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An Assessment of Sustainable Energy Management at a Major United Kingdom Based Hub Airport: A Case Study of London Gatwick Airport

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***Abstract*—*Due to their extremely energy intense nature, airports are increasingly focusing on their energy consumption and energy efficiency as a key part of their sustainability policies and strategies. Based on an in-depth longitudinal case study research design, this study has examined London Gatwick Airport, a major United Kingdom-based hub airport, sustainable energy management. The case study covered the period 2014 to 2021. London Gatwick Airport has two principal energy sources: electricity and natural gas. The case study revealed that London Gatwick Airport contributes to a lower carbon grid through its procurement of 100% certified renewable electricity. The airport has purchased this 100% certified renewable electricity since 2013. This measure has enabled the airport to mitigate its environmental impact. An important energy-related development at London Gatwick Airport, has been the airport's waste processing and biomass generation facility, which began operations in November 2016. Category 1 and other types of organic waste are converted into biomass fuel that is used to power the processing plant and provide heating for the airport's North Termina and the airport's waste management site. The waste plant also provides power to the site's water recovery system. Throughout the study period, London Gatwick Airport introduced a range of energy efficiency related measures. These measures include the installation of high efficiency lighting, heating, air conditioning, and ventilation (HVAC) systems, the upgrading of the airport's boiler plant, the installation of an electricity powered hydrant dispenser, and the installation of more energy efficient light emitting diode (LED) lighting. The airport is also replacing its fleet of airport vehicles with electric powered vehicles. In addition, the airport is transitioning towards the use of electricity powered ground service equipment (GSE).*

Keywords— ***Airports, Airport energy efficiency measures, Airport energy consumption, London Gatwick Airport, Sustainable airport energy management.***

I. INTRODUCTION

Air transport infrastructure development is considered crucial for both economic and social development and growth (Karagkouni & Dimitriou, 2022). Airports have substantial economic, and social impacts on local, regional, and often in many instances, national levels as well (Culberson, 2011). However, airports adversely affect the surrounding environment (Chourasia et al., 2021; Culberson, 2011; Dimitriou & Voskaki, 2012; Dimitriou et al., 2014). In recent years, the development of green airports has increased, with this growth partly due to the aviation industry ambition to be a carbon-neutral industry by 2050 (Korba et al., 2022). A "green airport" is an airport which has a minimal impact on the environment and is one that endeavors to become a carbon neutral facility in terms of carbon emissions, with the aim to ultimately produce zero greenhouse gas emissions (González-Ruiz et al., 2017). The notion underpinning a "green airport" is for the airport to create a centre of sustainable practices (Sumathi et al., 2018). Airports play a significant role in the air transport industry; therefore, their effective operation is crucial. Airports must be built according to sustainable standards to maintain reduced energy, water, or heat consumption (Korba et al., 2022). Furthermore, applying sustainable airport practices can enable airports to improve their economic and social effects and reduce their harmful impact on the environment (Eid et al., 2022).

Airports are critical nodes in the global air transport system. Along with the growth of airport infrastructures, airport-related business, commercial, residential, and spatial development often occurs in the airport surroundings with these developments being connected by surface transport infrastructure (Ferrulli, 2016). Airports are one of the most critical stakeholders in the global air transport industry value chain. This is because airports provide the necessary landside and airfield infrastructure that facilitates both the passengers and air cargo shippers interface between the ground-based and air transport modes. To facilitate the movement and handling of passengers and air cargo consignments, airports provide extensive landside infrastructure and facilities as well as runways, taxiways, and aircraft parking stands. Air traffic, both passenger and air cargo, has increased very significantly over the past 20 years or so and this has led to an increased energy requirements of airports to accommodate this air traffic demand (Ortega Alba & Manama, 2016). Importantly, airport systems and their infrastructure consume large amounts of electrical energy. Airports are thus regarded as being energy intensive (Baxter et al., 2019; Cardona et al., 2006; Ortega Alba & Manama 2016). This is due to the energy requirements of airport buildings and facilities, for example, passenger terminal air conditioning systems, pre-conditioned air and power at aircraft gates, power supply for equipment, and other special airport systems (International Civil Aviation Organization, 2015). Airport passenger terminals are indeed extremely energy intensive (Kareem et al., 2021; Orukpe et al. 2020; Yildiz et al., 2021). The dynamic structure of airports, 24-hour operations, performing flight operations safely, and the provision of comfortable conditions for passengers in the airport's terminal buildings, has often resulted in increased energy consumption of airports. Energy management has become an important focus for airports, and thus, airports are seeking continuous improvement of energy performance as they are sites with high and intense energy consumption (Akyuz et al., 2019). Energy management is now considered as being of critical importance for airports (Almaz, 2022). According to Greer et al. (2020), "energy management refers to a process by which airports can characterize and monitor their energy consumption and enact measures to reduce it". In airports with high energy consumption areas, energy management allows the reduction of both costs and environmental impacts (Akyüz et al., 2021). Considering this, many airports have increased their focus on energy efficiency as part of their efforts to reduce their impact on the environment (Preston, 2015). Moreover, airport managers have become aware of the requirement to reduce energy consumption as well as make a more efficient use of it. In addition, airports are now confronting growing pressure to use energy-efficient systems whilst at the same time ensuring their compliance with increasingly stringent regulations (Taber & Steele, 2020). Accordingly, energy management has become extremely important for airports (Graham, 2018; Uysal & Ziya Sogut, 2017).

The United Kingdom has the biggest aviation network in Europe and the third largest in the world. London has the busiest airport system of any city in the world (Ministry of Transport, 2017). London is a major air travel market for Australia, Canada, India, Singapore, South Africa, and the United States of America. In addition, London is the home base for British Airways and Virgin Atlantic Airways, as well as an essential market for some of the industry's most successful airlines. easyJet and Ryanair, who are low-cost carriers (LCCs) have positioned London as a strategic hub. For many international airlines including Emirates, Qatar Airways, Singapore Airlines, Finnair, Aer Lingus, Qantas, United Airlines and American Airlines, London remains a key market that is core in their strategic growth and investment plans. In more recent times, JetBlue, Vistara and Norse Atlantic have launched services to London (Malik, 2022). The city of London is served by five main airports: London Heathrow Airport, London City Airport, London Gatwick Airport, London Stansted Airport, and Luton Airport (Pels et al., 2009; Saayman, 2012). London Southend Airport also serves London (Pearson, 2022).

The objective of this research is to empirically examine the sustainable aspects of London Gatwick Airport, a major United Kingdom-based hub airport, energy management. A further objective of the study is to examine the airport's energy sources and the trends in the annual consumption of these energy sources and to identify the impact that the growth in passenger traffic and aircraft movements has had on the airport's energy consumption throughout the study period. A final aim of the study is to examine the measures and technologies that have been implemented throughout the study period by London Gatwick Airport to achieve its goal of sustainable energy management. The study period is from 2014 to 2021.

The remainder of the paper is organized as follows: Section 2 presents a review of the literature on airport energy management. The research method used to underpin the study is described in Section 3. The case study of London Gatwick Airport sustainable energy management is presented in Section 4. Section 5 presents the findings of the study.

II. BACKGROUND

2.1. Airport Energy Sources

The actors operating within the airport's airside and landside precincts require a reliable and highly efficient supply of energy. Historically, an airport's two primary energy sources have been electricity and fuel, for example, diesel, natural gas, and propane (Ortega Alba & Manana, 2016). Electrical energy is normally sourced from different sources. The electrical energy is supplied directly to the airport through dedicated sub-stations. This energy is primarily used for operating the airport's facilities, equipment, and other devices that are necessary in servicing passengers and their baggage and air cargo consignments in the airport's respective passenger and air cargo terminals. Electrical energy is also used for the provision of heating, cooling (air conditioning), and lighting other administrative buildings at airports (Janić, 2011). Normally, airports purchase electricity from the commercial grid and this electricity is supplied by a power company to the airport (Nam, 2019; Ortega Alba & Manana, 2016).

Importantly, airports around the world are shifting toward the utilization of clean energy technologies together with the implementation of practices that reduce local emissions. This environmental-related strategy includes replacing fossil fuel-based with electricity-based operations at airports (Sajed Sadati et al., 2018). Indeed, in recent times, several new energy technologies have undergone development and implementation as energy sources for airports. These new technologies include solar photovoltaic (PV), concentrating solar power, wind power, oil and natural gas extraction, steam-generated power production and electricity transmission (Barrett et al., 2014).

Some airports have also developed and operate new power-generation systems that provide reliable and affordable sustainable energy. Many airports have installed biomass boilers, have worked to improve the natural light and ventilation, and, in some instance, have installed wind turbines to generate electrical energy and some airports have used boreholes to exploit sources of geothermal energy (Budd & Budd, 2013).

2.2. Energy Usage at Airports

Airports and their key stakeholders require power to operate their equipment, systems, heating, ventilation, and air conditioning (HVAC) systems, as well as for the lighting of their buildings. In addition, airports require power for their airfield infrastructure, for example, runway and taxiway lighting. Airport energy usage also includes the fuel necessary to power ground support equipment (GSE) (Nam, 2019).

The principal areas of energy consumption at an airport are heating, cooling, lighting, and the energy required for operating the airport's facilities and systems (Janić, 2011; Radomska et al., 2018). Fuel is also used for airport's heating boiler systems and emergency generators (Ortega Alba & Manana, 2016). Airports consume large quantities of electricity (Sreejaya et al., 2020). Typically, airport terminal buildings consume more energy than other buildings that are located within the airport precinct due to the terminal building's functional and operational characteristics (Yildiz et al., 2022). The airport terminal's heating, ventilation, and air conditioning (HVAC) systems use the largest amount of energy. It has been estimated that around 70% of the energy consumed in airport terminal buildings is used for heating, cooling, and air conditioning purposes. This energy consumption rate is higher in those countries that have a cold climate (Akyüz et al., 2017). Indeed, airport terminals have a high level of energy consumption for space heating in cold climate zones (Liu et al., 2021). Airport terminal buildings also have a high energy demand due to their cooling demand. This is especially so in hot arid climates, where airports cool their terminal buildings to achieve passenger thermal comfort (Abdallah et al., 2021).

Electrical energy is also used at airports for powering the aids that are used to facilitate air transport operations, and for airport buildings, aircraft hangers and other airport facilities (Kazda et al., 2015). As previously noted, airports are extremely energy-intensive areas (Baxter et al., 2019; de Rubeis et al., 2016; Ortega Alba & Manana, 2017). An airport terminal is an industrial building which may be of considerable size. Energy consumption is necessary to provide lighting; to provide operation of electronic devices and the related equipment that is necessary to facilitate passenger boarding activities, and to provide heating and cooling systems (Fossi & Esposito, 2015). Airport terminal buildings also require power to serve the requirements of the airport administration and the airport's tenants so that they can conduct their business activities (Nam, 2019). Airport buildings are thus particularly energy intensive (Danjuma Mambo et al., 2015; Kim et al., 2020; Yildiz et al., 2021). The large energy usage at airports is due to the large buildings, for example, passenger terminal buildings, which are equipped with heating and air-conditioning systems. Also, there is a very high-power demand for lighting and electric equipment, and for the various facilities that are located within the airport precinct (Cardona et al., 2006; Ortega Alba & Manana, 2017). The passengers handled at the airport significantly affect airport terminal energy consumption and the airport's indoor environmental quality (Tang et al., 2023).

Airports require a guaranteed, appropriately priced, and secure energy supply to satisfy peak demand from their service partners and passengers (Thomas & Hooper, 2013).

Crude oil is often used at airports for producing the gasoline that is used to power the ground service equipment (GSE) and other vehicles that are operated in an airport's airside and landside precincts (Janić, 2011). Ground service equipment (GSE) refers to vehicles and equipment that are used in the airport precinct to service aircraft whilst they are at the gate in between flights (Hazel et al., 2011).

Energy consumed by airports can be broken down into the energy consumed by the airside activities undertaken at the airport as well as the energy consumed in the provision of the airport's landside area activities (Janić, 2011). The airside means the movement area at an airport, adjacent terrain and buildings/infrastructure, or portions, the access to which is restricted. Landside means those parts of an airport as well as the adjacent terrain and buildings or portions thereof that are not in the airside precinct (Rossi Dal Pozzo, 2015). In the airport's airside area, energy requirements include the fuel that is consumed by aircraft during the landing and take-off (LTO) cycles. Also, ground vehicles serving aircraft during the turnaround process at the apron/gate complex consume energy. In the airport landside area, the principal consumers of energy are the airport ground access systems/modes and passenger and air cargo terminals together with other administrative buildings serving the airport. In most cases, the primary energy sources are from non-renewable fossil fuels and to a smaller extent from renewable wind, water, and solar sources (Janić, 2011).

The operation of more efficient heating and cooling systems and the performance of the building envelope can result in significant reductions in energy consumption. This can be achieved without compromising comfort conditions in the airport terminal buildings (Akyüz et al., 2018). To ensure that energy demand can be met when the needs arise, airports are increasingly focusing on energy-conservation measures in the design (and operations) of terminal buildings and infrastructure (Thomas & Hooper, 2013).

2.3. The Factors that Influence an Airport's Energy Consumption

An airport's energy consumption is influenced by a range of factors, which include:

- The airport's size.
- The airport's architecture (compact, finger passenger terminals, satellite passenger terminals, and remote satellite passenger terminals).
- Location and climate.
- Airport operational hours.
- Insulation level of terminal(s) building(s),
- Heating, ventilation, air conditioning (HVAC) system.
- Airport energy actors' energy usage behavior.
- Energy management.
- Level of airport maintenance.
- Capacity of aircraft maintenance facilities.
- Daylight utilization.
- Solar heating.
- Traffic density.
- Number of passengers handled at the airport.
- Smooth operations of electrical and mechanical systems (Akyuz et al., 2019, p. 28).

III. RESEARCH METHODOLOGY

3.1. Research Approach

This study was underpinned by an in-depth qualitative longitudinal research design (Derrington, 2019; Hassett & Paavilainen-Mäntymäki, 2013; Neale, 2018). Qualitative longitudinal research aims to expand and develop theories (Derrington, 2019). A case study enables the researcher(s) to explore complex phenomena (Remenyi et al., 2010; Taber, 2014; Yin, 2018). Case studies also enable the researcher(s) to collect rich, explanatory information that provides in-depth insights into the phenomenon under investigation (Ang, 2014).

3.2. Data Collections

The data used in the study was obtained from a range of documents, company materials available on the internet and records as sources of case evidence. Documents included London Gatwick Airport's annual Decades of Change sustainability reports, London Gatwick Airport's annual reports, and the airport's websites. An extensive search of the leading air transport journals and airport-related magazines was also conducted in the study.

The key words used in the database searches included "London Gatwick Airport's environmental policy", "London Gatwick Airport's energy sources", "London Gatwick Airport's annual energy consumption", "London Gatwick Airport's annual electricity consumption", "London Gatwick Airport's annual natural gas consumption", "London Gatwick Airport's annual renewable energy consumption", and "London Gatwick Airport's annual renewable energy consumption as a share of total energy consumption".

This study used secondary data. The three principles of data collection as suggested by Yin (2018) were followed: the use of multiple sources of case evidence, creation of a database on the subject and the establishment of a chain of evidence.

3.3. Data Analysis

The data collected for the case study was examined using document analysis. Document analysis is quite commonly used in case studies. Document analysis focuses on the information and data from formal documents and a firm's records that are collected by a researcher(s) when conducting their case study (Andrew et al., 2011; Yin, 2018). The documents gathered for the study were examined according to four key criteria: authenticity, credibility, representativeness and meaning (Scott, 2014; Scott & Marshall, 2009).

The document analysis was undertaken in six distinct phases:

- Phase 1: The first phase involved planning the types of the required documentation and ascertain their availability for the study.
- Phase 2: The data collection phase involved sourcing the documents and developing and implementing a scheme for the document management. The documents were stored in a case study database.
- Phase 3: The collected documents were examined to assess their authenticity, credibility and to identify any potential bias.
- Phase 4: The content of the collected documents was carefully examined, and the key themes and issues were identified and recorded in the case study.
- Phase 5: This phase involved the deliberation and refinement to identify any difficulties associated with the documents, reviewing sources, as well as exploring the documents content.
- Phase 6: In this final phase the analysis of the data was completed (O'Leary, 2004, p. 179).

Following the guidance of Yin (2018), the study's documents were downloaded and stored in a case study database. All the documents gathered for the study were all written in English. Each document was carefully read, and key themes were coded and recorded in the case study research framework (Baxter, 2022).

IV. RESULTS

4.1. An Overview of London Gatwick Airport

The origins of London Gatwick Airport date back to the 1930s. However, the airport was officially opened on the 9th of June 1958 (Woodley, 2014). In 1987, the British government privatized seven major airports through a share flotation (Graham, 2011). London Gatwick Airport was one of the airports that was privatized by the British Government in 1987 (Arblaster, 2017; Augustyniak, 2009). London Gatwick Airport was sold by the British Airport Authority (BAA) in late 2009 to Global Infrastructure Partners (Budd & Ison, 2018). Gatwick Airport Limited is now the company that has been licensed by the Civil Aviation Authority (CAA) to operate London Gatwick Airport. On 14 May 2019, the airport's ownership transferred to new management with VINCI Airports acquiring a shareholding of 50.01%. The remaining shares are owned by a consortium of investors, and these are managed by Global Infrastructure Partners (GIP), who have operated London Gatwick Airport since 2009 (Airport Technology, 2019; Bates, 2019).

London Gatwick Airport (IATA airport code: LGW) is the second largest of the main London airports and is ranked as the second busiest airport in the United Kingdom, as measured by passenger traffic (International Airport Review, 2023, Mann, 2022). London Gatwick Airport is the busiest single runway airport in the World (Budd & Ison, 2017; Irvine et al., 2015; Liaghat et al., 2011; Woodford, 2013). The largest passenger airline at London Gatwick Airport is the low-cost carrier easyJet (Gatwick Airport Limited, 2023a).

London Gatwick Airport's main runway is 3,316 metres long and 45metres wide. The northern runway can only be used on those occasion when the primary runway is not is use. The runways cannot be used simultaneously because there is insufficient separation between aircraft (Bowman & Simmons, 2011). The airport's South passenger terminal opened in 1958, whilst the North terminal opened in 1988. The airport's South Terminal is 160,000 square metres in size, whilst the North Terminal occupies an area of 98,000 square metres. The airport has 119 aircraft parking stands, with a total of 186 centrelines. The ability to use a stand flexibly means a total of 186 aircraft can be parked at the airport (Gatwick Airport Limited, 2023a).

London Gatwick Airport holds the Airport Council International Airport Carbon Accreditation Level 3+ "Neutral" level for direct emissions (Scope 1 and 2 Fuels and Electricity). In 2019, the airport signed the Airports Council Europe pledge to reach Net Zero for direct emissions prior to 2050. In addition, London Gatwick

Airport Gatwick was the first airport to join "RE100", the global coalition committed to renewable electricity (Gatwick Airport Limited, 2023c). In 2010, London Gatwick Airport obtained its ISO14001 Environmental Management System (EMS) accreditation (Gatwick Airport Limited, 2023b).

Figure 1 presents London Gatwick Airport's annual enplaned passengers and the year-on-year growth (%) from 2014 to 2021. One passenger enplanement measures the embarkation of a revenue passenger, whether originating, stop-over, connecting or returning (Holloway, 2016). As can be observed in Figure 1, the airport's annual enplaned passengers displayed an upward growth trend from 2014 to 2019, when the annual passenger volumes handled at the airport increased from 38,127,690 passengers in 2014 to a high of 46,568,000 passengers in 2019. The most significant annual increase in the airport's passenger traffic was recorded in 2016, at which time it increased by 7.12% on the 2015 levels (Figure 1). Figure 1 shows that there was a very substantial decrease in the annual passenger traffic handled at the airport in 2020, when it declined by 78.17% on the 2019 levels. This large decrease could be attributed to the adverse impact that the COVID-19 virus pandemic had on air passenger demand in 2020 (Leppävuori et al., 2022). During the COVID-19 pandemic, the demand for passenger air transportation services declined significantly in 2020 (Barczak et al., 2022; El Zowalaty et al., 2020; Hotle & Mumbower, 2021; Mumbower, 2022) as the COVID-19 pandemic caused a significant decrease in the world air travel market supply and demand chain in 2020 (Dube et al., 2021). Furthermore, due to the global coronavirus crisis, most countries placed restrictive measures to confine the pandemia (Iacus et al., 2020). These pandemic response measures included many countries imposing travel restrictions (Akkucuk, 2020; Fabeil et al., 2020; Mat Dawi et al., 2021). In 2020, British Airways suspended all flights to and from London's Gatwick airport due to the collapse in passenger demand. The airline's passenger demand was affected by the CORONA-19 virus pandemic (BBC News, 2020). Virgin Atlantic Airways also cancelled all operations at London Gatwick Airport at the beginning of the COVID pandemic (Amaro, 2020; Bodell, 2022).

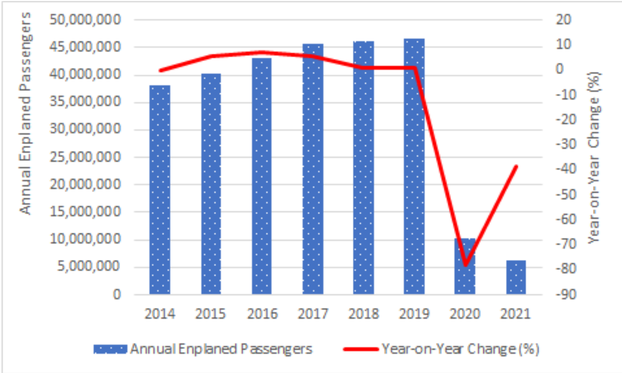

Fig.1: London Gatwick Airport's Annual Enplaned Passengers and the Year-on-Year Change (%): 2014-2021.

Source: Data derived from Gatwick Airport Limited (2014, 2016, 2018a, 2020a, 2022a).

Figure 2 presents London Gatwick Airport's annual aircraft movements and the year-on-year growth (%) from 2014 to 2021. Figure 2 shows that there was an upward trend in the airport's annual aircraft movements from 2014 to 2018. The airport's annual aircraft movements increased from 247,863 movements in 2014 to a high of 280,792 movements in 2018. In 2019, the airport's annual aircraft movements decreased by 0.04% on the 2018 levels. The airport's annual aircraft movements were adversely impacted by airline aircraft fleet deployment patterns in 2020 in response to the downturn in passenger demand because of the CORONA-19 virus pandemic. In 2020, the airport's annual aircraft movements decreased by 72.79% on the 2019 levels (Figure 2). The same situation occurred in 2021 when the airport's annual aircraft movements decreased by 31.93% on the 2020 levels (Figure 2). The COVID-19 pandemic continued to have an impact on the air transport industry in 2021 (Gao, 2022).

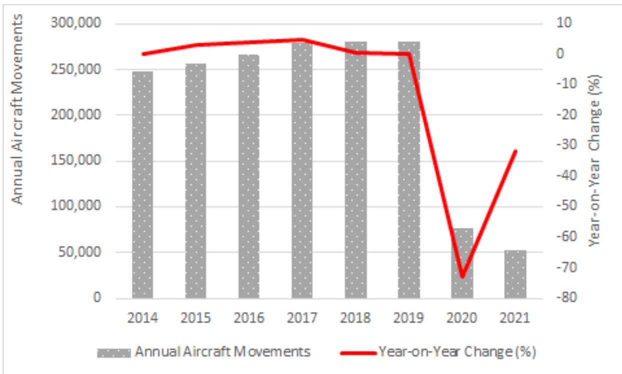

Fig.2: London Gatwick Airport's Annual Aircraft Movements and Year-on-Year Change (%): 2014-2021.

Source: Data derived from Gatwick Airport Limited (2014, 2016, 2018a, 2020a, 2022a).

4.2. London Gatwick Airport Environmental Policy

In June 2021, London Gatwick Airport implemented its second "Decade of Change Sustainability Policy". This policy contains the airport's 2030 targets. The policy also contains the airport's goals for the transition to becoming a net-zero airport that also contributes to local environmental stewardship as well as supporting the local economy, people, and communities (International Airport Review, 2021a; Gatwick Airport Limited, 2021b).

As part of the policy, London Gatwick Airport aims to be a responsive and responsible airport operator and, in so doing, it undertakes various activities that enable the airport to:

- Deliver a strong community-based program.
- Maximize the airport's local regional and national economic benefits.
- The airport aims to remove or mitigate its direct environmental impacts whilst at the same time collaborating on industry-wide solutions to climate change.
- Set the right standards and practices.
- The airport enables its staff to be sustainability champions.

The airport also endeavors to understand the requirements of its stakeholders and partners (Gatwick Airport Limited, 2021b, p. 3). In-line with the policy, London Gatwick Airport's sustainability policy goals will continue to centre on:

- Enabling London Gatwick Airport to be the airport of choice for its passengers and customers.
- Ensuring the safety and security of our passengers, partners, and staff members.
- Generating national and regional economic wealth, and connectivity.
- The airport aims to increase its traffic catchment area and employment.
- London Gatwick Airport aims to reduce the adverse impacts to the environment.
- The airport aims to develop and maintain constructive relationships with stakeholders.
- The airport aims to recognize the value of its employees, key stakeholders, and communities (Gatwick Airport Limited, 2021b, p. 3).

In delivering and achieving its sustainability goals London Gatwick Airport will continue to:

- Set clearly defined targets and policies for delivery from today to 2030.
- Operate today as efficiently as it can, and the airport will invest appropriately for the future.
- Protect the business and ensure the airport has the appropriate resilience.
- London Gatwick Airport communicates its approach and performance with key stakeholders.
- Partner with organizations who can help the airport to achieve its goals.
- Work with government, industry, and regulators to develop policy and plans; and
- Engage with its community explaining both its positive and negative impacts (Gatwick Airport, 2021b, p. 3).

To achieve its sustainability goals, the airport will continue to set clearly defined targets and policies for delivery from 2021 to 2030. The airport's 2030 goals take into consideration local and national sustainability priorities and will enable the airport to play its part in national and international action to deliver on the Paris Climate Agreement together with the United Nations' (UN) Sustainable Development Goals (SDGs) (Gatwick Airport Limited, 2021b). In 2015, all United Nations Member States adopted the "2030 Agenda for Sustainable Development" (Boeren, 2019; Lenkaitis, 2022; Miola & Schiltz, 2019). The "2030 Agenda for Sustainable Development" has seventeen 17 Sustainable Development Goals (SDGs) (Calabrese et al., 2021; Scholz & Brandi, 2017). Each SDG comprises a range of targets to be achieved by 2030 (Katila et al., 2019). The United Nations (UN) has acknowledged that "the goal to achieve affordable and clean energy is particularly important as it interlinks with its other sustainable development goals (SDGs) (Munguia et al., 2020). At the time of the present study, London Gatwick Airport's environmental policy was aligned with five of the United Nations Sustainable Development Goals (SDG) themes and targets. The UN Sustainable Action Goals (SDGs) adopted by London Gatwick Airport are SDG 8 Decent work and economic growth, SDG 9 Resilient infrastructure, SDG 10 Reduced inequalities, SDG 11 Sustainable cities and communities, and SDG 13 Climate action (Gatwick Airport Limited, 2021b).

At London Gatwick Airport, energy efficiency is incorporated in the airport's refurbishments and capital projects, ranging in scope from the passenger terminals to the airport fire station (Gatwick Airport, 2023b).

4.3. London Gatwick Airport Energy Sources

London Gatwick Airport's two principal energy sources are electricity and natural gas. London Gatwick Airport uses energy 24 hours a day to operate the airfield, the airport's two terminal buildings and the operation of more than 120 businesses based at the airport. The largest percentage of energy is used for the airport's lighting, heating, and cooling of buildings. The airport buildings have a large number of lifts, escalators, as well as passenger walkways. The airport's baggage handling system, the fixed electrical ground power system (FEGP) for aircraft and the lighting for stands, taxiways, car parks and the runway plus there is a system for the baggage also require energy (Bilton, 2019). Natural gas is primarily used for heating buildings (Gatwick Airport, 2017). England has cold winters (Lamb, 2011), and thus, the airport needs to provide heating for its buildings during the cold winter months.

It is important to note that not all the energy used on the airport is within Gatwick's direct control, as over a third of energy is re-sold to third party businesses (Gatwick Airport Limited, 2017). During the period 2019 to 2021, London Gatwick Airport also procured and used vehicle and equipment fuel (MI), refrigerant gas, and propane (Gatwick Airport Limited, 2022b).

In November 2016, operations commenced at London Gatwick Airport's waste processing and biomass generation facility (Baxter & Srisaeng, 2022). Following the commencement of operations of this new facility, London Gatwick Airport was the first airport in the world that could legally dispose of Category 1 waste on site (Gatwick Airport Limited, 2017; James, 2017; Manuel, 2016). At London Gatwick Airport, Category 1 and other types of organic waste are converted into biomass fuel that is used to power the processing plant and provide heating for the airport's North Terminal (James, 2017; Manuel, 2016). The system also heats Gatwick's waste management site (Bioenergy Insight, 2017). The waste plant also provides power to the site's water recovery system (Lyons Hardcastle, 2017). London Gatwick Airport contributes to a lower carbon grid through its procurement of 100% certified renewable electricity. The airport has purchased this 100% certified renewable electricity since 2013 (Bilton, 2019; Gatwick Airport Limited, 2019).

4.4. London Gatwick Airport Annual Energy Consumption

London Gatwick Airport's total annual energy consumption and the year-on-year change (%) from 2014-2021 is presented in Figure 3. Figure 3 shows that there were two discernible trends in the airport's total annual energy consumption during the study period. There was a general upward trend from 2014 to 2018, at which time it increased from 199,885 MWh in 2014 to a high of 215,392 MWh in 2018 (Figure 3). The most significant annual increase in this metric during this period was recorded in 2016, when the airport's total annual energy consumption increased by 4.21% on the 2015 levels (Figure 3). Over the period 2014 to 2018, London Gatwick Airport annual enplaned passengers and aircraft movements increased on a year-on-year basis. Consequently, there was a slightly greater energy requirement to accommodate the growth in passenger traffic and aircraft movements during the period 2014 to 2018. Figure 3 also shows that the airport's annual energy consumption decreased on a year-on-year basis in 2019. In 2019, the airport's annual energy consumption decreased by 1.61% on the 2018 levels. This was a favorable outcome as the airport handled higher levels of passenger traffic in 2019, and this passenger growth was accommodated without an increase in additional energy consumption. Figure 3 shows that London Gatwick Airport's annual energy consumption decreased by 35.25% on the 2019 levels (Figure 3). This decrease reflected lower levels of passenger traffic and aircraft movements due to the CORONA-19 virus pandemic and the associated government and airline response measures. In 2021, London Gatwick Airport's consumed 136,854.42 MWh of energy (Figure 3). This was the lowest annual amount of energy consumed by the airport during the study period and represented a 0.24% decrease on the 2020 levels.

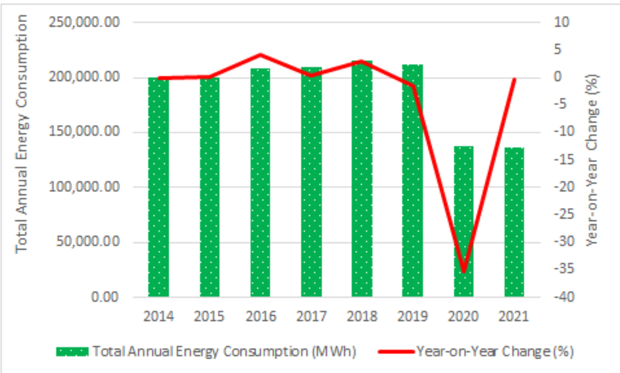

Fig.3: London Gatwick Airport's Total Annual Energy Consumption and Year-on-Year Change (%): 2014-2021.

Source: Data derived from Gatwick Airport Limited (2017, 2019, 2021a, 2022b).

4.5. London Gatwick Airport Annual Electricity Consumption

London Gatwick Airport's annual electricity consumption and the year-on-year change (%) from 2014 to 2021 is presented in Figure 4. As can be observed in Figure 4, London Gatwick Airport's annual electricity consumption fluctuated over the period 2014 to 2021. There were three years in this period where the airport's annual electricity consumption increased on a year-on-year basis. These increases occurred in 2016 (+3.13%), 2017 (+1.39%), and

2018 (+1.8%), respectively (Figure 4). The airport handled higher levels of passenger traffic and aircraft movements in these respective years. These increases in both passengers and aircraft movements had a concomitant impact on the amount of electricity that was needed to handle the increased passenger traffic and aircraft movements. During the period 2014 to 2021, there were four years where the airport's annual electricity consumption decreased on a year-on-year basis. These annual decreases were recorded in 2015 (-3.17%), 2019 (-2.15%), 2020 (-37.75%), and 2021 (-8.05%) respectively (Figure 4). In 2015 and 2019, the airport handled increased passenger volumes and was able to accommodate this traffic growth without an associated increase in its electricity consumption, which is a very favorable outcome. As previously noted, the airport handled significantly fewer passengers and aircraft movements in 2020 and 2021 due to the COVID-19 virus pandemic and this too contributed to the lower electricity requirements in 2020 and 2021. Over the period 2014 to 2021, the airport's highest annual electricity consumption occurred in 2018 (154,212.37 MWh), whilst the lowest annual electricity consumption was recorded in 2021 (89,108.60 MWh) (Figure 4). .

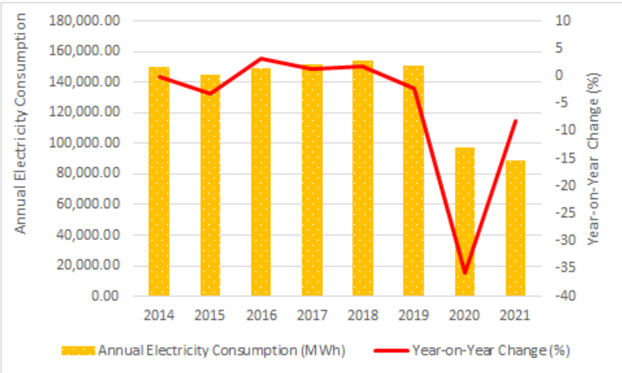

Fig.4: London Gatwick Airport's Annual Electricity Consumption and Year-on-year Change: 2014-2021.

Source: Data derived from Gatwick Airport Limited (2017, 2019, 2021a, 2022b).

An important measure of an airport's energy efficiency is the energy consumption (electricity, gas, or fuel) per enplaned passenger (Graham, 2005) or per workload unit (WLU) (Baxter et al., 2018). One workload (WLU) or traffic unit is equivalent to one passenger, or 100 kilograms of air cargo handled (Doganis, 2005; Graham, 2005; Teodorović & Janić, 2017). London Gatwick Airport's annual electricity consumption per workload unit (kWh/WLU) and the associated year-on-year change (%) from 2014-2021 is presented in Figure 5. Figure 5 shows that there were two discernible trends in this metric during the study period. There was an overall downward trend in this metric over the period 2014 to 2019. This overall downward trend is demonstrated by the year-on-year percentage change line graph, which is more negative than positive, that is, all bar one value is below the line. Over this period, there was a single year when the annual electricity consumption per workload unit (WLU) increased on a year-on-year basis. This increase occurred in 2018, at which time the annual electricity consumption per workload unit (WLU) increased by 0.90% on the 2017 levels (Figure 5). The airport's annual electricity consumption increased by 1.8% in 2018 and this was higher than the 1.12% increase in passenger traffic in 2018. As a result, the annual electricity consumption per workload unit (WLU) increased on a year-on-year basis in 2018. Over the period 2014 to 2019, the two most significant annual decreases in the airport's electricity consumption per workload unit (WLU) occurred in 2015 (-8.16%) and 2017 (-4.04%) (Figure 5). These annual decreases were very favorable as London Gatwick Airport handled higher passenger traffic volumes in both 2015 and 2017, and the airport was able to accommodate this passenger traffic growth whilst also reducing the amount of electricity consumed per passenger or per workload unit (WLU) in these respective years. Figure 5 shows that in 2020, the airport's annual electricity consumption per workload unit (WLU) increased by 194.13% on the 2019 levels. This was the most significant annual increase in this metric during the study period. This significant annual increase in 2020 could be attributed to the airport's annual electricity consumption decreasing by 35.73% whilst passenger volumes declined by 78.17% in 2020, and thus, there were fewer passengers or workload units (WLUs) available to spread the airport's annual electricity consumption over in 2020. A similar situation occurred in 2021, when this metric increased by 49.52% on the 2020 levels (Figure 5). In 2021. The airport's annual passenger traffic decreased by 38.46% on the 2020 levels, whilst its annual electricity consumption decreased by 8.05% on the 2020 levels. So, once again, there were fewer workload units (WLUs) available to spread the slightly lower electricity consumption over. As noted earlier, in both 2020 and 2021, London Gatwick Airport's passenger traffic was impacted by the COVID-19 pandemic and the related pandemic response measures. This led to the situation where the electricity consumption per workload (WLU) increased on a year-on-year basis in both years. However, it is important to note that London Gatwick Airport procures 100% certified renewable electricity so the higher annual electricity consumption per workload unit (WLU) in 2020 and 2021 is still friendly from an environmental perspective given that renewable energy is regarded as being an environmentally friendly energy source (Jäger-Waldau et al., 2011). Indeed, renewable electricity reduces environmental harm (Sovacool, 2010).

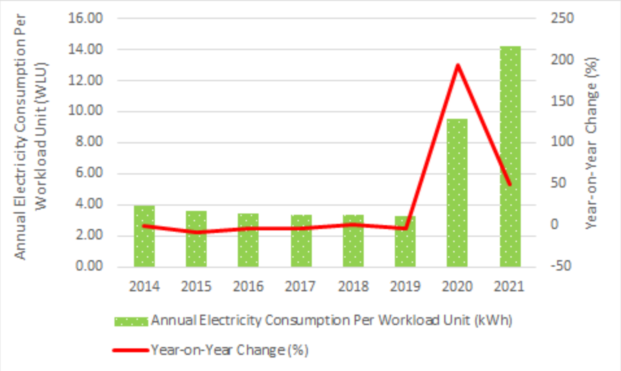

Fig.5: London Gatwick Airport's Annual Electricity Consumption Per Workload Unit (WLU) and Year-on-Year Change (%): 2014-2021.

Source: Data derived from Gatwick Airport Limited (2017, 2019, 2021a, 2022b).

An airport's energy efficiency can also be measured by energy consumed per aircraft movement (Janić, 2011). London Gatwick Airport's annual electricity consumption per aircraft movement and the associated year-on-year change (%) from 2014 to 2021 is depicted in Figure 6. Figure 6 shows that there was a general downward trend in the annual electricity consumed per aircraft movement over the period 2014 to 2019. This overall downward trend is demonstrated by the year-on-year percentage change line graph, which is more negative than positive, that is, all bar one value is below the line. This is a very favorable result and shows that the airport has been able to handle more aircraft each year without incurring a concomitant increase in the amount of electricity consumed per aircraft movement. Figure 6 shows that the annual electricity consumption per aircraft movement increased by 1.85% in 2018. In 2018, the annual aircraft movements increased by 0.68% whereas the airport's annual electricity consumption increased by 1.80%, and this resulted in the higher annual electricity consumption per aircraft movement in 2018. The largest single annual decrease in electricity consumption per aircraft movement was recorded in 2015, at which time it decreased by 3.57% on the 2014 levels (Figure 6). Figure 6 shows that there was a very pronounced spike in this metric in 2020, at which time it increased by 135.18% on the 2019 level. As noted earlier, the airport's annual electricity consumption in 2020 decreased at a lower level than the annual reduction in the number of aircraft movements at the airport, and thus, this translated into the higher electricity consumption per aircraft movement in 2020. The same situation occurred in 2021, at which time the airport's annual aircraft movements decreased at a higher rate than the decrease in electricity consumption, and thus, there were fewer aircraft movements to spread the reduced electricity consumption over in 2021.

It is important to note that over the past two decades or so, the size of commercial aircraft has increased. The Airbus A380 first entered commercial service with Singapore Airlines in October 2007 (Jackson, 2021; Simons, 2014). Singapore Airlines was the first airline to take delivery of the Airbus A380 (Flottau, 2023). The Airbus A380 is the world's largest passenger aircraft (Marsch, 2016; Vermeeren, 2003). Due to its size, the Airbus A380 can carry at once approximately twice as many passengers as any other medium-sized aircraft (Ussinova et al., 2018). Emirates Airline operates the Airbus A380 to London Gatwick Airport. In February 2000, Boeing Commercial Airplanes announced the launch of two new longer-range Boeing 777s (Kemp, 2007). Depending upon the aircraft cabin configuration selected by airlines, the Boeing B777-300ER can carry around 20% more passengers than the Boeing B777-200 (Aviation Week & Space Technology, 1998). The Boeing B777-300ER entered commercial service in April 2004 (Eden, 2017). The Boeing 747-8 Intercontinental passenger aircraft's first commercial flight took place on 1 June 2012 (Asian Aviation, 2012). The Boeing 787-8 entered commercial service in 2011, whilst the Boeing 787-9 entered commercial service in August 2014 (Hitt et al., 2019; Kumar & Padture, 2018). The Airbus A350-900XWB first commercial flight was operated by Qatar Airways in 2014 (Aircraft Commerce, 2015). Singapore Airlines took delivery of the first Boeing 787-10 on March 14th, 2018 (Davis & Davis, 2020). The Boeing 787-8 is around 20 seats larger than the Boeing 767-300ER, whilst the Boeing 787-9 has about 20 seats more capacity than the A330-200 (Aircraft Commerce, 2016).

London Gatwick Airport's annual electricity consumption as a share of the airport's total annual energy consumption and the associated year-on-year change (%) from 2014 to 2021 is depicted in Figure 7. Figure 7 shows that the airport's annual electricity consumption as a share of total energy consumption has exhibited an overall downward trend, decreasing from a high of 74.85% in 2014 to a low of 65.11% in 2021. This overall downward trend is once again demonstrated by the year-on-year percentage change line graph, which is more negative than positive, that is, all bar one value is below the line. Figure 7 shows that this metric increased by 1.06% in 2017. This increase could be attributed to the airport's increased annual electricity consumption in 2017 (+1.39%) and the lower annual gas consumption (-2.32%) in the same year. The most significant annual decrease in this metric was recorded in 2021, at which time it decreased by 7.82% on the 2020 levels. This decrease came about because of the lower annual electricity consumption (-8.05%) and increased gas consumption (+18.54%) in 2021. Figure 7 shows that electricity was still the largest energy source used by the airport during the study period (2014 to 2021).

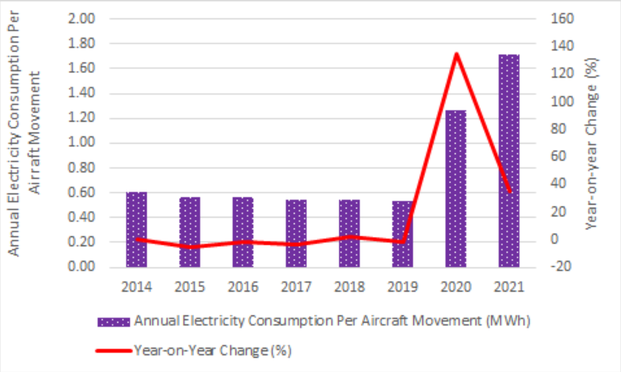

Fig.6: London Gatwick Airport's Annual Electricity Consumption Per Aircraft Movement and Year-on-Year Change (%): 2014-2021.

Source: Data derived from Gatwick Airport Limited (2017, 2019, 2021a, 2022b).

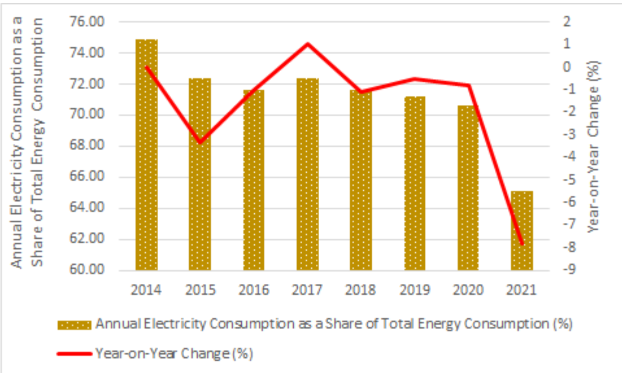

Fig.7: London Gatwick Airport's Annual Electricity Consumption as a Share of Total Energy Consumption and Year-on-Year Change (%): 2014-2021.

Source: Data derived from Gatwick Airport Limited (2017, 2019, 2021a, 2022b).

4.5. London Gatwick Airport Natural Gas Consumption

As previously noted, natural gas is one of London Gatwick Airport's key energy sources. Natural gas (NG) is a naturally gaseous hydrocarbon mixture that is formed beneath the earth's surface (Faramawy et al., 2016; Speight 2019). Natural gas is a clean burning fuel (Papagiannakis et al., 2010). Natural gas (NG) is regarded as the cleanest fossil fuel and is a safe source of energy when transported, stored, and used (Faramawy at al., 2016). Thus, natural gas is widely considered to be an environmentally cleaner fuel than coal (Cathles et al., 2012; Liang et al., 2012; Pilavachi et al., 2009).

London Gatwick Airport's total annual natural gas consumption and the year-on-year change (%) from 2014 to 2021 is presented in Figure 8. As has been previously noted, at London Gatwick Airport, natural gas is primarily used for heating buildings and so gas use at the airport is significantly affected by the prevailing winter weather conditions (Gatwick Airport, 2017). As can be observed in Figure 8, there were two discernible trends in London Gatwick Airport's annual gas consumption during the study period. Over the period 2014 to 2018, there was a general upward trend in London Gatwick Airport's annual gas consumption, when it increased from 50,278.09 MWh in 2014 to a high of 61,179.86 MWh in 2018 (Figure 8). Figure 8 shows that there was quite a pronounced spike in this metric in 2015, when it increased by 11.95% on the 2014 levels due to the higher gas requirements at the airport in 2015 (Figure 8). There was a further increase in this metric in 2016, when it increased by 5.14% on the 2015 levels, with this increase being the result of higher natural gas usage requirements. In 2018, the airport's annual gas consumption increased by 5.82%, the third highest annual increase in the study period, and this increase higher natural gas usage patterns (Figure 8). During the early years of the study period, that is, 2014 to 2018, there was a single year when the airport's annual natural gas consumption decreased on a year-on-year basis. This decrease occurred in 2017, when it decreased by 2.32% on the 2016 levels. This decrease could be attributed to a lower natural gas usage requirement in 2017. Figure 8 shows that the airport's annual natural gas consumption once again decreased on a year-on-year basis in 2019 (-0.26%), and 2020 (-33.99%). As noted earlier, the airport's annual passenger and aircraft movements in 2020 were adversely impacted by the COVID-19 virus pandemic and the related government and airline response measures and these factors led to the airport's lower gas requirements in 2020. Figure 8 shows that London Gatwick Airport's annual natural gas consumption increased by 18.54% in 2021. Colder than average conditions were experienced in England in the early part of 2021 and the 2021 winter was colder than average (The Met Office, 2021).

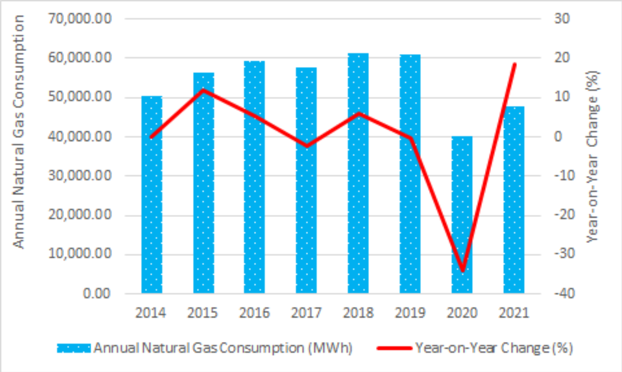

Fig.8: London Gatwick Airport's Annual Natural Gas Consumption and Year-on-Year Change (%): 2014-2021.

Source: Data derived from Gatwick Airport Limited (2017, 2019, 2021a, 2022b).

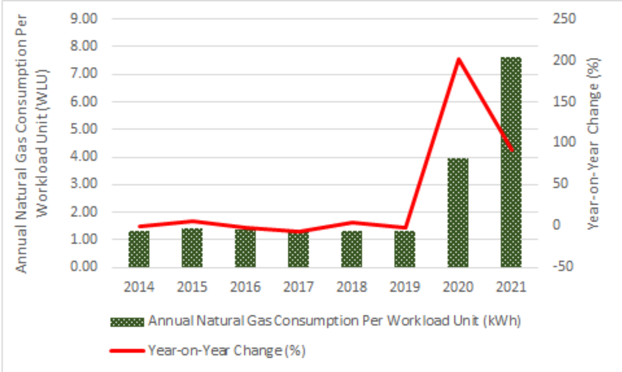

Fig.9: London Gatwick Airport's Annual Natural Gas Consumption Per Workload Unit (WLU) and Year-on-Year Change (%): 2014-2021.

Source: Data derived from Gatwick Airport Limited (2017, 2019, 2021a, 2022b).

London Gatwick Airport's annual natural gas consumption per workload unit (kWh/WLU) and the associated year-on-year change (%) from 2014 to 2021 is depicted in Figure 9. As can be observed in Figure 9, London Gatwick Airport's annual natural gas consumption per workload unit (WLU) oscillated over the study period. Figure 9 shows that there were two years during the period 2014 to 2020 where the airport's annual natural gas consumption per workload unit (WLU) increased on a year-on-year basis. These annual increases were recorded in 2015 (+6.06%), and in 2018 (+4.72%), respectively (Figure 9). These increases were due to the airport's higher natural gas consumption in both 2015 and 2018, which increased at a higher rate than the annual passenger growth rate in these respective years. Figure 9 shows that there was a very significant spike in this metric in 2020, when it increased by 202.29% on the 2019 levels (Figure 9). This increase could be attributed to the lower number of passengers handled at the airport in 2020. In 2020, passenger traffic declined by 78.17%, whist natural gas consumption declined by 33.99%. A different situation occurred, however, in 2021, when this metric increased by 92.67% on the 2020 levels (Figure 9). In 2021, the airport's annual passenger traffic or workload units (WLUs) decreased by 38.46% on the 2020 levels, whilst the airport's natural gas consumption increased by 18.54%. This led to the situation where there were fewer workload units (WLUs) available to spread the increased natural gas consumption over in 2021.

London Gatwick Airport's annual natural gas consumption as a share of the airport's total annual energy consumption and the associated year-on-year change (%) for the period 2014 to 2021 is depicted in Figure 10. Figure 10 shows that there has been a general upward trend in London Gatwick Airport's natural gas consumption as a share of its total energy consumption. This general upward trend is once again demonstrated by the year-on-year percentage change line graph, which is more positive than negative, that is, all bar one value is above the line. Figure 10 shows that there was a spike in this metric in 2015, when it increased by 11.84% on the 2014 levels. The airport's annual electricity consumption decreased on a year-on-year basis in 2015, whereas the natural gas consumption increased by 11.95% in that year. There were several smaller annual increases in this metric during the study period. These increases were recorded in 2016 (+0.88%), 2018 (+2.82%), 2019 (+1.37%), and 2020 (+1.97%), respectively (Figure 10). In 2016 and 2018, the airport's annual natural gas consumption increased at a higher rate than the airport's annual electricity, and hence, this led to the natural gas consumption as a share of total energy consumption being higher in both 2016 and 2018. In 2019 and 2020, the airport's natural gas consumption decreased at a lower rate than the airport's electricity consumption, and this resulted in the natural gas consumption accounting for a greater share of the airport's annual energy consumption. Figure 10 shows that there was a quite pronounced spike in this metric in 2021, at which time it increased by 18.83% on the 2020 levels. As previously noted, London Gatwick Airport's annual natural gas consumption increased by 18.54% in 2021, whilst its annual electricity consumption decreased by 8.05%, and thus, these disparities in the energy consumption trends resulted in natural gas consumption accounting for a higher share of the airport's total annual energy consumption in 2021.

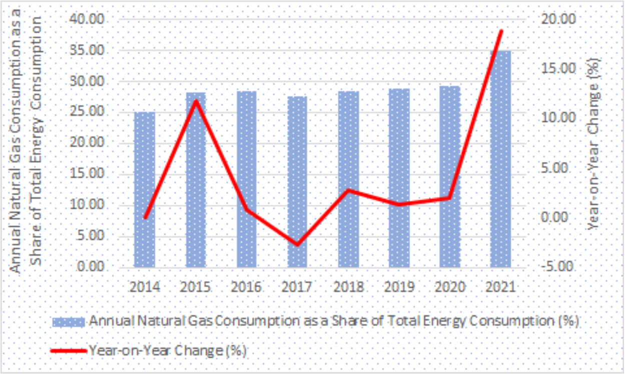

Fig.10: London Gatwick Airport's Annual Natural Gas Consumption as a Share of Total Energy Consumption and Year-on-Year Change (%): 2014-2021.

Source: Data derived from Gatwick Airport Limited (2017, 2019, 2021a, 2022b).

4.6. London Gatwick Airport Annual Onsite Renewable Energy Generation

As noted earlier, London Gatwick Airport has installed a waste-to-energy (WTE) system that produces renewable energy from the biomass boiler and the system also produces heating. London Gatwick Airport's annual onsite renewable energy generation and the associated year-on-year change (%) from 2014 to 2020 is depicted in Figure 11. Figure 11 shows that the airport's annual onsite renewable energy generation oscillated throughout the study period. The highest annual onsite renewable generation was recorded in 2017, at which time the airport produced 57.09 MWh of renewable energy. The lowest annual onsite renewable generation was recorded in 2019, at which time the airport produced 33.99 MWh of renewable energy (Figure 11). Figure 11 shows that there were two pronounced spikes in this metric during the study period. The first spike was recorded in 2017, at which time it increased by 31.74% on the 2016 levels, and in 2020, when it increased by 32.85% on the 2019 levels (Figure 11). The airport was able to increase its operational and commercial waste recovered for energy (%) in both 2017 and 2020. Figure 11 also shows that there were two quite pronounced annual decreases in this metric during the study period. These decreases were recorded in 2016 (-18.35%), and 2019 (-36.97%), respectively (Figure 11). The airport's annual operational and commercial waste recovered for energy (%) declined quite significantly in 2019 (Gatwick Airport Limited, 2020b).

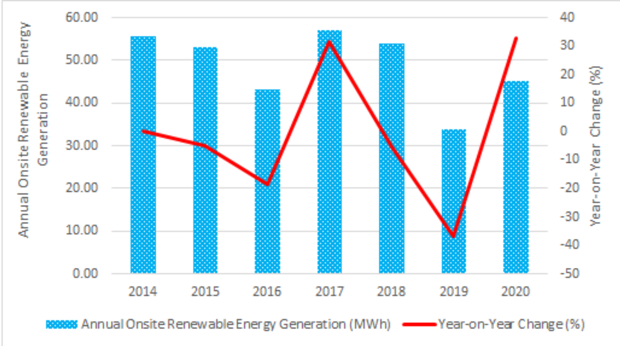

Fig.11: London Gatwick Airport's Annual On-Site Renewable Energy Generation and Year-on-Year Change (%): 2014 -2020).

Note: 2021 data not available.

Source: Data derived from Gatwick Airport Limited (2017, 2019, 2021a).

London Gatwick Airport's annual onsite renewable energy consumption as a share of total energy consumption and the associated year-on-year change (%) from 2014 to 2020 is depicted in Figure 12. Figure 12 shows that this metric oscillated over the study period, decreasing from a high of 74.8% in 2014 to a low of 70.6% in 2020. There was one year in the study period where this metric increased on a year-on-year basis. This increase occurred in 2017, when it increased by 1.1% on the 2016 levels. The most significant single annual decrease in this metric was recorded in 2015, when it decreased by 3.20% on the 2014 levels (Figure 12). This decrease in 2015 reflected differing energy consumption and energy production patterns in that year.

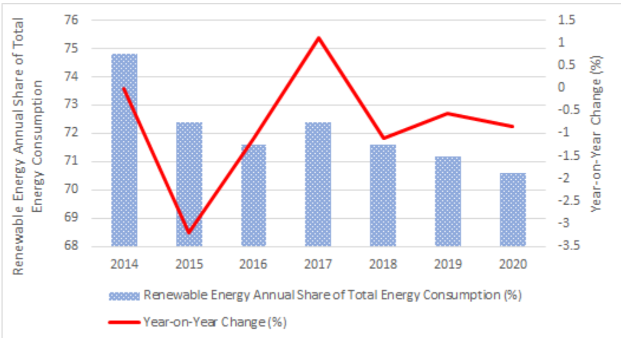

Fig.12: London Gatwick Airport's Annual Renewable Energy Consumption as a Share of Total Energy Consumption and Year-on-Year Change (%): 2014 -2020).

Note: 2021 data not available.

Source: Data derived from Gatwick Airport Limited (2017, 2019, 2021a).

An important environmental benefit of the waste-to-energy (WTE) system at London Gatwick Airport is that it generates 1MW of renewable energy from the biomass boiler (Walker, 2016). London Gatwick Airport's waste-to-energy plant can also generate 22,500kW of heat each day. Importantly, green, or renewable energy, produces no greenhouse gas emissions from the combustion of fossil fuels. Consequently, this reduces some forms of harmful air pollution (United States Environmental Protection Agency, 2022). In addition, the use of green or renewable energy sources enables a firm or user to reduce their dependency on fossil fuels, improve their energy efficiency, and mitigate their greenhouse gas emissions (Arman & Yuksel, 2013).

4.7. London Gatwick Airport Energy Saving Measures

Airports all around the world are increasingly focusing on energy efficiency and, as a result, are implementing energy saving measures. The improvement of energy efficiency and environmental performance of buildings is increasingly regarded as being a major priority for airports all around the world (Fesanghary et al., 2012). In recent years, there has been a growing interest in targeting energy efficiency as a roadmap for carbon mitigation strategies and measures, limiting energy use, improving buildings' energy performance, and reducing energy consumption for achieving sustainable buildings (Hafez et al., 2023). Energy efficiency through investment in energy saving measures leads to long lasting results for the firm (Henryson et al., 2000). The measures employed to save energy vary in nature, and the decision maker is required to establish an optimal solution, considering multiple and usually competitive objectives such as energy consumption, financial costs, environmental performance, and so forth (Diakaki et al., 2010). Furthermore, saving energy has an important role in the concerted actions to mitigate the effects of global warming, especially the energy consumed by the existing buildings (with various energy consuming functions, or possibly inefficient energy), by implementing environmentally friendly solutions (Prada et al., 2020). Consequently, a very important trend in recent times has been the introduction of a wide range of energy saving measures by airports (Baxter, 2021; Emeara et al., 2020). These energy saving measures are enabling airports to optimize their energy consumption, whilst at the same time mitigating their impact on the environment. Gatwick Airport Limited has been one such company that has implemented various energy efficiency measures and these are discussed below.

During 2016, "Airport Cars", London Gatwick Airport's on-airport taxi provider, began introducing electric and hybrid vehicles to its fleet, including state-of-the-art Tesla cars. The use of electric powered vehicles enabled Airport Cars to provide emission-free travel within a 10-mile radius of the Airport. In 2016, the airport joined the Government's "Go Ultra Low Companies" initiative and in the same year London Gatwick Airport launched a low-emission taxi service with Airport Cars, the airport's on-airport taxi company (Gatwick Airport Ltd, 2017).

In April 2016, the airport opened its new Pier 1, a modern pier and combined baggage handling facility that was designed to meet its latest technical standards. The new Pier 1 incorporated high efficiency lighting, heating, ventilation, and air conditioning (HVAC) and baggage systems. In 2016, major project work was undertaken in the airport's North Terminal to create a new passenger security area, provide a large new airline check-in facility as well as the refurbishment of international arrivals; all these projects enabled the airport to upgrade the energy efficiency of lighting, controls, and plant. The airport also commenced a program to relocate several airlines to different terminals - the "Airline Moves" project. This project involved the refurbishment of offices, passenger lounges, workshops, passenger check-in and other facilities; this work allowed many systems to be upgraded in terms of energy efficiency – many directly by the airport. In particular, third-party office accommodation in Jubilee and Atlantic House, was fully fitted out to Gatwick Airport Limited technical standards which included energy efficient LED lighting and controls. Also, in 2016, London Gatwick Airport announced the first point-to-point electric car sharing service at a UK airport, opened its new Pier 1, which features high efficiency lighting and baggage systems, completed major upgrades to the North Terminal passenger check-in, security, and arrivals areas, which incorporated energy efficient lighting and controls. The airport also commenced a multi-year program to decentralize its South Terminal boiler plant during 2016 (Gatwick Airport, 2017).

London Gatwick Airport is investing in electric vehicle infrastructure for airport operations and public transport. As part of this policy, the airport's fleet of light medium duty vehicles that can be replaced with suitable electric models are being replaced at the end of their life cycles. In 2017, the airport also trialed the Volkswagen e-Crafter van in pre-production, becoming the first UK-based airport to do so. In addition, the airport was the first United Kingdom-based airport to take up the "Bluecity" electric car sharing service (Gatwick Airport Limited, 2018b). The replacement of internal combustion engine powered airport ground support vehicles and equipment with cleaner energy powered vehicles could potentially reduce carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter (PM) (Gellings, 2011). This is because electric powered vehicles (EVs) have high energy efficiency and low pollutant and greenhouse gas (GHG) emissions when compared with conventional internal combustion engine vehicles (ICEVs) (Zhao et al., 2015).

Airports are increasingly installing light-emitting diodes (LED) systems as an energy efficiency and reduction measure (Budd et al., 2015; Freyssinier, 2014). Light-emitting diodes (LEDs) are regarded as being a practical option for airports due to airport's requirements for colored light as well as low light output requirements (Baxter et al., 2018). In 2017, London Gatwick Airport completed the second phase of a multi-year runway lighting upgrade by installing over 550 light emitting diode (LED) "threshold and approach" lights that are used guide incoming aircraft to the airport. The light emitting diode (LED) lights have a lifespan of 50,000 hours and are 50% more energy efficient than the previous halogen lights. In 2012, the airport's main runway lighting was switched to light emitting diode (LED) lighting, so Gatwick's runway lighting, which is comprised of 1,100 individual lights, is now 100% LED-based (Gatwick Airport, 2018b). Importantly, LED light sources have significantly lower maintenance costs due to their lower power requirements and have a longer life span (Bullough, 2012; Stasinopoulos et al., 2009; Steele et al., 2016). LED lighting is also regarded as being more environmentally friendly (Atlas, 2013; Lee et al., 2020; Roland, 2018). Also, in 2017, the airport completed Phase 2 of the South Terminal boiler plant decentralization program as well as three large scale terminal lighting upgrade projects (Gatwick Airport, 2018b).

London Gatwick Airport has introduced more than 200 charging points that are to charge electric-powered ground service equipment (GSE). Installing electric charging stations enables an airport to support sustainable ground transportation (Nam, 2019). In addition, fixed electrical ground power systems (FEGP) are fitted at all the airport's aircraft parking stands. Also, in 2018, the airport completed the full refurbishment of its airfield maintenance workshop building. The building refurbishment included a complete upgrade of the building fabric, HVAC system, and lighting. The airport also progressed designs for Phase 3 of the South Terminal boiler plant decentralization (Gatwick Airport, 2019).

In 2020, London Gatwick Airport continued to work on infrastructure planning for electric and fuel-cell vehicle with partners including Metrobus, UKPNS, Gridserve and Source London (Gatwick Airport, 2020b).

The low-cost carrier (LCC) Easyjet, in partnership with World Fuel Services, has introduced an electric hydrant dispenser system at London Gatwick Airport which will serve the airline's fleet at the airport (Craig, 2021; Otley, 2021). This system was the first in the United Kingdom. Based on diesel equivalents which are estimated to burn 6,630 litres of diesel every year, the new electric hydrant dispenser can reduce 18,000 kgs of carbon dioxide (CO_2) emissions annually. The electric hydrant dispenser adds to the electric ground services equipment (GSE) already supporting Easyjet aircraft operations at London Gatwick Airport (Otley, 2021). As noted earlier, ground service equipment (GSE) refers to vehicles and equipment that are used in the airport precinct to service aircraft whilst they are at the gate in between flights (Hazel et al., 2011). At London Gatwick Airport, 40% of the airfield's ground support equipment (GSE) is electric, including baggage tugs and an increasing number of pushback tugs and aircraft high loaders (Gatwick Airport, 2023c).

4.8. The Use of Sustainable Aviation Fuel (SAF) at London Gatwick Airport

Prior to examining the deployment of sustainable aviation fuels (SAF) at London Gatwick Airport, it is important to note that one of the most significant trends in the global aviation industry in recent times has been the uptake in the use of sustainable aviation biofuel. Airlines now regard the use of aviation biofuel as being a key environmental sustainability measure (Baxter et al., 2020; Bittner et al., 2015; Cortez et al., 2015). As a result, alternative jet fuel (AJF) technologies have gained considerable interest and are now regarded as a way for the air transport industry to achieve large, near-term emissions reductions (Staples et al., 2014). The use of renewable jet fuels (RJFs) is being viewed as an option for the aviation sector meeting its greenhouse gases (GHG) reduction targets (Capaz et al., 2020). Consequently, aviation biofuels are therefore becoming an important substitute for fossil fuel in the airline industry. The use of aviation biofuels help with an airline's sustainability goals as they are environmentally friendly (Su et al., 2015). Furthermore, the replacement of fossil fuels by sustainable aviation biofuels is one of the principal strategies adopted by airlines to decrease their carbon dioxide (CO_2) emissions by 50% by 2050 (Bauen & Nattrass, 2018; Dodd et al., 2018).

On 3rd October 2018, Gatwick welcomed Virgin Atlantic's history making flight VS16 from Orlando. This was the first commercial flight into the United Kingdom with fuel made partly from industrial waste gas missions. In a process pioneered by LanzaTech, waste emissions are converted into ethanol alcohol which is blended with conventional jet fuel (Gatwick Airport, 2019).

In October 2021, London Gatwick Airport utilized sustainable aviation fuel (SAF) on all Easyjet flights that were operated during the COP26 climate conference that was held in Glasgow, Scotland. The first of a total of 42 Easyjet flights departed the airport on 19 October 2021, and this flight was powered by a 30 percent Neste SAF blend. This was the first flight to depart from the airport that has used sustainable aviation fuel (SAF). The flight was also the first usage by any easyJet service operating in the United Kingdom (International Airport Review, 2021b; Otley, 2021).

The sustainable aviation fuel (SAF) was delivered by Q8Aviation to Gatwick. The SAF, which was manufactured by Neste, was produced from 100 per cent renewable and sustainable waste and residue raw materials, such as used cooking oil and animal fat waste (Craig, 2021; Otley, 2021). For delivery into aircraft, the sustainable aviation fuel (SAF) is blended with Jet A-1 fuel at a depot upstream of Gatwick Airport to create a drop-in fuel that is compatible with existing aircraft engines and the airport infrastructure. Q8Aviation then delivers the fuel to the main storage tanks at Gatwick Airport for supply to EasyJet aircraft via the airport's hydrant system (International Airport Review, 2021b; Otley, 2021).

V. CONCLUSION

This case study, which was based on an in-depth longitudinal research design, has examined London Gatwick Airport's energy management. The case study covered the period 2014 to 2021. The qualitative data used in the study was examined by document analysis.

London Gatwick Airport has two principal energy sources: electricity and natural gas. During the period 2019 to 2021, London Gatwick Airport also procured and used vehicle and equipment fuel (MI), refrigerant gas, and propane. The case study revealed that London Gatwick Airport contributes to a lower carbon grid through its procurement of 100% certified renewable electricity. The airport has purchased this 100% certified renewable electricity since 2013. This measure has enabled the airport to mitigate its environmental impact. An important energy-related development at London Gatwick Airport, has been the airport's waste processing and biomass generation facility, which began operations in November 2016. At London Gatwick Airport, Category 1 and other types of organic waste are converted into biomass fuel that is used to power the processing plant and provide heating for the airport's North Terminal. The system also heats London Gatwick Airport's waste management site. The waste plant also provides power to the site's water recovery system.

The case study also showed that London Gatwick Airport's annual electricity consumption fluctuated over the period 2014 to 2021. There were four years in this period where the airport's annual electricity consumption increased on a year-on-year basis. These increases occurred in 2016 (+3.13%), 2017 (+1.39%), and 2018 (+1.8%), respectively. The airport handled higher levels of passenger traffic and aircraft movements in these respective years. These increases in both passengers and aircraft movements had a concomitant impact on the amount of electricity that was needed to handle the increased passenger traffic and aircraft movements. During the period 2014 to 2021, there were four years where the airport's annual electricity consumption decreased on a year-on-year basis. These annual decreases were recorded in 2015 (-3.17%), 2019 (-2.15%), 2020 (-37.75%), and 2021 (-8.05%), respectively.

The case study revealed that there were two discernible trends in London Gatwick Airport's annual natural gas consumption. Over the period 2014 to 2018, there was a general upward trend in London Gatwick Airport's annual gas consumption. In the latter years of the study, that is, 2019 and 2020, there was a downward trend in the airport's natural gas consumption. Like other airports around the world, London Gatwick Airport was impacted by the COVID-19 pandemic and the related pandemic response measures in both 2020 and 2021. In 2021, the airport's annual; natural gas consumption increased by 18.54%. England experienced a cold winter in 2021, and thus, this had a concomitant impact on the airport's heating requirements in 2021.

Throughout the study period, London Gatwick Airport introduced a range of energy efficiency related measures. These measures include the installation of high efficiency lighting, heating, air conditioning, and ventilation (HVAC) systems, the upgrading of the airport's boiler plant, the installation of an electricity powered hydrant dispenser, and the installation of more energy efficient light emitting diode (LED) lighting. The airport is also replacing its fleet of airport vehicles with electric powered vehicles. In addition, the airport is transitioning towards the use of electricity powered ground service equipment (GSE).

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