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# An Assessment of the use of the ISO 50001 Certified Energy Management Systems by Airports

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***Abstract*****—*****This study has examined the airports located throughout the world that have implemented an ISO 50001 certified Energy Management System (EMS). The research used an in-depth instrumental case study research design. The study period was from 2011 to 2022. The study found that ISO 50001 certified Energy Management Systems are increasingly being adopted by airports and these systems are playing a key role in their environmental management. Airports located in China, Cyprus, Hong Kong, Europe, India, Turkey, Sweden, United Kingdom, United States of America have implemented ISO 50001 certified Energy Management Systems since the inception of this standard in 2011. ISO 50001 certified Energy Management Systems have been implemented by hub airports, by airports that service both domestic and international airlines services, and by smaller regional airport. The case study found that airports are using their ISO 50001 certified Energy Management System to optimize their energy efficiency. These airports have implemented a very wide range of energy conservation measures, including the use of light emitting diode (LED) systems, the electrification of ground service equipment and vehicles, the installation of electric vehicle charging stations, the installation of photovoltaic (PV) solar systems, building heating and cooling systems optimization, and the optimization of energy for plant and equipment. The case study also highlighted the importance that the airports using an ISO 50001 certified Energy Management System are placing on the use of more environmentally friendly renewable energy sources.*
***Keywords*****— Airports, case study, energy, energy management, ISO 50001 Energy Management Systems.***

## I. INTRODUCTION

Airports are an integral component of the world air transport system (Dempsey, 2000) and act as a forum in which discrete elements and activities are brought together to facilitate, for passengers and air cargo, the interchange between air and surface transport modes (Doganis, 2005). The basic infrastructure and facilities provided by airports compromises runways, taxiways, apron space (ramp), passenger terminals, air cargo terminals, and ground transport interchange facilities (Ashford et al., 2011; Seyanont, 2012). Airports provide both aeronautical services (infrastructure, facilities and in some cases ground handling services) and non-aeronautical services (for example, car parks and retail concessions) to two main groups of customers: airlines and air travelers (Marques & Brochado, 2008).

To reduce their long-term operating costs and to ensure that energy demand can be satisfied when the needs arise, airports are placing a higher focus on energy-conservation measures in the design (and operations) of terminal buildings and infrastructure (Thomas & Hooper, 2013). Some airports have also developed and operate new power-generation systems that provide reliable and affordable sustainable energy whilst also lowering their energy costs (Budd & Budd, 2013). Furthermore, airports often work closely with tenants, concessionaires, and service partners to reduce energy consumption through the introduction of low-energy equipment and systems (Thomas & Hooper, 2013).

Airports are extremely energy intensive (Baxter, 2021; Baxter et al., 2018; de Rubeis et al., 2016; Ortega Alba & Manana, 2017). This is due to the large buildings (both passenger terminals and non-passengers' areas) equipped with heating and air-conditioning systems, and the high-power demand for lighting and electric equipment and the energy requirements from the many facilities located within the airport precinct (Cardona et al., 2006). Airports also consume large amounts of energy due to the comfort requirements of airport terminal buildings (Akyüz et al., 2017). An airport terminal cooling demands can also be energy intensive (Abdallah et al., 2021). Consequently, the maintenance of an ambient temperature and air quality within airport passenger terminals to ensure passenger comfort typically represents the single most significant contribution to energy usage and management at most airports (Thomas & Hooper, 2013).

In addition to the provision of electrical energy required for the aids to air transport operations, for example, lighting and meteorological systems, electrical energy also needs to be provided for airport buildings, aircraft hangers and other airport facilities (Kazda et al., 2015). Thus, energy management, which includes heating, ventilation, air conditioning, and lighting, is extremely important for airports (Graham, 2018).

The implementation of energy management policies over the past thirty years or so has been regarded as being particularly important for firms wishing to save energy resources, to tackle the issue of climate change, whilst also maintaining their competitive edge in an ever-changing business environment (Tachmitzaki et al., 2020. A firm's energy efficiency can be controlled and systematized by using an Energy Management System (Fiedler & Mircea, 2012). In 2011, the International Organization for Standardization (ISO) released its ISO 50001 Energy Management System standard, which has been embraced by organizations all around the world. As a result of its implementation of an ISO 50001 Energy Managements System by an organization, besides the support provided to reduce the energy consumption of the company, the certified ISO 50001 Energy Management System also enables better cost management and greenhouse gas (GHG) emission reduction (Rampasso et al. 2019). In recent times, airports have adopted the use of ISO 50001 certified Energy Management Systems (Baek et al., 2016; Fossi & Esposito, 2015; Strelkova &Agieieva, 2014; Uysal & Sogut, 2017). The key objective of this study is to empirically examine the airports located throughout the world that have implemented an ISO 50001 certified energy management system (EMS) as a system to manage their energy usage in a sustainable manner. A secondary objective is to identify the types of airports, for example, major hub or regional airports, that have implemented ISO 50001 Energy Management Systems. A further objective is to examine how airports are using their ISO 50001 certified Energy Management System to optimize their energy efficiency. The study period is from 2011, the year in which the ISO 50001 standard came into effect, to 2022.

The remainder of the paper is organized as follows: The literature review is presented in Section 2. The research method that underpinned the study is outlined in Section 3. The case study is presented in Section 4. Section 5 presents the key findings of the study.

## II. BACKGROUND

### 2.1 Core Functions of an Airport

An airport is a complex transportation hub serving aircraft, passengers, air cargo shippers and surface vehicles (Doganis, 2005). An airport is either an intermediate or terminal point of an aircraft operating the air portion of a flight, either on a scheduled or non-scheduled basis. In simple functional terms, the airport must be designed to enable an aircraft to land and take-off. In between these two operations, it may, if required, unload and load passengers, air cargo, mail and crew and service the aircraft (Ashford et al., 2013, p. 8).

The core function of an airport is the operation of premises and facilities for the servicing and handling of aircraft, passengers, and air cargo and mail. This includes the supply and operation of ground handling facilities, aprons, runways, aircraft, and ground service equipment (GSE) maintenance areas, gates, people movers, baggage handling, car parks, passenger and visitor waiting areas, areas for security and social services, and so forth (Meincke & Tkotz, 2010, p. 95).

In addition, airports may also offer/provide non-aviation services. These are primarily the supply of space for shopping and retail operations, convention centres, restaurants, and business centres. The non-aviation revenues are often a major source of revenue and profits, and hence, an essential part of an airport's business model (Graham, 2018). Increasingly more aviation-related businesses are establishing operations near airports (Reiss, 2007). Another important development in the airport industry is that airports are increasing evolving from simple infrastructure providers to complex multiproduct, multiservice enterprises (Appold & Kasarda, 2011). Indeed, airports all around the world have developed into multimodal, multifunctional enterprises, which has driven substantial commercial development both within and beyond their boundaries (Kasarda, 2006). Many airports have diversified their activities and revenue streams and have created so-called "airport cities" (Kasarda, 2013; Orth & Weidmann, 2014). In the case where the airport operator is responsible for the provision of energy, then the airport's non-aviation facilities will also need to source power, and this will have a concomitant impact on the airport's overall energy requirements and energy consumption.

**2.2 Airport Energy Sources**

Airports consist of the landside and airside precincts both of which have significant energy requirements (Janić, 2011, 2017). The airside precinct includes the aircraft movement area, and the adjacent terrain and buildings/infrastructure. The landside precinct includes those parts of an airport together with the adjacent terrain and buildings that are not located in the airside precinct (Rossi Dal Pozzo, 2015). The key stakeholders, for example, airlines and ground handling agents, operating within the airport's airside and landside precincts require a reliable and highly efficient supply of energy. Historically, the two primary energy sources have been electricity and fuel, for example, diesel, natural gas, and propane (Ortega Alba & Manana, 2016). Electrical energy is typically supplied directly to the airport through dedicated sub-stations (Janić, 2011). Airports often purchase electricity from the commercial grid and this electricity is supplied by a power company (Ortega Alba & Manana, 2016). In recent years airports have started to adopt the use of renewable energy sources. These 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).

**2.3 Energy Usage at Airports**

The major 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). At many airports, crude oil is often used for producing the fuel used to power the ground service equipment (GSE) and vehicles that are used in an airport's airside and landside areas, especially in the aircraft ground handling process (Janić, 2011). Ground service equipment (GSE) refers to vehicles and equipment that are used in the airport precinct to service whilst they are at the gate in between flights (Hazel et al., 2011). Fuel is also used for airport's heating boiler systems and emergency generators (Ortega Alba & Manana, 2016). The airport terminal's heating, ventilation, and air conditioning (HVAC) systems use the largest amount of energy (Akyüz et al., 2017; Yildiz et al., 2022).

Energy consumed by airports can be broadly divided 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. 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 service equipment (GSE) and vehicles serving aircraft at the apron/gate complex consume energy. In the airport landside area, the primary consumers of energy are the airport ground access systems/modes and passenger and air cargo terminals as well as other administrative buildings serving the airport. The primary energy sources are from non-renewable fossil fuels and to a moderate degree from renewable wind, water, and solar sources (Janić, 2011).

**2.4 An Overview of the International Organization for Standardization ISO 50001 Energy Management System Standard**

Different standards motivate firms to use energy more efficiently (Jovanović & Filipović, 2016). Energy management has been increasingly considered as a way for a firm to improve energy performance and at the same time reduce their greenhouse gas emissions (Hasan & Trianni, 2020; Sola & Mota, 2020). The United Nations Organization for Industrial Development requested the International Organization for Standardization (ISO) to develop an international standard for energy management. This standard development took place within the framework of industries' requirements to have an effective response to global climate change (Castro et al., 2017). Introduced in June 2011, the ISO 50001 International Standard was developed to provide a unified framework for energy management efficiency (Dzene et al., 2015; Gopalakrishnan et al., 2014; Yuriev & Boiral, 2018). According to Brown and Desai (2014), "the adoption of the ISO 50001 Energy Management System standard by the International Organization for Standardization (ISO) served to unite the previously separate national standards and provide a structured, globally accepted approach to the management of energy" The ISO 50000 family of standards developed by the ISO provides guidelines and recommended practices for the utilization, savings, efficiency, and continuous improvement in energy performance. As previously noted, ISO 50001 establishes the requirements for an Energy Management System (EnMS) (Poveda-Orjuela et al., 2018). Since the launch of the ISO 50001 standard in 2011 there has been the growing adoption of Energy Management Systems (EnMSs) by firms around the world (Laskurain et al., 2017). The ISO 50001 Energy Management System standard supports an organizational cost-and-benefits oriented perspective of energy (Kals, 2015). ISO 50001 Energy Management System is a voluntary standard (Lira et al., 2019).

The principal goal of the ISO 50001 standard is for an organization using an Energy Management System to improve the energy performance of the organization continuously and sustainably so that it can reduce energy consumption and the associated costs. These also include alleviating environmental climate change impacts (Nakthong & Kubaha, 2020). The standard stipulates the measurement of energy performance improvement using energy performance indicators (EnPIs) and the energy baseline (EnB) (Nakthong & Kubaha, 2020; Wulandari et al., 2014).

An ISO 50001 certified Energy Management System is comprised of five key components: Roles and responsibility, energy policy, energy objectives and energy targets, energy efficiency improvement plan, and the monitoring, measurement, and analysis (Energy Efficient Singapore, 2021; International Organization for Standardization, 2021).

The ISO 50001 Energy Management System standard also provides a basis for energy management improvement by a firm (Jovanović & Filipović, 2016). This is because the ISO 50001 Energy Management System standard is based on the management system model of continual improvement. Thus, the ISO 50001 Energy Management System standard makes it easier for a firm to integrate energy management into their overall efforts to improve their quality and environmental management (International Organization for Standardization, 2021).

The ISO 50001 Energy Management System (EnMS) framework is a tool that can be used by organizations to assess their energy management sustainability. The system allows for the determination of an organization's actual strengths and weaknesses in its energy management. The benefits of using this framework (and an energy management system) include the possibility of determining guidelines for correcting and improving the Energy Management System (EnMS) to achieve the sustainability goals of the organization (Nakthong & Kubaha, 2019).

According to the International Organization for Standardization, the ISO 50001 standard provides a framework of requirements for a firm to:

- Develop a policy for more efficient use of energy
- Define targets and objectives to meet the policy
- Use data to better understand and make decisions about energy use
- Measure the results
- Review how well the energy policy works, and
- Continually improve energy management (International Organization for Standardization, 2021).

As previously noted, ISO 5001 is a voluntary standard. In today's business environment, some firms have decided to implement the standard solely for the benefits it provides. Conversely, other firms decide to get certified, to show external parties they have implemented an Energy Management System. The International Organization for Standardization (ISO) does not perform any certification (International Organization for Standardization, 2021).

The ISO 50001 Energy Management System standard has been designed for implementation by any organization that operates in either the public or private sector, whatever its size, activity, or geographical location. ISO 50001 does not set fix targets for improving energy performance, rather this left up to the user organization or regulatory authorities. As a result, any organization, regardless of its current level of energy performance, can implement the ISO 50001 Energy Management System standard to establish a baseline and improve on it at its own rate (International Organization for Standardization, 2018a).

The ISO 50001 Energy Management System standard has been designed for organizations to improve their energy performance by making better use of its energy-intensive assets. Improvements in energy performance can deliver rapid benefits to the firm using an Energy Management System by maximizing its use of energy sources and energy-related assets, thus, reducing both cost and energy consumption. The ISO 50001 standard is used by both large and small organizations located throughout the world. The benefits of using an ISO 50001 certified Energy Management System include a reduction in the organizations environmental impact, an enhanced reputation, and the ability to drive down costs and improve the firm's competitiveness (International Organization for Standardization, 2018a). The use of an ISO 50001 certified Energy Management System can assist organizations to achieve full compliance in line with the various environmental regulations applicable to their organization (Capital NDT, 2021; Eccleston et al., 2012). In addition, a very important benefit is that the ISO 50001 Energy Management System standard provides an organization with a powerful tool to improve their overall energy performance (Marimon & Casadesús, 2017). The use of an ISO 15001 certified Environmental Management System can also enable an organization to improve the efficient use of existing technologies and practices so they can optimize their energy efficiency. In addition, the use of the system will enable the organization to promote environmental performance whilst also reducing greenhouse gas (GHG) emissions (Eccleston et al., 2012).

As previously noted, the ISO 50001 standard was first published in 2011. However, since its inception, a number of other related standards have been developed by the ISO technical committee ISO/TC 301, Energy management and energy savings. These changes have been made to complete the energy management and energy savings family (International Organization for Standardization, 2018a).

These include:

- ISO 50002, Energy audits – Requirements with guidance for use
- ISO 50003, Energy management systems – Requirements for bodies providing audit and certification of energy management systems
- ISO 50004, Energy management systems – Guidance for the implementation, maintenance and improvement of an energy management system
- ISO 50006, Energy management systems – Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) – General principles and guidance
- ISO 50007, Energy services – Guidelines for the assessment and improvement of the energy service to users
- ISO 50015, Energy management systems – Measurement and verification of energy performance of organizations – General principles and guidance
- ISO 50047, Energy savings – Determination of energy savings in organizations

Other ISO energy related standards include:

- ISO 17741, General technical rules for measurement, calculation, and verification of energy savings of projects
- ISO 17742, Energy efficiency and savings calculation for countries, regions, and cities
- ISO 17743, Energy savings – Definition of a methodological framework applicable to calculation and reporting on energy savings
- ISO/IEC 13273-1, Energy efficiency and renewable energy sources – Common international terminology – Part 1: Energy efficiency
- ISO/IEC 13273-2, Energy efficiency and renewable energy sources – Common international terminology – Part 2: Renewable energy sources (International Organization for Standardization, 2018a, pp. 9-10).

The ISO 50001 Energy Management System standard was updated in August 2018 (Kohl, 2020; Naden, 2018). This standard contributes to the following United Nations Sustainable Development Goals 7 (Affordable and clean energy), 11 (Sustainable cities and communities), 12 (Responsible consumption and production), and 13 (Climate action) (International Organization for Standardization, 2018b).

## III. RESEARCH METHODOLOGY

### 3.1. Research Method

To achieve the research objectives, this study utilized an in-depth qualitative instrumental case study research design. An instrumental case study is the study of a case, for example, a business or company, that provides insights into a specific issue, redraws generalizations, or builds theory (Stake, 1995, 2005). The instrumental case study research approach enables researchers to gain an enhanced understanding of a specific phenomenon. An instrumental case study is designed around established theory of the phenomenon that is being empirically examined (Grandy, 2010). The present study was designed around the established theory of ISO 50001 Environmental Management Systems (Eccleston et al., 2012; Kals, 2015; Wulandari et al., 2014; Yuriev & Boiral, 2018).

### 3.2 Data Collection

The data used in the study was obtained from a range of company materials that were available on the internet and these records formed the source of the case study evidence. An extensive search of the leading air transport and airport-related journals and magazines was also conducted in the study. This study used secondary data. The three principles of data collection as recommended 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 study (Andrew et al., 2011; Yin, 2018). Following the guidance of Scott (1990, 2014) and Scott and Marshall (2009), the documents gathered in the present study were examined according to four criteria: authenticity, credibility, representativeness and meaning.

The document analysis was undertaken in six distinct stages:

- Phase 1: The first phase involved planning the types and required documentation and 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.
- 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.
- 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 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, 2021).

## IV. RESULTS

Aéroports de Paris was awarded its ISO 50001 Energy Management System certification for its operations and development activities at Ile-de-France airports and its energy management using fossil and renewable sources (biomass, geothermal, solar) by LRQA France, on 25 July 2015. Aéroports de Paris became the first group managing a multi-airports system to have an Energy Management System with an ISO 50001 certification. To achieve the company's strategic objective of reducing carbon dioxide ($CO_2$) emissions by 25% between 2009 and 2015, beginning in 2008 Aéroports de Paris invested in a major renewable energy development program. As a result, geothermal energy at Paris-Orly airport and a biomass and a solar farm at Paris-Charles de Gaulle airport have resulted in renewable energy sources making up over 15% of internal energy use. To attain its goals of achieving ISO 50001 certification, Aéroports de Paris worked on improving all its internal processes to develop an energy management system (EMS) in line with the international ISO 50001 standard. Importantly, since January 2014, the Energy Management System has complemented the Integrated Management System (IMS) and the Environment Management System (EMS) at Aéroports de Paris. The Aéroports de Paris managed, and operated airports are Paris Charles de Gaulle, Paris-Orly, Paris-Le Bourget, and Issy-les-Moulineaux, all of which have held an ISO 14001 environmental certification for many years (Aéroports de Paris, 2015).

Amsterdam-based Schiphol Airport has implemented an ISO 50001 certified Energy Management System. The airport has implemented energy saving measures including the use of electricity powered buses and cars, electric car charging stations and the use of solar power (Schiphol Group, 2021).

Bali's Ngurah Rai International Airport has introduced an ISO 50001:2018-based Energy Management System for energy conservation and management. The goal of the system is to minimize the environmental footprint of the Island's sole air gateway. The new ISO 50001:2018-based Energy Management System was implemented at Bali's Ngurah Rai International Airport in February 2021, as the result of a Memorandum of Understanding (MOU) signed in October 2020 between Angkasa Pura I, the Director-General of New Energy Sources from the Directorate of Energy Conservation, and the Director-General of Energy Conservation from the Ministry for Energy and Natural Resources. The aim of Ngurah Rai Airport's active participation in the energy management system is to reduce the greenhouse gas (GHG) emissions that contribute to the climate change. The airport's energy conservation measures include the use, whenever possible, of solar energy, lighting powered by solar cells, the use of light emitting diode (LED) lighting, and the deployment of many energy-saving devices in the day-to-day operation of the airport gateway. The energy saving measures implemented at the airport will reduce energy consumption by 3,627.686 MWh and will also reduce the airport's annual carbon dioxide ($CO_2$) emissions (Daniels, 2021).

Bangalore International Airport Limited (BIAL) in India achieved its ISO 50001:2011 Energy Management System certification on 8 April 2013. The goal of the airport is to create a greener environment. The certification was awarded by DNV (Det Norske Veritas). The implementation of the ISO 50001:2011 Energy Management System has enabled the airport to achieve its policy commitments, and to act as required to improve its energy performance at the airport. This includes energy cost reduction, greenhouse gases (GHGs) mitigation, waste minimization, resource conservation and compliance with all applicable legal requirements (GVK, 2013).

Bologna Airport in Italy uses a certified ISO 5001 Energy Management System. During 2013, the airport began the process of implementing the ISO 50001 Energy Management System into its operations (Bologna Airport, 2014). In 2021, Bologna Airport focused on its active energy efficiency, which are an integral part of the airport's sustainable development policy. Between cogeneration, photovoltaics, and high-efficiency light emitting diode (LED) lighting, it is estimated that the airport was able achieve energy savings of around 2,600,000 kWh. Bologna Airport has recently completed the energy efficiency upgrade to the workshop lighting and launched an initiative to replace the old lamps in the lighting towers - which will reduce the installed power by over 70% while guaranteeing the same lighting performance. The airport is also renewing the lighting in the Baggage Handling System, which will reduce energy consumption by over 70%. Importantly, Bologna Airport self-produces around 20 MWh of electricity through a photovoltaic system and manages a high-performance trigeneration plant, covering around 58% of its own energy requirements. In addition, the airport has decided to commit to the construction of a new photovoltaic system of around 190 kW, which will be installed on the roof of the passenger terminal, and a photovoltaic system of around 100 kW that will be located on the roof of the BHS building, which will enable the production of over 300,000 kWh of electricity. Furthermore, in 2021, the airport operator only purchased electricity from renewable sources and natural gas with offset-certificated emissions, linked to forest and biodiversity conservation projects certified by third parties (Bologna Airport, 2021).

Brussels Airport Company successfully completed its Environmental Management System audit in 2012 and became the first airport in the world to be awarded the ISO 50001 certificate for its energy management (Brussels Airport, 2021b). A key element of the airport's Environmental Policy Statement is the airport's objective to achieve a continuous improvement in its energy performance and to achieve a structural reduction in carbon dioxide ($CO_2$) emissions by focusing on energy efficient installations. The airport also aims to increase the share of renewable energy used at the airport (Brussels Airport, 2021a).

Delhi Airport also has introduced an ISO 50001:2018 certified Energy Management System. This system improves the energy performance of the airport by making better use of the energy-intensive assets, and through these concerted efforts, the airport has successfully reduced both fuel and electricity consumption over the years. As part of sustainability goals, the airport has installed 7.84MW solar power plant on the airport site. Delhi Airport has also signed a long-term power purchase agreement with a hydropower plant. The plant, expected to be commissioned by 2022-23, will supply the entire electricity need of the airport, thereby ensuring a clean energy supply to Delhi Airport (Kumar Jaipuriar, 2022).

Dresden Airport in Germany introduced its Energy Management System that was certified to the international standard ISO 5000: 2011 during 2016. Increasing its energy efficiency has the added benefit of reducing emissions of air pollutants from our airport operations. Dresden Airport is also generating renewable energy from the solar panels that were installed on the roof of the car park extension in 2010 (Mittel-Deutsche Flughafen AG, 2021a).

Dublin Airport was granted ISO 50001 Energy Management System certification in 2016. The airport was subsequently recommended for recertification in accordance with the ISO 50001: 2018 standard (DAA International, 2021). In recent times, Dublin Airport has introduced a wide range of energy management measures that enable it to monitor and improve its overall energy use across the campus. The energy savings measures include the use of building management systems, the installation of efficient light emitting diode (LED) lighting, a pilot solar farm project, which will significantly reduce its overall energy consumption. Other energy-related include the transition of all of its light vehicle fleet to low emission vehicles (LEVs) by 2024 and building a second solar farm on campus with a capacity of 7.5MWp. This will contribute 10% of the airport's total annual electricity requirements and will have the potential to generate up to 7.5 megawatts of power (Dublin Airport, 2021).

Geneva Airport achieved AFAQ ISO 55001 energy management system certification on 12 July 2016 (AFNOR Group, 2016). Geneva Airport has installed a photovoltaic (PV) solar system that can produce 7.5 GWh of clean energy per year. Geneva airport's energy strategy is based on lowering the airport's energy requirements, producing, and efficiently using energy and promoting the use of renewables (Petrova, 2017).

GMR Hyderabad International Airport Ltd. (GHIAL) in India obtained its ISO 50001: 2011 Energy Management Systems Standard, 'Design, Construction, Operation and Maintenance of airport facilities' certification in May 2013. The Japan Accreditation Board (JAB) was responsible for the airport's ISO 50001: 2011accreditation (SGS SA, 2013). The airport has maintained a high focus on its energy management and has implemented a range of energy efficiency measures. These measures include power optimization by scheduled operation of AHU and lights, operation of new energy efficient sewage treatment plant, cooling tower efficiency enhanced by upgradation, the installation of a photovoltaic (PV) solar system, and the extensive upgrading of lighting with the latest light emitting diode (LED) lighting (Potdar et al., 2020).

Hartsfield-Jackson Atlanta International Airport received its ISO 50001 Energy Management System certification in

March 2016. The airport was the first United States-based airport to achieve ISO 50001:2011 certification (AECOM, 2016; Weinschenk, 2016). The City of Atlanta Department of Aviation ensures that energy efficiency and conservation is taken into consideration in the planning, design, construction, maintenance, and operational decisions of the airport. The airport also aims to use renewable energy sources wherever feasible (Hartsfield-Jackson Atlanta International Airport, 2016).

Incheon Airport in Korea has also implemented an ISO 50001 certified Energy Management System. The system plays a key role in the airport's goal to be energy efficient. The airport plans to advance the use of its energy management system. A range of energy saving measures have been implemented at the airport in recent times and these include the installation of light emitting diode (LED) lighting, replacement of freezers with more energy efficient models, and the expanded use of photovoltaic solar power generation facilities (Incheon International Airport Corporation, 2021).

Istanbul Airport's (IGA) ISO 50001 Energy Management System was certified by the British Standards Institution (BSI) in October 2020. The airport has placed a high focus on increasing its energy efficiency, decreasing consumption, and protecting resources for future generations and these goals are underpinned by the airport's Energy Management System (International Airport Review, 2020b). To achieve a reduction in carbon dioxide ($CO_2$) emissions at Istanbul Airport, the airport has achieved system Improvements with energy audits, and has implemented energy saving measures, which include the use of electric vehicles, and the installation of vehicle charging stations (International Air Transport Association, 2021). Istanbul Airport also plans to implement the use of hydrogen fuel for heating and transportation purposes, as well as introducing carbon capture technologies, solar power plant fittings, and the usage of biodiesel (Air International, 2021).

Leipzig/Halle Airport has had a certified Energy Management System in line with the international DIN EN ISO 50001 standard since 2016. A key objective of the airport is to continually improve energy efficiency at the airport. Leipzig/Halle Airport has installed a photovoltaic (PV) solar system, which has annual output of up to approximately 200 MWh (Mittel-Deutsche Flughafen AG, 2021b).

London Heathrow Airport acquired its ISO 50001 Energy Management System certification in 2015 (Virmany & Fitch, 2016). London Heathrow Airport has set a goal to operate zero carbon airport infrastructure (buildings and other fixed assets) by 2050. To achieve this goal, the airport has implemented a range of energy efficiency measures. These measures include embedding leading edge energy efficiency thinking into the design of new airport infrastructure, investing in improvements to the energy efficiency of existing buildings, assets and other infrastructure, the proactive influence of business partners' operations and growth to improve energy efficiency, maximizing the proportion of energy generated from on-airport or local renewable sources, and the purchase of renewable energy from off-site sources (Heathrow Airport Holdings, 2021).

London Stansted Airport received its ISO 50001 Energy Management System certification in 2018 (MAG Airports, 2019). The airports ISO 50001 Energy Management System was recertified on 11 August 2020 (Stansted Airport Holdings, 2020). The airport has defined and implemented an Environment and Energy Policy. In accordance with this policy, Stansted Airport is committed to continually improving its environmental and energy performance. The airport also aims to prevent pollution, protect the environment, reduce carbon emissions, and comply with all environmental legal and other requirements. Furthermore, the airport assesses the impact on the environment and energy consumption of all activities undertaken at the airport and establishes objectives and targets to drive continual improvement performance in these areas (London Stansted Airport, 2020).

Luton Airport in the United Kingdom was awarded its Energy Management Standard ISO 50001 certification in September 2015. The airport has implemented various energy-saving initiatives including light emitting diode (LED) lighting and PIR motion sensors. Other energy efficiency measures include a new coach fleet, more fuel-efficient security vehicles, and a refurbished toilet facility with more efficient lighting and hand dryers (Allen, 2015).

Lyon-Saint Exupéry Airport in France was awarded with its ISO 50001 Energy Management System certification by the French standardization association AFNOR in December 2018. The certification was in recognition of the airport's energy management and the improvement in its energy performance. The energy action plan implemented by Lyon-Saint Exupéry Airport was part of the "Air Pact" environmental strategy defined by VINCI Airports, the airport's owner, for all its facilities. VINCI Airports aims to maintain its energy consumption at a stable level despite its airport's activities increasing significantly. Lyon-Saint Exupéry Airport has implemented various energy saving measures. These include the sensible use of equipment (desktop computer, lights, heating, etc.) by employees, investing in the design and use of buildings (new Terminal 1 constructed to France's HQE high environmental quality standard), and installing light emitting diode (LED) lighting in the airport's terminals and aircraft parking areas (Burns, 2018; VINCI Airports, 2018). Light-emitting diodes (LEDs) are a feasible option for airports due to their requirement for colored light as well as low light output requirements (Baxter et al., 2018). Consequently, airports are increasingly transitioning to the use of LED systems (Freyssinier, 2014). During 2011, Lyon-Saint Exupéry Airport was the first French airport to purchase 100% green energy (Burns, 2018; VINCI Airports, 2018).

Mumbai International Airport is another Indian airport that has attained ISO 50001 Energy Management System certification. GVK managed Mumbai International Airport (MIAL) received the ISO 50001: 2011 accreditation in July 2015 (Financial Express, 2015). The airport maintains a very high focus on its energy management and has implemented various green energy initiatives across its site. A goal of the airport is to use renewable energy sources. The airport has installed solar panels on the rooftops, contributing to approximately 5% of the airport's total energy consumption (Shergill, 2021). The airport has saved substantial energy of around 38500 MWh due to its sustainable approach towards energy efficiency measures (International Airport Review, 2021). Maharaj International Airport (CSMIA) has entirely switched to green sources for its energy consumption requirements, thereby ensuring it is one of India's 100 percent sustainable airports (Shetty, 2022).

Operated by TAV Airports, Ankara Esenboğa Airport in Turkey is another airport that completed all the work necessary to control energy consumption and is has subsequently received the ISO 50001 Energy Management System certification. The airport has implemented rules in its passenger terminal to minimize our energy losses and achieve more sustainable energy consumption. The airport has also defined energy consumption targets and has provided energy efficiency training to its employees (TAV Airports, 2021).

Salzburg Airport in Austria has attained ISO 50001: 2011 Energy Management System certification (Salzburg Airport, 2018). At Salzburg Airport around 40 per cent of the airport's vehicle fleet is powered by electricity, including an electric high loader. The airport is also changing from conventional to light emitting diode (LED) lighting and is using solar energy (International Airport Review, 2020a).

Shenzhen Airport (Group) Company Ltd has received ISO 5001 certification for its Energy Management System. The company which operates Shenzhen International Airport has implemented a wide range of energy efficiency measures. These measures include the installation of a photovoltaic (PV) solar system, the purchase of new energy vehicles, installation of light emitting diode (LED) lighting, and the installation of a central air conditioning magnetic levitation cold water main engine (Clean Energy Ministerial, 2019).

Stockholm Arlanda Airport received its ISO 50001 Energy Management System certification on 23 December 2016. The airport's Energy Management System was recertified in accordance with ISO 50001: 2018 standard on 24 December 2019 (Swedavia, 2019). At the time of the present study, essentially all heating, electricity and cooling used by the airport are generated from renewable sources. The buildings at Stockholm Arlanda Airport are warmed during the winter period with district heating based on biofuel. Swedavia, the operator of Stockholm Arlanda Airport, also purchases "green electricity certificates". These certificates are equivalent to its entire electricity consumption at the airport. These certificates guarantee electricity production from exclusively renewable sources. The renewable sources include wind, solar, hydropower and/or biofuels. According to Swedavia (2021), "in the summer of 2009, Stockholm Arlanda also inaugurated the world's largest energy storage unit – a so-called aquifer – in the nearby boulder ridge known as Brunkebergsåsen". The airport is both heated and cooled efficiently using the aquifer and there is no adverse environmental impact during the summer or winter. The airport has also installed more efficient and better controlled lighting indoors and outdoors. Other energy saving measures include heat recycling in the airport's terminal buildings, more efficient ventilation, and the use of RPM-regulated electric motors (Swedavia, 2021).

Torino Airport in Italy has implemented an ISO 50001 certified Energy Management System. In October 2020 Sagat S.p.A., the airport operator, along with DNV-GL (the certification body) renewed the airport's Energy Management System certification. The airport's system is certified in accordance with the international standard ISO 50001:2018. The system recertification involved an energy diagnosis update in line with the manner provided for by Italian Legislative Decree n. 102/2014. The airport is focusing on limiting energy consumption both through investments in plants and systems with significant potential for improvement and through the enhancement of management and control systems. In 2020, 75% of the electricity came from certified renewable sources (Sagat S.p.A, 2021).

The Airport Authority of Hong Kong (AA) achieved the ISO 50001:2011 Energy Management System (EnMS) Certification for its Terminal 1 in February 2017. The use of the system will enable the airport authority to continuously improve energy efficiency and to identify energy reduction opportunities. At the time of the certification, the airport authority envisaged that it would expand the scope to other terminal areas, office buildings and the airport's apron area. The company's goal is to become the most energy efficient international airport (Airport Authority of Hong Long, 2017). The airport's ISO 50001 Energy Management System (EnMS) certification covers Terminal 1 and the Midfield Concourse, and it was envisaged that it would be expanded to cover all terminal buildings at the airport by January 2020 (Airport Authority of Hong Long, 2019). The airport in recent times has implemented energy efficiency initiatives, such as, the replacement of light emitting diode (LED) lights in Terminal Building 1, the modification of gantry lighting control in Terminal Building 1, the replacement of apron high mast lighting with light emitting diode (LED) lighting, the replacement of three energy efficient chillers in the airport's Ground Transportation Centre, and the replacement of energy efficient pump sets and motors at Seawater Pump House No.5. The airport has also acquired electric cars and buses and electric ground services equipment (e-GSE) are being introduced (Airport Authority of Hong Long, 2018). In 2018, Hong Kong International Airport introduced the ground service equipment (GSE Pooling Scheme) which centralizes the deployment of GSE used at the airport in the aircraft turnaround process (Airport Authority of Hong Kong, 2021). The new scheme optimizes and expedites the allocation and maintenance arrangements for the equipment. During the first phase of the scheme, which comprised over 250 units of critical GSE operating in the Midfield Apron precinct, led to an improvement in air quality and reduction of GHG emissions at the airport as 95% of the GSE are powered by electricity (Airport Authority of Hong Kong, 2021). In the 2018/19 financial year, Hong Kong International Airport continued with the replacement of end-of-service-life light emitting diode (LED) lights in terminals with higher efficient model. Also, in the 2018/2019 financial year the modification of gantry lighting control from 3 stages to 9 stages in Terminal Building T1 was completed (Airport Authority of Hong Kong, 2019). Hong Kong International Airport has also installed an "Air-conditioning Control System" (Weather FACTS) and "Battery Energy Storage System" (BESS), which enhances HKIA's energy efficiency. The airport's "Weather FACTS" system automatically collects hourly weather data, for example, temperature, humidity, cloud amount, wind direction, wind speed and solar radiation, from the Hong Kong Observatory, and the airport's own flight index, passenger flow and seawater temperature information. The system subsequently employs big data and machine learning to forecast the cooling demand of the airport's Terminal T1 building for the coming 24 hours. Based on the forecast, the chiller system is set to deliver the appropriate amount of cooling volume required. The optimization of the cooling levels eliminates unnecessary energy consumption. Together with the replacement of two new 5,000-refrigerant tonne chillers in 2021, an estimated 5.1-gigawatt hours of electricity is saved annually. The airport plans to introduce the same system in other passenger facilities to further optimize the airport's energy efficiency. The airport has also developed the BESS system to cope with the airport's continued traffic growth and requirement for a backup power supply. Importantly, the airport's BESS system, which operates without fuel, is more environmentally friendly than other existing backup generators and can efficiently store up electricity generated from routine testing of backup generators for future use (Airport Authority of Hong Kong, 2021). It is important to note that many airports in recent times are utilizing clean energy technologies and have also implemented practices that reduce local emissions. This environmental-related strategy includes replacing fossil fuel-based with electricity-based operations at the airport (Sajed Sadati et al., 2018). Hong Kong International Airport has introduced electric powered vehilces. Electric-powered vehicles are considered more environmentally friendly because they reduce vehicle emissions when deployed at an airport (Gellings, 2011).

The Delhi International Airport Limited (DIAL) attained its ISO 50001:2011 Energy Management System accreditation on 8 September 2011. Delhi International Airport Limited (DIAL) became the first airport operator in India to receive this certification. The certification was granted by the British Standards Institution (BSI) India (Josh, 2011). The airport has implemented various energy efficiency programs which include the use of renewable energy, development of green airport infrastructures, energy conservation and efficiency improvements. The airport's energy-related infrastructure includes electric vehicle charging facility, state-of-the-art Sewage Treatment Plant (STP) and Water Treatment Plant (WTP), and energy efficient lighting systems. The airport has also adopted the use electric vehicles and "taxibots" (Garg, 2021).

The Energy Management System of Biju Patnaik International Airport (BPIA) in Odisha, India, was certified as ISO 50001:2018 standard in October 2020. The airport places a very high focus on energy efficiency (Sambad English Bureau, 2020).

TÜV Austria Cyprus certified the Energy Management Systems of Hermes Airports Ltd, which is responsible for the management and operation of international Larnaca and Paphos airports in Cyprus in accordance with the requirements of EN ISO 50001 in January 2017 (TÜV Austria Cyprus, 2017). Hermes Airports places a high focus on its energy management, and energy-related issues are addressed within the framework of the Energy Management System (EnMS) (Hermes Airports, 2021).

## V. CONCLUSION

Airports are extremely energy intensive, and thus, there has been a growing trend by airports around the world to optimize their energy efficiency. In addition, airports are also focusing on mitigating their environmental impact and are also seeking ways to reduce their carbon footprint. This study has examined the airports located throughout the world that have implemented an ISO 50001 certified Energy Management System (EMS). The study found that ISO 50001 certified Energy Management Systems are increasingly being adopted by airports and these systems are playing a key role in their environmental management. Airports located in China, Cyprus, Hong Kong, Europe, India, Turkey, Sweden, United Kingdom, and the United States of America have adopted the use of the ISO 50001 certified Energy Management Systems since the inception of this standard in 2011.

The case study revealed that the ISO 50001 certified Energy Management Systems have been implemented by hub airports, for example, Hartsfield-Jackson Atlanta International Airport and Hong Kong Airports, by airports that service both domestic and international airlines services, and by smaller regional airport, such as, Lyon-Saint Exupéry Airport in France.

The case study further revealed that airports are using their ISO 50001 certified Energy Management System to optimize their energy efficiency. These airports have implemented a very wide range of energy conservation measures, including the use of light emitting diode (LED) systems, the electrification of ground service equipment (GSE) and vehicles, the installation of electric vehicle charging stations, the installation of photovoltaic (PV) solar systems, building heating and cooling systems optimization, and the optimization of energy for plant and equipment. The case study also highlighted the importance that the airports using an ISO 50001 certified Energy Management System are placing on the use of more environmentally friendly renewable energy.

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