Energy Efficiency in Airports and Airplanes.

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Abstract: The actual work is motivated by the exploration of energy efficiency in two major pillars of aviation, and it was conceived through bibliographic research based on case studies to present several factors that contribute to improve the use of energy in the processes and systems addressed. For airports, an analysis of energy consumption was carried out to propose a sustainable model not only from an environmental point of view, but also from a financial point of view. When it comes to airplanes, alternatives have been proposed both to reduce the emission of polluting gases through an alternative to fuel, and a totally disruptive aircraft model powered by electricity.

Keywords: efficiency, sustainability, energy saving.

1. Introduction

Civil aviation plays a catalytic role: it opens up new markets for producers, facilitates the dissemination of new technologies, provides access to essential services for society.

Currently, airports have become truly highly sophisticated and diversified service centers, often employing advanced technologies, of direct interest to commercial transport and its users.

According to [1] most energy efficiency programs developed by airports have three simultaneous objectives: to reduce the energy bill, reduce energy consumption and reduce their carbon footprint.

In the context of aircraft, [2] states that the search for efficiency added to the objective of cost savings, the need to adapt to the standards and conventions that stipulate the maximum acceptable levels of emission of gases produced by engines. The author concludes by noting that other initiatives focused on replacing internal combustion engines or jets with electric motors have already proved to be viable and are on the verge of being produced and put into operation in a short period of time.

It is undeniable that energy is an essential resource for human life, for the quality of life of citizens, and one of the greatest factors linked to the socioeconomic development of any nation [3].

Based on this, it is important to look for alternative forms of energy, the future scenario is promising for airplane that use them, especially for those that use electrical energy, a source totally free of CO2 emissions and renewable in several ways.

Throughout the work, different ways to improve energy efficiency in different types of processes are discussed, using the data extracted from relevant references, aiming to elucidate knowledge in relation to the subject with the areas of airports and aircraft.

2. Airports

As [4] states, most airports around the world do not exist for the purpose of generating profits, but rather for the need to move people and cargo. Thus, it is plausible to state that a more sustainable operation is feasible, as the mode of operation of an airport provides the opportunity to reduce energy consumption.

Airports are large consumers of electricity, fuel, water, digital network and several other inputs and consumables, this consumption is high due to its operating mode and its large size [5].

As for energy use, [6] states that the energy consumed by airports can be divided into energy consumed by its activities in the airside area and the part consumed in its activities in the landside area, following the classic operational division in airports.

Fig. 1 – Subsystems [7] (adapted).

2.1 Airside

The airside area of the airport includes the fuel consumed by aircraft during LTO (takeoff and landing) cycles and the energy consumed by ground vehicles that service the complex operations on the aircraft apron.

In this area, the energy requirements include the fuel that is consumed by the aircraft during the landing and take-off cycles as well as by the aircraft support vehicles on the ground, in their operations on the apron and boarding bridges [8].

2.2 Landside

The landside comprises the passenger and cargo terminal, the support area (where service providers are located), parking lots, public transport and access roads.

Thus, [8] reiterates stating that the main energy consumers are the systems/modes of access to the airport via ground, the passenger and cargo terminals and other administrative buildings that serve the airport.

Normally, passenger terminals are large buildings equipped with air conditioning and heating systems, which require a high load of electrical energy, in addition to lighting systems.

Finally, [6] confirms that in all cases, the primary sources of energy are non-renewable fossil fuels and, to a moderate degree, wind, water and solar renewable sources.

2.3 Energy Consumption Analysis

In a study carried out by MDPI, at airports in Spain, whose focus was the energy consumed, corroborates the fact that the landside, in fact, presents the highest concentration of consumption, more specifically in the passenger terminal, as seen below:

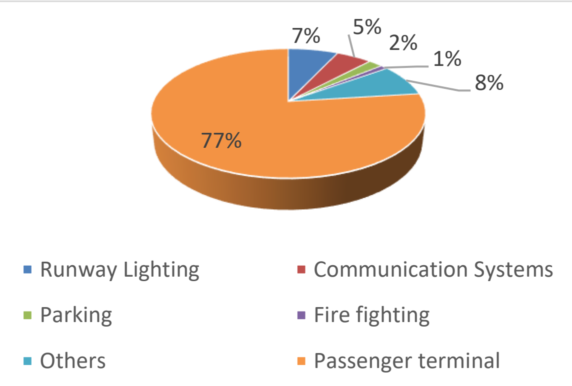

Fig. 2 – Energy Consumption Graph by MDPI.

In the meantime, the study also reveals the areas with the highest energy consumption in the passenger terminal, which are respectively: lighting system, temperature control system and electromechanics, such as elevators, moving walkways, baggage conveyors and bridges for accessing aircraft.

2.4 The case of Rio de Janeiro International Airport

Based on the assumptions presented and discussed above, it is possible to analyze energy consumption data at Tom Jobim International Airport. This analysis is relevant, since it is one of the most visited cities in the country, which leads to a high flow of passengers through the airport.

The exploration is focused on the area with the highest energy consumption, previously elucidated, the lighting system, in which [4] assertively accounts that it is also the highest financial cost and presents the following survey, using the value of R as a parameter R$ 0.24 per KW, effective in the period:

Tab. 1 - Monthly energy consumption [4].

Total KWh month consumed	1410333,12
System monthly cost	BRL 338.479,95

The lighting system consists of 34,521 lamps, of the most varied types, among which are: tubular, PL-C, sodium vapor, metallic vapor and electronics. Most are fluorescent and incandescent in nature [4].

2.5 Proposal for improving Energy Efficiency

In the situation presented, aiming at improving energy efficiency, it is considered vital to replace the types of lamps presented with LED lamps, as [9] assures, they are components that provide lighting and consume electricity more efficiently, in addition to Therefore, the useful life of an LED lamp can reach 100,000 hours, which is far superior to lighting systems made up of incandescent and fluorescent lamps.

In addition, [10] mentions other advantageous characteristics of the LED, they are: low energy consumption; low maintenance cost; high mechanical resistance; less heat generation; absence of mercury; absence of infrared radiation or ultraviolet radiation in visible light.

Equipped with these concepts, [4] proposes the implementation of a lighting system composed of LEDs, with an emphasis on reducing maintenance costs, better cost-effectiveness, greater energy efficiency and sustainability. It is important to note that the materials used in the implementation have a 5-year warranty, which in itself reduces maintenance costs. The effectiveness of the new system in a decrease of 45.28% as seen in the following table:

Tab. 2 - Monthly energy consumption [4].

Total KWh month consumed	771710,04
System monthly cost	BRL 185.210,41

Despite the system having a high installation cost, BRL 7,420,511.83, including the cost of components and labor, there is a significant decrease in the monthly cost when comparing the two systems:

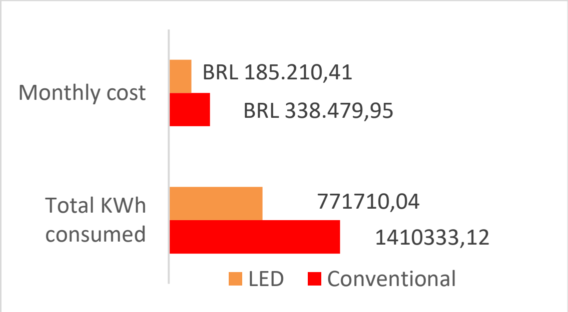

Fig. 3 - Comparison of systems consumption [4].

The large monthly savings, from an energy and financial point of view, offset the high value of the investment for the implementation of the system, as the author shows us in the following table:

Tab. 3 - Payback Calculation (monthly) [4].

Total investment amount	BRL 7.420.511,83
energy savings	BRL 153.269,54
Estimated spending on components	BRL 80.212,00
Estimated cost of labor	BRL 250.000,00
payback in months	15,3
Real profit with lamps with a 5-year warranty	BRL 21.588.380,52

With the data presented by the author, it is still possible to estimate the evolution of profit, resulting from the LED lighting system, in which it is noted below that in 24 months of validity of the proposed model, it accumulates just over 11.6 million brazilian "reais", which represents a profit of approximately 4.1 million in relation to the amount initially invested.

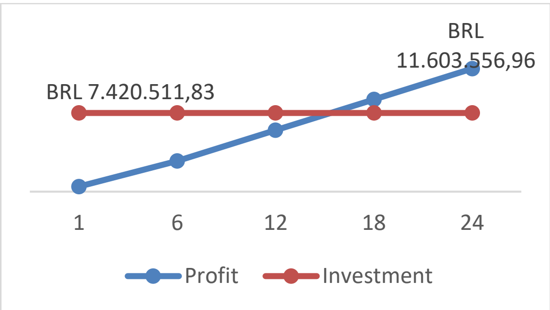

Fig. 4 - Profit evolution in months.

3. Airplanes

Fuel costs represented, on average between 2002 and 2015, about 33% of the total cost in an airline [11].

In 2015, this cost was 28.8% and follows a downward trend, mainly due to the evolution of aeronautical engines, which produce more power using less fuel, in addition to the aerodynamic efficiency of modern aircraft.

Even so, aviation is responsible for 2.5% of the world's $CO2$ emissions, considering the use of fossil fuels in aircraft.

[12] points out that there are still several challenges to be overcome in order to make an economically sustainable aircraft project viable, especially in aircraft for passenger transport, usually medium and large. The author lists as main impasses: the excessive weight of the batteries, the low autonomy and the high recharge time.

However, small-scale aviation already has consolidated projects to reduce pollutants, as well as the efficient use of energy through experimental electric aircraft being commercialized. Some of these projects are discussed below.

3.1 EMB 203

Commonly known as "Ipanema", in Brazil, it is a plane for agricultural use, whose engine uses ethanol as fuel, stimulating the mixture made by burning and generating a cost reduction that reaches almost zero in cases of sugar cane cultivation, where the product used is produced by the company that will consume it.

Fig. 5 - EMB 203 [13].

It has been a success story for 18 years; however, it remains the only series-produced aircraft in the world powered by ethanol [14].

Most general aviation aircraft are small aircraft using conventional engines. These engines use aviation gasoline (AVGAS) as fuel, and can be converted to use ethanol [15].

According to the RAB (Brazilian Aeronautical Registry), where all Brazilian aircraft are registered, in December 2018 Brazil had a total of 22,189 registered aircraft, of which 17,286 were aircraft with conventional engines [16]. In this way, it is possible to perceive how great the market potential for the use of ethanol is.

3.2 Disadvantages of using ethanol for general aviation

According to [17] ethanol has a lower energy density than AVGAS, so it has an increase in consumption of around 30% compared to aviation gasoline to maintain engine performance. This reduces the autonomy of the aircraft.

The reduction in autonomy and the lack of refuelling points at Brazilian airports represent two negative factors in the use of ethanol for general aviation, but they are not relevant for agricultural aviation, given the characteristics of its operation.

Since the short duration of the flight and the need for only one fuelling point are characteristics that explain why ethanol has proved to be viable for agricultural aviation.

3.3 Advantages of using ethanol

Aeroclubs and civil aviation schools are part of general aviation and use aircraft with conventional engines [15].

Generally, the piloting lesson lasts 60 minutes and the plane returns to the starting point. This flight time is still relatively short and as the aircraft returns to its starting point, there is no need for other fueling points.

In the scenario described, the advantage of using ethanol by flying clubs is mainly in its value in relation to AVGAS, even though it consumes 30% more compared to aviation gasoline, as previously mentioned, the value of the fuel represents the highest cost in the value of the flight time, with the use of ethanol this cost should decrease, thus providing an increase in demand by students, the cost comparison between fuels, in the situation presented, is seen below:

Tab. 4 - Pilot course fuel cost [15]

	Average consumption per hour	Cost per liter in BRL	Cost per flight hour	Cost BRL/40h
AVGAS	21	8,2	172,2	6.888,00
Ethanol	27,3	2,5	68,25	2.730,0
Savings (BRL) when using Ethanol in the 40h course				**4.158,00**

3.4 Pipistrel Velis Electro

Known for being the first electric aircraft to be certified in the world. It is a two-seat aircraft primarily intended for pilot training, it is revolutionary in terms of technological innovations and cost efficiency, it can be operated commercially and it is fully approved for pilot training as well as other operations [18].

Because it does not produce greenhouse gases, it represents a 100% decrease in CO2 emissions than aircraft powered by AVGAS [19].

In this way, Velis Electro will contribute to reducing impacts on the environment, and to making aviation more sustainable.

Fig. 6 - Pipistrel Velis Electro [20].

In comparison with the Cessna 150 aircraft, which fits in the same category as the Velis, but is powered by an internal combustion engine, according to [21], it presents the cost per flight hour:

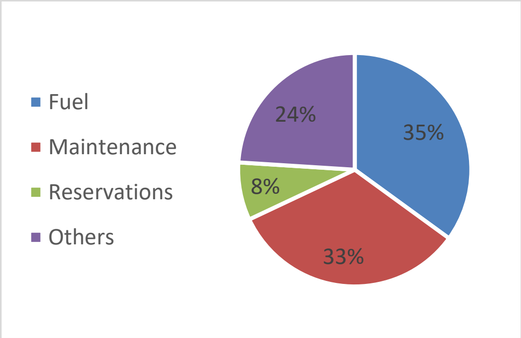

Fig. 7 - Cost per flight hour - Cessna 150

For comparative purposes, [12] states that at the time of data collection, an hour flight in a Cessna 152 cost an average of BRL 530.00, so in a private pilot course the student would pay an average of BRL 23,850.00.

Figure 7 shows that there is a 90% reduction in fuel costs, as electricity costs less than AVGAS, in addition to a 52% reduction in maintenance costs, as the electric motor has simpler maintenance than the internal combustion engine, there is also a 54% reduction in other operating costs.

With all these reductions, [21] stipulated the value of BRL 345.00 for the flight time of the Pipistrel Velis Electro, therefore, the Private Pilot course will cost BRL 15,525.00, this amount represents a 35% decrease in the cost of the course, if it was carried out in the Cessna 152.

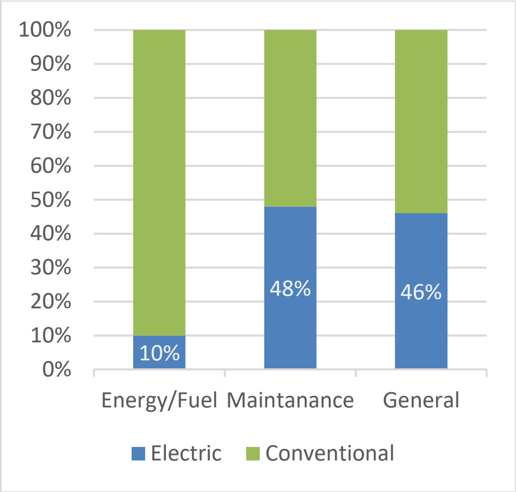

Fig. 8 - Comparison of Operating Costs

Such a reduction in the flight hour price brings benefits both pilots and piloting schools, which will be able to receive more students due to the low price, which would increase the number of flight hour packages acquired by the students.

The aircraft has an autonomy of 50 minutes, plus 30 minutes of reserve for a recharge time of 40 to 70 minutes [18]. Pipistrel offers different models of charging stations for sale; when purchasing the aircraft, the buyer can choose to purchase extra charging stations, and four options are available: 10kW or 20kW off-board charger, Skycharge charging station with two 15kW outlets or two 20kW outlets.

Fig. 9 - Skycharge Station [20].

Fig. 10 - Off-board Charger [20].

The plane manufacturer claims that Off-Board Chargers can be moved, unlike charging stations, which must be installed in a fixed location. These stations offer different charging times according to their power, which must be considered when purchasing.

4. Final Thoughts

The development of the present study made it possible to obtain the real magnitude of the impact of implementing energy efficiency methods in systems and processes. From an economic point of view, it is noted that it was not the reduction in energy consumption that generated positive results, but rather the expenses involved in all operational activities.

For airports, it became evident that just one change in a single system is already of great value, when planned correctly and especially considering seeking solutions to control energy consumption. For the LED lighting system, in addition to reducing the monthly financial cost, there was a severe improvement in the service provided to the user.

In terms of aircraft, given the above facts, the possibility of adopting new fuel sources for certain activities was verified, which in the case mentioned has already been operating for 18 years, however it is certified for a specialized air service, where the norms safety requirements are less demanding than other general aviation aircraft due to the type of operation. ANAC certification for the use of ethanol in other general aviation aircraft, which, due to the various requirements for greater safety in air operations, can be more time-consuming and costly.

In addition to the alternative for aircraft fuel, a new conception was also discussed, although in the initial phase, electric aircraft projects are of paramount importance, since in addition to characteristics such as engine efficiency, ease of handling and need for runways smaller to operate, it is also worth mentioning that the gains for the environment are naturally relevant in this process, given that the reduction in greenhouse gas emissions - such as CO_2 - will practically be reduced to zero.

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