parking bays for aircraft), air traffic control tower, radar tower, fire fighting facilities, Jet A1 fuel storage and hydrant network, runways, taxiways. Hospital, car rental facilities and wash bays, car parking lot, office building.</td>
<td>0.66 MVA</td>
</tr>
</tbody>
</table>
### Energy Consumption and Energy Efficiency of Airports: A Case Study of Airports in South Africa

#### 2.2 Determining Drivers of Energy Consumption at the Nine Airports in the Case Study

The common misconception is that passenger numbers at airports drive the airports’ energy consumption. This can be easily tested using the airports’ passenger throughput and energy consumption data. Figure 5 to Figure 13 shows the airports’ regression analysis of energy consumption against their passenger numbers for a period of 12 months from 1 April 2019 to 31 March 2020.

<table>
<thead>
<tr>
<th>Airport</th>
<th>Details</th>
<th>Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>George Airport</td>
<td>Passenger terminal building that includes restaurants, baggage conveyor belts, waste sorting area, HVAC plant. Aprons (parking bays for aircraft), air traffic control tower, radar tower, fire fighting facilities, Jet A1 fuel storage tank, runway, taxiways. Car rental facilities and wash bays, car parking lots, office building.</td>
<td>0.7 MVA</td>
</tr>
<tr>
<td>Upington International Airport</td>
<td>Passenger terminal building that includes restaurants, baggage conveyor belt and carousel, water storage tank, HVAC packaged plant. Aprons (parking bays for aircraft), air traffic control tower, radar tower, fire fighting facilities, Jet A1 fuel storage tank, runways, taxiways. Car rental facilities and wash bays, car parking lot, office building.</td>
<td>0.33 MVA</td>
</tr>
<tr>
<td>Kimberley Airport</td>
<td>Passenger terminal building that includes a cafe, baggage conveyor belt and carousel, HVAC decentralized units. Aprons (parking bays for aircraft), air traffic control tower, radar tower, fire fighting facilities, Jet A1 fuel storage tank, runways, taxiways. Car rental facilities and wash bays, car parking lot, office building.</td>
<td>0.3 MVA</td>
</tr>
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Figure 5: OR Tambo International Airport’s (ORTIA) Energy Consumption Regression Analysis for Passenger Numbers
Figure 6: Cape Town International Airport’s (CTIA) Energy Consumption Regression Analysis for Passenger Numbers

Figure 5 shows that the correlation of OR Tambo International Airport’s (ORTIA’s) energy consumption with passenger numbers is not strong. The $R^2$ value is 0.4066 which means that 40% of the time there is a correlation between energy consumption and passenger numbers. The slope shows energy consumption increases when passenger number increase, but due to the weak correlation, passenger numbers are not a driver for the airport’s energy consumption. Figure 6 shows that there is a weak correlation between Cape Town International Airport’s (CTIA’s) energy consumption and passenger numbers (43.39%, $R^2 = 0.4339$), and for these instances. At these times there is an increase in energy consumption with passenger numbers increase, but due to the weak correlation, passenger numbers are not a driver for the airport’s energy consumption.

Figure 7: KingShaka International Airport’s (KSIA) Energy Consumption Regression Analysis for Passenger Numbers
Figure 7 shows that for King Shaka International Airport (KSIA), there is almost no correlation (3.19%, $R^2 = 0.319$) between its energy consumption and passenger numbers, in fact the slope is negative, i.e. there is an energy consumption decrease with passenger number increase. Thus, passenger numbers are not a driver for the airport’s energy consumption. Figure 8 shows that for Port Elizabeth International Airport (PEIA) there is 0.3% ($R^2 = 0.003$) correlation between energy consumption and passenger numbers. The slope is almost a vertical line, i.e. there is no increase in energy consumption with passenger numbers. Thus, passenger numbers are not a driver for the airport’s energy consumption.

Figure 9 shows that for East London Airport (EL Airport) there is 12.3% ($R^2 = 0.123$) correlation between energy consumption and passenger numbers. The slope is negative, i.e. there is a decrease in energy consumption with passenger number increase. Thus, passenger numbers are not a driver for the airport’s energy consumption.
Figure 9 shows a weak correlation of 12.3% ($R^2 = 0.123$) between East London (EL) Airport’s energy consumption and passenger numbers. The graph shows a negative slope meaning that energy consumption decreases when passenger numbers increase. Due to this weak correlation, passenger numbers are not a driver for the airport’s energy consumption.

Figure 10 shows that Bram Fischer International Airport’s (BFIA’s) energy consumption has almost no correlation (0.02%, $R^2 = 0.0002$) with its passenger numbers. From the slope of the graph, energy consumption decreases when passenger numbers increase. Due to the weak correlation, passenger numbers are not a driver for the airport’s energy consumption.
George (GG) Airport’s energy consumption correlation with passenger numbers shown in Fig. 11 shows almost no correlation (0.08%, $R^2 = 0.0008$). The slope is also close to zero, showing that there is no real increase or decrease of energy consumption with passenger numbers increase. The very weak correlation shows that passenger numbers is not a driver of the airport’s energy consumption. Figure 12 shows that Upington International Airport’s (UPIA’s) energy consumption has 11.54% ($R^2 = 0.1154$) correlation with passenger numbers. The slope of the graph indicates that energy consumption decreases when passenger numbers increase. Due to the weak correlation passenger numbers are not a driver of energy consumption.

![UPIA total passengers Line Fit Plot](image)

**Figure 12:** Upington International Airport’s (UPIA) Energy Consumption Regression Analysis for Passenger Numbers

Figure 13 shows that KIM airport’s energy consumption does not have much correlation (0.63%, $R^2 = 0.0063$) with passenger numbers. The negative slope indicates that the energy consumption decreases with passenger number increase. Due to the low correlation, passenger numbers are not a driver for the airport’s energy consumption.

![KIM airport total passengers Line Fit Plot](image)

**Figure 13:** Kimberley Airport’s (KIM airport) Energy Consumption Regression Analysis for Passenger Numbers

It can be seen from these graphs that there is no correlation of passenger numbers with energy consumption. The
R² values of the regression analysis for all these airports are significantly below 1. This also implies that an increase in passenger numbers does not mean an increase in energy consumption and the converse is true, i.e., if passenger numbers decrease, this does not mean that energy consumption will linearly decrease. This means that greater occupancy does not have a significant effect on energy consumption.

The regression-based approach is the most rigorous approach and can provide the most accurate results when applied effectively. This approach utilizes regression analysis to provide normalized facility-level energy consumption and annual and total changes in energy intensities that account for the effects of variables such as changes in production and weather. This provides facility and corporate energy managers with a better window into how they use energy at the facility, and whether their energy management efforts are succeeding [3].

Due to the large capacity of centralized HVAC systems at airports, the weather is another possible driver that can be tested for correlation. KSIA and CTIA only have cooling functions in their centralized HVAC systems, therefore their regression analyses will only be using cooling degree days (CDD) while the rest of the airports will have a summation of cooling and heating degree days or degree days (CDD + HDD or DD). Refer to Figures 14 to 22.

![Figure 14: OR Tambo International Airport's (ORTIA) Energy Consumption Regression Analysis for the weather](image1.png)

![Figure 15: Cape Town International Airport's (CTIA) Energy Consumption Regression Analysis for the Weather](image2.png)
Figure 14 shows that ORTIA’s energy consumption has 15.62% ($R^2 = 0.1562$) correlation with the need for space heating and cooling as provided by its HVAC system. This is a weak correlation and its slope being positive indicates that energy consumption increases with the need for HVAC. The weather, however, is not a driver of ORTIA energy consumption. Figure 15 shows that there is a 32.17% ($R^2 = 0.3217$) correlation between CTIA’s energy consumption and need for space cooling. The slope of the graph indicates that the energy consumption increases with the need for space cooling. The weather is not a driver for CTIA’s energy consumption as the $R^2$ value is low.

![KSIA Cooling Degree Days Line Fit Plot](image)

**Figure 16:** King Shaka International Airport’s (KSIA) Energy Consumption Regression Analysis for the weather

![PEIA Degree Days total Line Fit Plot](image)

**Figure 17:** Port Elizabeth International Airport’s (PEIA) Energy Consumption Regression Analysis for the weather

Figure 16 shows a definite and strong correlation (82.72%, $R^2 = 0.8272$) between KSIA’s energy consumption with the need for space cooling. There is a direct relationship, i.e. energy consumption increases with the need for space
cooling. Due to the high $R^2$ value, the need for space cooling (weather) is a driver of KSIA’s energy consumption. PEIA’s energy consumption has a 32.94%, $R^2 = 0.3294$ correlation with the need for space cooling and heating, and the slope of the graph (Figure 17) shows that energy consumption increases with the demand for HVAC. The low $R^2$ value, however, shows that the need for space cooling and heating is not a driver of the airport’s energy consumption.

![EL Airport Degree Days total Line Fit Plot](image)

**Figure 18:** East London (EL) Airport’s Energy Consumption Regression Analysis for the Weather

![BFIA Degree Days total Line Fit Plot](image)

**Figure 19:** Bram Fischer International Airport’s (BFIA) Energy Consumption Regression Analysis for the weather

Figure 18 shows that there is a weak correlation (33.93%, $R^2 = 0.3393$) of EL Airport’s energy consumption with the need for space cooling and heating. The positive slope indicates that energy consumption increases with the need for space cooling and heating. Space cooling and heating is not a driver of the airport’s energy consumption due to the low $R^2$ value. Figure 19 shows that there is a 0.33%($R^2 = 0.0033$) correlation between BFIA’s energy consumption and the need for space heating and cooling. The slope of the graph is positive indicating that energy consumption increases with the need for space heating and cooling. However, space heating and cooling is not a driver of the airport’s energy consumption due to the very weak $R^2$ value.
Figure 20 shows GG airport’s energy consumption has a weak correlation (1.53%, $R^2 = 0.0153$) with the need for space heating and cooling. The positive slope indicates that energy consumption increases with the need for space heating and cooling. The need for space heating and cooling is not a driver of the airport’s energy consumption due to the low $R^2$ value. Figure 21 shows UPIA’s energy consumption has a 25.42% ($R^2 = 0.2542$) correlation with the need for space heating and cooling. The positive slope indicates that energy consumption increases with the need for space heating and cooling. However, space heating and cooling is not a driver for the airport’s energy consumption due to the low $R^2$ value.
Figure 22 shows that KIM airport’s energy consumption has a weak correlation with the need for space heating and cooling (21.52 %, \( R^2 = 0.2152 \)). The positive slope indicates that energy consumption increases with the need for space heating and cooling. The need for space heating and cooling is not a driver of the airport’s energy consumption due to the low \( R^2 \) value.

When reviewing the regression analysis of the weather, one can see that KSIA has the most significant correlation to cooling degree days (\( R^2 = 0.8 \)) compared to the rest of the airports in the group. King Shaka International Airport has the newest technology and control systems for their HVAC system.

The general conclusion in energy management when there are no identifiable, clear drivers for energy consumption, is that the energy consumption is not predictable and in some cases is interpreted to be ‘out of control’. Being an operational site where many tenants and other stakeholders use energy on the site and join and leave the site without any conscious monitoring of this process from an energy perspective, it is difficult to predict future monthly energy consumption, so one can say the situation is ‘out of control’ in this regard. When activity and routine is fairly constant or changes are negligible in the context of the total load, it may seem that the energy consumption is predictable and when energy saving projects are undertaken, one can see the difference in the total figures as can be seen in Figure 1 in the energy savings for the airports over the last 5 years. For example, if a Measurement and Verification (M&V) exercise for an energy saving project were to be executed, one will realize that the impact of the energy savings could be significantly reduced in the total energy context caused by unaccounted for increases in electrical loads. The converse is also true in that it could be that no concerted effort has been made to save energy, however, the airports in general reflect energy saving. For the ACSA group of airports, both cases were observed, however, the reduction in energy consumption is largely due to energy saving projects being undertaken over the years.

Figure 23, Figure 24, Figure 25 and Figure 26 show 30-minute interval electricity demand profiles for 4 days of the year in different seasons for OR Tambo International Airport and Figure 27, Figure 28, Figure 29 and Figure 30 for Cape Town International Airport.
Energy Consumption and Energy Efficiency of Airports: A Case Study of Airports in South Africa

Figure 23: ORTIA 24-hour demand in 30-minute Intervals for the 2nd July 2019

Figure 24: ORTIA 24-hour demand in 30-minute Intervals for the 17th April 2019
In Figure 23, for ORTIA for the 2nd July 2019, the maximum electrical demand is 15.5MVA, the minimum electrical demand and base load is 11.5MVA, which is 74% of the total electrical load. The green bars show the off-peak electricity tariff period, the red bars show the peak electricity tariff period and the yellow bars show the standard electricity tariff period. In Figure 24, the maximum electrical demand is 15MVA, the minimum electrical demand and base load is 11.5MVA, which is around 76% of the total electrical load. Similarly, for the 7th October 2019 (Figure), the maximum electrical demand is 14.1MVA, the minimum electrical demand and baseload is 10.3MVA, 73% of the total electrical demand and for the 6th January 2020 (Figure 26), the maximum electrical demand is 15MVA, the electrical demand and baseload is 11MVA, 73% of the total electrical load. A similar pattern can be observed for CTIA in the following figures.
Figure 27: CTIA 24-hour demand in 30-minute intervals for the 17th April 2019

Figure 28: CTIA 24-hour demand in 30-minute intervals for the 2nd July 2019

Figure 29: CTIA 24-hour demand in 30-minute intervals for the 7th October 2019
In Figure 27, for CTIA on the 17th April 2019, the maximum electrical demand is 7MVA, the minimum electrical demand and baseload is 4.2MVA, which is 60\% of the total electrical load. In Figure 28, for CTIA on the 2nd July 2019, the maximum electrical demand is 6.3MVA, the minimum electrical demand and baseload is 3.5MVA, which is around 55\% of the total electrical load. Similarly, for the 7th October 2019 (Figure 29), the maximum electrical demand is 6.4MVA, the minimum electrical demand and baseload is 3.5MVA, 54\% of the total electrical demand and for the 6th January 2020 (Figure 30), the maximum electrical demand is 7MVA, the electrical demand and baseload is 4.3MVA, 61\% of the total electrical load.

The maximum demand and baseload for each airport varies everyday, what was presented here is just a sample of the results and was not meant to show the highest or lowest electrical demands, but to demonstrate the baseload percentage of the total electrical load. Daily electrical demand profiles for the other airports are not available, however, due to the similarity in design, facilities installed and operations of the airports, the electrical energy consumption profile patterns can be inferred to be similar. These electrical demand profiles tell us that airports have a large baseload, at least 50\%.

2.3 Determining and quantifying significant energy users for airports

From an investigation conducted at King Shaka International Airport in 2013 to determine the airport’s significant energy users, the lighting energy consumption was measured at the electrical distribution boards during the day and at night. From the readings, it can be seen that lighting is the most significant energy user, taking up around 61\% of the total airport load during the day and around 69\% during the night as shown in Figure 31 and Figure 32 respectively.
A similar study was conducted for KSIA’s air-conditioning load and it was shown that the primary air conditioning plant electrical load makes up at least 19% of KSIA’s total load, as shown in Figure 33. Figure 34 shows the split in energy consumption of the chillers, cooling towers, and the various sets of pumps. Chillers take up 41% of the energy requirement, followed by cooling towers (21%) and the rest are split between the pumps. This means that chiller load is around 8% of the total airport electricity load.
Due to the facilities being very similar for the airports as can be seen in Table 2, it is estimated that lighting makes up at least 50% of an airport’s total load for the international airports (ORTIA, CTIA, KSIA) and at least 60% for regional airports (PEIA, EL, BFIA, GG, UPIA, KIM) due to their lack of full baggage handling systems and large onsite HVAC plants. Air conditioning can make up around 20% to 30% of an airport’s electricity consumption depending on whether the airport provides heating as well as cooling. The airports also incorporate a significant motor and pump load due to the various systems such as wastewater systems, Jet A1 fuel systems, baggage handling systems, fire-fighting systems, potable
water systems, irrigation systems, etc. Motors also drive large fans for fire compliance extraction systems and compliance with building ventilation.

In summary, the significant energy users are lighting (around 50%), HVAC (around 30%), and there are also a significant number of pumps, motors and fans within the airport facilities. Achieving energy efficiency requires a focus on the significant energy users, i.e. lighting, HVAC, pumps, motors and fans. It will be beneficial too to address the architecture of new buildings, their envelope and determining the energy sources that will serve their energy demand as these factors also drive the energy demand of the significant energy users.

3. CONCLUSIONS

This study has established that passenger numbers are not drivers for energy consumption for any airport. KSIA’s energy consumption showed an 82% correlation with the cooling degree days (CDD). KSIA has the newest air conditioning system (11 years old) in the group and is the best maintained when compared to the other airports.

As seen with the daily electricity demand profiles for ORTIA and CTIA, baseload energy consumption is at least 50% of the total energy consumption. With the services being very similar from airport to airport, it can be inferred that the baseload energy consumption is at least over 50% for each airport. Airports generally by design have high baseloads due to the lighting load of runways and the requirement that they be on at all times during operational hours and due to the general design of the terminal buildings and other facilities which are leased to various external tenants. This makes it extremely difficult to control and standardize lighting technologies and control. Due to the double and triple (“triple volume”) glass and steel structure design of terminal buildings, the air conditioning load is significant and demand is driven by weather conditions and not as a result of the number of people within the building. It is evident from the energy consumption of KSIA that lighting is a significant energy user taking up at least 61% of the airport’s energy consumption in the day and 69% at night, while air conditioning takes up 19% of the total energy consumption.

Due to facilities across the airports being similar, including designs and operations, it can be concluded that the significant energy consuming items are related to lighting which takes up at least 50% of an airports’ energy consumption, and air conditioning which can take up to between 20% and 30% of an airport’s energy consumption, depending on whether the airport’s air conditioning system also provides heating. Pumps, motors and fans are also significant energy using technologies as they are used in vast quantities to pump water, fuel, sewerage and storm water and for ventilation (fans).

To achieve energy efficiency across the airports, the focus of energy efficiency initiatives should be on lighting, air-conditioning, pumps, motors, and fans which have been established to be significant energy using technologies. The best available technologies (BAT) should be adopted for lighting, including lighting control technologies. For air-conditioning systems, reducing air-conditioning demand as well as controlling the air conditioning supply to respond to demand should be the focus of energy efficiency initiatives. Pumps, motors, and fans should be sized correctly for the application and be energy efficient technologies. Focussed technology and control of demand will ensure that energy efficiency reduces total energy consumption significantly and effectively.

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