Research on Airport Energy Framework and Energy Efficiency Index
--Based on the Current Situation of Airport Energy Management in China
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Abstract. The sustained and vigorous aviation demand has brought tremendous pressure to China's airport energy conservation. Enhance the airport energy management is urged by both the airport and the civil aviation industry authorities, In view of the energy metering, statistics and monitoring system is imperfect, as well as the airport energy consumption quota and energy efficiency standards have not yet been formed, this paper establish the energy management framework by region, variety and use, which is based on the current situation of China's airports, According to a goal oriented way, comprehensive energy efficiency index are put forward, including 5 airports index and 6 terminal index. Suggest that to build a "airport energy management platform" based on a unified airport energy management framework and energy efficiency index.

Introduction
The airport is always a large energy consumption facility in the city. The annual energy consumption of the airport throughput more than 10 million is over 10 thousand tons [1]. Predictably, China's airport construction is still in a rapid development stage in the future, the strong demand for aviation will further drive the total airport energy consumption, while the industry requires "By the end of 2020, airport energy consumption per passenger throughput in five years average decreased by more than 15% compared with the end of the 2015"[2], airports are facing enormous energy-saving pressure.

In 2017, the Civil Aviation Administration put forward to promote the construction of "four airports" which are consist of Safe Airport, Green Airport, Smart Airport and Humanities Airport. In considering of the weakness of energy conservation and emission reduction, the imperfect measurement, statistics and monitoring system of energy consumption and emissions, and the inability of industry management to meet the needs of low-carbon development. It is of great significance to strengthen the measurement and management of airport energy consumption and to build the airport energy management system for promoting the development of green airport and intelligent airport.

Current Situation of Airport Energy Use and Management
The energy varieties of the airport is mostly determined by the regional climate and energy supply conditions. The northern winter is long and cold, where heating period is often as long as more than four months or even more than half a year. The airport mainly uses coal and natural gas for winter heating. The southern summer is hot and the cooling period is long. The airport mainly uses electricity for summer cooling and winter heating [2]. With the development of energy conservation and emission reduction, each airport also takes the use of renewable energy as an important direction of its construction and transformation according to its own sunshine intensity, geothermal reserves and other conditions. Overall, the primary energy of the airport mainly include electricity, natural gas, coal, diesel, gasoline, thermal power and renewable energy.

The systems and equipment in airport are various, scattered and complex, meanwhile, the administrative division is independent, it is difficult to carry out unified manage and control. The airport energy metering is far away from meeting the actual energy management needs. Some
metering instruments do not conform to the standard, and even if some metering instruments are installed, it is difficult to distinguish the scope of their metering. The total energy consumption of terminal can be mastered basically, whereas the sub-metering are often unknown, and other areas can only be roughly estimated from the cold and heat, electricity, gas which can be charged.

The automation of extensive traditional mode of airport energy management was at a low level, which accompanied by simple monitoring, manpower dispatching and on-site treatment, and result in the timeliness and large error. It is difficult to analyze, rectify and predict the use of energy. In recent years, due to the actual needs of energy-saving and consumption-reducing, airports have made a useful attempt in energy intelligent management and control. They have built some systems operate independently, which including chiller control system, building automation system, building energy management system and so on, but they cannot interactive with each other. Some large-scale airports actively develop quantitate analysis tools of airport energy consumption, such as airport energy management system. Airport energy management gradually stepped into the stage of refinement and systematization.

Airport Energy Management Framework

In order to guide the terminals saving energy and standardize the airports energy management, "Guideline for energy efficiency evaluation on civil terminals" (MH/T 5112-2016) and "Specification for equipping of measuring instruments of energy and resource in civil airport" (MH/T 5113-2016) has been respectively issued (hereinafter referred to as "MH/T 5113"). Unified energy management framework and energy efficiency indicators are the basis for airports energy management. Based on the existing industry standards and the actual airport energy management, this paper constructs an energy management framework suitable for China's current airport use.

Energy Management Framework by Region

According to the "Construction Standard of Civil Airport Project"(Construction Standard 105-2008), the civil airport project is composed of the main production facilities of airport, production auxiliary facilities as well as airport ground transportation and public facilities, including airfield area, passenger terminal area, freight area, aviation food and on-board supply facilities, airport heating and cooling facilities, etc. China's airport companies generally have terminal management sector, airfield area management sector, public area management sector and other departments, and other professional companies such as power energy companies. "MH/T 5113" respectively stipulated the metering facilities requirement for terminal, energy center (cold and heat source station) and airfield area.

According to the comprehensive analysis of the airport main functions, the key energy consumption areas, the administrative departments and the requirements of measurement, the energy management framework by region should include at least the terminal, the energy center, the airfield area, the freight area and the working area, and the other area. The energy consumption of the areas are small, such as aviation food and on-board supply facilities, engine maintenance facilities, ground transportation facilities and power supply facilities, etc. therefore classified as a large category, named after other area.

The energy management framework by Region is shown in Fig 1.

In particular, the airport energy center generally supply cold and heat for the airport buildings, which mainly provides for the terminal. Due to the directly energy consumption measurement of the terminal does not actually include the cold and heat provided by the energy center, in order to add up
the comprehensive energy consumption, the cold and heat provided by the energy center should be
calculated into the terminal, and this part should be eliminated in the energy center.

**Energy Management Framework by Varieties**

Although the energy structures of airports are diverse in different regions in China, the energy types
are basically the same, mainly including electricity, natural gas, coal, diesel, gasoline, purchased heat,
renewable energy and so on.

The airport energy statistics in this paper are primary energy, for the waste heat generated in
airport, which belong to the recycling of energy, is not included in the statistics.

The energy management framework by varieties is shown in Fig 2.

![Energy management framework by varieties](image)

**Fig. 2 Energy management framework by varieties**

**Energy Management Framework by Use**

Airport is the transportation facilities which provides civil aviation transport services for passengers,
cargo, etc. Its energy consumption also centers on transport services, mainly including air
conditioning, lighting, equipment, vehicle, office, freight, commercial energy consumption, etc.
Energy consumption does not fall into the above categories is classified as other consumption.

Specifically, the energy consumption of terminal can be divided into air conditioning, lighting,
equipment and commercial; energy consumption of energy center can be divided into air conditioning
and office; energy consumption of airfield area can be divided into lighting, equipment and vehicle;
energy consumption of freight area can be divided into freight and vehicle; Energy consumption can
be divided into office, vehicle and commercial; energy consumption in other areas are included in
other energy consumption.

According to MH/T 5113-2016, the main secondary energy-consuming units are divided into first
and second levels, the refrigeration units, direct-fired machines, boilers, refrigeration/cooling pumps,
cooling towers, refrigeration/cooling pumps, primary/secondary hot water pumps, fresh air fans,
blowers and exhaust fans of air-conditioning should be equipped with measuring instruments. As
well as baggage system, boarding bridge equipment, GPU, PCA, elevator and walkway of equipment.
Airport should collect energy consumption statistical data of the above in the future. Although the
office, freight and commercial energy consumption also include air conditioning and lighting, but all
airports have not achieved sub-measurement at present, and no relevant provisions were made in
MH/T 5113-2016, whereas office, freight, commercial use is relatively clear and independent, so it is
unified as office, freight and commercial use. Meanwhile, the lighting, vehicle energy consumption in
each airport is lack of further subdivision data, thus no subdivision is taken in this paper.

The energy management framework by use is shown in Fig 3.
Under the existing energy management framework, airports can be further refined in light of actual conditions, such as lighting can be divided into building lighting, landscape lighting and navigational lighting; vehicles can be refined into public ferry vehicles, airfield area command vehicles, office vehicles, etc. The third-party consultation is encouraged to adopt by the airport to establish the energy management system conforming to its own characteristics.

**Airport Energy Efficiency Index**

Target-oriented, select comprehensive indexes that reflect the energy use and characteristics of airports and terminals, and provide guarantees for energy management benchmarking, evaluation and forecasting of airports and terminals. The comprehensive energy efficiency index of the airport includes 5 items, and the comprehensive energy efficiency index of the terminal includes 6 items. The energy consumption and electricity consumption per unit area/passenger can reflect the overall energy consumption level of the airport. The proportion of renewable energy utilization and clean energy vehicles mainly measure the energy structure of the airport. Energy system efficiency can test the strengths and weaknesses of energy system planning and the level of operational management. As shown in Table 1:

<table>
<thead>
<tr>
<th>Index category</th>
<th>Index name</th>
<th>formula</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport comprehensive energy index</td>
<td>Airport energy consumption per unit passenger</td>
<td>$TE_{UP} = TE / PAX$</td>
<td>[kgce/p]</td>
</tr>
<tr>
<td></td>
<td>Airport energy consumption per unit area</td>
<td>$TE_{UP} = TE / TA$</td>
<td>[kgce/m²]</td>
</tr>
<tr>
<td></td>
<td>Proportion of airport renewable energy utilization</td>
<td>$TE_{UR} = TE_{UR} / TE$</td>
<td>[%]</td>
</tr>
<tr>
<td></td>
<td>Proportion of clean energy vehicles</td>
<td>$TE_{UC} = VE / TE$</td>
<td>[%]</td>
</tr>
<tr>
<td></td>
<td>Airport energy system efficiency</td>
<td>$TE_{ES} = (TE_{C} + TE_{H}) / (TE_{C} + TE_{H})$</td>
<td>[%]</td>
</tr>
<tr>
<td>Terminal comprehensive</td>
<td>Terminal energy consumption per unit passenger</td>
<td>$E_{UP} = E / PAX$</td>
<td>[kgce/p]</td>
</tr>
</tbody>
</table>

**Fig. 3 Energy management framework by use**

<table>
<thead>
<tr>
<th>Energy system efficiency index</th>
<th>Formula</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air conditioning</td>
<td>$TE = TE_{C} + TE_{H}$</td>
<td>kgce/m²</td>
</tr>
<tr>
<td>Lighting</td>
<td>$TE_{C} = TE_{C}$</td>
<td>kgce/m²</td>
</tr>
<tr>
<td>Heating</td>
<td>$TE_{H} = TE_{H}$</td>
<td>kgce/m²</td>
</tr>
<tr>
<td>Airfield</td>
<td>$TE_{AF} = TE_{AF}$</td>
<td>kgce/m²</td>
</tr>
<tr>
<td>Office</td>
<td>$TE_{OF} = TE_{OF}$</td>
<td>kgce/m²</td>
</tr>
<tr>
<td>Business</td>
<td>$TE_{BS} = TE_{BS}$</td>
<td>kgce/m²</td>
</tr>
<tr>
<td>Cargo</td>
<td>$TE_{CR} = TE_{CR}$</td>
<td>kgce/m²</td>
</tr>
<tr>
<td>Aircraft</td>
<td>$TE_{AC} = TE_{AC}$</td>
<td>kgce/m²</td>
</tr>
<tr>
<td>Fuel</td>
<td>$TE_{FU} = TE_{FU}$</td>
<td>kgce/m²</td>
</tr>
<tr>
<td>Trend</td>
<td>$TE_{TN} = TE_{TN}$</td>
<td>kgce/m²</td>
</tr>
<tr>
<td>Total</td>
<td>$TE = TE_{C} + TE_{H}$</td>
<td>kgce/m²</td>
</tr>
</tbody>
</table>
energy efficiency index

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Terminal electricity consumption per unit passenger</td>
<td>$\frac{E_E}{P_A}$  [kWh/p]</td>
</tr>
<tr>
<td>Terminal energy consumption per unit area</td>
<td>$\frac{E}{A}$  [kgce/m²]</td>
</tr>
<tr>
<td>Terminal electricity consumption per unit area</td>
<td>$\frac{E_U}{A}$  [kWh/m²]</td>
</tr>
<tr>
<td>Proportion of terminal renewable energy utilization</td>
<td>$\frac{E_R}{E}$  [%]</td>
</tr>
<tr>
<td>Terminal energy system efficiency</td>
<td>$\frac{(Q_c + Q_h)}{E} / \frac{(E_c + E_h)}$  [%]</td>
</tr>
</tbody>
</table>

E —— The total comprehensive energy consumption of the terminal, including all kinds of energy consumed in a full calendar year of the terminal, converted into standard coal;
Ee —— The electricity consumption of a complete calendar year of the airport, in units of kWh;
Qc —— The cooling consumption of a complete calendar year of the terminal, in units of GJ, converted into standard coal;
Qh —— The heat consumption of a complete calendar year of the terminal, in units of GJ, converted into standard coal;
E_c + E_h —— The total energy consumption of the terminal cooling system and heating system for a calendar year, converted into standard coal;
A —— The construction area of the terminal, in units of m²;

Airport Energy Management Platform Construction Proposal

At present, the airport energy management is constantly in-depth practice, which has not only the appeal of the airport micro-control and management, but also the demand of the industry macro-control and management. From a micro perspective, airports have actively built energy intelligent management and regulation platforms to form a complete cycle of production, transmission, storage and consumption of airport energy, real-time response from supply and demand sides, and maximum use of renewable energy. The coordinated optimization of energy demand and production supply, and the optimal allocation of resources will create an exclusive energy-saving space for the airport; From the perspective of macro regulation and control, the civil aviation comprehensive statistical survey system requires the airport to report monthly energy consumption and carbon dioxide emissions, and is exploring the implementation of the “energy efficiency leader” program.

In order to promote the combination of industrial macro-control and micro-airport subject in airport energy management, and promote the construction of airport energy supervision system and green airport development, the "airport energy management platform" (hereinafter referred to as the "platform") should be established according to the unified airport energy management framework and indexes. On the one hand, the platform can analyze the energy use and energy efficiency indexes of airports and terminals through the energy management data uploaded by airports, and find the weak links of airport energy conservation and tap the energy saving potential of the airport according to the national and industrial energy management related regulations and standards; On the other hand, the platform can build the industrial airport energy big data and form the industrial airport energy consumption quota, which not only provides reference for each airport to understand its own position in the industry energy management and further improve its performance, but also provides data support for the industry to implement the "energy efficiency leader" plan.

Acknowledgements

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