Research and Analysis on Energy Consumption Features of Civil Airports

Bo Li¹²  Wen Zhang¹²  Jianping Wang¹²  Junku Xu ¹²  Jixiang Su ¹²

1 China Airport Construction Group Corporation, China
2 Beijing Super-Creative Technology Co., LTD, China
E-mail address:elizabeth0423@163.com

Abstract Civil aviation is an important part of China’s transportation system, and also the fastest-growing field of comprehensive transportation. Airports, as a key infrastructure of the air transportation system, are the junctions of air and ground transportation. Large airports are generally comprehensive transportation hubs that integrate various modes of transportation, serving as important functional zones of cities. Compared with other transportation hubs, airports cover a wide area, with plenty of functional sections, complex systems and strong specialization, while airport buildings represented by terminals have exhibited characteristics of large space, massive energy consumption, high requirement for safety and comfort, as well as concentrated and rapidly changing passenger flows. Through research and analysis on energy consumption features of civil airports, and analysis on energy consumption features of airports with different sizes or in different climate regions, this article has drawn conclusions therefrom.

1. Introduction
Airports, as a key infrastructure of air transportation system, are the junctions of air and ground transportation. According to statistics, the total energy consumption of the civil aviation industry accounts for approximately 8% of the total energy consumption of the whole transportation industry. Wherein, aviation oil consumption accounts for 94% of energy consumption across the industry, energy consumption of airports accounts for approximately 3% of the total energy consumption of the civil aviation industry, energy consumption of ground services of airlines accounts for approximately 2%, while energy consumption of other civil aviation units is no more than 1%

[1]. This research has been conducted on energy consumption features of airports, main energy consumption varieties, energy structures and energy-consuming modes of civil airports have been sorted and organized, and through analysis on energy consumption data, energy consumption features of airports have been summed up. This is conducive to improving the energy consumption situation of airports, which has far-reaching significance to the sustainable development of airports.

As an important part of the transportation industry, high attention has been given both at home and abroad to analysis on and management of energy consumption and research on sustainable development of airports. Federal Aviation Administration conducted research on the sustainable development of the aviation industry, and published an indicator system in 1996. The British government issued airports sustainable development plans and sustainable development reports in 2004. In recent years, many domestic scholars and experts conducted research on energy consumption of airports, primarily including mode and purpose of energy utilization by airports[3], effect of energy consumption by airport sections[3], energy consumption measurement and energy management[4], problems in energy utilization by airports and appropriate improvement measures, etc.[5], which had certain inspiration on the
construction of green airports and the sustainable development of civil aviation, although they did not systematically analyze energy consumption features of airports. This article, on the basis of massive survey information and energy consumption data, combined with the impact of climate conditions of different regions on energy consumption of airports, analyzed energy consumption features of airports, has drawn conclusions and put forward suggestions.

2. Data and Method

2.1 Data
The main energy consumption varieties of airports, which are the important infrastructure of air transport, include electric power, coal, natural gas, fuel, and water, etc. The top ten airports make up 60% of the total capacity of airports nationwide with their energy consumption accounting for approximately 40% of total energy consumption of airports nationwide.

We carried out field test and environmental monitoring spot setting for several typical airports in five major climate regions of China. After sorting and analyzing survey results, we revised and improved some data. In this article, to ensure the comparability of data and the accuracy of analysis results, we performed unified conversion of passenger capacity and cargo capacity, and selected the energy consumption data of airports with converted capacity of 5 million - 40 million and that tend to or have become saturated as our research objects.

2.2 Method
Energy consumption statistics of airports are conducted mainly by investigative analysis method and comparative analysis method, while for some small airports, as they have not yet established independent secondary measurement, their energy consumption statistics primarily rely upon inverse calculation of energy costs. Given certain deviation of feedback data completeness or accuracy caused by the existence of problems mentioned above, this article carried out appropriate data screening when analyzing energy consumption data of airports.

3. Analysis on Total Energy Consumption of Airports

3.1 Airport Energy Structure
Energy varieties of civil airports comprise electric power, coal, natural gas, diesel, and purchased heating, gasoline and other energy. Wherein, electric power is accounting for approximately 52.06% of total energy consumption of airports, followed by coal with approximately 17.06%, natural gas and diesel with 10.86% and 10.38% respectively, while purchased heating, gasoline and other energy account for smaller proportions (see Figure 1).

Figure 1 Energy Consumption Structure of Airports
3.2 Analysis on Energy Consumption of Airports

Generally, energy consumption of each functional zone of airports can be considered as formed by energy consumption of buildings (structures) and energy consumption of the corresponding functional facilities and equipment.

3.2.1 Energy Consumption of Buildings

There are a variety of airport buildings (structures). For energy consumption indicators of office buildings, employee dormitories, etc., reference can be made to relevant standards for public buildings; for energy consumption of buildings such as warehouse, reference can be made to relevant standards for factory buildings; for aircraft maintenance rooms or aviation food buildings, specific analysis will be needed according to aircraft maintenance levels or food supply types, which vary greatly in respect of energy consumption. Terminals, as a big energy consumer of airports, have their energy consumption generally account for more than 50% of energy consumption of airports, and present large differences from ordinary public buildings in respect of architectural structure, indoor environmental requirement, utilization intensity, facility/equipment type, etc., with their energy consumption features mainly reflected as follows:

1) Terminal buildings mostly embody a high and large space structure, and diverse styles. As a result, the shape coefficient of buildings is relatively big, which will increase heat transfer load that enters the indoor through enclosure structures, and further increase energy consumption for heating and air conditioning.

2) The indoor environmental requirement is high. To ensure the airport service level and satisfy the needs of passengers, the indoor environmental comfort parameter requirement within terminals is high, including temperature and humidity, illumination, noise, carbon dioxide concentration, which has increased energy consumption within terminals.

3) Passenger flow concentration produces a great effect on passenger comfort. During peak hours, the sharp increase of passengers at such venues as terminal check-in islands, boarding gates or baggage claim areas will lead to a sudden spike of thermal and humid load, and consequently, an increase of pressure for air conditioning capacity and supporting peak load.

Airport terminals of different sizes vary in their energy consumption features. For large and medium-sized airports, the energy consumption per unit area of buildings is higher than that of other public buildings. As for annual energy consumption is concerned, the energy consumption proportion of air conditioning, heating and lighting systems is greater than that of ordinary public buildings, accounting for approximately 80% of total energy consumption of terminals. Small airports usually have smaller capacity and fewer flights, so basically only when there are flights would energy-utilizing equipment be enabled, with the amount of energy utilization being closely related to the number of flights and passengers. Compared with large and medium-sized airport projects, terminals of small airports adopt a simple architectural structure, with fewer energy-utilizing equipment categories and lower quantity. Varieties of energy consumption are limited, thus total energy consumption being less.

3.2.2 Energy Consumption of Equipment

Energy consumption of equipment accounts for a big proportion of the total energy consumption of airports. There is a variety of airport equipment in large quantity, with long running hours throughout the year, even exceeding 18 hours per day for energy-utilizing equipment of some large airports, such as lighting equipment, HVAC equipment, baggage-handling facilities, boarding bridges, public supporting facilities and equipment, etc.

4. Analysis on Energy Consumption Features of Airports in Different Climate Regions

4.1 Energy Utilization Features of Airports in Each Climate Region

As our country is vast in territory with hugely different climate features, based on thermal design of buildings, we divided airports by five climate regions into airports in freezing regions, airports in cold
regions, airports in hot-summer & cold-winter regions, airports in mild regions, and airports in hot-summer & warm-winter regions, and analyzed features of airports in each climate region.

In terms of energy utilization features, the energy structure, heating time and cooling time of airports in each climate region vary significantly (see Table 1).

**Table 1 Energy Utilization Features of Airports in Each Climate Region**

| Region                | Freezing          | Cold              | Hot-Summer & Cold-Winter | Hot-Summer & Warm-Winter | Mild                      |
|-----------------------|-------------------|-------------------|--------------------------|--------------------------|---------------------------|
| Heating Time          | October - Next April | November - Next March | Late December - Early Next February | Extreme Weather          |
| Cooling Time          | June - September  | May - October     | April - October          | Full Year                | July - August             |
| Main Energy Utilization Structure | Electric Energy Coal | Electric Energy Coal | Electric Energy Natural Gas | Electric Energy Natural Gas |

4.2 Energy Consumption Features of Airports in Each Climate Region

Energy consumption of airports in each climate region shows apparent climate features (see Figure 2).

4.2.1 Energy Consumption Features of Airports in Freezing Regions and Cold Regions

Airports with passenger capacity of approximately 10 million in freezing and cold regions, compared with airports in other regions, have higher energy consumption per passenger, with highest value at 0.88kgce/passenger, lowest at 0.48kgce/passenger, while airports in freezing regions have the highest energy consumption per passenger. The reason for high energy consumption per passenger in freezing and cold regions is that, these regions have higher cooling-heating load throughout the year, longer heating time in winter, and cooling supply demand in summer, so the full-year energy consumption is higher.

4.2.2 Energy Consumption Features of Airports in Hot-Summer & Cold-Winter Regions

Airports in hot-summer & cold-winter regions, full-year energy consumption is lower than that of airports in freezing and cold regions. Energy consumption of airports with an annual capacity of less than 10 million is 0.47-0.53kgce/passenger, energy consumption of airports with a capacity of 10 million - 20 million is 0.39-0.46kgce/passenger, and energy consumption of airports with a capacity of 20 million - 30 million is 0.30-0.34kgce/passenger, from which it can be seen that for airports in hot-summer & cold-winter regions, the bigger the capacity is, the lower the energy consumption per passenger will be.

4.2.3 Energy Consumption Features of Airports in Hot-Summer & Warm-Winter Regions

Airports in hot-summer & warm-winter regions, as the annual average temperature is higher than that of other regions, the annual cooling demand increases, leading to an increase of energy consumption. And energy consumption per passenger has little difference, basically at around 0.3kgce/passenger.

4.2.4 Energy Consumption Features of Airports in Mild Regions

Airports in mild regions, due to comfortable climate and suitable temperature throughout the year, have small demand for cooling in summer or heating in winter. Among airports of all climate types, airports in mild regions have the lowest energy consumption, 0.26kgce/passenger and 0.23kgce/passenger respectively, from which it can be inferred that airports in mild regions have lower energy consumption per passenger than airports in other regions.
4.3 Analysis on Energy Consumption Features of Airports
Given big differences in airport size, energy measurement method and energy utilization statistics of functional zones, on the basis of sorting, integrating and analyzing survey date, we selected a number of typical airports with relatively complete data over recent three years as analysis objects. In order to ensure comparability of energy consumption data, all of selected airports have their actual capacity already reach or basically reach the designed capacity. According to analysis, energy consumption per passenger is 0.88kgce/passenger at highest, and 0.24kgce/passenger at lowest, wherein, airports with a capacity of 10 million passenger/annum have higher energy consumption per passenger, which varies greatly. With the increase of passenger capacity, energy consumption per passenger declines gradually. Airports with larger designed passenger capacity have lower energy consumption per passenger, for the main reason that after capacity gets close to saturation, energy consumption per passenger will remain in a stable state (see Figure 3).

5. Conclusions
1. Energy consumption of airports has direct connection with passenger capacity changes. Airports with
larger designed passenger capacity have lower energy consumption per passenger, for the main reason that after capacity gets close to saturation, energy consumption per passenger will remain in a stable state.

2. Energy consumption of airports has close connection with climate features of their location, as in case of the same size, energy consumption of airports in freezing or cold regions > energy consumption of airports in hot-summer & cold-winter regions > energy consumption of airports in hot-summer & warm-winter regions > energy consumption of airports in mild regions.

3. Methods for assessment on energy consumption of airports need further improvements. At present, energy consumption of airports is mainly assessed by two methods. The first is to calculate annual energy consumption per unit building area, the other is to assess energy consumption per passenger by dividing annual total energy consumption with total number of annual passengers of terminals. And we need to gradually improve measurement methods to improve accuracy, and establish uniform standards for energy consumption statistics to enhance comparability of energy consumption data.

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