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OPTIMIZING AIRPORT SUSTAINABLE WASTE MANAGEMENT FROM THE USE OF WASTE-TO-ENERGY TECHNOLOGY AND CIRCULAR ECONOMY PRINCIPLES: THE CASE OF LONDON GATWICK AIRPORT

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Abstract: Underpinned by an in-depth qualitative instrumental case study research approach, this paper reviews the waste-to-energy (WtE) system at London Gatwick Airport. The airport opened its waste-to-energy (WtE) plant in 2016 and London Gatwick Airport was the first airport in the world to covert wastes to energy onsite. 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 waste plant also provides power to the site's water recovery system. London Gatwick Airport's waste-to-energy plant generates 1MW of renewable energy and can generate 22,500kW of heat each day. The environmental-related benefits from this system include a reduction in truck vehicle journeys to external waste plants, which has resulted in lower vehicle-related carbon dioxide (CO_2) emissions, lower vehicle noise levels, and less vehicle congestion. The water recovered from the waste-drying stage is also used to clean waste bins located throughout the airport. This re-use of water has enabled the airport to reduce its annual water consumption by 2 million litres per annum. The ash recovered from the system's biomass boiler can be used to make low carbon concrete thereby reducing carbon dioxide (CO_2) emissions. Importantly, since 2016, no wastes have been disposed to landfill thereby mitigating the environmental impacts associated with landfill wastes. London Gatwick Airport has applied the circular economy principles to its waste management. As such, the airport aims to re-use and recycle waste wherever possible and those wastes that are unsuitable or not permitted for re-use or recycling are recovered for energy. Since Gatwick Airport's waste-to-energy plant (WtE) became operational in 2016, the annual volumes of wastes recovered for energy were 5,677 tonnes in 2016, 5,509.6 tonnes in 2017, 4,939.9 tonnes in 2018, 3,930.5 tonnes in 2019, and 1,243.6 tonnes in 2020, respectively.

Keywords: airports, case study, circular economy waste management principles, energy, London Gatwick Airport, sustainable waste management, waste-to-energy (WtE).

1. Introduction

Two of the most significant issues confronting airports all around the world at the present time are the generation of waste and energy management. This is because airports generate large quantities of waste (Baxter *et al.*, 2018a, 2018b; Li *et al.*, 2018; Sebastian and Louis, 2021), and airports are also extremely energy intensive (Baxter *et al.*,

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2018c, 2018d; de Rubeis *et al*., 2016; Ortega Alba and Manana, 2017). Considering these issues, airports have sought to become more environmentally friendly. Some airports have sought to become "eco-friendly" (Allett, 2008; Lie Ling Piao *et al*., 2021), whilst others have sought to become "green airports" (Cosgrove, 2018; Sun *et al*., 2021; Winter *et al*., 2021). 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 goal of producing zero greenhouse gas emissions (González-Ruiz *et al*., 2017). Typically, airports generate both hazardous and non-hazardous solid wastes (Baxter *et al*., 2018a, 2018b). These wastes need to be re-used, recycled, utilized for energy recovery, or disposed to landfill (Sarbassov *et al*., 2020). As part of their environmental policy, some airports have adopted the use of waste-to-energy systems to minimize the environmental impact from waste disposal. Two airports that have adopted such a waste handling strategy are London Gatwick Airport (James, 2017), and Osaka's Kansai Airport (Baxter *et al*., 2018a).

The objective of this study is to empirically examine London Gatwick Airport's waste-to-energy (WtE) and to identify the environmental benefits that the airport gains from the use of the system. London Gatwick Airport was selected as the case airport as it was the first airport in the world with the ability to legally dispose of Category 1 waste on site. Category 1 waste, which is the most hazardous grade of animal by-products, is particularly problematic for airports. Listed under this category is international catering waste (James, 2017). Hence, the waste-to-energy system (WtE) utilized at London Gatwick Airport has reduced the logistics complexity associated with the safe handling of Category 1 wastes. A second objective of the study is to identify how London Gatwick Airport has applied the circular economy principles to its waste management. A further objective is to quantify the annual volume of the airport's wastes that are treated at its waste-to-energy (WtE) plant.

The remainder of the paper is organized as follows: the literature review presented in Section 2 sets the context for the in-depth case study. The research method used in the study is described in Section 3. The London Gatwick Airport case study is presented in Section 4. The key findings of the study are presented in Section 5.

2. Background

2.1. Circular Economy and Waste Minimization

The circular economy is an economic system that is based upon business models that replace the "end-of-life" concept with reducing or alternatively reusing, recycling, and recovering materials during the product/distribution and consumption processes of a firm. This approach results lower volumes of waste produced and discarded from both manufacturing and raw materials processes (Ginga *et al.,* 2020). The circular economy extends beyond recycling and is based upon a restorative industrial system that focuses on the treatment of waste as a resource (Ghosh, 2020). The circular economy consists of three principal activities: the reduction in the use of virgin raw materials, the re-use of already processed materials, and the recycling of waste (Burneo *et al.,* 2020). In some cases, there is a fourth circular economy activity, that of the redesign of products (Burneo *et al.,* 2020; Kyriakopoulos *et al.,* 2019). Furthermore, the adoption of the circular economy principles enables a firm to improve the value adding of products and processes through the avoidance of waste (Ghinea and Gavrilescu, 2019).

2.2. Sustainable Airport Waste Management

While most of the waste is generated by the airlines serving the airport, it is often the case that the airport operators will have the overall responsibility for waste management for all the airport-related activities (Graham, 2018). In addition to the waste that is generated from aircraft, waste is produced in airport offices, retail outlets, restaurants, restrooms, and flight catering centres; from air cargo operations, maintenance facilities and areas, and from landscaping, construction, and demolition projects undertaken at the airport. Each of these areas creates discrete waste streams (Atkin *et al*., 2006), all of whom have the potential to generate substantial volumes of waste (Thomas and Hooper, 2013).

There are seven discrete types of waste generated at airports can be divided into seven discrete types of waste: (1) municipal solid waste (MSW); (2) construction and demolition waste (C&D); (3) green waste; (4) food remediation waste; (5) waste from aircraft flights (deplaned waste); (6) lavatory waste; and (7) spill clean-up and remediation waste (United States Federal Aviation Administration, 2013; Mehta, 2015).

Waste mitigation measures form part of the airport waste management system, which are in place at virtually all airports. The airport waste management system is normally designed and operated in accordance with the airport's applicable regulatory framework. This especially applies to the storage and disposal of waste in dedicated areas which cannot be used for other, more profitable activities. The airport waste management system generally includes the identification of the various waste sources, facilities, equipment, and the infrastructure required to deal with the different types and volumes of waste produced at the airport. The waste management system also measures the efficiency and effectiveness of the waste collection, storage, recycling, and waste disposal (Janić, 2011).

An efficient and effective airport waste management system normally implies waste avoidance, waste minimization, and waste disposal. This will involve the separation (sorting) of the waste at airport's waste collection points, that is, at the source, into solid and liquid, hazardous and non-hazardous waste, a reduction in the generated waste volumes, continuous increase in reuse, recycling and reprocessing of wastes, and permanent improvement in airport waste management practices (Janić, 2011).

There are five key waste disposal options available to airports:

1. Re-use of wastes: Re-using waste, wherever possible, is preferable to recycling because the waste items do not need to be processed again before their re-use (Güren, 2015). Reuse occurs when something that has already achieved its original function is later used again for another purpose (Zhu *et al*., 2008). Airports may reuse and repurpose materials. The reuse or repurposing of recovered materials also has the advantage of reducing the demand for new materials (International Civil Aviation Organization, 2020).

2. Recycling: with this option the waste fraction is re-used again to produce raw materials that can be used for making new products or new forms of energy (Spilsbury, 2010).
3. Incineration: with this option the waste fraction is incinerated. An option is for the waste to be incinerated in a combined heat power plant (CHP) that produces heat and/or electricity (McDougall *et al*., 2007; Scragg, 2009).
4. Composting of wastes: Composting waste is a process whereby the organic portion of solid waste is converted into a humus-like product. The final product can be used as a soil conditioner or for landfill cover (Harper, 2004). The composting of rubbish reduces environmental pollution (Taiwo, 2011).
5. Landfill: this option is typically only used for inert materials. Waste that is considered not suitable for recycling or incineration may be disposed to landfill (Hauser, 2009; Westlake, 2014).

Airports can operate either centralized, de-centralized waste management systems or a combination of both procedures (Mehta, 2015; Kazda *et al*., 2015). A centralized airport waste management systems will have a single waste management point for all airport terminal and aircraft waste except for flight catering centres, which often manage their own waste (Atkin *et al*., 2006).

2.3. Waste-to-Energy: A Background Note

The thermal conversion of wastes in specially designed chambers at very high temperatures reduces the waste to around one tenth of its original volume whilst at the same time recovering materials and energy. The heat that is produced from the combustion or gasification is converted into steam, which flows through a turbine to produce electricity. This process is referred to as waste-to-energy (WtE) (Klinghoffer *et al*., 2013). Also, waste-to-energy (WtE) refers to the recovery of useable heat and power produced from waste (Tabasová *et al*., 2012; Zhao *et al*., 2016), but especially from non-recyclable wastes (Tabasová *et al*., 2012). On other occasions, waste-to-energy (WtE) has been referred to as the generation and utilization of energy by treating solid wastes (Tayeh *et al*., 2021).

The utilization of energy produced from waste, and waste-to-energy (WtE), has become increasingly significant in recent times (Leckner, 2015) as waste to energy (WTE) has become an important strategy in waste treatment (Zhang *et al*., 2015). Indeed, the conversion of waste into energy has become one of the most effective tools in waste management and energy generation in recent times (Ahmadi *et al*., 2020). Furthermore, the process of waste-to-energy also supports a circular economy by reducing the volumes of waste that are disposed to landfill (Murer *et al*., 2011).

Historically, waste-to-energy (WtE) plants have been designed for the clean and economical disposal of wastes (Dhir *et al*., 2018). Waste to energy (WtE) conversion technologies can be used to convert residual wastes into clean energy. This practice avoids the requirement to dispose of wastes to landfill (Klinghoffer *et al*., 2013). The disposal of wastes to landfill is regarded as the least desirable waste disposal method (Biron, 2020; Williams, 2013). Often in the past, waste treatment often did not have any energy recovery objectives. However, today, there are now state of the art waste-to-energy facilities. These facilities are often coupled with not only mechanisms to recover heat and energy in combined heat and power plants, but also have sophisticated mechanisms to clean flue gas. Furthermore, these systems can utilize wastewater, and they assimilate diverse streams of waste with high efficiency (Makarichi *et al*., 2018). The use of thermal treatment of waste with the heat recovery (waste to energy– WtE) provides firms and society with clean and reliable energy in the form of heat as well as power (Pavlas *et al.,* 2010).

Airport waste typically contains a large proportion of substances and raw materials which should be sorted and recycled (Kazda *et al*., 2015). Airports may decide to implement a strategy to recover their wastes. This strategy primarily relates to the recovery of energy that is recovered from waste (Baxter and Srisaeng, 2021). Furthermore, waste that is not considered suitable for reuse, recovery or recycling can be incinerated to generate heat or electricity (Makarichi *et al*., 2018; Waters, 2020). In conjunction with prevention and recycling measures, waste-to-energy (WtE) facilities can make a significant contribution to a firm attaining its waste management goals. Nowadays, sophisticated air pollution control (APC) devices have ensured that emissions produced at waste-to-energy (WtE) facilities are environmentally safe. This is achieved because incinerators provide the complete destruction of hazardous organic materials. Moreover, waste-to-energy (WtE) systems reduce the risks from pathogenic microorganisms and viruses, and they also concentrate valuable and toxic metals in certain fractions. In addition, bottom ash, and Air Pollution Control (APC) residues have now become new sources of secondary metals (Brunner and Rechberger, 2015).

3. Research Methodology

3.1. Research Approach

The research undertaken in this study was underpinned by an in-depth qualitative instrumental case study research approach. An instrumental case study is the study of a case, for example, a firm. An instrumental case study provides insights into a specific issue, enables the researcher(s) to redraw generalizations, or builds theory (Stake, 1995; 2005). The instrumental case study research approach also facilitates the understanding of a specific phenomenon and is designed around established theory (Grandy, 2010). The present study was designed around the established theory of circular economy and waste management (Ghosh, 2020; Ibrahim, 2020; Pillay and Pillay, 2020), sustainable airport waste management (Baxter *et al.,* 2018a, 2018b; Baxter & Srisaeng, 2021), and waste-to-energy (WtE) (Klinghoffer *et al*., 2013; Kalogirou, 2017; Michaels, 2013; Rogoff & Screve, 2019; Stehlik, 2016).

3.2. Data Collection

The qualitative data gathered for this study was obtained from Gatwick Airport's sustainability reports and environmental policy. Qualitative data was also gathered from Gatwick Airport's websites as well as from the key airport industry trade journals. These journals included Airport Technology, Airports International, Airport World, and the International Airport Review. Thus, in this study secondary data was used to investigate the research problem. The three guiding principles of data collection in case study research as suggested by Yin (2018) were followed in this study: 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

Document analysis focuses on the information and data from formal documents and company records (Oates, 2006; Gil-Garcia, 2012). Existing documents provide researchers with aa vital source of qualitative data. These documents may be publicly available, or they may be private in nature (Woods & Graber, 2017). Documents are one of the principal forms of data sources for the interpretation and analysis in case study research (Olson, 2010). The documents collected for the present study were examined according to four criteria: authenticity, credibility, representativeness, and meaning (Scott, 2014; Scott & Marshall, 2009).

The key words used in the database searches included "Gatwick Airport environmental management policy", "Gatwick Airport waste management policy", "Gatwick Airport total annual wastes", "Gatwick Airport total annual wastes converted to energy", and "Gatwick Airport waste-to-energy system".

The study's document analysis was conducted in six distinct phases. The first phase involved planning the types and required documentation and ascertaining their availability for the study. In the second phase, the data collection involved sourcing the documents from Gatwick Airport and the secondary data sources and then subsequently developing and implementing a scheme for managing the gathered documents. The collected documents were examined to assess their authenticity, credibility and to identify any potential bias in the third phase of the document analysis process. In the fourth phase, the content of the collected documents was carefully examined, and the key themes and issues were identified and recorded. The fifth phase involved the deliberation and refinement to identify any difficulties associated with the documents, reviewing sources, as well as exploring the documents content. In the sixth and final phase, the analysis of the data was completed (O'Leary, 2004).

In this study, the documents used in the qualitative analysis were stored in a case study database (Yin, 2018). The documents were all in English. Each document was carefully read, and key themes were coded and recorded (Baxter, 2020).

4. Results

4.1. A Brief Overview of London Gatwick Airport

Operations commenced at London Gatwick Airport in the 1930s, however, the airport was officially opened on the 9th June 1958. London Gatwick Airport has a single runway that is 3,316 metres long and 45metres wide. 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 (London Gatwick Airport, 2021a).

In 1987, the British government privatized seven major airports through a share flotation. Gatwick Airport was privatized as part of this change in British government policy (Augustyniak, 2009). London Gatwick Airport was sold by the British Airport Authority (BAA) in late 2009 to Global Infrastructure Partners (Poole, 2012). Gatwick Airport Limited is now the company that has been licensed by the Civil Aviation Authority to operate Gatwick Airport [82]. 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, 2021b). London Gatwick Airport handled 10.2 million passengers in 2020, which was significantly lower than the 46.6 million passengers handled in 2019 (London Gatwick Airport, 2021a). In 2020, the COVID-19 pandemic caused a major decline in economic activity around the world, and this resulted in severe disruptions in the air travel market's supply and demand chain (Dube *et al*., 2021). The airline industry has confronted many threats over time, but none have been quite as bad as the rapid and severe as the one posed by the spread of COVID-19 around the world (Sobieralski, 2021). In addition, because of the global coronavirus crisis, most countries placed restrictive measures to confine the pandemic (Iacus *et al*., 2020). These restrictions had a very adverse impact on airline passenger demand during 2020. The largest airline serving London Gatwick Airport is easyJet. easyJet carried 4.8 million passengers from the airport during 2020 (London Gatwick Airport, 2021a).

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 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; London Gatwick Airport, 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 endeavors to understand the requirements of its stakeholders and partners (London Gatwick Airport, 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;
- 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 (London 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) (London Gatwick Airport, 2021b). In 2015, all United Nations Member States adopted the "2030 Agenda for Sustainable Development" and its seventeen 17 Sustainable Development Goals (SDGs). Each SDG comprises a range of targets to be achieved by 2030 (Katila *et al*., 2019; United Nations, 2021). At the time of the present study, Gatwick Airport environmental policy was aligned with several of the SDG themes and targets. The relevant SDGs 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 (London Gatwick Airport, 2021c).

A key element of the airport's sustainability policy is that London Gatwick Airport will aim to repurpose all materials used at the airport for beneficial use. This includes recycling operational, commercial and construction waste, donating items that are considered no longer use (re-use), and converting waste to fuel for heating and transport, including at the airport's onsite biomass boiler (waste recovery). Importantly, the airport aims to dispose of no wastes to landfill (London Gatwick Airport, 2021d).

4.4. London Gatwick Airport Circular Approach to Reducing Waste

At London Gatwick Airport, each day waste is collected from around 2,000 bins located throughout the airport. This covers the airport's passenger terminals, offices, and car parks. The airport aims to reuse or recycle most of the waste collected, while converting the remainder into energy. As noted earlier, the airport aims to send zero waste to landfill. The reuse of waste is a key strategy implemented at the airport. As such, all food scraps collected from retail outlets, offices, and European Union (EU) flights are converted onsite to biomass for heating. In addition, all warehouse pallets and 95% of airfield and cargo pallets are returned to suppliers for subsequent reuse (London Gatwick Airport, 2021c).

The recycling of waste is a key part of London Gatwick Airport's environmental strategy. At the airport, all dry mixed materials collected, including from European Union (EU) flights, are recycled. These waste items include dry paper and cardboard, all empty bottles, cans and other beverage cartons, plastic bags, and sheeting. In addition, used cooking oil is de-packed, heated, cleaned, and subsequently filtered prior to it being sent for recycling into biodiesel. All batteries and the glass, metal and plastic in lighting tubes are also recycled. Around 40% of clothing that is discarded in bins is sent to be recycled into fibres. Furthermore, ash from the airport's biomass boiler and from the offsite recovery for electricity is recycled into secondary aggregates for use in the construction industry (London Gatwick Airport, 2021c).

At London Gatwick Airport, all mixed materials collected from non-European Union (EU) flights as well as mixed materials affected by food or liquid that are not able to be recycled are recovered off site and are used to produce electricity (London Gatwick Airport, 2021c).

In summary, the wastes from recycling bins, landside general waste and European Union (EU) flights are processed at the airport's Materials recycling facility, where they are baled by waste type. These wastes are then sent to United Kingdom-based processors for recycling or for their reuse in the UK. The waste from food scrap bins including "Category 1" food waste from non-EU flights is processed in the airport's dryer system, where the organic waste that is not able to be recycled is dried out and turned into biomass fuel. The water that is recovered from the dryer is used to wash the bins that are located within the airport precinct. These wastes are also processed in the airport's Biomass boiler. The biomass fuel is then used for energy to heat the Recycling Centre. Hence, the renewable energy is subsequently reused onsite. The ash collected from the Biomass boiler is reused in low carbon concrete. Other general wastes are compacted and are then sent offsite where they are used for energy recovery. This latter process turns the waste into electricity that is distributed from the grid (London Gatwick Airport, 2021c).

4.5. Total Annual Operational and Commercial Wastes at London Gatwick Airport

The total annual operational and commercial wastes at London Gatwick Airport and the year-on-year change (%) from 2011 to 2020 are presented in Figure 1. As can be observed in Figure 1, the annual operational and commercial wastes at London Gatwick Airport have increased throughout the study. This is demonstrated by the year-on-year percentage change line graph, which is more positive than negative, that is, more values are above the line than above. Figure 1 shows that the lowest annual wastes tonnage was recorded in 2012 (8,803 tonnes), whilst the largest wastes tonnage was recorded in 2018 (13,722 tonnes), respectively. The highest annual single increase in wastes was recorded in 2017, when these wastes increased by 10.91% on the 2016 levels. Figure 1 shows that there were three years in the study period where the total annual wastes decreased on a year-on-year basis. These decreases occurred in 2012 (-4.37%), 2019 (-1.66%), and 2020 (-71.97%), respectively. Throughout the study period, London Gatwick Airport recorded increases in the number of passengers using the airport as well as increased aircraft movements, both of which contribute to increased waste tonnages. The very significant decrease in 2020 could be attributed to the decrease in the number of passengers handled at the airport together with the small number of aircraft movements because of the Corona 19 virus pandemic.

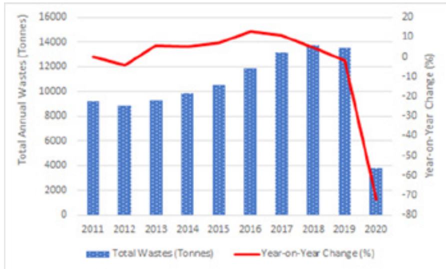

Fig. 1.
The Total Annual Operational and Commercial Wastes at London Gatwick Airport and the Year-on-year Change (%): 2011-2020
Source: data derived from London Gatwick Airport (2017, 2018, 2019, 2020).

The total annual amount of operational and commercial wastes at London Gatwick Airport that were recovered for energy and the year-on-year change (%) from 2011 to 2020 are presented in Figure 2. As can be observed in Figure 2, the annual amount of operational and commercial wastes at London Gatwick Airport that were recovered for energy oscillated throughout the study period. There was a very pronounced spike in 2012, when such wastes increased by 218.74% on the 2011 levels. Figure 2 shows that there was a significant increase in the total wastes recovered for energy in 2015, when these wastes increased by 25.97% on the 2014 levels. Figure 2 shows that there were five years during the study period where the annual wastes recovered for energy decreased on a year-on-year basis. These annual decreases occurred in 2014 (-19.85%), 2017 (-2.94%), 2018 (-10.34%), 2019 (-20.43%), and 2020 (-68.36%), respectively. From 2014 to 2020, there was an upward trend in the wastes that were recycled or re-used. Also, from 2015 to 2019, no wastes were disposed to landfill.

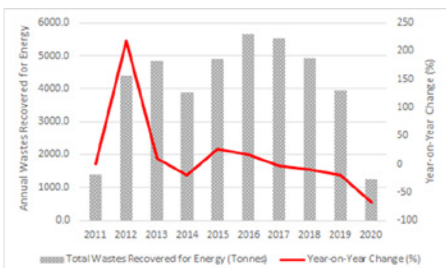

Fig. 2.
The Total Annual Operational and Commercial Wastes recovered for Energy at London Gatwick Airport and the Year-on-year Change (%): 2011-2020
Source: data derived from London Gatwick Airport (2017, 2018, 2019, 2020).

Figure 3 presents the total annual operational and commercial wastes at London Gatwick Airport that were recovered for energy as a share of total wastes and the year-on-year change (%) from 2011 to 2020. As can be observed in Figure 3, the annual operational and commercial wastes that were recovered for energy as a share of total wastes have fluctuated throughout the study period. Figure 3 shows that there was a pronounced spike in 2012 when this metric increased by 233.33% on the 2011 level. The highest annual wastes to energy as a portion of total wastes was recorded in 2013 (52%), whilst the lowest level in this metric was recorded in 2011 (15%). Figure 3 shows that there were four years during the study period where the annual wastes recovered for energy as a portion of total wastes decreased on a year-on-year basis. These annual decreases occurred in 2014 (-23.84%), 2017 (-12.5%), 2018 (-14.28%), and 2019 (-19.08%), respectively.

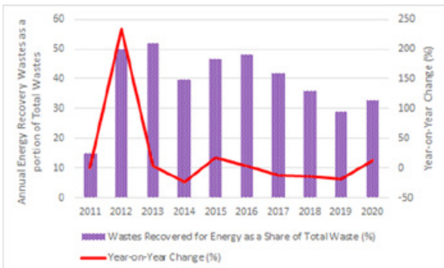

Fig. 3.
The Total Annual Operational and Commercial Wastes recovered for Energy as a Portion of Total Wastes and the Year-on-year Change (%): 2011-2020
Source: data derived from London Gatwick Airport (2017, 2018, 2019, 2020).

4.6. London Gatwick Airport Waste-to-Energy System

In November 2016, operations commenced at London Gatwick Airport's waste processing and biomass generation facility. Following the commencement of operations of this new facility, London Gatwick Airport was the first airport in the world with the ability to legally dispose of Category 1 waste on site (James, 2017; London Gatwick Airport, 2017; Manuel, 2016). The new waste processing plant cost £3.8 million (James, 2017. The London Gatwick Airport facility is operated in partnership with DHL Supply Chain. Category 1 wastes forms most of the airport waste from non-EU flights. Category 1 wastes are food wastes, or anything mixed with it, for example, packaging, cups, meal trays that comes from international transport vehicles (Hardcastle, 2017; Manuel, 2016). As previously noted at 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 waste plant also provides power to the site's water recovery system (Hardcastle, 2017). The project was managed by the airport's waste handling contractors DHL. The biomass combustion and preparation systems were supplied by food waste technology specialists Tidy Planet (James, 2017).

At London Gatwick Airport wastes are transported to the site's Materials Recovery Facility (MRF), where DHL staff sort them into two categories – recyclable and non-recyclable (Tidy Planet, 2020). The wastes are also sorted dry and wet (London Gatwick Airport, 2017). Recyclates, for example, paper, cardboard, and plastic are diverted along one conveyor belt to be sent off-site for resource recovery. The other waste items such as wet food waste and food packaging undergo a drying process whereby, they are turned into a biomass fuel (Tidy Planet, 2020). At London Gatwick Airport all Category 1 wastes go straight to the dryer for processing. Because the manual processing and separation of organic wastes is a time-consuming and difficult task, this waste is sent directly for drying. These wastes are dehydrated at high temperatures, to create a granular biomass fuel for the use in the IED-compliant biomass boiler (Tidy Planet, 2020) which generates 1MW of renewable energy (James, 2017). The food-waste-to-energy system can also generate 22,500kW of heat each day (Tidy Planet, 2020).

The disposal of Category 1 wastes is governed by strict rules that prior to the opening of the waste-to-energy plant required specialist processing offsite. This was to protect against the potential spread of any disease and infectious material (Manuel, 2016). International regulations require Category 1 waste to be either incinerated or rendered. As a result of this requirement, airports normally must transport it offsite, thereby incurring haulage fees and vehicle emissions (Hardcastle, 2017). Gatwick Airport complied with the strict regulations and worked very closely with the Department for Environment, Food & Rural Affairs (DEFRA) and the Animal Plant Health Authority to ensure that the technology and our processing system satisfied their requirements (James, 2017).

Once the plant commenced operations, the main priority for the airport was to create a waste disposal procedure that permitted all the on-site businesses to participate without having to make considerable process changes or perform extensive retraining. This situation was helped by the fact that each business was not required to separate its own recycling wastes as London Gatwick Airport does the waste sortation for the on-site businesses (James, 2017) on their behalf. At the time the facility became operational, London Gatwick Airport was handling around 2,200 tonnes of Category 1 waste each year (Recycling Product News, 2017). This accounted for approximately 20% of the total wastes generated at the airport. The plant will process approximately 10 tonnes of wastes per day (James, 2017; Hardcastle, 2017). By concentrating all waste related activities in a single location, the airport can transport waste four times more efficiently than before. This has provided valuable benefits for the airport as this more efficient waste management process has reduced both local traffic volumes and carbon dioxide (CO_2) emissions. London Gatwick Airport's waste-to- energy plant also has the capacity to produce additional energy that could one day be used to power other areas of the airport (Hardcastle, 2017). London Gatwick Airport's biomass boiler has been designed to operate to emission standards that are stricter than those required by European Union (EU) regulation (London Gatwick Airport, 2017). In addition, the plant has also been designed with the future in mind. As such, the plant has the capacity to produce additional energy that could one day be used to provide power to other areas of the airport (Recycling Product News, 2017).

Figure 4 presents a schematic drawing of the London Gatwick Airport waste-to-energy system.

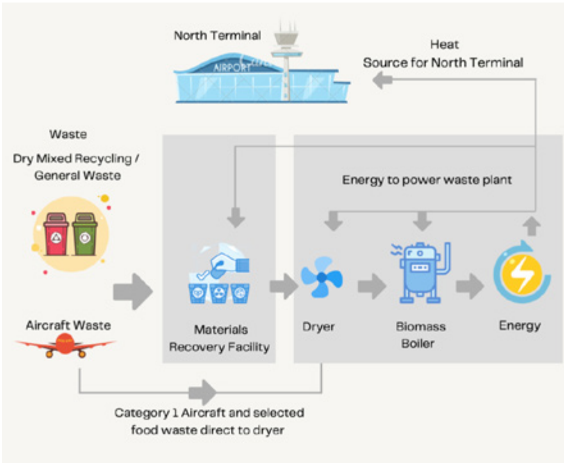

Fig. 4.
The London Gatwick Airport Waste-to-Energy System
Source: adapted from London Gatwick Airport (2017)

4.7. Environmental Benefits of the London Gatwick Airport Waste-to-Energy System

An important environmental benefit of the waste-to-energy system at London Gatwick Airport is that it generates 1MW of renewable energy from the biomass boiler (Infrastructure Intelligence, 2017). Green or renewable energy produces no greenhouse gas emissions from the combustion of fossil fuels. Consequently, this reduces some forms of harmful air pollution (International Renewable Energy Agency, 2021; United States Environmental Protection Agency, 2021). In addition, the use of green or renewable energy sources provides a firm or user with an important opportunity to optimize their energy efficiency (Arman & Yuksel, 2013).

Using small balers in the airport terminals and large 'mill size' bales to compress waste, there are 200 fewer industrial-size waste bin collections per day at the airport. As a result, truck vehicle journeys to external waste plants have been reduced by fifty per cen. An associated benefit of this is lower vehicle carbon dioxide (CO_2) emissions, lower vehicle noise levels, and less vehicle congestion. As previously noted, water recovered from the waste-drying stage is also used to clean waste bins located throughout the airport. This re-use of water has helped to reduce airport water consumption by 2 million litres per annum (Infrastructure Intelligence, 2017; London Gatwick Airport, 2017).

The ash that is recovered from biomass boiler can be used to make low carbon concrete thereby reducing carbon dioxide (CO_2) emissions (Infrastructure Intelligence, 2017).

London Gatwick Airport was the first airport to be awarded the Carbon Trust Standard for Zero Waste to Landfill. This independent certification recognizes businesses that apply a best practice approach to waste management and who actively divert all appropriate waste streams from landfill (London Gatwick Airport, 2018). It is important to note that the least desirable waste disposal option is the disposal of wastes to landfill (Manahan, 2011; Muthu, 2020; Williams, 2013). This is because waste that is disposed of through landfilling and open dumping, is regarded as being environmentally unsafe as they produce greenhouse gases (GHGs) emissions (Trabold and Nair, 2019). The certification is applicable for Gatwick Airport's operational and commercial waste (London Gatwick Airport, 2018).

In 2016, Gatwick Airport made a substantial investment in a systemic "circular" waste management approach which increased its recycling and reuse rates (London Gatwick Airport, 2019). This approach by Gatwick Airport delivers environmental benefits. This is because the goal of a circular economy approach is to respect environmental boundaries through increasing the share of renewable or recyclable resources whilst at the same time reducing the consumption of raw materials and energy. As a result, emissions and loss of resources will therefore be reduced. Circular economy approaches such as re-using, and recycling existing products and materials, plays a very important role in maintaining the use of products, components and materials and retaining their value (European Environment Agency, 2016). Circular economy principles therefore provide important benefits for the environment and society. These include a reduction in the use of resources, a reduction in waste production, and more favorable energy consumption (Ahmed *et al.*, 2020). In 2019, Gatwick Airport was awarded the United Kingdom Airport Operators Association's "Best Environmental Initiative" in recognition of the airport's circular economy waste management approach (London Gatwick Airport, 2020).

5. Conclusions

Underpinned by an in-depth qualitative instrumental case study research design, this study has examined London Gatwick Airport's waste-to-energy (WtE) system. The case study revealed that this system became operational in 2016 and, upon opening, London Gatwick Airport was the first airport in the world to operate such a plant. 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 waste plant also provides power to the site's water recovery system. London Gatwick Airport's waste-to-energy plant generates 1MW of renewable energy and can generate 22,500kW of heat each day. The case study found that there are many environmental-related benefits from this system. These benefits include a fifty percent reduction in truck vehicle journeys to external waste plants, which has resulted in lower vehicle-related carbon dioxide (CO_2) emissions, lower vehicle noise levels, and less vehicle congestion. Another important benefit of the system is that the water recovered from the waste-drying stage is also used to clean waste bins located throughout the airport. This re-use of water has enabled the airport to reduce its annual water consumption by 2 million litres per annum. Another environmental-related benefit is that the ash recovered from the system's biomass boiler can be used to make low carbon concrete thereby reducing carbon dioxide (CO_2) emissions. Importantly, since 2016, no wastes have been disposed to landfill thereby mitigating the environmental impacts associated with landfill wastes.

London Gatwick Airport has applied the circular economy principles to its waste management. Consequently, London Gatwick Airport aims to re-use and recycle waste wherever possible and those wastes that are unsuitable or not permitted for re-use or recycling are recovered for energy.

Since London Gatwick Airport's waste-to-energy plant (WtE) became operational in 2016, the annual volumes of wastes recovered for energy were 5, 677 tonnes in 2016, 5,509.6 tonnes in 2017, 4,939.9 tonnes in 2018, 3,930.5 tonnes in 2019, and 1,243.6 tonnes in 2020, respectively. The lower volume in 2020 could be attributed to the downturn in air traffic and aircraft movements due to the Corona virus pandemic. The case study also revealed that the annual wastes recovered for energy as a share of total waste (%) decreased on a year-on-year basis, which was in-line with the lower tonnages of wastes recovered for energy.

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