A Qualitative Assessment of a Full-Service Network Airline Sustainable Energy Management: The Case of Finnair PLC

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Abstract: - Airlines are extremely energy intensive. Around the world airlines are increasingly focusing on the environmentally sustainable energy management. Using a qualitative longitudinal case study research approach, this study examines Finnair's sustainable energy management over the period 2010 to 2019. The airline's major energy source is jet fuel used for the operation of the airline's aircraft fleet and the electricity which is used to power its facilities located at Helsinki Airport. The study found that Finnair's annual jet fuel consumption has grown throughout the study due to the airline's route network and aircraft fleet expansion. The fuel required for ground vehicles has risen reflecting greater operational requirements due to the company's expansion. The annual consumption of electricity and electricity for heating has displayed a general downward trend during the study period. The annual electricity per passenger has also decreased despite the large growth in passenger numbers. Finnair has increased its use of renewable energy sources for its flight and ground operations. A key energy saving strategy has been the acquisition and operation of a modern state-of-the-art, fuel efficient aircraft fleet.

Key-Words: - airlines, case study, energy consumption, energy saving initiatives, Finnair, jet fuel consumption

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1 Introduction

The airline industry is a critical part of both national and the world economies, facilitating the transportation of people and air cargo consignments around the world whilst at the same time enabling global economic growth [1]. However, the airline industry has a range of adverse impacts on the environment [2-5]. These include aircraft emissions, noise, waste generation, and substantial consumption of water and energy. The airline industry is indeed highly energy intensive [6]. Large quantities of fuel are required to operate aircraft and ground vehicles and ground service equipment (GSE). In addition, airlines use large amounts of power and heating and cooling for their buildings and facilities. Considering the environmental impact associated with the different forms of energy usage, airlines all around the world are increasingly defining and implementing a range of strategies and measures to sustainably manage their energy consumption, and thus, mitigate their adverse impact on climate change and global warming. These energy saving measures include the operation of next generation, highly fuel-efficient aircraft such as the Airbus A350-900XWB and the Boeing 787, and the use of sustainable aviation fuels. For example, the major full-service network airlines such as British Airways, Finnair, Qatar Airways and Singapore Airlines have in recent times inducted the Airbus A350-900XWB and the Boeing 787 aircraft into their fleets. At the same time, many of the low-cost carriers have acquired and operate the next generation narrow-body aircraft, for example, the Airbus A320neo and Boeing 737 MAX aircraft.

Air transport services are provided by full-service network airlines (FSNCs), low-cost carriers (LCCs), charter/holiday airlines, and by regional airlines [7]. The focus of this study is on a full-service network airline. A full-service network airline is defined as an "airline that focuses on providing a wide range of pre-flight and onboard services, including different service classes, and connecting flights" [8].

In this study, Finnair PLC, Finland's major air carrier, was selected as the airline due to its long commitment to sustainable energy management. Sustainable energy management has been a core element of Finnair's sustainable management policy The objective of this paper is to analyse how Finnair manages its energy consumption and energy sources whilst at the same time ensuring a sustainable approach to their flight and ground operations. The paper also examines the airline's approach to the use of renewable energy resources. A further objective is to examine the airline's fleet modernization strategy as this forms a key part of Finnair's objective to operate fuel efficient aircraft, and thus, optimise their annual jet fuel consumption. A final objective of the present study is to examine the energy savings measures implemented by Finnair as part of its commitment to environmentally sustainable operations.

The remainder of the paper is organized as follows: Section 2 sets the context of the case study by providing a review of the extant literature on environmentally sustainable airline energy management. The research method used in the study is presented in Section 3. The Finnair case study is presented in Section 4. Section 5 presents the key findings of the study.

2 Background

2.1 Airline jet fuel consumption

One of the unique characteristics of the global airline industry is that it is highly energy intensive. Jet fuel is the major component of airlines energy consumption. There are many different types of jet fuel used in the air transport industry as well as for military aviation. During the 1960s, Jet-A fuel became the standard fuel used in the United States and by many commercial airlines [9]. This type of fuel was selected over the more highly flammable JP-4 for passenger safety reasons [10]. Nowadays, it is typically only available in the United States, where it is used for domestic flights and for international flights originating in the United States. Jet A-I is available globally, including in the United States [9]. In terms of the costs of operating an airline, jet fuel typically represents the highest cost for an airline [11, 12]. In addition, there is an environmental impact from the burning of jet fuel. Aircraft produce carbon dioxide (CO_2), nitrogen oxides (NO_X), particles (principally soot) of sulphur oxides, carbon monoxide (CO) emissions. Hydrocarbons are also produced from the consumption of jet fuel. First, and generating largest percentage share, are the emissions of carbon dioxide (CO_2) which are produced in direct proportion to the volume of jet fuel used to operate flights over any distance [13, 14]. Water vapor is also formed from the burning of jet fuels [15]. Considering the negative environmental impact and the cost of burning fuel, airlines and the aircraft and engine manufacturers have consistently sought to reduce the amount of fuel that is required to transport one passenger one kilometre, and great advances have been made in this regard recent times [16].

2.2 Airline ground service equipment (GSE) consumption

To perform ground handling services of aircraft when they are on the ground in between flights, sophisticated technical equipment is required to perform the tasks required in servicing an aircraft [17, 18]. The ground service equipment (GSE) used in servicing an aircraft includes push-back tugs, lower deck loaders, (main deck loaders for freighter aircraft), toilet and water truck, tugs (for towing cargo to and from the air cargo terminal and for towing baggage to and from the airport's baggage makeup area), aircraft container and pallet dollies, ground power unit, aircraft tail stand (for freighter aircraft), and aircraft bulk hold loaders. This ground service equipment is typically powered by diesel engines. Vehicles used by airlines are also often petrol-powered.

It is important to note that as part of the ground handling of an aircraft that ground service equipment (GSE) will have periods when their engine is in idle mode. Thus, to reduce fuel consumption, whilst also mitigating the environmental impact of emissions, the idle rotation speed should be as low as possible. Furthermore, rotating speed with too low speed should also be avoided by ground service equipment operators [19].

2.3 Airline property and facilities energy consumption

Airlines require a consistent source of electricity to power their airport and non-airport located buildings, facilities, and equipment. Electrical power is also required to run machinery, heating, ventilating, and air conditioning (HVAC) systems, building lighting, computers and so forth. It has been estimated that HVAC systems typically account for as much as 30% of energy use and costs in commercial buildings and office spaces [20]. Aside from leasing an airport terminal(s), airlines may be one of several tenants in other airport-located multi-tenant buildings, for example, air cargo terminals or ground service equipment (GSE) maintenance facilities [21]. Airports are very energy-intensive areas [22-24]. This is due to the large buildings (both terminals and non-passenger areas) that are equipped with heating and air-conditioning systems, the significant lighting usage as well as the energy requests from many of the facilities that are located within the airport precinct [25]. Thus, an airline's airport operations can be extremely energy intensive.

Furthermore, in recent years, there has been a growing shift to renewable energy by businesses operating all around the world. This change is being driven by stricter climate laws as well as the political risks associated with the dependence on oil and gas exporters [26]. Renewable energy is being increasingly used for generating electricity, heating, and cooling [27]. There are a variety of renewable energy technologies for a firm considering adopting this energy source. The renewable energy technologies now include wood heating, solar thermal, geothermal ground or water source heat pumps, hydropower [28], biomass for electricity, hydrokinetic energy [29], solar photovoltaic, and wind energy [28, 30]. Renewable energy offers environmental, economic, and social benefits. These include little or very small amounts of global warming emissions, enhanced public health and environmental quality, stable energy prices, a more reliable and resilient energy system, as well the creation of jobs and other economic benefits [29]. Renewable energy, including solar power, is especially pertinent to this study as Finnair, the case airline, has embraced the use of renewable energy as a key part of its sustainability policy over the past few years.

3 Research Methodology

3.1 Research approach

The selection of the research methodology that underpinned the study was influenced by the research objectives and its corresponding research questions, as well as the current state of this field of study as presented in the study's literature review [31]. The literature review has revealed that airline sustainable energy management has attracted little research attention and therefore not only is the question of "why" and how" being addressed in this study but the more fundamental question of how sustainable energy measures can be employed by airlines to mitigate the environmental impact of their flight and ground operations. Yin [32] has observed that a case study is the preferred method when "how" and "why" research questions are posed, provided the focus is on a contemporary phenomenon. According to Babbie [33] (p.293), the case study can be defined as the in-depth examination of a single instance of some phenomenon of interest. Furthermore, Zonabend [34] has suggested that case study research is undertaken by paying special attention to complexities in observation, reconstruction, and analysis of the case(s) under study and is undertaken in such a way that it incorporates the views of the "actor's in the case under study. Case study research enable researchers to examine specific events, settings, and phenomena. An advantage of a case study is that enables the researcher(s) to develop and test theories. Another advantage of a case study is that enables researchers to secure, triangulate, and use a variety of evidentiary sources [35].

This study used a qualitative longitudinal research design [36-38]. A qualitative longitudinal research aims to expand and develop theories [36]. The researcher's role when undertaking case study research is to expand and generalize theories (analytical generalization). The researcher does not enumerate frequencies or makes any statistical generalizations [39].

This qualitative research case study used the following research question: How does Finnair PLC manage the company's energy consumption in an environmentally sustainable manner? The sub-questions to the research question were: What role have Finnair's aircraft fleet modernization played in mitigating the company's annual energy consumption? What energy saving measures have been implemented by Finnair as part of its commitment to environmentally sustainable operations?

3.2 Data collection

Finnair's annual sustainability reports, Finnair's annual reports, and media releases, and company materials available on the internet were the source of the documentation used in the study.

The key words used in the database searches included "Finnair's fuel-efficient aircraft fleet strategy", "Finnair's annual jet fuel consumption", "Finnair's annual ground equipment and vehicles fuel consumption", "Finnair's annual electricity consumption", "Finnair's annual facilities heating consumption", "Finnair's use of renewable energy sources", and "Finnair's energy saving measures".

The present study used multiple sources of case evidence wherever possible. A database for the case study documentation was established. In addition, the researcher ensured that there was a chain of case study evidence [32].

3.3 Data analysis

Document analysis was the research technique used to examine the case study evidence. Document analysis focuses on the information and data from formal documents and company records that are gathering for the case study research [41,42]. The study's documents were examined for their authenticity, credibility, representativeness, and meaning [43-45].

The study's document analysis was undertaken in six discrete phases. Planning the types and required documentation and ascertaining their availability for the study were undertaken in the first phase. In the second phase, the data collection involved sourcing the documents from Finnair and 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 study's 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. The final analysis of the data was completed in the sixth phase of the document analysis process [46].

Following the recommendation of Yin [32], all the collected documents were downloaded and stored in a case study database. All the documents collected for the study were in English. Each document was carefully read, and key themes were coded and recorded [47].

4 Results

4.1 A brief overview of Finnair

Finnair was formed by private interests as Aero O/Y on 1 November 1923. The airline started operations on 20 March 1924 with a service from Reval in Estonia. Shortly thereafter the airline started a Helsinki-Stockholm service via Turku. This service commenced in conjunction with ABA of Sweden [48, 49]. In the immediate post World War II period, the airline operated a fleet of ex-military Douglas DC3 aircraft. Services were expanded to include other European countries. The Finnish Government began acquiring a shareholding in the airline in the 1950s and 1960s, and today the airline is substantially government owned [50,51].

In 1986, the airline changed its name to Finnair when the company was seeking to establish a more distinctive, nationalistic image [48].

Today, Finnair is a full-service network carrier (FSNC) that specializes in both passenger and air cargo transportation. Finnair operates two tourism-related firms that offer package tours. Then two firms are Aurinkomatkat-Suntours (later Aurinkomatkat) and Finnair Holidays brands [52]. At the time of the present study, the Finnair aircraft fleet consisted of 83 aircraft, which included 14 state-of-the art Airbus A350-900XWB aircraft [53].

Figure 1 presents Finnair's total annual enplaned passengers and revenue passengers kilometres performed (RPKs) over the period 2010 to 2019. According to Holloway [54], "revenue passenger kilometres (RPKs) are a distant weighted measure because they are produced by an airline flying one passenger one kilometre". In the global airline industry, one passenger enplanement is a measurement of the embarkation of a revenue passenger, whether they are originating, stopping-over at an airport, or connecting or returning [54]. Finnair's total annual enplaned passengers and RPKs grew from 7.13 million passengers and 19,222 million RPKs in 2010 to 14.6 million enplaned passengers and 38,533.60 million RPKs in 2019 respectively, as illustrated in Figure 1. As can be observed in Figure 1, there has been a consistent growth in both RPKs and enplaned passengers during the period 2010 to 2019.

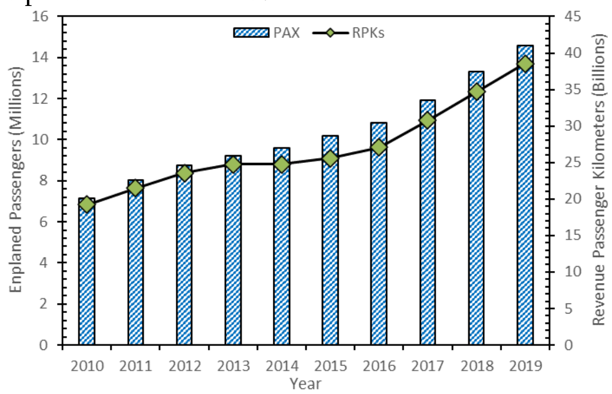

Fig. 1. Finnair's total annual enplaned passengers (PAX) and revenue passenger kilometres performed (RPKs): 2010-2019, Source: [52, 55-61]

4.2. Finnair's Annual Direct Energy Consumption for Flight Operations

4.2.1. Jet fuel consumption

Finnair's principal energy consumption is from transport fuels, but particularly jet fuel. Finnair's total annual fuel consumption comprises flights operated by the airline itself, but also flights that are operated by Norra on Finnair's behalf. The flights operated by Norra are wet leased flights [61]. A wet lease involves the leasing of an aircraft complete with its flight and cabin crews together with technical support, maintenance, and insurance [62, 63]. Jet fuel is also used by Finnair on transfer and training flights, as well as for aircraft test runs by its Technical Services Department [61].

Figure 2 presents Finnair's annual jet fuel consumption for the period 2010 to 2019. In 2010, Finnair's total annual fuel consumption was 70,488,500kgs (Figure 2). The airline's fuel consumption in 2010 was influenced by the volcanic ash cloud in the spring and by a year-end cabin crew strike which resulted in the total fuel consumption being 9% lower than the previous year (Figure 1) [64]. During 2011, Finnair's total annual fuel consumption rose by 13.55% to 80,044,900kgs. This was the large single annual increase recorded during the study period (Figure 2). The higher fuel consumption could be attributed to traffic growth, for example, Singapore was added to the airline's route network, and there was also a 11.8% increase in RPKs during 2011. Finnair's total jet fuel consumption decreased by 1.9 % (a saving of 15,273,000 kgs) in 2012, compared to the previous year (Figure 2). The savings in fuel consumption were achieved through route network optimisation, developing flight and taxi practices, and through reductions in aircraft empty weight [55]. In 2013, Finnair's total annual jet fuel consumption was 74,188,300kgs which was 5.51% lower (4,329,300kgs) than 2012 levels (Figure 2). The savings in fuel consumption were once again achieved through the airline's route network optimisation, developments in flight and aircraft taxi practices, and through the reduction in the empty weight of aircraft [57].

In 2014, Finnair's total annual jet fuel consumption decreased by 0.91% (6,823,000 kilograms) as compared to the previous year (Figure 2) [58]. Finnair's annual fuel consumption in 2015 increased by 13.36% (98,234,000kgs), which was the second highest annual increase in jet fuel consumption over the study period (Figure 2). During 2015, new routes to Gdansk, Luleå and Umeå were launched with these services being operated by Norra. Also, in 2015, Finnair operated summer seasonal routes to Athens, Chicago, Dublin, Malta, and Split. Miami was also added to the airline's route network with year-round services [59]. In 2016, Finnair's annual jet fuel consumption increased by 4.9% or 40,854,200 kgs, on the 2015 levels. The higher total annual consumption of fuel was principally due to traffic growth [65]. Finnair expanded it route network in 2016 with the addition of Fukuoka and Guangzhou to its route network [66].

Finnair's total annual fuel consumption increased by 5.41% (47 million kilograms) during 2017. This increased fuel usage can principally be attributed to traffic growth. During 2017, Finnair commenced services to Goa, Havana, Puerto Plata, Puerto Vallarta, San Francisco, and Reykjavik. Also, in 2017, Finnair added additional flight frequencies to Hong Kong and Tokyo [67]. In 2018, Finnair's annual fuel increased by 11.9% or by 109.6 million kilograms (Figure 2). This growth in annual fuel consumption was attributed to traffic growth and some operational challenges [68]. During 2019, Finnair's annual fuel consumption increased by around 9.8% (101,094kgs) compared to the 2018 due to the expansion in services by the airline (Figure 2) [61]. There has been a steady rise in the airline's annual fuel consumption over the study period. During this time, Finnair has expanded its aircraft fleet as well as its route network, all of which result in greater amounts of jet fuel being used to meet the growing operational requirements of the airline.

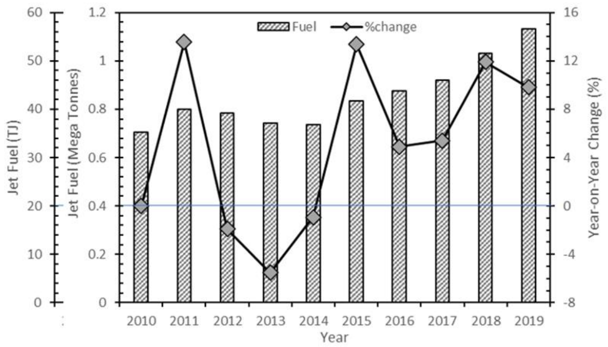

Fig. 2. Finnair's annual jet fuel consumption (mega tonnes and TJ equivalent) and year-on-year change (%): 2010-2019. Source: Finnair [55, 57, 60, 61]

Figure 3 shows the total consumption of jet fuel per enplaned passenger. This is a key metric, because it is a form of fuel efficiency; that is, the amount of fuel per person carried by the airline. Similarly, in Figure 4, the total fuel consumption per revenue passenger kilometre (RPK) is also a metric of fuel efficiency. The fuel per RPK is also more representative, as it not only normalizes the fuel consumption to the number of passengers, but it also normalizes to the distance travel. This is not an infallible metric, typically by traveling further an aircraft will become more fuel efficient. As such, when the route networks grow, and more long-range point to point links are made, it can artificially appear more fuel efficient. This, however, is not the case with Finnair. A significant reducing trend is apparent as seen in Figures 3 and 4.

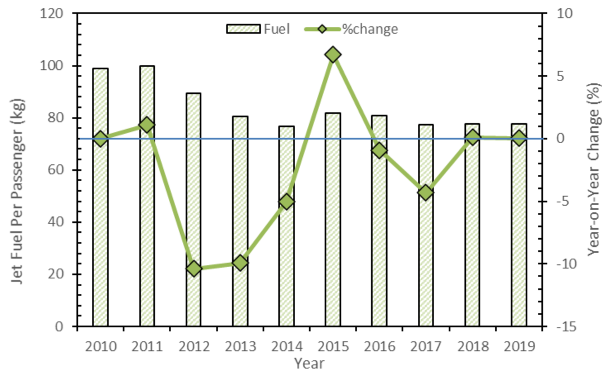

Fig. 3. Finnair's annual jet fuel consumption per enplaned passenger (kg) and year-on-year change (%): 2010-2019. Source: Finnair [47, 50-56, 61]

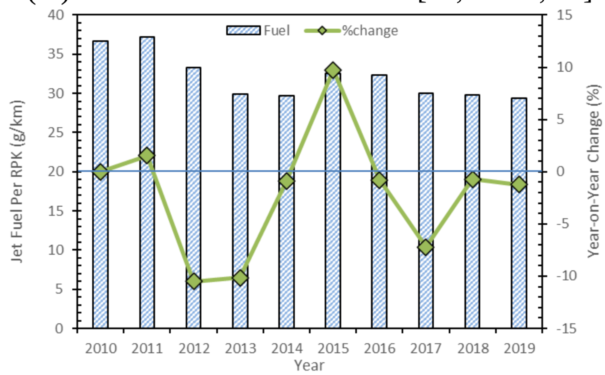

Fig. 4. Finnair's annual jet fuel consumption per revenue passenger kilometer (RPK) (g/km) and year-on-year change (%): 2010-2019. Source: Finnair [52, 52-61]

Recently, the global air transport industry has been pursuing large scale, secure, sustainable refined aviation biofuels. These aviation biofuels have a low carbon footprint and do not have any adverse environmental or social impacts [68]. Consequently, the use of aviation fuels has become quite popular as they have low levels of greenhouse gas emissions (GHGs) [69, 70]. Finnair plans to increase the use of sustainable aviation fuels. The airline envisages that by the end of 2025, it will be spending approximately €10 million annually on sustainable aviation fuels. Finnair's biofuel partner Finland-based Neste. Neste is the world's largest producer of sustainable aviation fuels. The company refines sustainable aviation fuels from waste. As at the time of the present study, Finnair had operated three flights that were powered by sustainable aviation fuels [71]. In 2019, Finnair purchased 32,452 kgs of renewable aviation fuel [61].

4.2.2. Ground vehicles fuel consumption

As noted earlier, during the time that an aircraft is on the ground it needs to be serviced, which is done using specialized ground service equipment. Figure 5 presents Finnair's annual fuel consumption for ground vehicles and ground service equipment (GSE) for the period 2010 to 2019. As can be seen in the figure, the annual consumption of fuel has increased on a year-on-year basis, with steep increases experienced in 2012 (154.86%) and 2017 (226.36%), respectively (Figure 5). Also, as can be observed in Figure 5, in 2013, Finnair's ground vehicles and ground service equipment (GSE) consumed a significantly lower amount of fuel than in the previous year. The reason for this reduction was the outsourcing of the airline's ground handling services. The largest consumption of ground-based vehicles and ground service equipment (GSE) has occurred in over the period 2017 to 2019. This higher fuel usage can be attributed to the expansion in Finnair's aircraft fleet and services operated, the greater the aircraft fleet size, the greater the requirement for GSE to service those aircraft.

These increases reflect the growth in both the airline's network and fleet growth over the period. During 2018 and 2019, Finnair's ground operations also used renewable energy sources. A total of 33,108kgs (14.18% of the annual total fuel consumption) of renewable energy was used in 2018, whilst in 2019 this increased to 54,887kgs (26.93% of the annual total fuel consumption) [61]. The growing use of renewable energy services is a key part of Finnair's sustainability strategy and will help the company to mitigate its environmental impact from its ground operations.

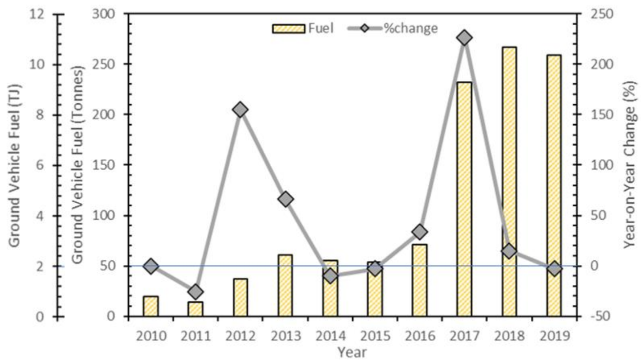

Fig. 5. Finnair's annual ground vehicles consumption (tonnes, and equivalent TJ) and year-on-year change (%): 2010-2019. Note: 2018 and 2019 data include both renewable and non-renewable fuel. Source: Finnair [55, 57, 60, 61]

4.2.3. The use of solar power

The year 2018 was the first full year when the solar panels that had been installed on the airline's Cool Cargo terminal generated electricity for the air cargo terminal. During 2018, the solar panels produced 287 MWh of electricity [62]. In 2019, the solar panels that had been installed on Finnair's Cool Cargo air cargo terminal at Helsinki's Vantaa Airport produced 297 MWh of power for the terminal's own use. This represented 8.7% of the total energy consumption of the air cargo terminal building [61].

4.3. Finnair's Annual Facilities Energy Consumption

4.3.1. Electricity for ground-based facilities

Finnair's properties, which are either owned or leased, are principally located in the Helsinki Airport precinct. The combined volume of these properties was about 2.6 million cubic meters in 2019. Finnair's annual energy consumption data does not include energy consumption figures for Finnair's offices that are abroad (which are generally sales offices), as their energy consumption is typically invoiced as a fixed part of rent [61]. In 2010, Finnair opened its "Finnair Spa and Sauna Centre" at Helsinki Vantaa Airport. Energy efficiency of the new facility was the focus of attention during the design phase; heat recovery is used in the facility's dressing room and spa facility machines, and an effort was made to use the building's automation system to optimize energy consumption by regulating equipment according to requirements. In addition, energy-saving lamps were used, whose electrical requirement is small. The lights also have a long-life cycle [64].

Finnair is a member of a Finnish energy efficiency agreement in the service sector. This agreement is part of the implementation of Finland's long-term energy and climate strategy. The agreement also follows the framework decision of the Council of State on energy efficiency measures. Finnair's membership in this energy efficiency initiative obliges Finnair to reduce its properties' energy consumption by 7% based on its 2016 level by 2025 [61].

Figure 6 presents the annual trends in Finnair's consumption of electricity (GWh) for the period 2010 to 2019. As can be observed in Figure 6, throughout the study period Finnair has been able to successfully decrease its annual electricity consumption. This is demonstrated by the year-on-year percentage change line graph, which is more negative than positive, that is, more values are below the line than above. During the study period, there were just one year when the airline's annual electricity requirements increased on a year-on-year basis. This increase was recorded in 2018 when the annual electricity consumption increased by 19.98% on the 2017 levels. This increase reflected greater energy requirements in 2018. The most significant annual decrease in the annual electricity consumption occurred in 2019, when the airline's annual electricity consumption decreased by 26.92% on the 2018 levels (Figure 6) [61]. The smallest annual decrease in electricity consumption was recorded in 2011, when Finnair's annual electricity consumption decreased by 2.34% on the 2010 levels (Figure 6). The overall downward trend in electricity consumption is a very favourable outcome for Finnair. This is despite the increase in the company's operations, expanded fleet and route network over the study period.

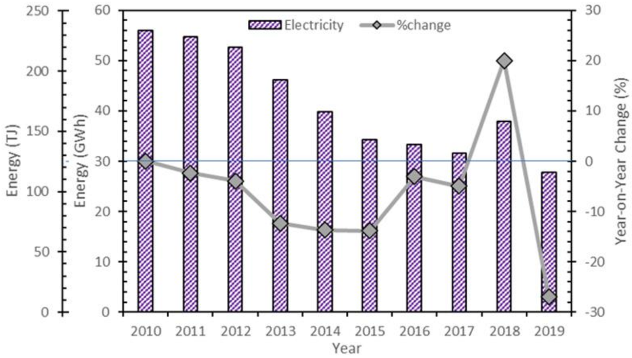

Fig. 6. Finnair's annual electricity consumption (GWh and equivalent TJ) and year-on-year change (%): 2010-2019. Source: Finnair [55, 57, 60, 61]

One of the important metrics used in airport industry is the energy consumption per passenger [72]. This metric can be also be usefully applied in the airline industry. Figure 7 presents Finnair's total annual energy consumption per enplaned passenger from 2010 to 2019. As can be observed in Figure 7, despite the increase in passengers carried, Finnair has been able to reduce the amount of electricity consumption per enplaned passenger. This is demonstrated by the year-on-year percentage change line graph, which is more negative than positive, that is, all but one value is below the line. During the study period, there were just one year when the airline's annual electricity requirements per enplaned passenger increased on a year-on-year basis. This increase was recorded in 2018 when the annual electricity consumption per enplaned passenger increased by 7.54% on the 2017 levels. The most significant annual decrease in the annual electricity consumption per enplaned passenger occurred in 2019, when the airline's annual electricity consumption decreased by 33.68% on the 2018 levels (Figure 7) [61]. The smallest annual decrease in electricity consumption per enplaned passenger was recorded in 2016, when Finnair's annual electricity consumption per enplaned passenger decreased by -8.63% on the 2015 levels (Figure 7). The results suggest that Finnair has been able to sustainably manage its electricity consumption per enplaned passenger very effectively given the large increase in passengers carried over the study period.

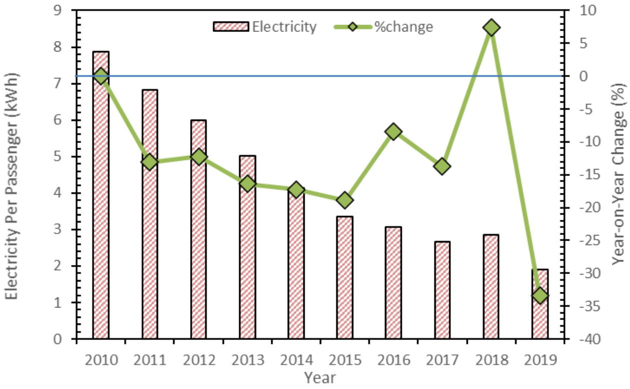

Fig. 7. Finnair's annual electricity consumption per enplaned passenger (kWh) and year-on-year change (%): 2010-2019. Source: Finnair [55, 57, 60, 61]

4.3.2. Electricity for the heating of facilities

Finland has cold winters [73] and winter is the longest of Finland's four annual weather seasons [74]. Consequently, there is a requirement for Finnair to heat its facilities during the cold winter season. Figure 8 presents Finnair's annual energy consumption for heating its facilities for the period 2010 to 2019. As can be observed in Figure 10, there have been pronounced spikes in the annual energy acquired for heating in 2010, 2012, 2015 and 2017. These spikes could be attributed to the cold winter temperatures recorded in Finland. Figure 8 shows that the largest amount of energy for heating occurred in 2010. This was because Finland experienced a particularly cold winter in that year [75]. The largest single annual increase in electricity consumption for facilities heating was recorded in 2016, when this metric increased by 37.07% on the 2015 levels (Figure 8). The largest single annual decrease in electricity consumption for facilities heating occurred in 2015, when the annual electricity consumption for the heating of facilities decreased by 48.64% on the 2014 level (Figure 8).

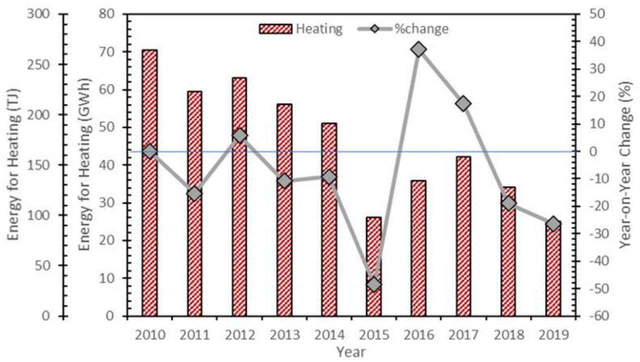

Fig. 8. Finnair's annual electricity consumption for facilities heating (GWh and equivalent TJ) and year-on-year change (%): 2010-2019. Source: Finnair [55, 57, 60, 61]

Another airport-related environmental performance measure - the consumption of heating energy passenger [76] - can be usefully applied to the airline industry. Such analysis should however consider outside temperatures [76]. Figure 9 shows that over the period 2010 to 2019 there was a general downwards trend in Finnair's annual energy used for heating per enplaned passenger This is demonstrated by the year-on-year percentage change line graph, which is more negative than positive, that is, more values are below the line than above. As can be observed in Figure 9, there were just two years in the study period when the annual electricity consumption for facilities heating (GJ) per enplaned passenger increased on a year-on-year basis. These increases were recorded in 2016 (+29.68%) and in 2017 (+6.21%), this could have been due to particularly cold temperatures experienced in those years. Figure 9 shows that largest single annual decrease in the annual electricity consumption for facilities heating (GJ) per enplaned passenger was recorded in 2015, when this metric decreased by 51.78% on the previous year's level. The lowest single annual decrease in the annual electricity consumption for facilities heating (GJ) per enplaned passenger occurred in 2012, when this metric decreased by 3.36% on the 2011 levels.

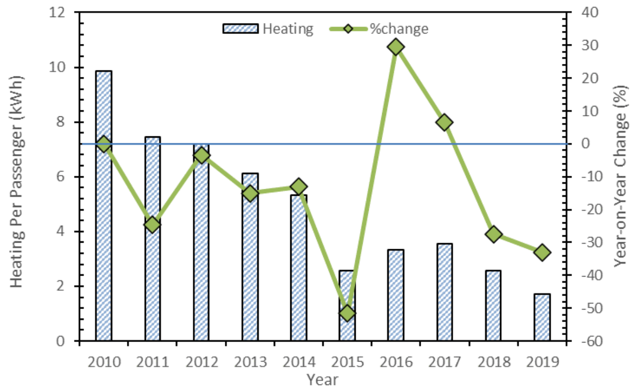

Fig. 9. Finnair's annual electricity consumption for facilities heating (GJ) per enplaned passenger and year-on-year change (%): 2010-2019. Source: Finnair [55, 57, 60, 61]

4.4. Finnair's Energy Saving Initiatives

The most substantial measure by which Finnair has been able to reduce its energy consumption is through the modernization of its aircraft fleet, which commenced in the late 1990s. The first stage of the airline's aircraft fleet modernization was completed in 2010 [64]. In October 2007, Finnair firmed an order for eleven Airbus A350-900XWB aircraft [77]. In September 2013, Finnair became the world's first commercial operator of the Airbus A321 aircraft that were equipped with new, fuel-saving "Sharklet" wing tip devices [78]. The

"Sharklet" reduces the aircraft's fuel consumption by decreasing the turbulence and vortex generation of the wings [79]. Three Airbus A321s with "Sharklets" were added to Finnair's fleet in 2013 [56]. In the first half of 2014, Finnair retired the last of its Boeing 757 aircraft. These aircraft were replaced with Airbus A321 aircraft that were equipped with the new, fuel-saving "Sharklet" wing tip devices. The Airbus A321 "Sharklet" has the lowest fuel burn in its class and is around 7% more fuel-efficient per seat than the Boeing 757 aircraft that they replaced [57]. The Boeing 757 aircraft were used primarily for leisure and charter flights. Also, in 2014, Finnair confirmed a further order for eight Airbus A350-900XWB aircraft [80]. The Airbus A350-900XWB burns 25% less fuel than the current generation of equivalent aircraft [81]. Finnair became the first European-based airline to operate the new A350-900XWB aircraft, when it took delivery of is first Airbus A350 in October 2015 [53]. In 2016, Finnair took delivery of four new Airbus A350-900XWB widebody aircraft [54]. During 2017, four new Airbus A350-900XWB aircraft were added to Finnair's aircraft fleet [61]. In 2018, Finnair added one new Airbus A350-900XWB as well as one Airbus A321 to its fleet [60]. During 2019, Finnair added two Airbus A350-900XWB aircraft to its fleet. Finnair was planning to take delivery of two Airbus A350-900XWB aircraft in 2020, two in 2021 and one in 2022[61].

The average age of Finnair's fleet was around 10 years as at the end of 2019. Finnair has adopted a new updated strategy whereby it is aiming to renew its narrow body aircraft fleet. This will result in 10–15% further energy savings as compared to the current similar types of aircraft used by the airline [61].

Finnair's initiatives to improve fuel efficiency include all activities within its operations, from flight and service planning to aircraft maintenance. Both operational punctuality and fuel efficiency are the focus areas in flight planning [61].

Due to the flexible deployment of the company's Airbus fleet, it is possible to assign an optimal aircraft type to each route on any given day of the year. In addition, the optimal flight path calculation is based on aircraft payload, weather forecast, and airspace capacity of airspace. Besides weather factors and air traffic control, an aircraft's fuel consumption is affected by its weight and its payload. Finnair regularly monitors its aircraft weight, as well as all the materials loaded onboard [61]. The use of new technologies and materials have also successfully reduced aircraft weight in recent times. Finnair considers weight as an important factor whenever new aircraft materials are being purchased [67]. Finnair has also reduced the amount of potable water uplifted on its flights [72], achieving annual fuel savings of 100 tonnes of jet fuel [67].

Another energy saving initiative implemented by Finnair has been the optimization of its aircraft auxiliary power units (APU). This measure has resulted in annual fuel savings of several thousand tonnes of fuel [56].

It is important to note that every commercial airline flight commences with a flight plan. An airline's flight plan includes the route the flight crew will fly the aircraft and specifies altitudes and speeds. The flight plan also provides calculations for how much fuel the aircraft will consume and the additional fuel it will need to carry to meet various safety requirements. By varying the route flown (that is, ground track), altitudes, aircraft speeds, and amount of departure fuel, an effective flight plan can reduce fuel costs, time-based costs, overflight costs, as well as lost revenue from commercial payload that could not be accommodated. These variations are subject to aircraft performance, weather, the permitted route and altitude structure, flight schedule constraints, and operational constraints. Furthermore, airlines are able to reduce fuel consumption and costs through improvements in the accuracy of their flight plans [82]. Finnair's flight planning achieves optimal fuel efficiency by selecting the most economical air route alternatives and through the negotiation of more efficient overflight routes for the airline's flights. During 2013, Finnair secured several new flight routes, particularly in Asia, that reduced flight times and thereby improved fuel economy [56].

Finnair has sought to reduce the empty weight of its aircraft fleet through the use of new technology and high-quality lightweight materials. For example, the aluminium aircraft unit load devices (ULDs) used in Finnair's wide-body aircraft were replaced by composite hold containers at the end of 2012 [55]. According to Baxter and Kourousis [83], "aircraft unit load devices, or ULDs, are pallets and containers which are used to carry air cargo, mail and passenger baggage on wide-body passenger and freighter aircraft". This weight reduction produced annual fuel savings of approximately 800 tonnes. The seats on Finnair's Airbus A320 fleet were also replaced in 2011 by lighter models, which resulted in annual fuel savings of around a thousand tonnes [50].

During 2018, Finnair began to improve and measure the efficiency of loading aircraft unit load devices (ULDs) on its aircraft. This initiative has resulted in an annual saving of around 200 tonnes. Also, in 2018, Finnair introduced new software (PACE) in its Airbus A350-900XWB aircraft fleet to optimise flight profiles. The airline also trained pilots to do a single engine taxi out. The single engine taxi-out procedure saves about 120 tonnes of jet fuel annually. A re-configuration process for Finnair's narrow-body fleet that commenced in 2017 continued into 2018. The modification of the aircraft cabin interiors has resulted in noticeable weight savings. On average, there has been a weight saving of around 150 kg per aircraft. This weight saving has resulted in an annual decrease in jet fuel consumption of 450 tonnes [67].

Finnair also participates in the annual international Earth Hour by switching off all advertising lights at airports and in various properties for an entire weekend. Finnair also informs its personnel on ways to conserve energy whilst at work as well as when they are on duty [67].

4 Conclusion

This study has examined Finnair's sustainable energy management over the period from 2010 to 2019. The qualitative data was analysed using document analysis. The advantage of the present study is that it highlights the measures and strategies that are available to an airline, irrespective of their chosen business model, to sustainably manage their energy consumption. Despite the importance of sustainable energy management in the global airline industry, there has been little previous research that has examined this phenomenon; thus, the present study provides useful insights and adds to the literature on sustainable airline energy management. Furthermore, the present study provides a framework that future researchers can use when empirically examining an airline's sustainable energy management. The case study highlighted that the adoption of energy saving initiatives delivers important environmental benefits, which are principally achieved through the lower fuel burn of the next generation aircraft. The lower fuel burn results in lower engine emissions, and thus, the airline can mitigate the environmental impact of their services.

Finnair has three principal sources of energy: jet fuel for use in its aircraft fleet, fuel for its ground vehicles and ground services equipment (GSE), and electricity for powering and heating its facilities. Over the study period, Finnair's annual jet fuel consumption increased from 704,885 tonnes in 2010 to 1.13 million tonnes in 2019. The increase in the annual consumption of jet fuel can be attributed to the route network and aircraft fleet expansion that took place over the study period. To service its aircraft during the periods they are on the ground in between flights, Finnair utilises specialised ground service equipment (GSE). The total annual fuel consumption for these vehicles and GSE rose from 19.27 tonnes in 2010 to 258.6 tonnes in 2019. However, the case study revealed that there were substantial increases in the fuel used for ground vehicles and GSE during the period 2017 to 2019. This could be attributed to the greater number of services provided by Finnair as well as the greater levels of GSE required to service Finnair's larger aircraft fleet. Finnair also purchases electric to power its facilities. Over the study period, the annual consumption of electricity fell from a high of 56,034 MWh (201,722 GJ) in 2010 to 27,718 MWh (99,786 GJ) in 2019. A similar trend was observed in the total annual electricity per passenger. In 2010, the total annual electricity per passenger was 7.85 KWh (0.03 GJ) whilst in 2019 the total annual electricity per passenger had declined to 1.89 KWh (0.01 GJ). During the study period, the total number of enplaned passengers increased by 104.7%. Thus, despite such a large increase in passengers, Finnair has been able to sustainably manage its electricity consumption.

Finland has cold winters, and thus, there is a requirement for Finnair to heat its facilities during this period. Finnair's annual consumption of energy for heating fluctuated quite markedly over the study period peaking in 2010 (70,375 MWh: 253,350 GJ) before declining in 2011 and then spiking again from 2012 to 2014, and then declining in the three subsequent years. The annual consumption of energy for heating in 2019 was 25,123 MWh (90,444 GJ).

Since 2018, Finnair has adopted the use of renewable energy sources for its ground vehicles and ground service equipment (GSE). A total of 33,108kgs of renewable fuel was used in 2018 and this increased to 54,887kgs in 2019, an increase of 65.78% on the previous year. During 2019, Finnair purchased a small amount of renewable fuel to power its aircraft (32, 452kgs). Finnair is also using a solar power photovoltaic system, that is located on the roof of its Cool Cargo Terminal, to provide electricity to its air cargo terminal. During 2018 and 2019, the solar power photovoltaic system produced 287MWh (1,033 GJ) and 287MWh (1,069 GJ) of electricity, respectively.

The case study revealed that the most significant measure by which Finnair has been able to reduce its energy consumption has been through the modernization of its aircraft fleet. This has been a multi-stage process, with the first phase completed in 2010. Since that time, Finnair has acquired a fleet of state-of-the art Airbus A321 aircraft equipped with "Sharklets" as well as a fleet of Airbus A350-900XWB aircraft. As part of its ongoing aircraft fleet strategy, Finnair is aiming to renew its narrow-body fleet with aircraft that will deliver fuel savings of between 10-15% in the coming years.

The flexibility of aircraft fleet enables Finnair to deploy the optimal aircraft type to each route throughout its network. Finnair's flight planning aims to achieve optimal fuel efficiency through the selection of the most favourable air routes and the negotiation of more efficient overflight routes for the airline's flights.

Finnair has also sought to optimize its energy consumption by reducing the weight of its aircraft. These weight saving initiatives include the use of composite aircraft containers and aircraft unit load devices (ULDs), lighter seating on its narrow-body fleet, and the use of new technology and high-quality materials on its aircraft. Other energy saving measures include single engine taxying out from the airport gate, and the optimization of aircraft auxiliary power units (APUs).

As noted earlier, airlines around the world are focusing on sustainable energy management. The case study revealed that the operation of a modern fuel-efficient aircraft fleet delivers fuel savings whilst at the same time reducing the carbon footprint associated with aircraft operations. The use of sustainable aviation fuels also can be used by airline wishing to reduce their environmental impact. The use of renewable energy sources also offers airlines the opportunity to further reduce the environmental impact arising from the necessity to cool, heat and light their facilities and properties. Thus, airlines wishing to pursue energy savings and more environmentally friendly operations could adopt the approach and measures adopted by Finnair as these measures are quite easily transferrable.

A limitation of the study was that it was not possible to financially quantify Finnair's sustainable energy management measures as the required data was not available at the time of the present study. Should such data become available then a future study would then be able to quantify not only the environmental benefits of sustainable energy management but also the financial benefits as well.

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Glenn Baxter conceived the paper and wrote the first draft paper. All authors contributed equally to the data analysis and editing of the manuscript. Graham Wild prepared the study's figures.

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