frontiers | Frontiers in Sustainability

ORIGINAL RESEARCH
published: 31 May 2022
doi: 10.3389/frsus.2022.916038

Due Diligence of Transport Infrastructure Operators Sustainability: A Circular Economy Driven Approach

*Dimitrios Dimitriou and Aristi Karagkouni**

Department of Economics, Democritus University of Thrace, Komotini, Greece

Renewable energy usage, waste, and water management are all issues that airports must address in order to be able to adapt to changing situations and address environmental sustainability principles. This paper deals with an analysis of the development principle of airport renewable green facilities and activities by reviewing the areas that impact the sustainable transition of international mobility and freight hubs, such as airports. By a systemic review, the special focus is on airport landside business, in which comprehensive landside facilities data gathering framework, defining the context and key trends in landside development framework in European airports, serving popular tourist destinations in Mediterranean region. The analysis is based on the breakdown of the airports' key environmental aspects related to renewable green facilities and provides key message to planners and decision makers about the development of renewable green activities in airports located in popular tourist destinations as enabler for shifting them into greener infrastructure. Conventional wisdom is to provide a clear, coherent and well support view for the linkage of airports' sustainable transition with the development of renewable green facilities and activities in their landside area, providing a great picture for planners and decision makers in terms of managing airports serving tourist destinations.

Keywords: sustainable development, large transport infrastructure, transportation Due Diligence, sustainable development of transportation, tourist airports, green airports

OPEN ACCESS

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***Correspondence:**
Aristi Karagkouni
arkaragk@econ.duth.gr

Specialty section:
This article was submitted to Circular Economy, a section of the journal Frontiers in Sustainability

Received: *08 April 2022*
Accepted: *09 May 2022*
Published: *31 May 2022*

Citation:
Dimitriou D and Karagkouni A (2022) Due Diligence of Transport Infrastructure Operators Sustainability: A Circular Economy Driven Approach. Front. Sustain. 3:916038. doi: 10.3389/frsus.2022.916038

INTRODUCTION

The European Commission enacted the European Green Deal in 2020, with the goal of making Europe the first continent to be carbon-neutral by 2050. As a result, a 90% reduction in greenhouse gas emissions (GHG) by the middle of the century would need to be achieved by the transportation sector as a whole, with all modes making their due contribution. While the advent of the COVID-19 pandemic has created significant hurdles for most sectors of the economy, it has also become obvious that the Commission's level of climate ambition has remained unaltered in the interim period (Dimitriou and Sartzetaki, 2022a). In order to speed the transition to a more sustainable, intelligent, and resilient mobility system, the recovery phase has been positioned as an opportunity to do so. In 2021, the European Commission published its Sustainable and Smart Mobility Strategy. The strategy lays out a framework for how the EU transport sector can achieve its green and digital transformation while also being more resilient to future crises.

The aviation industry, in particular, has proven to be one of the most difficult sectors to decarbonize. Part of the reason for this can be traced to the industry's fragmented nature, with each piece that makes up the sector pursuing its own attempts to decarbonize while at times tugging in opposing directions from one another. The aviation industry has never been vertically consolidated under a common regulatory framework, in contrast to the other network sectors, such as railways, energy, and telecommunications, among others. As a result of this, the aviation industry has never had a more prominent systemic perspective (Air Transport Action Group, 2020). The importance of taking a systematic approach to regulating the aviation industry has been highlighted in recent years. This is especially important when it comes to the greening of air transport sector, where the efforts of the various factors that make up the aviation ecosystem will need to be coordinated, particularly at the sector's interfaces, in order to put the sector on a path to achieve net-zero emissions by the middle of the century.

While it is well-known that the actual flight is responsible for the vast majority of the aviation sector's carbon footprint, airports themselves have significant untapped potential for further and relatively simple greening, especially when compared to airlines, and this potential is particularly significant. Through the use of easily accessible technologies and techniques, airports have the potential to make a significant contribution to lowering aviation emissions. The Airport Carbon Accreditation program, which has been in operation for more than a decade, demonstrates airports' commitment to greening their assets in accordance with the net zero carbon objectives of the International Civil Aviation Organization (Airports Council International, 2019).

It is possible for greening efforts to touch on a variety of different aspects of an airport's design and operation (Ramakrishnan et al., 2022). Through an extensive literature review among business and organizations in air transport sector, it was revealed that a large number of airports, as Hamburg International Airport, are implementing measures to improve the energy efficiency of their buildings, including the renovation of ventilation and lighting systems, as well as the installation of photovoltaic facilities on-site. Others, such as Geneva International Airport, are providing financial assistance to ground handlers who electrify their activities in order to cut both emissions and operating costs while increasing efficiency. Furthermore, airports are attempting to improve public transportation connections to city centers while also supporting multi-modality and environmentally friendly modes of transportation. A few examples are electric shuttle bus fleets at AENA-operated Spanish airports, installation of required charging infrastructure, and the reinforcement of electricity distribution systems in the country's power infrastructures. Another example is Schiphol Airport is putting its taxi bot pilot to the test, which will allow planes to be towed off the runway with their engines turned off, saving fuel and emissions in the process.

Airports, in contrast to airlines and air traffic management (ATM), are deeply embedded in their communities, are frequently connected with local residents, and are generally subject to greater local pressures than airlines and ATM. Airports must also handle local issues such as air and noise pollution, waste generation, and potential impairment to wildlife habitats and water bodies while limiting their CO_2 impact. Airports have a unique opportunity and responsibility to serve as role models and enablers for the greening of the whole aviation industry, as outlined above (European Environment Agency, 2019). The experience of Schiphol Airport in electrifying its bus fleet in 2011 is a case in point of how airports rely on the products that are already available on the market to green their operations and provide services to their passengers. Several ways have emerged to address technological bottlenecks in the supply chain. These range from increasing their research and innovation efforts to reaching out to suppliers outside of Europe, to co-developing the products that are in high demand with suppliers in other countries.

Furthermore, major airports are extending their greening efforts outside their own grounds by sponsoring renewable energy initiatives and collaborating with suppliers of sustainable aviation fuels (SAFs). SAF manufacturing and deployment may be scaled up at airports by taking advantage of their unique position as a link between airlines, aircraft manufacturers, and inventors of smart energy management systems, which they hold in high regard. Airports can expedite the introduction of new aircraft technology connected to electrification or hydrogen by securing the requisite airport infrastructure, associated services, and, finally, by establishing incentives for passengers and businesses. Moreover, airports are getting more and more actively involved in the greater energy transformation by acquiring or producing their own carbon-free electricity on the grounds of the airports itself. In order to facilitate the uptake of SAFs and the greening of aviation, increased coordination amongst stakeholders from across the entire supply chain is essential. Of course, the specifics of these alternatives will vary depending on the regional situation.

This paper deals with an analysis of the development principle of airport renewable green facilities and activities by reviewing the areas that impact the sustainable transition of international mobility and freight hubs, such as airports. By a systemic review, the special focus is on airport landside business, in which comprehensive landside facilities data gathering framework, defining the context and key trends in landside development framework in 11 European airports, serving popular tourist destinations in Southern Europe and Mediterranean region. The methodological approach is based on desk research to gather and analyzed readily available data and statistics to gather data in order to integrate the perspectives of the key factors and drivers of change that influence landside development in the sample of the European airports. The sample is composed of airports located in tourism destinations heavily affected by climate change implications, as the Mediterranean region and, more specifically, its coastal zones, have been facing high disaster risks, including high temperatures, water scarcity, erosion and low precipitation (United Nations Environment Programme (UNEP)., 2020). The analysis is based on the breakdown of the airports' key environmental aspects related to renewable green facilities and provides key message to planners and decision makers about the development of renewable green activities in airports located in popular tourist destinations as enabler for

shifting them into greener infrastructure. Conventional wisdom is to provide a clear, coherent and well support view for the linkage of airports' sustainable transition with the development of renewable green facilities and activities in their landside area, providing a great picture for planners and decision makers in terms of managing airports serving tourist destinations.

BACKGROUND

In this section, the general background regarding airports' greening opportunities, as enablers for their sustainable transition are described. The existing regulatory framework and options for shifting toward greener airports are presented, providing useful information about emissions accreditation schemes and trading systems, as well as funding opportunities and prospects arising from the European Green Deal.

Regulatory Options Supporting the Shift Toward Greener Airports

While it is promising to see a few examples of best practices in place today, moving toward a more consistent effort across the airport industry toward greening will demand the adoption of favorable European Union legislative frameworks. It was discovered that there was an apparent market failure, and hence a need for intervention, in the ground handling industry; an industry with extremely low margins, making substantial upfront investments and greening considerations impossible to achieve (Dimitriou, 2021; Dimitriou and Karagkouni, 2022). Increased participation on the part of airports, such as through the inclusion of minimal CO_2 standards in licensing calls for tenders, could help to speed the greening of the industry. An overall legislative framework could also assist in mobilizing a collective effort toward greening, which is essential for achieving economies of scale and lowering the higher initial costs of newer technologies, such as electric vehicles, which are currently prohibitively expensive. Furthermore, airports must be encouraged and supported in their efforts to serve as enablers.

There are a variety of tools at airports' disposal to encourage cleaner and quieter aircraft, including airport taxes, incentive programs, operating standards, and slot regulations, among others (Dimitriou, 2020). Many airports are currently adjusting the prices paid by airlines based on environmental factors, for example, by cutting charges for aircraft that produce less noise and emit less air pollutants such as NOx. Other airports are considering similar measures. In practice, however, the ability of airports to modulate prices is heavily influenced by the applicable legislation, which differs from nation to country. All things considered, some fine-tuning and revision of the EU regulatory framework will be required in the next months and years. One of the most difficult challenges will be to ensure a systemic approach and coherence across the various pieces of legislation, from airport charges and slots to the implementation of the Single European Sky, State aid, the internalization of external costs, and the EU's Sustainable Finance workstream (for example EU taxonomy for sustainable activities, EU Green Bond standard etc.), among other things. This is a comprehensive list of initiatives that are all interconnected and contribute in some manner to advancing the European Green Deal agenda. Finally, the future regulatory framework must recognize that airports are complex systems of interconnected facilities and assets, with implications for assessing and managing their sustainability performance.

Carbon Accreditation Schemes

In addition to government legislation, voluntary sector measures, such as the provision of reputational incentives, can play a vital role in encouraging airports to become more environmentally friendly. In instance, the ACI Airport Carbon Accreditation program, which was started in 2009 and is based on existing, cross-industry standards for carbon management, is a particularly intriguing example of such an endeavor (Airports Council International, 2019). Initially, this program was based on four levels of accreditation (ranging from 1 to 3+), each of which became increasingly strict as time went on. At the first level of accreditation, an airport must map out its own emissions, develop action plans, and set CO_2 reduction goals in order to be accredited. As a result, the airports increasingly broaden the scope of their operations to include third-party emissions as part of their ongoing activities. In order to assist airports in their efforts to achieve net zero emissions by the middle of the century, the Airports Council International (ACI) recently announced the introduction of two new levels of accreditation, namely level 4, also known as the "transformation level," and level 4+, also known as the "transition level."

When applying for accreditation at the "transformation level," an airport must identify emission reduction targets exclusively in absolute terms (i.e., the establishment of CO_2 reduction targets per passenger does not suffice), with the level of the target being matched with the Paris Agreement (i.e., consistent with the IPCC scenarios defined for the 1.5- and 2-degrees pathways). Another difference between the "transformation level" and the previous levels is that airports accredited at the "transformation level" will have the option, under specific conditions, of include third party emissions in their goal scope. Level 4 accreditation includes a requirement for a more extensive carbon footprint, particularly in relation to third-party emissions, as well as a more stringent requirement for stakeholder participation than Level 3 accreditation. For its part, the "transition level" 4+ includes all of the conditions listed above in addition to a mechanism for compensating for any remaining emissions. Considering its global reach and extent, the Airport Carbon Accreditation program has had to strike a compromise between the requirements and context-specific circumstances of different airports from across the world while developing the various accreditation levels available. Although this is true, the program is aligned with the EU's climate goals, and a total of 394 airports globally, accounting for 48% of global air passenger volume, are currently carbon accredited. Another important point is the need for adequate accounting of airport emissions, as not all EU Member States are properly integrating the climate impact of airport growth into their plans at this time (e.g., currently ongoing legal case on London Heathrow). In this

framework, extensive environmental impact assessments should be conducted prior to any airport expansions.

Moreover, as discussed previously, the aviation industry is one of the most rapidly expanding sources of greenhouse gas emissions. The European Union is taking steps to cut aviation emissions in Europe, and it is collaborating with the international community to adopt policies that will have a global impact. Since 2012, CO_2 emissions from aviation have been included in the European Union's emissions trading system (EU ETS), which can be translated as "EU Emissions Trading System." To be eligible for emission credits under the EU ETS, all airlines operating in Europe—both European and non-European—are required to monitor, report, and verify for accessible translations of the previous emissions, in addition to surrendering allowances against those emissions (Bayer and Aklin, 2020). It provides them with tradeable allowances in exchange for readily available translations of the previous, which covers a specific level of emissions from their flights each year. In 2021, it has been proposed by the European Commission to revise the ETS aviation rules as part of the Fit for 55 legislative package, in order to help ensure that this sector contributes to the more ambitious goal of achieving net emission reductions of at least 55% by 2030, when compared to 1990 levels (Finger et al., 2021; Pietzcker et al., 2021).

Funding Possibilities to Enable Greening of Airports

Concerning EU funding prospects, the European Commission has announced a combined European Green Deal call for ports and airports, with the primary goal of reducing transportation-related emissions and encouraging smart and sustainable mobility. Sustainability (e.g., use of SAFs), smart operations (e.g., use of appropriate IT tools), multimodality (e.g., integrating multimodal linkages to city centers or other modes of transport such as rail) and "other" components of the built environment are clustered together (e.g., energy efficiency). This initiative's main goal is to bring together diverse stakeholders, including those from outside Europe, to test solutions locally, scale them up, and adapt them to different airport sizes and traffic volumes.

Increased infrastructure operating expenses are not usually associated with the implementation of greening projects. Some initiatives cut emissions simply by increasing efficiency. This is known as net zero emissions. In the case of more direct flight routes, this is the case. Some initiatives may necessitate a significant initial expenditure, but they will pay off in the long term. This condition applies with thermal insulation of buildings (including airport terminals) and electric automobiles. Even if these projects do not increase long-term expenses and may result in lower operational costs, funding their higher upfront expenditures will be an issue. However, lowering emissions frequently necessitates an increase in airport operational costs. In these circumstances, public authorities, airport administrators, airlines, and passengers must decide how to share the new expense. To achieve the emission reduction goals, it is also vital to promote the most efficient technology and solutions.

Moreover, the cost of infrastructure has been passed on to users for decades, easing the strain on public authorities and taxpayers (Dimitriou et al., 2018; Dimitriou and Sartzetaki, 2018b). The airlines are the immediate users of airports, whereas passengers are indirect users (and also the cargo shippers). The "polluter pays" principle and the overarching policy to internalize external expenses seem to apply to greening costs as well. Increased airport fees are expected to cover airport emissions reduction investments. Passengers and shippers would be charged for these expenses. But, in some cases, and to some extent, for more profitable airports, state funding seems justified. Islands, rural places, and regional airports may require governmental investment to green their infrastructure and operations. Even larger airports may struggle to afford investments that do not increase capacity or improve passenger amenities (Dimitriou and Sartzetaki, 2018a). State support would speed up investment and reduce emissions faster. The greening of airports appears to be particularly well-suited for attracting financial resources. These are the types of projects that the European Union and its member states seek to finance in order to reduce emissions while still encouraging economic activity and growth (Dimitriou et al., 2022; Dimitriou and Sartzetaki, 2022b). Another challenge will be to ensure that investments are made in the right projects, namely those that increase productivity while also effectively reducing emissions. This will be particularly difficult in a fragmented and complex ecosystem with numerous actors, such as the one that exists in the aviation and airport industries.

ENVIRONMENTAL ASPECTS OVERVIEW

The anticipated rise in demand for air travel, as well as the necessary changes to airport infrastructure, will exacerbate the environmental implications of airport development and operation, which will be compounded further (European Environment Agency, 2019). When developing and operating the next generation of airport infrastructure (e.g., terminal buildings), a systematic approach to evaluate the environmental implications of the project must be used to guide the process. Measures that examine the long-term viability of airport infrastructure design, building, and operation are a potential answer for airport operators to explore. The key pillars of airports' environmental aspects for shifting into greener and more sustainable infrastructure are depicted in **Figure 1** and further analyzed in the following paragraphs.

Energy Management

The term "energy management" refers to a procedure by which airports can assess and monitor their energy use, as well as implement strategies to lower it. On-site renewable energy generation is another common indicator of long-term viability that has been explored extensively in the literature (Alba and Mañana, 2016; Clean Energy Finance Corporation (CEFC)., 2020). However, due to their large land areas, airports are excellent candidates for using on-site renewable energy sources such as solar and wind. However, some forms of renewable energy such as solar and wind might present safety concerns (e.g., glare and radar interference). On-site renewable energy systems, such as solar photovoltaic (PV) systems, can be evaluated based

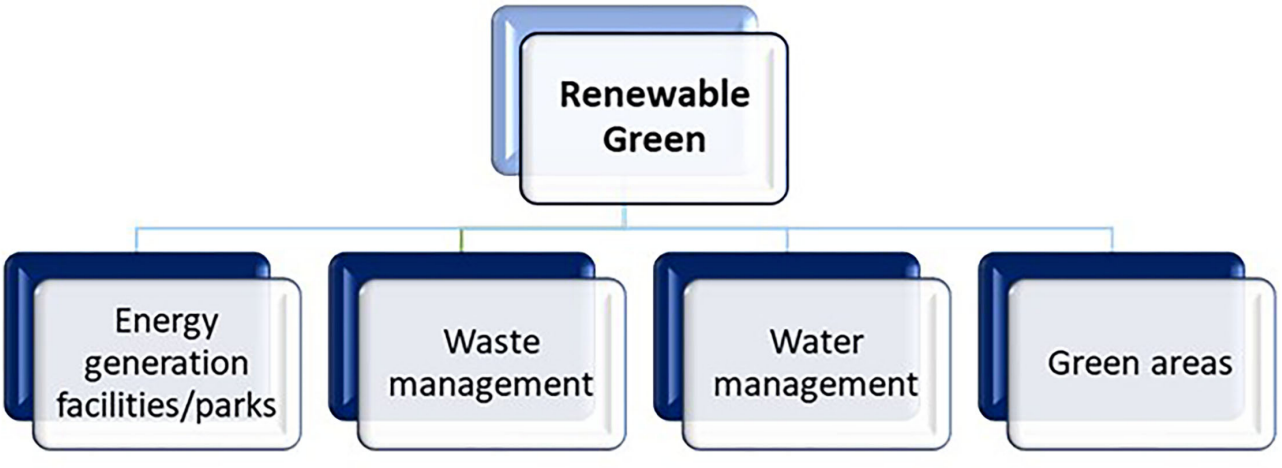

FIGURE 1 | Key pillars of airports' environmental aspects.

on a variety of metrics, including the percentage of energy demand satisfied by on-site renewables and exergy generated (Barrett et al., 2014; Yerel Kandemir and Yayli, 2016; Baxter et al., 2019b). In regards with on-site solar PV, exergy is a term that refers to the quality of the energy delivered; solar power tends to have substantial thermal losses unless cooling is used (National Academies of Sciences Engineering Medicine, 2015; International Renewable Energy Agency, 2016).

Accounting for GHG emissions from both the quantity (first law) and the quality (second law) of energy allows for a more realistic assessment of the possibility of reaching practices that are considered sustainable in terms of both quantity and quality (e.g., net zero-carbon airport terminal buildings). It is also possible to measure absolute reductions in fossil fuel usage when using renewable energy at airports (Boussauw and Vanoutrive, 2019). This statistic was used to evaluate a solar PV and battery storage project at Cornwall Airport Newquay in the United Kingdom, which is located in the country's southwest corner. The modeling of a solar PV farm at a rural airport in the United States suggests that this form of renewable energy may cover the electricity needs of both the airport and the local community without compromising pilot or airspace safety (Carlini, 2013). Groundwater source heat pumps for a Tibetan airport were found to be more energy-efficient (i.e., had a higher coefficient of performance) than conventional heat pumps in meeting indoor thermal needs, according to the study's findings. Moreover, in many cases, the LCA method is used to inventory the greenhouse gas emissions associated with the usage of a biomass-fired combined heat and power plant to meet the heating needs of the airport's terminal buildings.

Water Management

Airports use water for inside operations such as toilet flushing, food preparation, and HVAC systems, as well as for outside activities such as irrigation, aircraft/infrastructure washing and maintenance, among other things. The amount of water consumed by major airports is not negligible, and it is comparable to the water consumption patterns of small and medium-sized cities in most cases. The amount of water consumed per day is a common statistic for analyzing airport water consumption, however this metric does not provide a comprehensive picture of the types of water sources that are used or the management strategies that produce the best results (De Castro Carvalho et al., 2013). Water conservation strategies for airports include monitoring water use, the installation of water-efficient fixtures and fittings, lowering irrigation demand, and the use of alternate water sources, among other things (e.g., rainwater, greywater, recycled wastewater). According to the literature, a significant portion of airport water consumption is used for activities that do not necessitate the use of potable water (Baxter et al., 2019a).

The types of water quality hazards associated with airport activity can be divided into three categories: chronic, seasonal (e.g., from deicing operations), and unintentional (e.g., fuel spills). When it comes to groundwater and surface water bodies, airports make every effort to keep dangerous chemicals and fluids from entering. Rain gardens, green roofs, rainwater harvesting, porous pavement, sediment filters, and wetland treatment systems are some of the stormwater management options that can be used. When it comes to de-icing activities, which are important for airplanes and runways in cold-weather climates, the scholarly literature concentrates on water quality issues that arise as a result (International Civil Aviation Organization, 2019). As a result of increased levels of chemical oxygen demand and lower levels of dissolved oxygen, de-icing fluid runoff can have a severe influence on surface water quality, which in turn has an impact on aquatic flora and fauna. Among the potential mitigation techniques for managing airplane de-icing are the use of new soil filters and the treatment of ice-covered aircraft with artificial wetlands. Most research look at the influence of de-icing fluid on water quality, however the identification of greenhouse gas (GHG) emissions associated with foregoing collection and treatment of de-icing fluid at a wastewater treatment plant and instead employing on-site recycling is also crucial.

Waste Management

Airports have a wide range of consequences that go beyond pollution and noise. In order to reduce the negative consequences on the environment and social life caused by airports, regulators and airport authorities must pay close attention to a number of issues, including land use by airports, waste, and ground congestion. Land take is the term used to describe the use of land by airports for the purpose of constructing and operating airport-related facilities. The requirement for additional land for the construction of new runways and facilities will be avoided through the use of appropriate operational methods and the expansion of available capacity. Analysis of waste management at airports is a new research field that is being explored. Food waste from stores and concessionaires, construction garbage, and aircraft-related waste are some of the waste streams that can be found at airports (National Academies of Sciences Engineering Medicine, 2018). The quantity of waste, the waste source portion, and the amount of waste produced per operation are some of the metrics used to analyze waste at a major international airport. A series of waste management scenarios have been analyzed, with the results indicating that on-site incineration with heat recovery produced the best outcomes in terms of air emissions.

Airport waste is defined as waste generated as a result of the functioning of an airport. Passengers, airfield operations and maintenance activities, as well as garbage generated during construction and demolition, can all contribute to this type of waste. It has been proven that the better and more efficient waste management efforts of airports have been achieved by generating less garbage over a given time period (Baxter et al., 2018; International Civil Aviation Organization, 2018). Moreover, some airport activities, such as aircraft and airfield deicing and anti-icing, fuel storage and refueling, aircraft and vehicle cleaning and maintenance, and construction, may result in the discharge of pollutants into nearby water bodies, causing aquatic life and human health to suffer (Mousavi Sameh and Scavuzzi, 2016). Congestion and delays affecting airlines and flying passengers are another issue that arises while airports are in operation. The most efficient use of airport capacity, particularly runway capacity, is generally believed to be the key to reducing the congestion.

Green Areas

As discussed in previously, the establishment and operation of an airport necessitates the acquisition of adequate land. Land reclamation is utilized to produce a suitable airport environment in areas where the existing land is unsuitable for aviation purposes. The effects of land reclamation on existing ecosystems are being studied, with particular attention paid to the effects on soil, water, air, and animal species. Another indicator mentioned in the literature is the efficiency with which airport land is utilized, or the number of aircraft operations that occur per unit amount of land (Mousavi Sameh and Scavuzzi, 2016). Additional research areas focus on airport operation and its effects on wildlife populations, with the goal of developing specific strategies to discourage and accommodate wildlife populations on airport airfields, in airport water resources, in terminal buildings, and in control towers, among other things. Researchers have been studying the elements that attract birds to green roofs, the effects of solar panels on birds, and how airport expansion affects bat populations. They have also looked into how solar panels affect bat populations.

When it comes to airports, sustainable transport refers to the modes of transport that are used to shuttle passengers from terminals to parked aircraft as well as to transport passengers to and from the airports. On-site transportation sustainability strategies include the use of alternative vehicles (e.g., electric vehicles), the restriction of vehicle idling, and the reduction of the number of empty trips (Greer et al., 2020). The use of an underground rapid transport system (URTS) to transfer airport passengers across vast distances between major terminal buildings and satellite and midfield concourse terminals has also been studied. In addition to using automated vehicles, encouraging passengers to use existing public transportation options by increasing their capacity, discouraging the use of private vehicles, integrating with other transportation hubs, and installing dedicated electric vehicle charging infrastructure are all viable options for sustainable public transport.

For example, the new extension to Singapore Changi Airport, a $1.2 billion glass dome covering 134,000 square meters and mixing natural surroundings with recreational opportunities and airport operations is a good example of how this works (Peters, 2016). Changi Airport in Singapore, which was named Best Airport at the World Airport Awards in 2014, has been one of the most prominent instances of how natural amenities may be integrated into airport facilities for the benefit of passengers up to this point in time. The Butterfly Garden, located in Terminal 3, is home to around a thousand tropical butterflies representing 40 distinct species, as well as lush flora and a six-meter waterfall. Among the many attractions at the airport are the Cactus Garden in Terminal 1, where passengers are encouraged to "stretch out and bask in the sun," the Sunflower Garden in Terminal 2, where passengers can view the runway while surrounded by 500 flowers, and the Orchid Garden, which contains more than 30 different species of orchid.

Chicago O'Hare Airport, which established the world's first airport aeroponic garden in the Rotunda building of Terminal 3, is another airport that is interested in growing herbs as a method to provide clients with green surroundings. As opposed to traditional gardening methods, this garden pumps a nutrient solution around its 26 towers and 1,100 planting locations, creating a self-sustaining process. Some of the produce cultivated here, such as purple basil, thyme, oregano, and green beans, is used in the restaurants, while travelers lounging in the lounge area can take in the view of the garden (Peters, 2016). A vertical GSky green wall in Terminal 3 has 440 plants within a 100 square foot space, increasing air quality. The airport also has 30,000 square meters of green roofs in twelve sites, as well as a 30,000 square meter green roof in one location.

The following fundamental principles of greenspace were identified into the literature (Trofimova, 2020):

- Greenspace containing recommended plants must become an integral part of public airport space in order to improve its microclimate;

TABLE 1 | Key elements of airports' environmental aspects.

Energy generation facilities/parks	✓ Solar park
	✓ Wind farm
	✓ Geothermal facilities
	✓ Biomass facilities
Waste management facilities	➢ Liquid
	➢ Solid
	➢ Hazards
Water management supply	○ Exploration
	○ Re-use/ Recycle
Green areas	❖ Public space parks
	❖ Pedestrian area
	❖ Cycling
	❖ Vehicles charging
	❖ Agriculture Park

- Comfortable visuals, i.e., harmonious and non-aggressive interiors combined with greening, help mitigate the stress associated with staying at the airport; greenspace must be tailored to space classifications and optimized spatially;
- Greenspace is subject to zoning, as there must be different zones for crew members, departing and arriving passengers;
- A single closed greenspace instance may have a number of modules that are designed to support a variety of diverse use cases.

As passenger traffic grows, so does the need to make airports greener, more environmentally friendly, and more enticing to travelers and passengers. The steady growth of destination airports is merging natural green spaces with leisure and entertainment facilities, demonstrating that a standard terminal building's offering of restaurants, shops, and WiFi is no longer sufficient. Passengers require more in order to be satisfied, and they are responding positively to environmentally responsible environments, green surroundings, and natural lighting (Greer et al., 2020). Based on the study's literature review, the key elements of airports' environmental aspects related to green renewable facilities are presented in **Table 1** below.

DEPICTION OF AIRPORTS' RENEWABLE GREEN FACILITIES

This section concerns the analysis of the development principle of landside facilities and activities by reviewing the European airport industry market. Main concern is to present the key facilities related to airports' shifting into green and environmentally friendly infrastructures, which are critical tools in the formation of international businesses and the expansion of regional business ecosystems for tourist areas that rely on a seasonal market for their revenue (Dimitriou, 2018; Dimitriou and Sartzetaki, 2020). The analysis presented in this research is based on a comprehensive landside facilities data gathering framework developed for the European Mediterranean tourist destination, where are high attracted tourist destination in summer holiday period. The key features of the seasonal airports in Mediterranean tourist destinations are given briefly in **Table 2** below.

TABLE 2 | Key features of the reviewed seasonal airports in Mediterranean tourist destinations.

State	Airport	Code ICAO	Code IATA
Greece	Athens International Airport	LGAV	ATH
Italy	Aeroporto G. Marconi di Bologna	LIPE	BLQ
	Falcone Borsellino Airport (Palermo)	LICJ	PMO
Spain	Palma de Mallorca Airport	LEPA	PMI
	Gran Canaria	GCLP	LPA
	Málaga Airport	LEMG	AGP
France	Nice Côte d'Azur Airport	LFMN	NCE
	Marseille Provence Airport	LFML	MRS
Portugal	Francisco Sá Carneiro Airport (Porto)	LPPR	OPO
Malta	Malta International Airport	LMML	MLA
Cyprus	Larnaca International Airport	LCLK	LCA

Mediterranean Tourist Airports Review

Airport renewable green facilities are critical elements of the air transport infrastructure sustainable transition, especially for them serving tourist destinations and located in areas heavily affected by climate change implications, such as the Southern Europe and the Mediterranean region. The results of the analysis about the renewable green facilities located at airports serving popular tourist destinations are given in the table below (**Table 3**).

In general, in terms of the development of renewable energy generation facilities, solar PVs is the most widely applicable option, while wind, geothermal and biomass facilities do not seem to be applied in the reviewed airports. In terms of waste management facilities, few airports apply a holistic waste management system that includes both hazardous and non-hazardous waste management. Moreover, many airports apply water reuse and/or recycle systems, which is critical for airports located in areas with high temperatures and water scarcity, while none of them seem to develop water exploration facilities. Finally, in terms of the development of green areas and sustainable mobility supporting infrastructures, many of the reviewed airports seem to invest in the development of green space as well as pedestrian areas, in order to improve passengers' comfort and satisfaction during their stay at the airport. Apart from this, they support sustainable mobility by providing charging areas for electric vehicles as well as areas for bicycle use. The analysis results presented in **Table 3** above are based on an extensive review of the selected tourist Mediterranean airports' annual and sustainability reports as well as published data. These results indicate the actions taken and targets disclosed by airports' operators regarding energy, water and waste management, and green areas development, as well as the development of landside facilities and activities related to these aspects. The results regarding each of the reviewed airports are analytically presented in the following paragraphs.

TABLE 3 | Key Elements of airports' renewable green facilities for popular tourist destinations in Mediterranean.

Activity	AIRPORTS' IATA CODE										
	ATH	BLQ	PMO	PMI	LPA	AGP	NCE	MRS	OPO	MLA	LCA
Energy generation facilities/parks											
Solar Park	X	X	X	X	X	X	X	X		X	
Wind farm											
Geothermal facilities											
Biomass facilities											
Waste management facilities											
Liquid				X		X				X	
Solid	X	X	X	X	X	X	X		X	X	X
Hazards	X	X		X						X	
Water management supply											
Exploration											
Re-use/recycle	X	X	X	X	X		X		X	X	X
Green areas											
Public space parks		X		X			X	X	X		X
Pedestrian area	X	X		X	X	X	X	X	X	X	X
Cycling	X				X	X	X	X	X	X	X
Vehicles charging	X	X		X		X	X	X	X	X	X
Agriculture Park								X			

More specifically, Athens International Airport is committed to achieve Net Zero Carbon Emissions by 2025, prior to the target of 2050. The airport already has an 8 MW solar project, which generates around 13 GWh per year to provide around a quarter of the complex's electricity needs and 13% of its energy requirement. Regarding water management, AIA systematically monitors water consumption (potable and irrigation), as well as the quality of surface and ground water, trying to decrease water consumption in its facilities (Athens International Airport (AIA)., 2020). Moreover, the airport applies separate management systems for hazardous and non-hazardous waste. Finally, vehicles charging stations are installed in the airport's short-term parking 2, being the first ever electric or plug-in hybrid vehicle charging area at a Greek airport.

Bologna Guglielmo Marconi Airport is not currently using renewable sources to produce electricity for its facilities. Regarding water management, Bologna Guglielmo Marconi Airport systematically monitors water consumption (potable and irrigation), as well as the quality of surface and ground water, trying to decrease water consumption in its facilities (Aeroporto Guglielmo Marconi di Bologna Group, 2020). Moreover, the airport applies separate management systems for hazardous and non-hazardous waste. Finally, a vehicle charging station, located on the ground floor of P1 car park in front of the Terminal, is solar-powered and allows passengers to charge their cars while they are parked at the airport.

Palermo Airport is not currently using renewable sources to produce electricity for its facilities. Regarding water management, Palermo Airport systematically monitors water consumption (potable and irrigation), as well as the quality of surface and ground water, trying to decrease water consumption in its facilities. Moreover, the airport applies a recycling system for waste generated in its facilities (GES.A.P. S.p.A., 2021). Palma de Mallorca airport has only a solar park located at its facilities, while regarding its waste management facilities, Palma de Mallorca airport owns liquid, solid and hazard waste management facilities. Moreover, at the airport territory there is an EV charging station, a pedestrian area, and a public space park (AENA, 2020).

Gran Canaria airport has only a solar park located at its facilities, while regarding its waste management facilities, Gran Canaria airport owns a solid waste management facility (AENA, 2020). Moreover, there is a re-use/recycle water management supply and regarding the airport's green areas, there are pedestrian and cycling designated areas. Malaga airport has only a solar park located at its facilities, while regarding its waste management facilities, Malaga airport owns a solid and a liquid waste management facility (AENA, 2020). Moreover, sewage is treated into two different treatment plants, while in the airport facilities two vehicle charging stations, one cycling and one pedestrian area are including.

Nice Côte d'Azur Airport is committed to achieve Net Zero Carbon Emissions by 2030, prior to the target of 2050. The airport already has solar plant, regarding water management, the airport has a solid waste management facility, while for their water management supply, a re-use/recycle system is used (Aéroports de la Côte d'Azur, 2020). Regarding the airport's green areas, there is a public space park, a pedestrian and cycling areas and vehicles charging station. Marseille Provence airport already has solar plant installed, while regarding the airport's green areas, there is a public space park, a pedestrian and cycling areas and several vehicles charging stations (Marseille Provence Airport, 2021).

Porto airport doesn't have any renewable energy generation facilities. However, in terms of their waste management facilities, the airport does have a solid waste management system and

a re-use/recycle water management supply system (Aeroportos de Portugal, 2020). Regarding the airport's green areas, there is a public space park, a pedestrian and cycling area. Malta Airport launched the largest solar farm in Malta, in July 2020. The solar farm includes 16,896 photovoltaic panels spread over 90,000 sqm. The energy it generates will be fed into the national power grid (Malta International Airport, 2020). It is expected to reduce CO_2 emissions by some 4,000 tons annually. Regarding water management, Malta airport systematically monitors water consumption (potable and irrigation), as well as the quality of surface and ground water, trying to decrease water consumption in its facilities. Moreover, the airport applies separate management systems for hazardous and non-hazardous waste.

Larnaca international airport doesn't have any renewable energy generation facilities. However, in terms of their waste management facilities, the airport does have a solid waste management system and a re-use/recycle water management supply system (Hermes Airports, 2021). Regarding the airport's green areas, there is a public space park, a pedestrian and cycling area, as well as a vehicle charging station.

DISCUSSION

Based on the above, the review in the selected tourist Mediterranean airports' annual and sustainability reports and published data indicates that, even though airport operators acknowledge the urgency of shifting to the production of energy from renewable sources, this effort has been made only in the direction of the installation of photovoltaic systems. As discussed in this study, there is a variety of renewable energy options for airports, with multiple benefits. Especially, as far as regional tourist airports in the Mediterranean are concerned, the installation of wind farms could take advantage from local characteristics and weather conditions, and in combination with solar energy to lead to their energy autonomy. In this framework, as solar photovoltaic (PV) systems appear to be the most broadly, and, in many cases, the only applicable alternative in terms of the development of renewable energy generation facilities in the reviewed airports, airport operators should take advantage of the comparative advantages of the area and seek the appropriate financial tools for the energy upgrade of the infrastructure and the utilization of a combination of alternative renewable energy sources in their facilities.

Moreover, as a holistic waste management system, which covers both hazardous and non-hazardous waste management, is only implemented in a few of the reviewed airports, emphasis should be given to the sorting of hazardous waste, in accordance with the current legislation of each region, promoting a holistic waste management plan and strengthening airport environmental strategy. It is noteworthy that, an effective waste management system, based on the minimization of the produced waste and recycling and reusing as many resources as possible, is fully compatible with the principles of the circular economy and could be quite profitable for the airport operator (Modibbo et al., 2022). In this framework, investments are also needed for water exploration projects, as they could enhance water availability, especially in regions suffering from water scarcity, such as areas in the Mediterranean. Water reuse, recycle and exploration projects could be beneficial for airports in various ways, not only by covering the needs of the airport in water but also by contributing to the elimination of water scarcity in the wider area, upgrading the quality of life of the residents and of the region's tourist product. Finally, the development of agriculture activities could boost airport revenue, as well as create potential partnerships with local producers, highlighting the production of local products.

Regarding the financial issues, while the vast majority of the investments will come from private players, EU and national public monies, such as the Recovery and Resilience Fund and InvestEU, will also play an essential role in facilitating the process. Despite the fact that these latter funds are non-sectoral and demand-driven, it is apparent that the transport sector, which has been one of the most badly affected by the pandemic, will be a major beneficiary of these funds in the long run. In the Recovery and Resilience Fund, which has a total budget of €672.5 billion in loans and grants and which will be implemented in accordance with national objectives, the greening of airports will be one of the sectors that will be eligible (Dimitriou, 2021; Finger et al., 2021). Also, it is noteworthy that the European Investment Bank's (EIB) recently enacted climate policy is expected to open up new financing opportunities for airport greening projects.

CONCLUDING REMARKS

Airports have sustainability challenges to contend with, such as energy consumption, waste, water management as well as people who are disabled or require other types of assistance. Airports must be able to adapt to changing conditions in the future. Extreme weather and climate-related phenomena are projected to become increasingly common as our climate continues to adapt. Extreme weather events are projected to become more frequent, intense, and widespread in terms of spatial area, length, and timing, increasing the likelihood of flight interruptions and cancellations. The majority of airports in Europe have pledged to achieving net zero carbon emissions by 2050, and many airports throughout the world are working toward this long-term objective as well, despite the enormous hurdles the sector is facing as a result of COVID-19 (Dimitriou and Karagkouni, 2022). Moreover, except from emissions reduction, the development of airport renewable green facilities and activities by reviewing the areas that impact the sustainable transition of international mobility and freight hubs, such as airports, is crucial for shifting them into green infrastructures.

In this framework, the analysis of this paper is based on the breakdown of the airports' key environmental aspects related to renewable green facilities. In general, in terms of the development of renewable energy generation facilities, solar PVs is the most widely applicable option, while wind, geothermal and biomass facilities do not seem to be applied in the reviewed airports. In terms of waste management facilities, few airports apply a holistic waste management system that

includes both hazardous and non-hazardous waste management. Moreover, many airports apply water reuse and/or recycle systems, which is critical for airports located in areas with high temperatures and water scarcity, while none of them seem to develop water exploration facilities. Finally, in terms of the development of green areas and sustainable mobility supporting infrastructures, many of the reviewed airports seem to invest in the development of green space as well as pedestrian areas, in order to improve passengers' comfort and satisfaction during their stay at the airport. Apart from this, they support sustainable mobility by providing charging areas for electric vehicles as well as areas for bicycle use. The novelty of this paper is the analysis of the development principle of airport renewable green facilities and activities by reviewing the areas that impact their sustainable transition, focusing on the development of their landside business activities. Airport renewable green facilities are critical components of the sustainable transition of the air transport infrastructure, particularly for airports serving tourist destinations and located in areas that are particularly vulnerable to the effects of climate change, such as Southern Europe and the Mediterranean region. The paper outputs provide key message to planners and decision makers about the development of renewable green activities in airports located in popular tourist destinations as enabler for shifting them into greener infrastructure.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

DD contributed to conception, design of the study, manuscript supervision and revision. AK wrote the first draft of the manuscript. DD and AK wrote sections of the manuscript. All authors read and approved the submitted version. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

The paper research outputs was supported by the research project ENIRISST+ – Intelligent Research Infrastructure for Shipping, Supply Chain, Transport and Logistics Plus which is implemented under the Action Reinforcement of the Research and Innovation Infrastructure, funded by the Operational Programme Competitiveness, Entrepreneurship and Innovation (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

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