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SYSTEM APPROACH TOWARDS ENHANCEMENT OF AIRPORTS' ENERGY EFFICIENCY

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Abstract. The observed growth of aviation economy sector leads to increasing final energy consumption by both the air transport and airports. Nowadays, airports by their level of energy consumption are comparable to small towns with populations up to 50,000, which are integrated into the structure of megacities and urban areas. Comprehensive assessment of energy efficiency of aviation economy sector must include effectiveness of operation and maintenance of air transport services, ground services and efficiency of energy consumption by airport's terminals and facilities. For reliable forecasts of energy costs and adequate decision-making, it is required to improve a system analysis. A hierarchical system "Sustainable Airport" is offered as a methodological approach to reduce energy consumption and CO_2 emissions by improving energy and fuel efficiency. The key levels of hierarchical system "Sustainable Airport" are considered. An intelligent platform based on Smart technologies for air terminals, engineering processes, and related services in airports is proposed as a part of system's technical level.

Keywords: energy efficiency, sustainable airports, hierarchical system, integrated resource planning, smart technologies.

Introduction

The modern world is undergoing a transformation of traditional production systems with a stable trend of transition to systems based on the use of environmentally friendly and energy efficient technologies. The goal of the transition is a simultaneous combination of conditions, which are necessary for economic growth, with a requirement to reduce resource consumption and negative impact on environment.

Low-carbon economy must significantly counteract depletion of natural resources, including energy resources, and reduce greenhouse gas emissions as well as decrease impacts of human activities. On the other hand, development and implementation of environmentally friendly and energy efficient technologies have to improve country's energy independence, increase competitiveness of national economies in the world markets for goods and services, and improve a quality of life.

In perspective of sustainable development of civil aviation, the advance of system approach to assessment of energy and economic efficiency becomes a key issue for reduction of both energy costs and CO_2 emissions in this economy sector. To achieve a holistic integration of low-carbon technologies in aviation, the activities on improving the energy efficiency and economic operation must cover both air transport and airports including air transport services, ground services, airport's terminals and facilities.

The observed growth of aviation sector of economy leads to increasing consumption of energy resources and, consequently, to the growth of CO_2 emissions as well as to negative ecological impact. According to existing estimations, the share of aviation in global CO_2 emissions is about 2 %. However, these estimations do not take into account a contribution of emissions resulting from operation of ground facilities and services of airport's complexes. Airports as a part of megacities and urban areas are dynamically growing industrial enterprises, which are crucial points of economic activity within global, national, and urban transport systems. Thus, reliable forecasts of energy costs are required for adequate decision-making for sustainable aviation and airports.

On the other hand, since modern airports have essential growth of energy consumption, their impact on emissions, as well as their share in entire energy consumption

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must be included in assessments. Therefore, we need to improve a system analysis for comprehensive assessment of efficiency of energy consumption by air transport services, ground services and airport's terminals and facilities.

The aim of the article is to offer a hierarchical system "Sustainable Airport" and to describe briefly key structure levels for further modelling and simulation. It will allow us to make reliable forecasts of energy costs and to evaluate energy efficiency for both air transport and ground services as well as for airport's complexes.

1. Existing situation analysis

Assessments have shown that in the EU-28 air transport has become the fastest growing sector in final energy consumption in transport sector, and this growth from 2001 to 2011 was 16 %. The reason behind it is that use of air transport has been increased almost in the all EU countries. Nowadays, a significant number of air passengers and a substantial amount of goods freight are carried out by civil aviation.

In 2011, the number of air passengers in the EU-27 was approximately 827 million and cargo air delivered through airports was about 14 million tonnes.

Statistics of transport of air passengers and freight carried out through airports in the EU-27 from 2001 to 2011 is given in Table 1.

Table 1. Statistics of transport of air passengers and freight in the EU-27

Transport by Air	years				
	2007	2008	2009	2010	2011
Goods freight (thous. tons)	12 582	13 191	11 584	13 427	13 828
Passenger (1000 passengers)	800 499	803 963	757 541	786 630	827 068

In recent years, there has also been observed a positive trend of increasing transportation of air passengers in Ukraine that leads, therefore, to growth of passenger traffic through national airports. In 2012, compared with 2011, the number of air passengers carried out through the Ukrainian airports was increased by 13.2 % and reached 14.1 million passengers and, in fact, more than 98 % of them were serviced by eight Ukrainian airports.

The growth of the passengers transport by air leads to greater, than before, energy costs in aviation sector of economy. At permanently changing requirements, due to development of air transport market, it is crucial to provide competitiveness of national civil aviation that must be achieved by reducing energy costs through holistic and comprehensive measures on improving the energy efficiency in aviation sector of economy.

Considering the development of sustainable aviation as an economy sector, it should take into account its impact on megacities and urban areas. Comparative analysis of data let us conclude that buildings and transport are the most energy-intensive sectors in megacities and urban areas.

Statistics on final energy consumption (in million tonnes of oil equivalent, Mtoe) is shown in Figure 1.

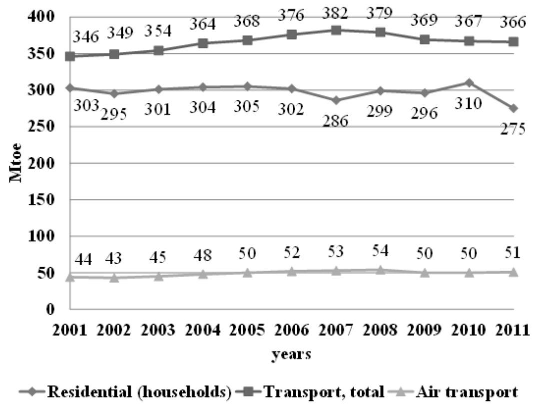

Fig. 1. Final energy consumption (Mtoe) by economy sectors in the EU-28, from 2001 to 2011

As we can see, the air transport, as economy sector, has a strong trend to growing in final energy consumption and its share in the energy balance of urban agglomerations becomes significant. In 2001, the amount of final energy consumption by air transport relative to the amount of final energy consumption by residential sector was 14.5 %, and, in 2011, it reached 18.5 %. However, the data on final energy consumption by airports themselves is not available. Analysis, that is more comprehensive, requires accounting a share of final energy consumed by airport's complexes and service including buildings and facilities as well as ground operation and air transport services.

Growth of air passenger and cargo traffics has already caused the increased energy costs for terminals and airport ground services. As a result, annual electricity consumption in large European airports is already about several hundred GWh, and there is also a high demand for heat. Therefore, the airports by level of energy consumption are comparable to small towns with populations up to 50,000. Under increase in passenger and freight traffics, an adequate forecasting on energy consumption is important issue for effective business of airports, as large industrial enterprises in urban area. For their sustainable growth in the frame of megacities and urban areas it is necessary to improve methodology of estimation of energy needs for operation modes of various groups of energy consumers in airport's complexes.

Regarding to Ukraine, the modernization and reconstruction of air terminals are required in 14 Ukrainian airports in order to improve service and to reduce energy consumption. Features of space-planning decisions, operation features, technical conditions of airport buildings and structures influence on energy consumption indicators. In most cases, service personnel cannot recognize inefficiency of final energy consumption. The typical causes are imperfect monitoring, data collection, processing and documenting. In some cases, the cause is a weak interaction between the services of airport. It results in incomplete energy data analysis. Since terminals have a large energy-savings potential (heating, air conditioning and ventilation, indoor and outdoor lighting, transportation systems, etc.) the Ukrainian airports can be attractive for investments. But investors expect forecasts, which are more reliable ones.

On the other hand, the modern airports are the part of megacities and urban areas, which are large, complex, changeable socio-economic systems formed by integrating a main city with its surrounding settlements and agglomerations, so their contribution to CO_2 emissions and negative ecological impact must be reduced through efficient operation of airport's complexes and air transport service.

Aviation economy sector is a very complex multilevel system; the modelling of this system faces the problems of uncertainty and nonlinearity of final energy consumption for the most of airports. Thus, new system approach and methodologies are required to identify significant and affecting parameters, which are essential for forecasting the energy consumption, energy costs and CO_2 emissions.

2. Hierarchical system "Sustainable Airport": structure and levels

A hierarchical system "Sustainable Airport" is a complex layered structure, which consists of several key levels. Functional purpose of "Sustainable Airport" is to enhance of airports' energy efficiency that leads to reduction of energy consumption and CO2 emissions.

Describing the hierarchy of system "Sustainable Airport", we should identify the framework and key levels, which must be included in the system. These will allow us to find out the main systems and subsystems as well as the types of links between them (i.e. economic, managerial, social, organizational, technical, or technological), according to which they interact within the system's framework. The system approach will also contribute to modelling and simulation of sustainable energy systems integrated into unified structure "Sustainable Airport" to enhance airports' energy efficiency.

The framework of hierarchical system covers all types of energy and fuel consumption by airport's complexes including buildings and facilities as well as ground operation and air transport services. The structure of hierarchical system provides a synergy of methodological approaches. To avoid a contradictory of objectives between the levels, they are combined by universal functional purpose of system. The purpose is to reduce energy costs by enhancement of airports' energy efficiency.

The hierarchical system "Sustainable Airport" includes three key levels: institutional, management and technical/technological ones. Subsystems (or sustainable modules) as well as their interrelationships, are identified according to this framework of hierarchical system. Thus, the hierarchical levels may include several sustainable modules, which are systems of lower rank. These modules are also associated with the simpler subsystems (or elements) of following rank.

Integrity of the proposed hierarchical system "Sustainable Airport" is provided by functional links between levels, as well as, systems and subsystems included therein.

Methodological approaches (i.e. tools, methods, ways etc.), which ensure the functioning and communication between the given levels, are briefly discussed below.

Institutional level of hierarchical system

At institutional level, the proposed tool for planning and decision-making is an integrated resource planning (IRP). By tradition, we use the IRP methodology for sustainable energy development. However, there are researches devoted to application of the IRP for the development of sustainable transportation systems as well as for aviation sector.

The concept IRP for sustainable airports' development, as a part of aviation sector, assumes creating the set of alternative scenarios for long-term forecasts and planning. The purpose of the IRP is to increase energy efficiency and reduce CO2 emissions in the long-term planning. The object of the IRP is to meet current and projected energy needs at the lowest cost with performing basic indicators of sustainability. The set of alternative scenarios covers possible changes on demand and supply sides in aviation economy sector including variables linked with technological, market, institutional and social drivers. To improve the accuracy of calculations, the problem statement should consider forward-looking long-run changes associated with development of aircraft technologies, increasing fuel efficiency, using biofuels, improving management and control of air traffic.

All alternative scenarios are evaluated by the set of specified criteria to find out the most cost effective scenario. Since the IRP tools give us forecasts about the air passenger and cargo traffics in airports, it helps us to evaluate the level of further energy consumption and energy needs. To minimize environmental impact, the problem statement should include a specified set of sustainable aviation indicators and least-cost analysis must be arranged together with perspectives of "green technologies" in aviation.

Due to proposed hierarchy of "Sustainable Airport" and set of links between levels, systems and subsystems, implementation of the IRP has a feedback, which provides the possibilities to improve the forecast based on scenario approach.

Management level of hierarchical system

The solutions and tools of institutional level are conducted through the management level. This level has two subsystems: the management system of energy and fuel efficiency (MSEFE) for air transport and ground services and energy management system (EMS) for airports' complexes and facilities.

MSEFE is targeted on optimization of fuel consumption. There are at least five potentials for fuel efficiency, linked to this subsystem: technological, operating modes, fuels, infrastructure, air traffic management. The objective of the MSEFE is to reduce the share of fuel consumption in the overall budget and to improve fuel efficiency.

EMS is targeted on optimization of energy consumption and energy supply for airports' complexes and facilities. It covers air terminals (heating, air conditioning, ventilation, indoor/outdoor lighting, escalators etc.) as well as the ground service and facilities. The standard ISO 50001 "Energy management systems. Requirements with guidance for use" must be used as a methodological tool for design and implementation of EMS in airports.

Technical / technological level of hierarchical system

For today, the challenge for implementation of two management systems mentioned above is an insufficient technical and technological level regarding interactive monitoring, measuring, checking, controlling, and recording the energy data. The reasons of insufficient measurements and managements are large area, branched infrastructure, variable loads for all types of airport facilities and services, and lack in smart technologies at airports' complexes. To reduce energy costs and to optimize energy supply the new innovative technical and technological solutions are required.

To reduce energy costs and to optimize energy supply the new innovative technical and technological solutions are required. Suggested methodological approach on technical and technological level is to design the intelligent plat-forms based on IT-systems and Smart technologies. This intellectual platform at the given level is especially important if alternative and renewable energy sources are applied. Implementation of Smart Grids is necessary if distributed generation is planned to use for improving the quality and reliability of electricity supply of airport's complexes.

Thus, described above hierarchical system "Sustainable Airport" also promotes a low-carbon economy through wide implementation of innovative high-tech environmental friendly technologies, systems, and equipment for air terminals, and related services in airport's complexes and facilities. Structurally, the IT-system must linked with the EMS and MSEFE for comprehensive information about energy performance indicators of airports.

3. Prospects for implementation of intelligent platforms based on Smart technology at airports

The goal of implementation of Smart grids in airports is to reduce transmission and distribution losses as well as to optimize the energy flows, especially for peak demand, due to connection of distributed generation systems to the grids. Other targets are to increase energy efficiency of final energy consumption by well-organized management and to rise up the energy security of airports.

As mentioned above, the intelligent platform based on Smart Technologies allows us to make smart collecting, processing, monitoring, controlling and accounting of energy data to optimize the energy flows.

To optimize electricity supply for airports, the Smart Grids must be implemented. This technology provides an effective connection between decentralized generating units and general network.

On the side of final energy consumers, the Smart Metering technologies must be used. This technology provides effective measurement and control of energy consumption.

Smart Building system can be used to optimize both the energy supply and energy consumption in the airport terminals.

Conclusions

To enhance of airports' energy efficiency the hierarchical system "Sustainable Airport" with complex layered structure is offered.

The framework of this hierarchical system covers all types of energy and fuel consumption by airport's complexes including air terminals and facilities, ground operation and air transport services.

The structure of hierarchy includes three key levels: institutional, management and technical/technological ones.

IRP is the tool for sustainable airports' planning and decision-making on institutional level of system.

The IRP is conducted on management level by two management systems (MSEFE and EMS) targeted on optimization of fuel and energy consumption as well as on optimization of energy supply in airports.

To improve energy performance indicators of entire hierarchical system, the intelligent platforms, based on IT-systems and Smart technologies, must be implemented on the technical/technological level.

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