

# AIRPORT ENVIRONMENTAL SUSTAINABILITY PRACTICES: ISTANBUL NEW AIRPORT CASE STUDY

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HILAL SAYKILI

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**AIRPORT ENVIRONMENTAL SUSTAINABILITY PRACTICES: ISTANBUL NEW AIRPORT CASE  
STUDY**

Author: HILAL SAYKILI

Supervisor: Professora Doutora Maria Emília da Silva Baltazar

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## ABSTRACT

Civil aviation has become one of the world's most important and innovative industries, bringing economic and social progress.

The civil aviation sector must maintain the optimal balance between economic progress, social development and environmental responsibility to meet the increasing demands in a “Sustainable” way.

Airport investments in the civil aviation sector are very expensive investments that do not have alternative uses for other purposes. For this reason, environmental sustainability approaches are needed in airports' planning, construction, and operation to use limited resources effectively.

Noise, air and water pollution, and natural resource consumption at an airport all adversely impact the environment. In addressing their environmental impact concerns, airports increasingly try to become “green” or more environmentally friendly. A "green airport" has a minimal impact on the environment and endeavours to become a carbon-neutral facility in terms of carbon emissions, aiming to produce zero greenhouse gas emissions.

In this study, the different sustainability strategies employed by airports are investigated to understand the carbon emissions caused by airline transportation, its impact on the environment, and the best practices for pro-longed sustainability.

Various applications are being developed and implemented at airports worldwide, thus trying to reduce carbon emissions. Airports are actively working to combat climate change with a net zero carbon target. Airports worldwide are parties to various regulatory bodies that apply environmental management and certification systems to their infrastructure and operations. In particular, airports' efforts to manage and reduce CO<sub>2</sub> emissions through Airport Carbon Accreditation are important in minimizing negative impacts on the environment and preventing pollution within the life cycle framework.

Turkish airports are also trying to implement an environmentally friendly policy and are trying to get the title of green organization by DGCA. In this regard, some initiatives have been taken by airline companies in Turkey to reduce carbon emissions.

Environmental sustainability studies at Istanbul Airport in Turkey are extremely comprehensive. At Istanbul Airport, work is carried out in line with the principle of sustainability at every stage, from design to construction and from the construction period to the operation process. Istanbul Airport fulfils the ISO 14064 Greenhouse Gas Calculation and Verification Management System Standard requirements and the Airport Carbon Accreditation program for measuring and reporting greenhouse gas emissions. The airport effectively identifies greenhouse gas emission sources, thanks to the greenhouse gas management system that works integrated with the ISO 50001 Energy Management System.

Istanbul Airport became the first airport in Turkey to receive Level 4 Transformation in Airport Carbon Accreditation.

Notably, Istanbul Airport has progressed from Level 1 to Level 4 within the scope of Airport Carbon Accreditation, recording a 21% reduction in Scope 1 and Scope 2 carbon emissions since 2019.

## **Keywords**

Airport, Environmental, Sustainability, Carbon Emission, Climate Change

## RESUMO

A aviação civil tornou-se uma das indústrias mais importantes e inovadoras do mundo, trazendo progresso económico e social.

O sector da aviação civil deve manter o equilíbrio ideal entre o progresso económico, o desenvolvimento social e a responsabilidade ambiental, a fim de responder às crescentes exigências de uma forma “sustentável”.

Os investimentos aeroportuários no setor da aviação civil são investimentos muito caros que não têm utilizações alternativas para outros fins. Por esta razão, no planeamento, construção e operação de aeroportos, a fim de utilizar da forma mais eficaz os recursos limitados; são necessárias abordagens de sustentabilidade ambiental.

O ruído, a poluição do ar e da água e o consumo de recursos naturais presentes num aeroporto têm um impacto adverso no ambiente. Ao abordar as suas preocupações com o impacto ambiental, os aeroportos estão cada vez mais a tentar tornar-se “verdes” ou mais amigos do ambiente. Um “aeroporto verde” é um aeroporto que tem um impacto mínimo no ambiente e que se esforça para se tornar uma instalação neutra em carbono em termos de emissões de carbono, com o objetivo de produzir zero emissões de gases com efeito de estufa.

Neste estudo, são investigadas as diferentes estratégias de sustentabilidade empregadas pelos aeroportos para compreender as emissões de carbono causadas pelos transportes aéreos, seu impacto no meio ambiente e as melhores práticas para a sustentabilidade prolongada.

Diversas aplicações estão sendo desenvolvidas e implementadas em aeroportos de todo o mundo, tentando assim reduzir a quantidade de emissões de carbono. Os aeroportos estão a trabalhar ativamente para combater as alterações climáticas com uma meta líquida de carbono zero. Os aeroportos em todo o mundo são partes de vários órgãos reguladores que aplicam sistemas de gestão e certificação ambiental às suas infraestruturas e operações. Em particular, os esforços dos aeroportos para gerir e reduzir as emissões de CO<sub>2</sub> através da acreditação de carbono aeroportuário são importantes em termos de minimizar os impactos negativos no ambiente e prevenir a poluição no âmbito do ciclo de vida.

Os aeroportos turcos também estão a tentar implementar uma política amiga do ambiente e a tentar obter o título de organização verde pela DGCA. A este respeito, algumas iniciativas foram tomadas pelas companhias aéreas na Turquia para reduzir a quantidade de emissões de carbono.

Os estudos de sustentabilidade ambiental no Aeroporto de Istambul, na Turquia, são extremamente abrangentes. No Aeroporto de Istambul, os trabalhos são realizados de acordo com o princípio da sustentabilidade em todas as fases, desde a concepção à construção, desde o período de construção até ao processo de operação. O Aeroporto de Istambul cumpre os requisitos da Norma ISO 14064 do Sistema de Gestão de Cálculo e Verificação de Gases de Efeito Estufa e do programa de acreditação de carbono aeroportuário para medir e relatar emissões de gases de efeito estufa. O aeroporto identifica eficazmente as fontes de emissão de gases de efeito estufa graças ao sistema de gestão de gases de efeito estufa que funciona integrado ao Sistema de Gestão de Energia ISO 50001.

O Aeroporto de Istambul tornou-se o primeiro aeroporto da Turquia a receber o Nível 4 de Transformação em Acreditação de Carbono Aeroportuário.

Vale ressaltar que o Aeroporto de Istambul progrediu do Nível 1 para o Nível 4 no âmbito da Acreditação de Carbono Aeroportuário, registrando uma redução de 21% nas emissões de carbono de Escopo 1 e Escopo 2 desde 2019.

## **PALAVRAS-CHAVE**

Aeroporto, Meio Ambiente, Sustentabilidade, Emissão de Carbono, Alterações Climáticas

**TABLE OF CONTENTS**

<b>ACKNOWLEDGEMENTS</b>	<b>V</b>
<b>ABSTRACT</b>	<b>VII</b>
<b>RESUMO</b>	<b>IX</b>
<b>LIST OF FIGURES</b>	<b>XIII</b>
<b>LIST OF TABLES</b>	<b>XIII</b>
<b>ABBREVIATIONS AND ACRONYMS</b>	<b>XV</b>
<b>1. INTRODUCTION</b>	<b>19</b>
1.1. GENERAL	20
1.2. SCOPE	21
1.3. MOTIVATION	21
1.4. OBJECT AND OBJECTIVES	22
1.5. METHODOLOGY	22
1.6. DISSERTATION WORK STRUCTURE	23
<b>2. LITERATURE REVIEW</b>	<b>25</b>
2.1. SUSTAINABILITY	25
2.1.1. <i>Sustainability at Airports</i>	29
2.1.2. <i>Responsibilities of the aviation sector</i>	32
2.1.2.1. Social sustainability	33
2.1.2.2. Economic sustainability	36
2.1.2.3. Operational sustainability	39
2.1.2.4. Environmental sustainability	40
2.1.3. <i>Environmental impact of airports</i>	43
2.1.3.1. Noise	44
2.1.3.2. Air pollution (emission)	48
2.1.3.3. Water Pollution	50
2.1.3.4. Environmental Waste	52
2.1.3.5. Wildlife Conservation	53
2.1.4. <i>Airport Environmental Management System</i>	54
<b>3. ENVIRONMENTAL SUSTAINABILITY PRACTICES IN THE WORLD</b>	<b>58</b>
3.1. APPLICATIONS RELATED TO NOISE	58
3.2. APPLICATIONS RELATED TO AIR POLLUTION	62
3.3. WASTEWATER RELATED APPLICATIONS	63
3.4. APPLICATIONS RELATED TO WASTE AND ENERGY MANAGEMENT	65
3.5. APPLICATIONS RELATED TO WILDLIFE PROTECTION	68

<b>4.</b>	<b>CARBON EMISSION REDUCTION PRACTICES</b>	<b>72</b>
4.1.	CARBON EMISSION REDUCTION PRACTICES IN THE WORLD	73
4.1.1.	<i>Emissions</i>	74
4.1.2.	<i>Greenhouse Gas Emissions from Aviation</i>	75
4.1.3.	<i>Regulations Regarding Carbon Emissions</i>	77
4.1.3.1.	European Union Emissions Trading System (EU ETS Regulations)	78
4.1.3.2.	Kyoto Protocol	81
4.1.3.3.	Carbon Offsetting and Reduction Scheme in International Aviation (CORSIA)	82
4.1.4.	<i>Benefits of Reducing Carbon Emissions at Airports</i>	84
4.1.4.1.	Renewable Energy Sources:	88
4.2.	EVALUATION OF CARBON EMISSION REDUCTION PRACTICES WITHIN THE SCOPE OF ENVIRONMENTAL SUSTAINABILITY AT ISTANBUL AIRPORT	95
4.2.1.	<i>Directorate General of Civil Aviation (DGCA)</i>	95
4.2.2.	<i>Green Airport Project</i>	95
4.2.3.	<i>Istanbul Airport</i>	96
4.2.4.	<i>Evaluation of Carbon Emission Reduction Practices at Istanbul Airport</i>	98
4.2.5.	<i>Use Of Resources</i>	104
4.2.5.1.	Water and Wastewater Management & Water Safety	104
4.2.5.2.	Energy efficiency	105
4.2.5.3.	Automation Systems	105
4.3.	EVALUATION OF ENVIRONMENTAL SUSTAINABILITY PRACTICES IN AIRPORTS AROUND THE WORLD WITHIN THE SCOPE OF CARBON EMISSIONS	107
<b>5.</b>	<b>CONCLUSIONS</b>	<b>112</b>
5.1.	FINAL CONSIDERATIONS	112
5.2.	LIMITATIONS	115
5.3.	FUTURE RESEARCH	115
	<b>REFERENCES</b>	<b>118</b>

**LIST OF FIGURES**

FIGURE 1 - SUSTAINABLE DEVELOPMENT WITH ECONOMIC, ENVIRONMENTAL, AND SOCIAL SECTORS \_\_\_\_\_ 26

FIGURE 2 - WASTE MANAGEMENT HIERARCHY \_\_\_\_\_ 53

FIGURE 3 - STRATEGIES USED IN SOLVING ENVIRONMENTAL PROBLEMS \_\_\_\_\_ 55

FIGURE 4 - THE PROGRESSION OF THE ICAO NOISE STANDARDS FOR AEROPLANES \_\_\_\_\_ 61

FIGURE 5 - WIND POWER PLANT INSTALLED AT LOGAN INTERNATIONAL AIRPORT \_\_\_\_\_ 90

FIGURE 6 - COCHIN INTERNATIONAL AIRPORT SOLAR POWER PLANT \_\_\_\_\_ 93

FIGURE 7 - SOLAR POWER PLANT INSTALLED ON THE ROOF OF THE SAN DIEGO AIRPORT PARKING LOT \_\_\_\_\_ 93

FIGURE 8 - ISTANBUL AIRPORT'S 2050 NET ZERO EMISSION COMMITMENT \_\_\_\_\_ 100

FIGURE 9- ISTANBUL AIRPORT'S RECYCLING TABLE FOR 2021 – 2022 \_\_\_\_\_ 104

**LIST OF TABLES**

TABLE 1 - WASTE TYPES AND THEIR EFFECTS ON THE ENVIRONMENT \_\_\_\_\_ 41

TABLE 2 - - AIRPORT ENVIRONMENTAL MANAGEMENT SYSTEM DUTIES AND RESPONSIBILITIES \_\_\_\_\_ 55



## **ABBREVIATIONS AND ACRONYMS**

**ISEC** – Instituto Superior de Ensino e Ciência

**AC** - Alternating Current

**ACI** - Airport Council International

**AEF** - Aviation Environment Federation

**APU** - Auxiliary Power Unit

**ASMA** - Arrival Sequencing and Metering Area

**A-SMGCS** - Advanced Surface Movement Guidance and Control System

**ATAG** – Air Transport Action Group

**ATC** - Air Traffic Control

**ATM** - Air Traffic Management

**BOT** - Build Operate Transfer

**CAA** - British Civil Aviation Authority

**CAEP** - Committee on Aviation Environmental Protection

**CDD** - Construction and Demolition Debris

**CEM** - Collaborative Environmental Management

**CHP** - Combined heat and power

**CO** - Carbon Monoxide

**CO<sub>2</sub>** - Carbon Dioxide

**CORSIA** - Carbon Offsetting and Reduction Scheme for International Aviation

**CWA** - Clean Water Act

**DALI** - Digital Addressable Lighting Interface

**DC** - Direct Current

**DGCA** - Directorate General Of Civil Aviation

## **HILAL SAYKILI**

**EEA** - European Environment Agency

**EU** - European Union

**EUA** - European Union Allowances

**EUAA** - European Union Aviation Allowances

**EU ETS** - European Union Emissions Trading System

**FAA** - Federal Aviation Administration

**GBRS** - Green Building Rating Standards

**GDS** - Global Distribution Systems

**GDSAA** - General Directorate of State Airports Authority.

**GHG** - Greenhouse Gases

**GMBM** - Global Market-Based Measure

**GSE** - Ground service equipment

**GWh** - Gigawatt hours

**H1 / H2** - Hypothesis

**HVAC** - Heating, Ventilating and Air Conditioning

**ICAO** - International Civil Aviation Organization

**IGA** - Istanbul Grand Airport

**IoT** - Internet of things

**LED** - Light-Emitting Diodes

**LEED** - Leadership in Energy and Environmental Design

**LET** - Lift, Escalator, and Travelator

**MRV** - Monitoring, reporting and verification

**MSW** - Municipal Solid Waste

**MTOM** - Maximum Takeoff Mass

**MTOW** - Maximum Take-Off Weight

**MWh** - Megawatt Hour

**NASA** - National Aeronautics and Space Administration

**NO<sub>x</sub>** - Nitrogen Oxides

**nvPM** - Non-volatile particulate matter

**O<sub>3</sub>** - Ozone

**RES** - Renewable energy sources

**RPK** - Revenue Passenger Kilometer

**SAF** - Sustainable Aviation Fuels

**SARPs** - Standards And Recommended Practices

**SCADA** - Supervisory Control and Data Acquisition

**SO<sub>x</sub>** - Sulfur Oxides

**THY** - Turkish Airlines

**TMDLs** - Total Maximum Daily Loads

**UN** - United Nations

**UNFCCC** - United Nations Framework Convention on Climate Change

**USGBC** - U.S. Green Building Council

**VOCs** - Volatile Organic Compounds



## **1. INTRODUCTION**

Human activities over the past century have greatly increased the amount of greenhouse gases in the atmosphere, causing the atmosphere to trap more heat, which causes various changes in its climate. Climate change affects people and the environment. In particular, it is predicted to increase exposure to flooding, heat stress, food insecurity, drought, and water-borne and vector-borne diseases.

The air transportation industry is one of the fastest-growing industries in the world, but in addition to its economic and social benefits, it negatively affects the environment. The aviation industry has long been mentioned as a sector that contributes to the causes of climate change through greenhouse gas emissions. The excessive growth that has emerged within the scope of efforts to expand the existing capacity and infrastructure at airports worldwide to meet the increasing air transportation demand brings some problems. As the demand for air transportation continues to increase, the impact of CO<sub>2</sub> emissions increases daily. The aviation industry is responsible for a small but growing proportion of greenhouse gas emissions. Aeroplanes are responsible for approximately three per cent of global carbon dioxide emissions. But nitrous oxide (NO<sub>x</sub>) emissions from water vapour and the formation of condensation trails at levels close to the stratosphere where commercial jets fly suggest that the real impact on global warming is much higher. The main environmental concerns regarding aeroplanes are climate change and stratospheric ozone depletion. During the flight, aircraft engines emit carbon dioxide, sulfur, nitrogen oxide, water vapour, hydrocarbons and various particles into the environment. These emissions change the atmosphere's chemical composition in various ways, both directly and indirectly. Similarly, emissions resulting from airport activities affect the atmosphere and cause climate change. In addition, delays caused by the density of airports, increased taxi times, and excessive noise and carbon gas emissions caused by the increased connection traffic in airports increase dissatisfaction among airport users and local people.

While air transportation contributes to global warming, it also faces many challenges due to global warming. Higher temperatures have an impact on the overall performance of the aircraft. Therefore, takeoff requires more thrust and runway length as air density and lift decrease as air temperature increases. Moreover, this is not a new problem, and

many airports worldwide schedule takeoffs for heavier aircraft during cooler times of the day to account for warmer temperatures, higher altitudes or shorter runways. However, as the impact of climate change increases, such situations will become more common and require changes to schedules or reduced loads. In the aviation sector, national and international authorities set important targets to reduce the environmental impacts of aviation, aiming to increase fuel efficiency and achieve carbon-neutral growth, and try to achieve these targets with sustainable practices. When the literature was examined, it was observed that there was information about the environmental impact of airports and the practices created and developed to prevent these impacts.

The subject of this study is to evaluate the applicability of carbon emission reduction strategies in Istanbul Airport in the context of environmental sustainability that emerged after the climate crisis.

This study examines sustainability in airports around the world. It aims to examine existing strategies and regulations by evaluating their practices in the context of carbon emissions and to determine to what extent they exist at Istanbul Airport. In the second part, the environmental impact of airports is explained by discussing sustainability and sustainability in airports. The third chapter discusses and explains environmental sustainability practices worldwide with examples. Finally, in the fourth chapter, carbon emission reduction practices at Istanbul Airport and airports in other countries are discussed, regulations regarding carbon emission are examined, and carbon emission practices, one of the biggest environmental problems in airports, are investigated.

### **1.1. GENERAL**

Airports are not just places where planes land and take off. They are also natural interfaces between ground modes of transport and air transport. An airport comprises various facilities, systems, users, workers, rules and regulations. In this context, considering the development and change of airports, good management of airports is an extremely important phenomenon. Accordingly, airports must have a professional management approach by keeping them under control through a systematic mechanism.

Airports are actively used, bringing vitality to the environment in economic and social terms. Despite all these benefits, airports are often seen as a source of noise and pollution and come face to face with society due to their negative effects on the environment. Considering airports' social and economic benefits, necessary precautions should be taken regarding the environmental impact, and sustainability studies should be carried out.

The place of airports in sustainability discussions is very important. Therefore, airports are the places where sustainability practices benefit the most. All of the practices that have been implemented today constitute the concept of airport sustainability. According to the ACI, airport sustainability is "a holistic approach to managing an airport to ensure its economic viability, operational efficiency, conservation of natural resources and integrity of its social responsibility.

### **1.2. SCOPE**

The concept of sustainability, which affects the whole world, undoubtedly affects the aviation industry deeply. Building sustainable airports is the key to airport planning and long-term success. Sustainability efforts help the airport improve its social life, maintain commercial activities, and minimise environmental impacts. A green airport project has been developed to reduce the negative environmental impacts of aviation activities. This study will research the concept of sustainability in air transport, the environmental effects of airports and airport sustainability practices. It will also focus on carbon emission strategies within the scope of environmental sustainability practices at Istanbul Airport and airports worldwide.

### **1.3. MOTIVATION**

Civil aviation has become one of the world's most important and innovative industries, bringing economic and social progress.

The civil aviation sector must maintain the optimal balance between economic progress, social development, and environmental responsibility to meet the increasing demands in a "Sustainable" way.

Airport investments in the civil aviation sector are very expensive investments that do not have alternative uses for other purposes. For this reason, environmental

sustainability approaches are needed to use limited resources effectively in airport planning, construction, and operation.

#### **1.4. OBJECT AND OBJECTIVES**

The object of research is the airport infrastructure's sustainable practices in general and the New Istanbul Airport in particular. The general objective of this research will be to study New Istanbul Airport's sustainability practices and whether they meet the necessary criteria for sustainability. The specific objectives are:

- Understand the existing solution to certify an airport to sustainable practices.
- What are the key indicators to measure the sustainable practices in an airport?
- How New Istanbul Airport can become a greener airport and
- How to increase environmental sustainability practices in Istanbul Airport.

#### **1.5. METHODOLOGY**

The rapid increase in the world population brings the question of “Are our resources sufficient?” to mind. When the current availability of resources is evaluated together with the increase rate of human beings and the destruction of nature, it is a general opinion that they are limited and should be used efficiently. For this reason, while the importance of environmental sustainability, one of the sub-dimensions of sustainability, is increasing daily, the aviation industry also takes precautions. The following Research Question is formulated:

Does the Istanbul New Airport meet the Environmental Sustainability Practices?

In this context, the hypotheses created for the Istanbul new airport within the scope of this study are:

H1: Istanbul New Airport applies the best practices for the Environmental Sustainability

H2: Istanbul New Airport is a Green Airport

In this research, a source research-based analysis method, which includes qualitative research features, is used. The basic method used in the research is primarily scanning and examining the sources. Information resources include publications and documents related to our research, such as books, journals, theses, conference documents, airport

sustainability reports, and reports published by international organisations. The Internet was used to access the information by specifying the access date. In the literature search, the problematic of this thesis, its hypotheses, and the questions to be answered were taken as the basis.

In addressing their environmental impact concerns, airports increasingly try to become “green” or more environmentally friendly. A "green airport" has a minimal impact on the environment and endeavours to become a carbon-neutral facility in terms of carbon emissions, aiming to produce zero greenhouse gas emissions.

Airports' carbon footprint is one of the crucial issues in terms of global warming. Airport Council International (ACI) owns the “Airport Carbon Accreditation” program. This program enables airports to implement carbon management processes. It consists of different scheme levels. The entry point to the scheme recognizes that an airport is quantifying its carbon footprint. The overall aim of the scheme is to manage carbon emissions by managing energy during the airport operation.

2019 is the basis for Istanbul Airport's 2050 Net Zero Emission commitment. For this reason, the applications implemented from 2019 to the present are discussed.

#### **1.6. DISSERTATION WORK STRUCTURE**

This dissertation is organized into five main chapters. The themes and organization of these chapters can be summarized as follows:

Chapter 1 describes the context of the project, explaining the scope and focus of the research work and presenting the problem addressed by the project, the objectives to be achieved, and the approach adopted to solve the problem, followed by the description of the organization and structure of the thesis.

Chapter 2 presents a systematic review of the published works on studies of the concept of sustainability in airline transportation, the aviation industry's responsibilities and the airports' environmental impact.

Chapter 3 presents the methodology for analysing the problem under study and the case study.

Chapter 4 presents an analysis and discussion of the results obtained in the case study.

Chapter 5 the study conclusions, limitations and future investigation proposals

## 2. LITERATURE REVIEW

### 2.1. SUSTAINABILITY

Environmental awareness and green management have become necessary today because of various mistakes made over time. The increase in population brought along a rapid increase in cultivated land over time, factories were built with the industrial revolution, machines were developed, and new inventions were realized. All of these have increased production, productivity and profitability while bringing with them air pollution, water pollution, increased resource consumption and waste that harms the environment. (Karakus, Polat, and Karsigil 2018)

In recent decades, global concern has emerged about the non-renewability of natural resources as a factor limiting production and the threat to long-term economic growth caused by environmental destabilization and pollution. (Basiago 1999)

In 1987, the United Nations World Commission on Environment and Development defined sustainability in its report titled "Our Common Future" for the first time as "the principle of not compromising the ability of future generations to meet their own needs while meeting the needs of the present"(Nations 1987)

While this concept has been used, expanded and developed over the years, it has continued to preserve its most basic meaning. Therefore, the strategic issue, corporate environmentalism or green management, emerged in the 1990s and became a popular slogan internationally in the 2000s. (K. Lee 2009)

In another definition, "sustainability" refers to the long-term ability to continue to engage in a particular activity, process, or use of natural resources. (Melinda Harm Benson and Craig 2014)

The three commonly agreed models for representing the interrelationship between environmental, social, and economic aspects of sustainability are the Venn diagram, which consists of three concentric circles, and the planning hexagon. In all of these models, the different pillars of sustainability are conceived as separate but connected independently. (Rasouli and Kumarasuriyar 2016)

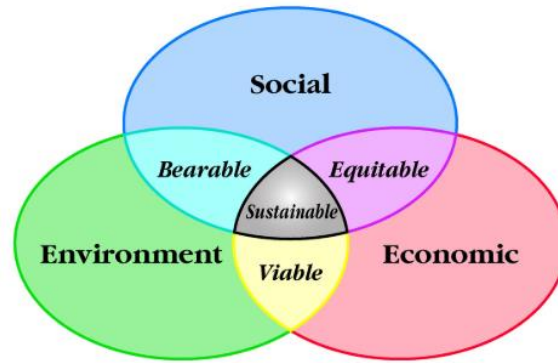


Figure 1 - Sustainable development with economic, environmental, and social sectors  
Source: (Purevjav 2011)

Both industry leaders and academics recognize that sustainability is important to the long-term success of both firms and the communities in which they operate.

Firms today need systemic approaches to sustainability to be competitive over the long term. Without a diligent effort to create an organizational infrastructure that supports the development of a sustainability strategy, the firm's efforts to successfully implement a sustainability strategy will be severely hindered. (Galpin 2015)

There are many reasons why the concept of sustainability is so prominent today (Torum and Yılmaz 2009)

- First, the fact that companies have become very large organizations in an international structure has also imposed social and environmental responsibilities on them. Thus, this shows that companies have a role in areas that were only associated with governments in the past,
- Today's integrated ways of doing business (supply chain) push companies to act responsibly in the entire supply chain process,
- The development of communication technologies has caused a negative development in any country related to a company to interact worldwide quickly. In this direction, companies have come to act responsibly in all geographies in which they operate.
- Investors look at companies' financial, social and environmental performances when making investment decisions. Awareness has emerged that companies working in this direction in the medium and long term will also create value for their partners,

- Customers and consumers now expect companies to be responsible for the products and services they produce. Consumer awareness is perhaps the most important reason companies act in this field today.
- Today, all stakeholders expect transparency and corporate governance from companies. All segments of society expect companies to be transparent and accountable. This transparency includes the effects of the products and services produced on society and the environment rather than the disclosure of simple financial statements,
- Environmental disasters such as global climate change also force the business world to be sensitive to these issues.

Another core part of the concept of sustainability that distinguishes it from other ways of viewing the environment, economy or society is its focus on intergenerational equity.

A final aspect shared by all definitions of sustainability, as opposed to traditional ways of looking at the environment, economy or society, is that they emphasize working beyond mere compliance with existing laws and regulations. (Vos 2007)

The word sustainability has come to be expressed in many forms in various contexts. Common phrases are: 'sustainable development', 'sustainable society', 'sustainable community', 'ecological sustainability', 'sustainable growth' and 'strategic sustainability'. (Yavuz 2022)

The concept of sustainability dates back to early UN conferences in the 1970s and has become increasingly difficult to disentangle from sustainable development. However, the two concepts are not necessarily the same. In general, “sustainability” refers to the long-term ability to continue to engage in a particular activity, process, or use of natural resources. (Melinda Harm Benson and Craig 2014)

In contrast, “sustainable development” reflects a broader societal goal of how economic and social development should proceed—namely, with sufficient consideration of the environment and natural resources to ensure the continuing availability of natural capital and other ecological amenities. The international community embraced sustainable development at the 1992 UN Conference on Environment and Development

in Rio de Janeiro, incorporating it into the Rio Declaration and Agenda 21. (Melinda Harm Benson and Craig 2014)

Sustainable development may be conceptualised as juxtaposing two schools of thought: development theory and environmental sustainability. (Sharpley 2000)

Although the history of sustainable development goes back to earlier times than today, it has recently come to the fore with the increasing environmental concerns. Sustainable development is not just an environmental concept. In addition to the environmental dimension, the social, economic and energy dimension complements sustainable development. (V. Yilmaz 2018)

The aviation industry, one of the indicators of development on a global scale, is one of the sectors that most affect the environment from the environmental perspective, bringing critical challenges in sustainability, environmental protection and climate change mitigation. The remarkable growth of the air transport sector in recent years has led to increasingly congested airports and airspace. (Yavuz 2022)

This increasing pressure on the aviation network is causing many airports and airfields to reach maximum capacity shortly, creating many challenges. First, a significant amount of land is required to build runways, terminals, parking lots, service areas and transportation networks. Airports are typically located on the outskirts of cities close to the countryside and, as more and more capacity is required to meet aviation demand, more. As excess land is used, direct loss of important habitats and possible reductions in biodiversity inevitably occur. Therefore, the aviation network requires operational policies and managerial directives to increase efficiency, new technologies to increase existing capacity, and infrastructure investments in the form of new airports or capacity expansion plans to cope with air traffic trends. However, uncontrolled growth can create additional clogging problems. Effective Air Traffic Management (ATM) is required to prevent airspace congestion. Poor management of these airspaces leads to additional noise and greenhouse gas emissions, which is already a sensitive issue in many countries. Delays caused by congestion can prevent passengers from accessing their flights whenever and wherever they want, hinder the main function of airports in the network, and disrupt airline transportation. In response to these negativities, planning,

developing, conducting and evaluating sustainability studies in the aviation industry is important. (Yavuz 2022)

### **2.1.1. SUSTAINABILITY AT AIRPORTS**

Airports are not just places where planes land and take off but also natural interfaces between ground and air transport modes. An airport comprises various facilities, systems, users, workers, rules and regulations. In this context, considering the development and change of airports, good management of airports is an extremely important phenomenon. Accordingly, airports must have a professional management approach by keeping them under control through a systematic mechanism. There are different applications in airport operations. Accordingly, airports are managed entirely by the state, by the joint action of the state and private sector, or by the absolute dominance of the private sector. These options may differ according to the budgets and financial strategies of the countries. (Yavuz 2022)

The place of airports in sustainability discussions is very important. Therefore, airports are the places where sustainability practices benefit the most. All the practices that have been implemented today constitute the concept of airport sustainability. According to the ACI, airport sustainability is "a holistic approach to managing an airport to ensure the airport's economic viability, operational efficiency, conservation of natural resources and integrity of its social responsibility". (Rodoplu and Gürsel 2022)

Sustainability in the aviation industry can be achieved by developing systems that can honour the environment, foster economic worth, and enhance the quality of life for society. The three significant aspects of aviation sustainability include a) environmental sustainability, consisting of the natural resource-system dependence; b) economic sustainability, which elaborates the economic capability, economic improvement, and financial manageability; c) social suitability, which explains the social righteousness, security, individual health, and superiority of life. (Kutty and Elhmod 2021)

Various applications can be found when sustainability is evaluated regarding air transportation. To examine these applications more easily, the sector, airline operators, airports and other stakeholders. Airports are important facilities where all stakeholders

related to sustainability come together. Therefore, airports' sustainability practices are important. (Yavuz 2022)

The sustainability practice at airports is very comprehensive due to the number of components and the variety of activities carried out, and it includes many types of initiatives. The main environmental impacts from airport operations and assets are based on discharges to water, air, and soil, as well as fuel and electricity consumption. Global practices carried out in the name of sustainability especially focus on the environmental pollution created by airports. While the airport industry has long focused on improving noise, air, and light pollution for regulatory and health reasons, there is an increasing focus on greenhouse gas management and climate change. ACI aims to reduce the net carbon emission at airports to zero by 2050. The Airport Carbon Accreditation Program was established for this purpose. Even today's technologies are more accessible and cheaper, and more environmentally friendly technologies are increasingly involved in new investments. In this context, some environmentally friendly applications and Technologies used in airport investments are as follows (Rodoplu and Gürsel 2022)

Ground support equipment and vehicles are electrically powered and have smart technologies. Energy is produced with wind and solar technologies that reduce energy costs. It is seen that new technology aircraft provide fuel savings compared to old technology aircraft. Technologies that provide energy efficiency and encourage savings are used in airport buildings. As new smart building technologies are produced to be more environmentally friendly, energy efficiency has also been achieved in offices and additional buildings at airports, and energy efficiency performance can be measured in real-time. Technologies that provide energy efficiency are also used in baggage handling and airport lighting systems. Systems that generate energy from waste started being used, and projects to reduce waste were also implemented. Classifying these exemplary sustainability practices at airports is possible under various headings. It is possible to classify the components within the scope of sustainability practice at airports as follows (Rodoplu and Gürsel 2022):

- Efficient and effective use of natural resources and protection of the environment

- Addressing the needs and expectations of all stakeholders as a social process
- Monitoring and evaluation of economic performance data

In this classification, which is the general classification of the concept of sustainability, it is seen that social, economic, and environmental sustainability subtitles are used. International and/or national regulations should also be collected under these three main headings. In this context, for sustainability applications, obligations, incentives, priorities, and obstacles should be determined under these three main headings., because sustainability practices may conflict with the resource allocation priorities of stakeholders at airports, and the importance that organizations attach to these three main topics differs. (Rodoplu and Gürsel 2022)

Air transport, which has shown rapid development parallel to economic growth, is expected to increase importantly in the coming years. As a result of this situation, airport expansion and development projects will inevitably become more important. Like any other industry, the airport industry is facing the effects of increasing environmental pressure. Environmental concerns vary depending on aviation views and other political and social attitudes. Increasing prosperity in many countries has led to greater expectations for quality of life and greater sensitivity to the environmental impact of airports. (Yavuz 2022)

Community concern about the airport's environmental impacts puts pressure on the completion of environmental projects. Airport operations include a range of activities that affect the environment. The environmental impacts of these activities can intensify if an airport expands. Sometimes, the airport authority must agree to implement certain environmental mitigation projects before a state or local agency allows airport expansion. Community concern about environmental impacts has begun to cause projects to be postponed or cancelled. (Luther 2007)

While the benefits of an airport's growth and development can be seen over a wide geographic area, local community opposition can limit growth and complicate efforts to obtain planning approval for further development. In addition to opposition from the disturbance caused by aircraft noise, congestion on local roads and incidents, local air

quality (particularly the smell of aviation fuel) and fear of air crashes are among the other major complaints raised against airports. (Yavuz 2022)

Airports play a vital role in the global air transport value chain, acting as the critical interface point between the surface-based and air transport modes. Waste management is now considered a critical environmental issue confronting airports. The value chain of air transport stakeholders, airlines, airports, ground handling agents, air traffic control (ATC), aircraft maintenance organizations and flight catering companies need reliable, safe and cost-effective energy. In addition, the production of CO<sub>2</sub> gases from energy use at airports and their potential impact on local communities and the environment is of utmost importance. In recent years, the global air transport industry has launched new sustainability practices in response to society's need to live in a healthier and more sustainable environment. (Baxter, Srisaeng, and Wild 2018)

Creating and developing sustainable airports is the future of airport planning. Sustainability studies are the studies carried out to improve the social life of the airport while continuing its commercial activities and minimising the environmental impacts. As a result, airports are focusing on performing more environmentally friendly activities while reducing their carbon footprint. The location of the airport, its status and available opportunities also play an important role in this situation. Therefore, environmentally friendly strategies, policies and environmental management plans are being adopted and implemented more and more by airports worldwide. (Baxter, Srisaeng, and Wild 2018)

### **2.1.2. RESPONSIBILITIES OF THE AVIATION SECTOR**

Today, sustainability is about to become one of the most important issues for the aviation industry. The industry pioneers advanced technologies. Therefore, it is closely followed by environmentalists and green organizations. All businesses serving at airports, one of the main components of the sector, are also under the influence of external influences and/or internal dynamics.

Sustainable growth should be considered a natural part of their business and a corporate responsibility for the owners, shareholders, managers, and all employees of the

institutions and organizations at the airports. These responsibilities can be listed as follows (Torum and Yılmaz 2009):

- Respecting the right of individuals to live in a healthy and good environment,
- To use and protect environmental and natural resources responsibly,
- To carry out the necessary studies for the protection and continuity of natural resources and biological diversity on earth,
- Developing standards to protect the environment, complying with these standards and legal regulations,
- To Publish and share information about resource use and environmental quality with the public.

#### **2.1.2.1. SOCIAL SUSTAINABILITY**

Sustainability includes environmental, economic, and social aspects. Specifically, social sustainability is a quality of society that fosters resilient conditions for particularly vulnerable individuals, groups, and human well-being. Social sustainability creates physical, cultural, and social spaces supporting social sensitivity and welfare. Social sustainability occurs when the social systems, processes, structures and relationships in a locality actively support the capacity of current and future generations to create liveable communities. That is, a socially sustainable community can maintain, tap into and build on its resources (physical, intellectual and social) to respond to current issues and prevent future problems. This resiliency is a core outcome of social infrastructure. (Robyn L. Keast, Douglas C. Baker, and Kerry Brown n.d.)

While the concept of social sustainability aims to ensure that today's living conditions are not better than the living conditions of future generations, management systems should be carried out proactively for this formation. Social sustainability as a system should include health, education, distributional equality, gender equality, political accountability, and participation, described as social services. (Rodoplu and Turan Erdoğan 2022)

Most current definitions of social sustainability, as opposed to general, are often determined by specific criteria or working perspectives. Some definitions are based on

equality and democracy, while others are based on fundamental predictions of values and democracy. Some studies emphasised social equality and justice by referring to needs, inclusion criteria and opportunities. Within the three-pillar sustainability discourse that has emerged over the past 25 years, social sustainability has been the least examined pillar. However, over the past 10 years, there has been a growing adoption of social sustainability as an independent concept, particularly by city governments in the Anglo context. (Davidson 2010)

Social sustainability can be guaranteed if the tasks within the public and the relevant forms of institutional action meet a large part of human needs and are shaped according to need. Social/economic criteria include community development, local employment and fair trade, support of local entrepreneurs, respect for local communities, policies against exploitation, particularly of children and adolescents, and equitable hiring and employee protection. (Alameeri et al. 2018)

The social dimension of sustainable development emphasizes meeting the basic needs of the members living in the society. A socially sustainable society must have the flexibility to conserve and develop its resources and to prevent and/or solve problems in the future. (Bilgili 2017)

In another definition, social sustainability is defined as: "Promoting an environment compatible with the evolution of civil society, conducive to the harmonious coexistence of culturally and socially diverse groups; it is also defined as 'development that promotes social cohesion with improvements in the quality of life for all segments of the population. A society with effective social sustainability should be able to protect and develop its resources. In addition, it should have the necessary flexibility to prevent and/or solve problems that may be encountered in the future. (Yavuz 2022)

Historically, long lists of indicators were established to describe the complexity of sustainable development, with a special focus on its environmental dimension. The importance of social sustainability was understood later. (Colantonio 2009)

Social sustainability is the name of maintaining healthy societies' positive social relations. It is the process of increasing a person's quality of life. (Öztürk 2019)

Social sustainability is one of the prerequisites for sustainable development. This condition's fulfilment requires equal consumption and distribution of resources and assets, harmonious social relations and an acceptable quality of life. The benefit of current and future generations from health, transportation, accommodation, recreation and education services is an example of social sustainability conditions. Social sustainability is a life-enhancing condition within communities and a process within communities that can achieve that condition. (McKenzie 2004)

A socially sustainable system must achieve distributional equity and adequate provision of social services, including health and education, gender equity, and political accountability and participation. (Harris 2000)

Ensuring sustainability in the context of equality, justice, social capital, and other topics, adopting environmentally friendly practices for individuals, and creating positive behaviours towards the environment, preserving sustainability when there are socio-cultural changes in society can be seen as three main tasks determined for social sustainability. (Vallance, Perkins, and Dixon 2011)

As the aviation industry grows, this growth must be environmentally and socially sustainable. Ensuring customer satisfaction and safety in the aviation industry; Aiming at the highest level in comfort, safety, health conditions and services; making a significant breakthrough with wider aircraft options in customer preferences and tariff flexibility; and good interaction are related to social sustainability principles. It is argued that socially sustainable communities operate according to principles such as equality, diversity, quality of life, connectivity, and democracy. The principles of connectivity and democracy are particularly important in the airport city concept, given the role airports play in connecting the local and global worlds. In the context of social infrastructure, connectivity is about the ability of local citizens to enjoy the additional benefits inherent in modern infrastructures, such as high-speed internet capacities, and designing the physical infrastructure to encourage interaction between citizens. It is extremely important how the space and the location of the facilities should be designed for better access and use of public facilities. Ideally, such facilities should be designed to serve a dual purpose and encourage the active participation of local and other citizens in terms of access and wider use patterns. Only in this way can some facilities, such as parks and

open meeting places, serve as airport and local community resources. Dual use expands the infrastructure purpose and the range of groups using the facilities while helping to integrate local people further into airport infrastructure development and planning processes. Moreover, it provides enhanced interaction between the local and airport communities. (Robyn L. Keast, Douglas C. Baker, and Kerry Brown n.d.)

#### **2.1.2.2. ECONOMIC SUSTAINABILITY**

Economic sustainability can be defined as the ability to maintain profitability for efficiency and effectiveness in the long-term use of business assets. Although profit optimization seems to be the goal of businesses, economic, social, and environmental sustainability should be considered together in businesses' future decisions. Economic sustainability as a system: To be protected from sectoral imbalances, it is to continue the continuous production of goods and services, which can protect against external debt and do not harm industrial or agricultural production, as well as the continuous production of goods and services. Sustainable strategies that combine environmental and economic sustainability strengthen the institution's competitiveness in its image and financial indicators. (Rodoplu and Turan Erdoğan 2022)

According to neo-classical economic theory, economic sustainability provides basic human needs (health, food, clothing, shelter, transportation, education services, etc.). (Harris 2000)

The characteristics of sustainable economies include regulating the relations between humans and nature, ensuring that present and future generations benefit from resources fairly, not being wasteful in natural resources and human-produced services and products, and prioritizing economic efficiency. (Baumgärtner and ; Quaas 2010)

In addition, the continuity in products and services, the manageable level of borrowing, and the presentation of agricultural and industrial products to society in an amount to meet the needs are important topics for economic sustainability. In addition, economic sustainability is expressed with weak and strong sustainability perspectives. (Öztürk 2019)

The substitution of natural resources with another capital is called weak sustainability. In strong sustainability, no natural resource can substitute any other capital, but

renewable and non-renewable resources can be used interchangeably, provided the total natural capital is preserved. As the welfare level in society increases, the efforts of the economies to move from weak sustainability to strong sustainability show that the increase in welfare is significant in ensuring sustainable development. (Öztürk 2019)

An economically sustainable business is future-oriented and concerned with ensuring that future sourcing options are not constrained by decisions made now. Therefore, this implies concepts such as producing and using renewable resources, minimizing pollution, and using new production and distribution techniques. It also means that any cost involved in the present is considered an investment in the future. (Crowther and Aras 2008)

In businesses where the traditional management approach based on growth and profit maximization dominates, activities mainly focus on economic issues such as increasing shareholder value or reducing costs. In such businesses, meeting the profit expectations of the shareholders, avoiding liquidity problems and fulfilling the continuity principle of accounting will be sufficient for economic sustainability. (Tüm 2014)

Economic sustainability is related to the enterprise's financial, tangible and intangible capital and emphasizes that these types of capital should be managed effectively. In other words, economic sustainability requires an optimal balance between various types of capital, such as financial capital, such as equity debt; tangible capital, such as land, machinery, and stocks; and intangible capital, such as corporate reputation and know-how. In this respect, to ensure the economic sustainability of the enterprises, they must always provide above-average earnings for their shareholders. On the other hand, they must always ensure cash flow so there is no liquidity shortage. (Tüm 2014)

Economic sustainability is the effective use of business assets to maintain and increase the business's profitability in the long run. Although the ultimate goal of businesses is to make a profit, economic sustainability should be considered in an integrated manner with environmental and social sustainability in business decisions. (Ertan 2018)

The enterprise's good financial and economic performance indicates that it can continue its activities in the short term. Still, it does not guarantee the existence of the enterprise

in the long term. It is necessary to consider the environmental and social factors in which the business operates to make long-term forecasts,. (Ertan 2018)

To make long-term forecasts, or in other words, for long-term sustainability, all three dimensions must be fulfilled simultaneously. Social, economic, and environmental constraints are not just analytical concepts but represent the driving forces a firm can use to align its business model with its business strategy. Although expensive, long-term adjustments to meet these constraints can be differentiators that increase firm competitiveness in the medium and long term. (Yavuz 2022)

Financial resources and human capital are very important in ensuring the economic sustainability of a business. Sustainability indicators highlight asset stocks or, more specifically, how a portfolio of assets has been managed over time. Changes in this portfolio include investments in traditionally generated asset forms (infrastructure, buildings and machinery) and human capital (through education and training expenditures and primary health care). (Yavuz 2022)

Economic sustainability, which means the protection of capital, in other words, its use without consumption, is related to the cost-benefit analysis of the enterprise that aims to be profitable while producing products and services that contribute to society. Economic sustainability, which expresses economic efficiency, economic development and financial affordability, has purposes such as giving up today's lifestyle that threatens the quality of life and ensuring energy efficiency in production and consumption processes. Businesses that see maximizing their profits as increasing their economic performance and providing the highest return to their shareholders as their main objective have focused on economic sustainability studies. Sustainability studies have become important in all sectors and affect airports worldwide. Due to its operations' significant environmental and socio-economic impacts, the aviation industry is increasingly managed within a sustainable development guidelines framework. (Yavuz 2022)

The aviation industry has shown a steady and steady increase in air traffic at the global level, especially in emerging economies, linked to demographic and economic development. The rapid increase in the sector in this way has increased costs. This situation has made the concept of sustainability in aviation important. Rapid growth

impacts airport stakeholders incredibly with its economic, social and environmental dimensions. Rapid growth affects negatively by increasing energy and fuel consumption, releasing greenhouse gases that cause climate change, creating significant solid and water waste, and increasing air and noise pollution. Airport infrastructure, which cannot be developed simultaneously due to its growth rate, causes flight delays, incorrect baggage delivery, poor service quality and customer dissatisfaction. All these problems disrupt economic sustainability in aviation. Constructing extra airport units, such as terminals and runways, will reduce the negative effects and prevent these problems. On the other hand, social and economic life could be supported with positive contributions such as creating job opportunities, providing fast and safe transportation, increasing incomes and supporting tourism. (Koç and Durmaz 2015)

### **2.1.2.3. OPERATIONAL SUSTAINABILITY**

Operational sustainability capability is the ability of the firm's operations management system to use a collection of interrelated sustainable operational routines to solve operational problems by reducing the impact on the natural environment. Operational sustainability is an operational capability that facilitates the execution of the operational strategy to improve firm performance. Operational sustainability can increase firm performance. Operational sustainability is an example of operational capacity that can improve firm performance by executing sustainable operational routines to earn more money and reduce firms' impact on the natural environment. Operational sustainability improves firm performance by reducing costs and increasing revenues. Sustainable operational routines foster product and process innovation, leading to higher firm performance. Thanks to operational sustainability, the company can improve product quality and develop its brand image, increasing its sales and revenues. Finally, firms with sustainable operations enjoy a better reputation, greater legitimacy and regulatory recognition, which allows them to gain approval for more capital projects and access more markets to increase their revenues. (Benitez-amado, Llorens-Montes, and Fernandez-Perez 2013)

Airport operational sustainability can be defined as “the ability to operate an airport most effectively and efficiently to safely transport people and cargo while providing enhanced levels of service and functionality without increasing environmental impacts

or compromising the needs and values of the local community". Airport operational sustainability is operating and maintaining facilities' infrastructure efficiently and sustainably, developing and encouraging employees, and increasing economic position and competitive advantages. Operational sustainability helps support the airport's long-term growth and resilience while providing a safe environment for airport users and nearby communities. (Yavuz 2022)

#### **2.1.2.4. ENVIRONMENTAL SUSTAINABILITY**

The rapid increase in the world population brings the question of "Are our resources sufficient?" to mind. When the current availability of resources is evaluated together with the increase rate of human beings and the destruction of nature, it is a general opinion that they are limited and should be used efficiently. For this reason, while the importance of environmental sustainability, one of the sub-dimensions of sustainability is increasing daily, its responsibility falls on businesses and individuals, especially governments. (Rodoplu and Turan Erdoğan 2022)

In general terms, the long-term sustainability of the factors and practices contributing to environmental quality can be called environmental sustainability. According to this definition, waste generation rates from activities should not exceed the absorptive capacity of the environment. Thanks to environmental sustainability, ecological integrity is preserved. In contrast, all the world's environmental systems are kept in balance, and the natural resources in them are consumed by people at a rate that they can renew themselves. (Yavuz 2022)

The basic perspective of operational management bases the performance of businesses on four basic areas: Cost, quality, speed, and service. However, taking environmental protection measures to ensure sustainable development necessitates rediscovering operational activities. (Karakus, Polat, and Karsigil 2018)

In this context, it is very important to understand sustainability and its sub-dimensions correctly. The environmental dimension of sustainability concerns an organization's impacts on living and non-living natural systems, including ecosystems, land, air, and water. Environmental Indicators cover performance related to inputs (e.g., material, energy, water) and outputs (e.g., emissions, effluents, waste). In addition, they cover

performance related to biodiversity, environmental compliance, and other relevant information, such as environmental expenditure and the impacts of products and services. (Guidelines 2011)

Environmental outputs or wastes are the release of substances into the air, water or soil that may harm human health or the environment, resulting from the unnecessary use of resources.

Only the limit with energy should not be considered to monitor environmental waste. Environmental assessments should also be made, including material and water consumption, solid waste generation, scrap emissions, wastewater discharges and hazardous waste generation. (“Lean and Environment Training Modules” 2006)

Waste types and their effects on the environment are shown in Table 1.

**Table 1 - Waste types and their effects on the environment**  
 Source:(“Lean and Environment Training Modules” 2006): 19-20 (Date of access: 22.08.2023)

Waste Type	Environmental Impacts
<b>Overproduction</b>	<ul style="list-style-type: none"> <li>• More raw materials are consumed in making the unneeded products.</li> <li>• Extra products may spoil or become obsolete, requiring disposal.</li> <li>• Extra hazardous materials use extra results in emissions, waste disposal, worker exposure, etc.</li> </ul>
<b>Inventory</b>	<ul style="list-style-type: none"> <li>• More packaging needs to store work-in-process.</li> <li>• Waste from deterioration or damage to stored WIP.</li> <li>• More materials are needed to replace the damaged WIP.</li> <li>• More energy is used to heat, cool, and light inventory space.</li> </ul>
<b>Transportation and Motion</b>	<ul style="list-style-type: none"> <li>• More energy is used for transport</li> <li>• Emissions from transport</li> <li>• More space is required for WIP movement, increasing lighting, heating, and cooling demand and energy consumption.</li> <li>• More packaging is required to protect components during movement.</li> <li>• Damage and spills during transport</li> <li>• Transportation of hazardous materials requires special shipping and packaging to prevent risk during accidents.</li> </ul>

Waste Type	Environmental Impacts
<b>Defects</b>	<ul style="list-style-type: none"> <li>• Raw materials are consumed in making defective products.</li> <li>• Defective components require recycling or disposal.</li> <li>• More space is required for rework and repair, increasing energy use for heating, cooling, and lighting.</li> </ul>
<b>Over Processing</b>	<ul style="list-style-type: none"> <li>• More parts and raw materials are consumed per unit of production.</li> <li>• Unnecessary processing increases waste, energy use, and emissions.</li> </ul>
<b>Waiting</b>	<ul style="list-style-type: none"> <li>• Potential material spoilage or component damage causing waste.</li> <li>• Wasted energy from heating, cooling, and lighting during production downtime</li> </ul>

Regarding businesses, it isn't easy to carry out economic growth and environmental targets in parallel. Businesses use the three zero paradigms. They should develop advanced programs to simultaneously achieve “zero defect (quality target)”, “zero stock (on-time stock and supplier relationships)”, and “zero waste and emissions (environmental target)” (Karakus, Polat, and Karsigil 2018)

Businesses are starting to show non-financial performance indicators such as social responsibility activities and environmental performance in their decision-making and strategic planning processes. Environmental performance indicators of enterprises can be listed under the following headings (Karakus, Polat, and Karsigil 2018):

- Energy usage rates,
- Renewable energy usage rates,
- Waste management systems,
- Water usage rates,
- Effective use of resources, recycling and reuse,
- Environmental sensitivity of production processes,
- Product life cycle studies,
- Reducing greenhouse gas emissions.

- Awareness-raising activities within the scope of environmental protection,
- Being in an environmentally friendly supply chain.

Environmental sustainability aims to ensure that ecosystems adapt to changing conditions. An environmentally sustainable system should keep its resource base stable, avoid exploitation of renewable resource systems or environmental investment functions, and consume only those that investments from non-renewable resources have adequately replaced. This system also includes the protection of biodiversity, atmospheric balance and other ecosystem elements that cannot be classified as economic resources. (Tıraş, n.d.)

### **2.1.3. ENVIRONMENTAL IMPACT OF AIRPORTS**

Contemporary technological and spatial developments have increased freight and passenger transport systems' cost, effectiveness and reliability. At the same time, the negative environmental impacts of transportation have gained a broad definition and are at the centre of sustainability issues, especially in urban areas. (Karakus, Polat, and Karsigil 2018)

As the passenger demand for air transport increases, the global air transport sector continues to develop. Today, although air transport contributes to the global economy and regional social and cultural development, airports face some pressures that may overshadow this development. Increasing environmental constraints may have adverse effects on the development of airports. (Korul 2003)

Air transportation is one of the methods perceived negatively in terms of environmental sustainability, especially due to its negative effects on climate change and the use of non-renewable resources. (Karakus, Polat, and Karsigil 2018)

Significant efforts are made in the aviation industry to minimize environmental impacts, from aircraft design to airport design, construction, and operation. (Karakus, Polat, and Karsigil 2018)

Together with the attempts to minimise the adverse effects that the operation and growth of airports may have, it is also important that airports develop strategies which seek to maximise the social and economic benefits. The growth of airports is encouraged

for its economic and social benefits; such growth should be a green growth in which an increase of capacity does not happen at the cost of more environmental burdens. Making airports sustainable means looking at all social, economic, and environmental factors and developing an effective approach. Reaching a desirable balance is achievable through careful studies that help to decide how to define airports' environmental capacities and constraints. This process should consider all the environmental, social, and economic parameters. (Sameh and Scavuzzi 2016)

Assessing environmental impacts in and around airports becomes much more difficult due to the many different institutions involved in or affected by airport operations. Affected institutions include airlines, governments, residents, facilities, airport operators and government agencies. These are different institutions that often have conflicting interests but work together. Issues such as the safety of residents or loss of wildlife habitat can cause anxiety among certain segments of society and create significant emotional concerns. However, complex technical data may need to be evaluated to measure overall impacts. Although the extent of environmental impacts caused by airport operations cannot be measured, it is possible to mitigate these environmental impacts by adapting many standard procedures to suit the individual conditions of each airport due to aircraft use, night flights, land use rules, proximity to residential areas and the general environmental sensitivity of the community. (Graham 2018)

#### **2.1.3.1. NOISE**

The environmental impacts of airports, especially noise, are a major issue in environmental sustainability. Airport operations can generate significant noise due to the high sound levels emitted by aircraft engines during takeoff and landing. This noise can cause environmental, health and quality of life problems and have a range of negative effects on the environment.

Environmental noise impacts of airports may include:

- **Health Problems:** Constant noise exposure can lead to health problems such as sleep disorders, stress, hearing loss and cardiovascular problems. Noise can cause physical and psychological health problems for people.

- **Decreased Quality of Life:** For people living near airports, noise can negatively impact the quality of daily life. Outdoor activities, rest and concentration may become difficult due to noise.
- **Ecosystem Effects:** Noise can also threaten birds and other wildlife. Birds may change their migration routes by avoiding noisy areas, which can impact local ecosystems.
- **Property Values:** Property values in areas close to airports may decrease due to noise levels. Therefore, this can lead to economic losses for property owners.

Several methods and policies can be applied to reduce or control noise in airports:

- **Quieter Aircraft:** With technological developments, quieter aircraft engines have been developed. The air transport industry could encourage using aircraft that produce less noise.
- **Runway Design:** Airport runways and take-off and landing paths can be designed to reduce noise. Approaches such as steeper landing and takeoff angles can reduce noise.
- **Flight Planning:** Air traffic management can reduce noise by optimizing flight routes and altitudes.
- **Quiet Night Operations:** Some airports may implement quiet flights or limited operations to reduce nighttime noise levels.
- **Development Control around Airports:** Local governments can reduce the impact of noise by regulating land use and zoning policies around airports.

These measures can help minimize the environmental noise impacts of airports, but the involvement of local governments, airport operators and the community is important.

Aviation noise may harm the quality of life and property values of members of a surrounding community. (Direct health impacts of noise are more difficult to determine.) Although the percentage of people affected by aircraft noise has been significantly reduced during the past 35 years by advancements in aircraft technology and noise abatement efforts, aircraft noise is often the principal focus for community

groups and larger non-governmental organizations that oppose runway expansion. (Luther 2007)

Despite improvements, the noise continues to be a significant problem because (Luther 2007):

- the amount of air traffic is growing,
- the number of airliners and corporate jets is increasing, and
- airline traffic and noise are concentrated at a small number of airports that are also likely to be among the largest airports.

Aircraft noise continues to be an issue at many airports, especially where capacity expansions are underway or being considered. (Nelson 2004)

Noise is an unwanted or unpleasant sound. At 65 dB and above, the most common human effects of aircraft noise are annoyance, speech and learning interference, and sleep disturbance. These effects disrupt normal daily activities, such as conversation, television viewing, school work, productivity, outdoor recreation and living, and family activities. (Nelson 2004)

Aircraft noise is related to the frequency of aircraft movements and the size of the aircraft engine, as well as the proximity of the location to the airport's arrival and departure routes. Monitoring and controlling aircraft noise is extremely important. Aircraft and engine manufacturers have made significant technological advances in recent years. Multiple air transportation system stakeholders, including aircraft manufacturers, airports, airlines, and air navigation service providers, are trying to find solutions to this problem. Noise is an inevitable consequence of air traffic but can be reduced in several ways, such as through technical innovations in aircraft design and legislation. (Yavuz 2022)

Historically, aircraft noise has been a major constraint to increasing civil aviation capacity. Despite the facts that community exposure to aircraft noise has decreased markedly over the past several decades and that the United States and the European Union have ambitious technology goals for the future, community expectations of continued decreases in noise levels may not reflect the reality of the extended time

frame required for development and adoption of advanced technology for the next generation of quieter aircraft. (Eagan, Stewart, and Steinhilber 2009)

Aircraft noise is considered the most important environmental problem at airports, and in many cases, the public's tolerance for aircraft noise is decreasing. Moreover, this is even though noise levels from aircraft movements have decreased over the years. The main reason for this decrease is the pressure to develop less noisy aircraft and stricter requirements for noise certification of new aircraft types. (Graham 2018)

Since 1990, the first generation of noisy aircraft Chapter/Stage 1, including Boeing 707s, have been prohibited. After that, the second-generation Chapter/Stage 2 aircraft were the noisiest types. They were phased out completely in the United States at the end of 1999 and worldwide in 2002. An issue that complicated this noise certification process was the treatment of hush-kitted or re-engined jets. Chapter/Stage 2 jets were modified to comply with the Chapter/Stage 3 rules. They are the noisiest of the Chapter/Stage 3 aircraft, so there were pressures, particularly in Europe, to phase them out. However, this was opposed elsewhere, especially by the United States, a major hush-kitting equipment supplier. Subsequently, in 2001, it was decided by ICAO that a new Chapter/Stage 4 standard would apply to all new aircraft designs, beginning in 2006, which had to be 10 decibels quieter than Chapter/Stage 3. Then, in 2013, a new standard, Chapter/Stage 4, was agreed upon. Thus, this meant that all large aircraft above 55 tonnes had to be at least 7 decibels quieter than the Chapter/Stage 4 standard from 2017, which applied to smaller aircraft from 2020. (Graham 2018)

The Aviation Environmental Protection Committee of the International Civil Aviation Organization (ICAO), realizing that noise reduction measures should not aim at a unique solution but rather at a combination of different solutions, has recommended procedures for reducing noise in the vicinity of airports. In the analysis of many international airports, it has been found that many measures have been developed and implemented to solve the noise problem in and around airports, thus responding to the demands for a 'balanced approach'. Due to the increasing volume of air traffic worldwide, the number of airports that face noise problems and the number of airports that take some measures to manage noise are increasing. Implementing these measures makes it possible for airports to develop further. (Netjasov 2012)

### 2.1.3.2. AIR POLLUTION (EMISSION)

Through the combination of the development of quieter aircraft and noise abatement operating procedures, most airports are attempting to contain many of the problems arising from aircraft noise. However, a comparatively newer environmental threat growing in recent years is that of aircraft emissions and their impact on climate change. By consuming fuel, aircraft are producing emissions of carbon dioxide (CO<sub>2</sub>), nitrogen oxide (NO<sub>x</sub>) particles (mainly soot) of sulphur oxide, carbon monoxide (CO) and other effects, including water vapour trails and induced cloudiness. (Graham 2018)

The aviation industry is growing rapidly, and aviation fuel usage is increasing rapidly. All other factors being equal, the number of emissions produced by aircraft is proportional to fuel consumption. Several factors determine the air quality around an airport. (Yavuz 2022)

Airport emissions affecting local air quality come from both mobile and stationary sources, including the following (Luther 2007):

- Aircraft.
- Motor vehicles (e.g., cars and buses for airport operations and passenger, employee, and rental agency vehicles).
- Ground service equipment (GSE) (e.g., aircraft tugs, baggage and belt loaders, generators, lawn mowers, snowploughs, loaders, tractors, air-conditioning units, and cargo moving equipment).
- Stationary sources (e.g., boilers, space heaters, emergency generators, incinerators, fire training facilities, aircraft engine testing facilities, painting operations, and solvent degreasers)

Airports generate air pollution from various sources, including on-site power and heating, equipment to service aircraft, on-site vehicles, airport-related traffic on surrounding roads, and aircraft. Vehicles travelling to and from airports are regarded as the biggest contributor to local concentrations of pollutants, especially where airports are located in or near major urban centres or transport networks where they exacerbate existing air quality problems. (The Aviation Environment Federation (AEF) 2023)

Airports are among the largest sources of air pollution in the United States, and they can adversely impact air quality in the vicinity of airports, leading to respiratory illness. (National Bureau of Economic Research 2023)

The emissions from airports can cause premature deaths globally, with particulate matter under 2.5 being the major contributor. (Riley et al. 2021)

One option for reducing emissions is advanced technology, and major advances in aircraft turbine engines in recent years have resulted from extensive efforts by engine manufacturers and conscious government agencies. In the United States, NASA is a significant contributor to these developments. From the beginning, the goals of these efforts have included durability and fuel efficiency. These all have significant economic implications for airlines. (Yavuz 2022)

CO<sub>2</sub>, nitrogen oxides (NO<sub>x</sub>) and emissions from airport operations Gas emissions, including particulate matter, can harm local air quality. While emissions from aircraft (either during the landing and take-off phase or taxiing) are generally the largest source of emissions at an airport, transportation to the airport by passengers and staff, vehicle use on the apron and energy production also significantly impact local air quality. (Budd, Budd, and Ison 2015)

Over the past two decades, air pollution associated with aviation and airport-related sources has become a prominent issue facing many large air carriers and general aviation airports in the United States. Today, criteria pollutants—carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>), ozone (O<sub>3</sub>) and its precursors, oxides of nitrogen (NO<sub>x</sub>) and volatile organic compounds (VOCs), sulfur oxides (SO<sub>x</sub>), and particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>)—from airports account for less than 0.5% of total emissions in the United States, according to the 2003 Government Accountability Office Report to Congress. Nevertheless, aviation sources, such as those associated with other transport modes, can contribute to local air quality issues and that contribution may grow. Worldwide aviation traffic is expected to increase at an annual rate of 4.6% over the next decade, albeit this is likely to be tempered by the recent market volatility and oil prices. Increased aviation demand and activities will likely lead to increased aviation emissions. (Eagan, Stewart, and Steinhilber 2009)

These factors can have a profound impact on air quality. At Heathrow Airport, for example, it is estimated that only 20% of local air pollution comes from aircraft, with the remaining 80% from emissions and surface access traffic. As a result, many airports, including Luton, Birmingham, Edinburgh and the East Midlands, have introduced charges for dropping off/collecting passengers on the kerb side of the terminal. (Budd, Budd, and Ison 2015)

Emissions from international flights are excluded from the Kyoto Protocol, which was adopted in 1997 and came into force in 2005. Through the Committee on Aviation Environmental Protection (CAEP), ICAO has been responsible for developing recommendations on international aviation emissions. (Graham 2018)

### **2.1.3.3. WATER POLLUTION**

Airports consume water for indoor operations such as toilet flushing, food preparation, and HVAC systems and for outdoor operations, including irrigation and aircraft/infrastructure washing and maintenance. The amount of water that major airports consume is not insignificant and is on par with the consumption patterns of small and medium-sized cities. A typical metric for assessing airport water consumption is volume per day. Still, this metric fails to offer a broader picture of what water sources are consumed and what management practices yield the best results. The water conservation techniques proposed for airports include monitoring water consumption, using water-efficient fixtures/fittings, reducing irrigation demand, and using alternative water sources (e.g., rainwater, greywater, and recycled wastewater). (Greer, Rakas, and Horvath 2020)

Airport operations include many activities likely to result in the discharge of pollutants to adjacent water bodies. Those activities include aircraft and airfield de-icing and anti-icing, fuel storage and refuelling, aircraft and vehicle cleaning and maintenance, and construction. These activities are regulated under the Clean Water Act (CWA) provisions. (Luther 2007)

Airports have a significant impact on water usage and wastewater management. Most water used in airports is for non-potable uses, such as cleaning airport facilities and

aeroplanes, sanitary and manufacturing purposes, and maintaining the air fleet. (Magazine 2021)

Water pollution at airports can occur for various reasons. Surface water discharge or runoff entering local waterways from runways, aprons, parking lots and other land developments can be contaminated by anti-icing and de-icing fluids such as glycol used during winter months. In addition to the chemicals used in washing and maintaining aircraft and vehicles in the terminal, fuel spills and fire training activities also cause this pollution. Leaks from underground tanks and pipes and lawn fertilizers used in landscaping activities are sources that can pollute the soil. (Graham 2018)

Airports need to consider water in three primary ways. The first is supply, the water entering the airport facility and whether there are ways that the airport can reduce its water demand. Secondly, handling capacity, airports experience water events such as flooding, drainage issues, erosion, and other impacts. Thirdly, airports must ensure that the water leaving the facility is clean and safe for the surrounding environment. Airport systems manage these processes in various ways. (ICAO, 2021)

Many airports and airlines are adopting different environmental strategies to reduce their water footprint, such as capturing rainfall and reusing grey water. (Magazine 2021)

Activated sludge is the most common technology used in municipal wastewater treatment plants and has been applied successfully at airports to treat de-ice that affected stormwater. (ACRP 2013)

The effects of airport operations on water quality have garnered attention as regulators look beyond the more obvious sources of water pollution, such as end-of-pipe industrial waste discharged into large water bodies and attempt to address issues such as stormwater runoff and non-point sources. Airports, which typically include large expanses of impervious surfaces and host activities that can generate discharges of potential contaminants, such as vehicle and aircraft fuelling, maintenance, and de-icing, have been subject to the requirements of the Clean Water Act for more than a decade. However, applying these rules to the unique operating environment of airports is still being refined. One challenge has been identifying the range of technologies available to minimize and manage de-icing runoff and then defining the climatological, operational,

cost, and other factors that enable or disable their use at specific airports. More recently, site-specific water quality considerations, such as those resulting in the identification of impaired water bodies and the establishment of total maximum daily loads (TMDLs) for specific pollutants for those water bodies, have added complexity to airport permitting. (Eagan, Stewart, and Steinhilber 2009)

For historical reasons, many airports are located on or adjacent to large bodies of water. These water bodies, associated marshes, and other wetlands often provide habitats for many birds and waterfowl known to cause severe aircraft damage or crashes. Some of these avian species are protected federally. Enhancing and preserving the water quality of these habitats is an important goal of the Clean Water Act. (Eagan, Stewart, and Steinhilber 2009)

#### **2.1.3.4. ENVIRONMENTAL WASTE**

In practice, airport operations encounter various types of waste, including Municipal Solid Waste (MSW), Construction and Demolition Debris (CDD), waste from aircraft flights (deplaned waste), compostable waste, hazardous and industrial waste; and lavatory waste. For MSW and CDD, airports have choices in managing collection, treatment, storage, and disposal. Those choices can improve airport operations and minimize environmental impacts when considered and carried out in beneficial ways. (ICAO, 2023)

Analysis of waste management at airports is another emerging research area. Waste sources at the airports include food waste from retailers/concessionaires, construction waste, and aircraft-related waste. Metrics for analysing waste at a major international airport include quantity of waste, waste source fraction, and waste amount per operation. One article assessed the life-cycle impact of air emissions on six waste management scenarios at Hong Kong International Airport, determining that on-site incineration with heat recovery yielded optimal results. (Greer, Rakas, and Horvath 2020)

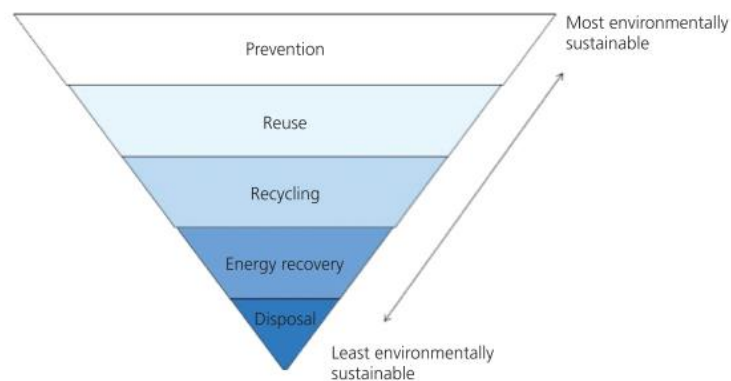
Airports also face certain operating constraints regarding waste due to the nature of the aviation business. For example, airports must incinerate all 'international' food waste from aircraft or send it to a controlled landfill. In addition, waste transfer from air to

ground sites at airports is problematic due to safety, security, customs and insurance restrictions. (Graham 2018)

Waste management has become very important for airports for sustainable aviation. For this reason, airports often try to reduce the amount of waste produced at the source. Moreover, this can be accomplished in various ways, including sending packaging back to suppliers or purchasing materials in bulk to keep packaging to a minimum. Where waste generation is inevitable, reuse, recycling or recovery of energy in waste is often sought, opting for waste disposal that is considered both environmentally and economically detrimental to the airport operator. Thus, this is called the 'waste hierarchy' (Figure 2) and represents the guiding principle of sustainable waste management at airports. (Budd, Budd, and Ison 2015).

Airports can reduce their environmental impact by implementing efficient and cost-effective waste management practices, such as recycling, reuse, and waste reduction programs.

Airports must comply with a range of legislation in terms of the environmental effects that they generate. Failure to do so could see them prosecuted. (UK Civil Aviation Authority 2023)



**Figure 2 - Waste management hierarchy**  
Source - (Budd, Budd, and Ison 2015)

#### **2.1.3.5. WILDLIFE CONSERVATION**

Airports, by their nature, cover large areas of land, affecting wildlife or an ecological monoculture (such as mowed grasslands). Threatened habitats may limit an airport expansion project. This problem often hinders the development of airports in areas

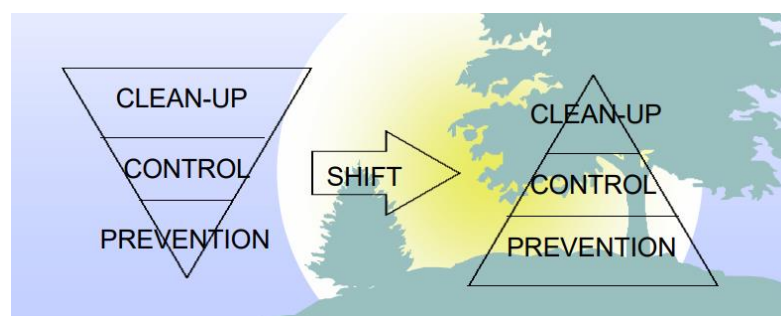
protected by national or international agreements. Given the commitments made at the Rio Earth Summit to protect biodiversity, such constraints are likely to become more pronounced in the future, even in less developed countries (Yavuz 2022)

There is also a need to protect the wildlife, heritage and landscape of the local environment, and there are many examples of how specific airport operators in the past have tackled the disturbance of certain wildlife habitats – particularly during the construction of a new airport or during airport expansion. (Graham 2018)

The need for easy access (both by land and by air) and to maintain aircraft safety means that airports are designed to be unattractive to mammalian and avian pests. However, many sites are located among habitats of ecological value or adjacent to wildlife reserves and, as such, airports are increasingly recognising the need to minimise the adverse ecological impacts of their operations or expansion while maintaining airfield safety. Thus, this involves engaging with a wide range of stakeholders, including government bodies and agencies, local communities, and wildlife groups, to implement a range of monitoring and assessment programmes to monitor and manage airport habitats and the plant and animal species within them. For example, constructing Manchester Airport’s second runway involved capturing and relocating protected mammalian and amphibian species away from the development. (Budd, Budd, and Ison 2015)

#### 2.1.4. AIRPORT ENVIRONMENTAL MANAGEMENT SYSTEM

Airports' environmental programs must comply with legislation/legal requirements, liability, policy, safety, harmonization, and public image/pressure. The pyramid, which includes three keywords that constitute the most effective strategy for solving environmental problems with the environmental management system, has changed its shape today, as shown below. (Simpson 2001)



**Figure 3 - Strategies Used in Solving Environmental Problems**

Source: (Simpson 2001)

As seen in Figure 3, preventing residual pollution is accepted as the process and practice of resource use to reduce or eliminate the formation of pollution and waste at the source. It is necessary to control all pollution released into the receiving environment and to develop assurances that can prevent ecosystems from being consumed at a rate greater than their ability to tolerate pollution or to renew themselves to protect environmental quality and prevent its deterioration. To achieve this goal, organizations responsible for environmental management must determine the values and apply the necessary sanctions to organizations that are determined to exceed the determined values.

As the importance of environmental management increases for businesses, the need for effective environmental management also increases. Although the establishment and operation of the Environmental Management System in businesses requires the participation of all employees, the environmental manager's role is very important, especially in the establishment phase of the system.

Duties and responsibilities must be clearly defined and known within the business to ensure effectiveness in establishing and operating the Environmental Management System. For the Environmental Management System to be successful, all personnel must assume responsibilities. Any mistake made at any stage will also affect other activity stages. To properly fulfil the duties and responsibilities assigned to each unit and individual, the people performing the duties must be competent, knowledgeable, skilled and have the necessary training. The duties and responsibilities of the personnel to carry out airport activities in a way that causes minimal damage to the environment are given in Table 2 as an example. (Korul 2003)

**Table 2 - - Airport Environmental Management System Duties and Responsibilities**

Source: (Korul 2003)

<b>Airport Manager</b>	<ul style="list-style-type: none"> <li>• Reviewing and approving environmental policy, goals and objectives</li> <li>• Leading the environmental management system</li> <li>• Distributing environmental duties and responsibilities among personnel</li> <li>• Providing the necessary resources for the implementation and maintenance of the environmental management system</li> </ul>
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<p><b>Environmental Management System</b> <b>Management Representative</b></p>	<ul style="list-style-type: none"> <li>• Developing environmental goals and objectives and leading the development of environmental management programs,</li> <li>• Compiling, analyzing and interpreting environmental monitoring information,</li> <li>• Managing programs to reduce environmental impacts,</li> <li>• Monitoring relevant environmental laws and regulations and ensuring their implementation in the business,</li> <li>• Participating in environmental organizations, introducing environmental policy to the society,</li> <li>• Submitting environmental reports to relevant legal units,</li> <li>• Following the technology developed in the production of environmentally friendly goods and services,</li> <li>• Preparing reports showing the benefits and costs of environmental programs</li> </ul>
<p><b>Environmental Technicians</b></p>	<ul style="list-style-type: none"> <li>• Perform environmental monitoring</li> <li>• Calibrating and maintaining monitoring tools,</li> <li>• Supervising studies on waste management and protection of natural life,</li> <li>• Operating waste cleaning systems</li> </ul>
<p><b>Maintenance Supervisor</b></p>	<ul style="list-style-type: none"> <li>• Ensuring control of fuel tanks with environmental control systems,</li> <li>• Ensuring that maintenance personnel comply with environmental instructions,</li> <li>• Programming annual environmental training of staff.</li> </ul>
<p><b>Anti-Icing Equipment Operator</b></p>	<ul style="list-style-type: none"> <li>• Ensuring that instructions regarding anti-icing activities are implemented,</li> <li>• Participating in training programs,</li> <li>• Immediately report any environmental incident to the environmental manager.</li> </ul>

In implementing the Environmental Management System at airports, senior management has a great role in motivating all personnel and showing the importance the airport attaches to environmental values. Encouraging all personnel to achieve environmental goals and objectives is considered one of the first steps in ensuring sustainable development. It is important to ensure continued communication with all personnel, local people, airport users, tenants, and other relevant legal units to raise their awareness about the issue and explain the results.

The view that transportation systems are an increasingly important source of environmental pollution is becoming widespread. Although land transportation

contributes more to environmental pollution, the quality of environmental management will play an important role in the airline industry's future. Especially as the communities living around airports become enlightened about the effects of airport activities on nature, airports face increasing pressures to reduce these adverse environmental effects. As a result of these effects, legislators are trying to raise standards and impose various environmental taxes and operational restrictions. Although the advantages brought by technology have reduced the impact of aviation on the environment, increasing sensitivity towards the environment suppresses this. (Korul 2003)

Environmental management techniques should be developed to minimize the impact of airports on the environment and improve the quality of life regionally and globally. First, an environmental department should be established covering various branches of expertise such as health, safety, energy, air and water quality, waste, noise and resource use control.

The environmental department will also liaise with airport neighbours and their representatives. The department's main purpose is to prove that the business is aware of the environmental situation resulting from its development and to determine strategies and present them in a report to the top management. The environmental management system should include evaluations regarding noise monitoring and control, control of water and air pollution quality, effects of airport activities on environmental public health, protection of the ecological system and natural life, land transportation and land use planning, and waste control (Korul 2003)

### **3. ENVIRONMENTAL SUSTAINABILITY PRACTICES IN THE WORLD**

Airports around the world are developing various practices to become environmentally sustainable. Airports try to reduce the impact of airports on the environment by implementing many practices on issues such as noise, air pollution, wastewater, waste and energy management, and wildlife protection.

#### **3.1. APPLICATIONS RELATED TO NOISE**

Current and future noise sources should be identified in the airport noise management program, and measures should be taken to minimize the noise impact, considering aviation systems and procedures, as well as the needs of airport neighbours and airline operators. As a result, Successful environmental relations, fulfilment of responsibilities towards airport users and reduced pressure against operational restrictions will be ensured. (Simpson 2001)

Various methods are used to reduce noise to prevent it from affecting the people's daily lives around the airport. Among the ways to reduce noise (Korul 2001)

- Noise reduction procedures,
- Regulation and control of aviation noise,
- Noise practices in aircraft operations,
- Night flight restrictions,
- Appropriate runway use,
- Noise monitoring and measurement,
- It is land use planning.

An airport can use a variety of approaches to solve noise problems. Ultimately, decisions regarding mitigation measures and operational changes are made by the airport authority following requirements of the state or local government; land use restrictions can be suggested by the airport authority but are implemented entirely at the discretion of the local government. The federal role is primarily to fund those efforts, establish aircraft noise limits, and fund research. (Luther 2007)

The impact of air transportation on the environment is subject to international legal regulations. The noise levels permitted by civil aviation are strictly defined

internationally. Among other aspects of international air transport, the International Civil Aviation Organization (ICAO) also covers environmental protection.

Jet engine aircraft used in the 1960s caused an increase in noise. Thereupon, the US Federal Aviation Administration (FAA) prepared the noise license regulation in 1969. The International Civil Aviation Organization (ICAO) changed this regulation in 1974 and published the basic document addressing aircraft noise issues, ICAO Annex 16, Volume 1 - "Aircraft Noise". 1981, the second volume on aircraft exhaust gases was added to Annex 16. This document contains standards, recommendations and guidelines for aircraft certification for noise, applicable to certain classes of aircraft used in international traffic. (Türkoğlu 2014)

Annex 16 has brought significant improvements in the noise performance of aircraft and has caused the noise from aircraft to decrease by at least 75% since the 70s.(Türkoğlu 2014)

The industry has begun to find new ways to combat the damages caused by airport noise as the demand for air transportation increases. The world's busiest airports have operational restrictions or capacity limits based on aircraft noise. Examples of these restrictions are quite diverse, such as the daytime use of noisier aircraft, the closure of airports at night, noise taxes, and the insulation of nearby settlements. There are critical issues for both airport operators and local governments. Examples include the sound insulation of buildings constructed in noise-sensitive areas around airports and the need for more effective land use planning to use airport capacity effectively. (Yavuz 2022)

The ICAO Balanced Approach identifies four elements to address noise around airports: reduction at source, land-use management and planning, noise abatement operational procedures, and operating restrictions. Operating restrictions are measures that limit or reduce access to an airport. Given their impact on airlines, passengers and local economies, operating restrictions should not be introduced as a first resort but only after a full assessment of all available measures to address a demonstrated noise problem at an airport. (IATA 2023)

Decisions to restrict night flights cause airlines to lose the flexibility to create connecting flights and to be unable to plan their flights efficiently. Night flight restrictions apply at

major European airports, such as Amsterdam, Frankfurt, London, Warsaw and Zurich. There are very few airports outside Europe where night flights are restricted. Tokyo Narita and Sydney are examples of these few airports. (Tuna 2020)

The intense competitive environment has led aircraft manufacturers to take advantage of developing technologies and thus design aircraft that operate more quietly by reducing the noise level. The ability of new-generation aircraft produced with high technology to travel long distances with less fuel also reduces the amount of carbon dioxide emissions released into nature. Airline companies must consider all the negative aspects of old-generation aircraft during fleet planning. Companies consider their goals and financial situation, the possible authority restrictions they may encounter in their operations, and take a predictable approach to the future of the fleet they will create.

Regulations have been made on aircraft noise levels since the 1970s with the updating of the Standards and Recommended Practices (SARPs) in Annex 16 published by ICAO. The main purpose of the regulations is to evaluate the noise reduction methods provided by the latest technology incorporated into aircraft design, make the rules more restrictive, and popularize the use of aircraft with low noise levels. In the pricing applied by airports to airline companies, newly produced aircraft with low noise levels have discounts according to their noise levels. (ICAO 2023a)

Applications regarding aircraft noise, which has an intense impact around airports, have been in force since 1972. In the regulations on this subject, the Maximum Take-Off Weight (MTOW) of aircraft was used to define noise limits based on the idea that heavier aircraft with high carrying capacity create much more noise pollution than lighter aircraft. (Tuna 2020)

Following the publication of the second part of Annex-16, aircraft with higher fuel efficiency and lower noise levels began to be produced with new technology. This situation made ICAO's approach to aircraft noise more stringent in the regulations it made in 1977, necessitating new noise regulations in Chapter 3. In the following years, constantly improving technology has introduced more noise reduction methods into engine and airframe designs. Moreover, this has led to improvements in aircraft noise performance. Thus, stricter noise restrictions have been introduced in the 4th part of Annex-16.

In February 2013, with the availability of much quieter and more efficient aircraft in the market, it was decided to reduce the noise restrictions in the 4th section by 7 decibels. The 14th section was accepted as the new noise restrictions for Annex-16. As of 2018, noise standards introduced by Chapter 14 are used. Chapters 1 to 14 The representation of noise restrictions according to maximum take-off weights is shown in Figure 4. (ICAO 2023a)

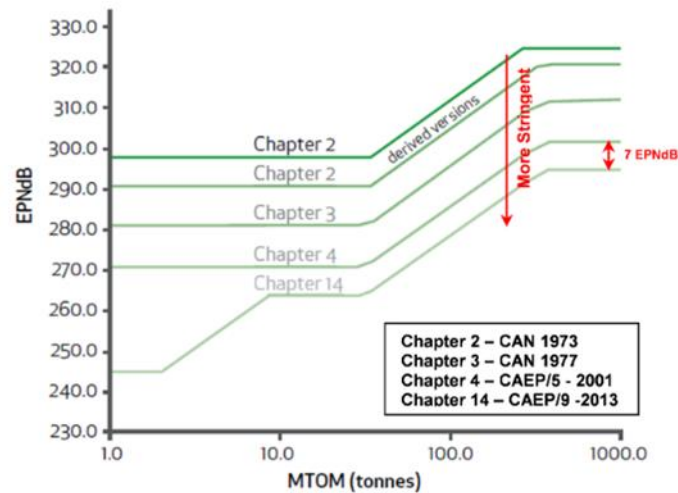


Figure 4 - The progression of the ICAO Noise Standards for aeroplanes  
Source: (ICAO 2023a)

IATA predicts that airline companies will invest \$4.5 trillion in new-generation aircraft that operate more quietly in the next 20 years. It is estimated that the noise caused by aircraft will decrease by 65% by 2050 with the new integrated wing and tail structure design with the fuselage and engine protection components. (Tuna 2020)

One of the other measures taken at the airport is installing fixed noise equipment. Fixed noise monitoring equipment has been installed, and a specific method has been applied to calculate noise contours to monitor air traffic noise at Tallinn Airport. The project enabled the identification and evaluation of the impact of noise caused by air operations on the environment and the preparation of a noise map based on the results. In addition to all these developments, in 2003, fixed noise monitoring equipment was installed at Tallinn Airport to measure the level of noise generated during the takeoff and landing of aircraft in anticipation of implementing preventive measures or sanctions. The Tallinn

Airport monitoring system allows noise caused by aircraft and airport operations to be analyzed and predictions made. (Vanker et al. 2013)

### **3.2. APPLICATIONS RELATED TO AIR POLLUTION**

Since air pollution can spread regionally and globally, environmental effects occur at different scales and values. Air pollution can have physical and psychological effects on human health and negative effects on the ecological system. Atmospheric conditions changed by air pollution affect the climate and harm plants and other living things. It requires international measures against problems such as acid rain, global warming and ozone layer depletion.

Airports are one of the important sources of local air pollution for their activities. Sources that cause air pollution at an airport are listed below.

- Aircraft engine exhaust,
- Aircraft fuel supply systems,
- Vehicles providing ground service,
- Airport heating and cooling systems,
- Construction works,
- Motor vehicles used by passengers, employees and visitors.

Various remedial programs are used to reduce air pollution at airports. The most commonly used one is to charge the polluter (airline operator) according to its environmental performance. Other measures include using electrical power systems instead of fuel in ground handling vehicles and choosing metro and railway instead of land transportation to reach the airport. (Korul 2003)

Because aircraft emissions are a significant source of emissions at an airport and are largely beyond the airport's control, emissions reduction efforts will need to be conducted in operations or processes the airport controls. For example, ground vehicles used at the airport can be replaced with alternative fuel vehicles, or old boilers and chillers can be replaced with more energy-efficient systems. Apart from these measures, vehicle use at airports can be reduced.

All these studies have a tremendous impact on air quality. At Heathrow Airport, for example, it is estimated that 80% of local air pollution comes from airport access traffic

and airside vehicles, with only 20% of emissions coming from aircraft. Passengers dropped off at the airport make two additional vehicle journeys to/from the airport for each return flight, leading to increased air pollution in particular, given the increase in the number of stationary vehicles on the airport grounds. Most airports offer travel cards, such as travel plans for staff and car-sharing clubs, to encourage employees to minimize driving. Some UK airports have replaced ground handling equipment with more fuel-efficient or low/zero emissions vehicles. In 2012, Stansted Airport replaced its fleet of 'Ranger' vehicles used for airside operations with newer, more fuel-efficient vehicles. The airport has determined that this practice has led to a 44% reduction in emissions compared to older vehicles. (Budd, Budd, and Ison 2015)

Kansai Airport has taken many measures to prevent air pollution. Flammable waste generated at the airport is burned in the incineration facility. Thanks to air heaters designed to prevent white smoke, the environmental impact of emissions occurring in the furnace at temperatures between 800 °C and 950 °C is tried to be reduced. After this process, all substances that may cause air pollution are directed to a cooling chamber through a reactor. A filter-type precipitator removes all dust and hazardous gases. The exhaust gases are released into the atmosphere through an induced fan and an exhaust chimney. The emissions produced at the facility are also well below the established standards.

Additionally, the heat from combustion is used as a heat source for air heaters to prevent white smoke. Hot water generators provide room heating and tap water heat in the combustion plant. (Baxter, Srisaeng, and Wild 2018)

### **3.3. WASTEWATER RELATED APPLICATIONS**

There are various activities among the sources of water pollution at airports:

- Use of anti-icing and de-icing compounds applied to aircraft and runway surfaces,
- Underground and aboveground fuel tanks,
- Oil and fuel splashes occurring during oil and fuel filling,
- Washing, maintenance and repair operations of aircraft and ground service vehicles,

- Emergency services such as fire extinguishing training and disinfection.

Monitoring and management programs and personnel awareness are required to control water pollution from the abovementioned activities. Automatically monitoring the water flow, using the least harmful chemicals, setting strict rules for polluters, imposing penalties if necessary, building a drainage system and collection pools for harmful substances and wastes and purifying them before they reach water resources may be a solution. (Korul 2003)

Airports are taking several initiatives to reduce both water consumption and pollution. These include revised operational practices to reduce the use of harmful chemicals, improve cleaning processes, and minimize spills and leaks. While de-icing services at Munich Airport are carried out in a specially designated remote area, they only take place on closed apron surfaces to ensure that the liquid does not leak elsewhere so that de-icing liquids can be recycled. Heat is a by-product of this recycling process, which can help warm the terminal. Many other airports recycle de-icing fluid, including Detroit, Seattle, and Dallas/Fort Worth. On the other hand, balancing reservoir treatment can be applied to surface water before it is added to local watersheds, such as at Auckland Airport. (Graham 2018)

Stansted Airport significantly reduced its annual water consumption from 753 million litres in 2007 to 412 million in 2012. Therefore, this includes investing £500,000 to upgrade surface water drainage pipes, pumping stations, and drinking and fire water services, as well as installing flow meters and low flow taps, pipework leak repair programs and water efficiency surveys to identify areas that can be further improved. Heathrow Airport's Terminal 5 uses a rainwater harvesting system and groundwater boreholes to collect the terminal's wastewater. The airport estimates that 85% of all rainwater falling on the terminal is reused, and together with boreholes, this reduces demand on the public water supply by 70%. Apart from water consumption, managing water discharges is also important to prevent pollution of local waterways and flooding of airports. Routine airport operations include aircraft maintenance, ground handling water discharges, aircraft washing, airfield maintenance, winter operations, de-icing services, and firefighter training. (Budd, Budd, and Ison 2015)

Munich Airport supplies its drinking water from the Moosrain water distribution company. This company extracts its water from tertiary layers through six boreholes at depths between 94 and 160 metres. Munich Airport participated in the infrastructure costs of this utility during the construction phase of the airport with a capital investment subsidy of approximately €20 million. The extracted water is subject to control and is of the highest quality. (Baxter, Wild, and Sabatini 2014)

During the winter, storm water mixed in winter with the agents used for de-icing aircraft and surfaces enters into a de-icing wastewater pond system and dosed into the central treatment plant. Only in the area of the taxiways does stormwater containing de-icing agents trickle following pre-treatment in a filter system (underground degrading system) directly in the green area adjacent to the runways. In addition, during winter operations, small quantities of de-icing agents may be carried by wind to the green areas bordering on the airport's air-side areas and, from there, enter along with stormwater into the groundwater. Since 2012, the airport has installed ground filters in the green areas around the runway heads to prevent this. These consist of underground storage areas filled with gravel and are sealed at the base. (Baxter, Wild, and Sabatini 2014)

### **3.4. APPLICATIONS RELATED TO WASTE AND ENERGY MANAGEMENT**

Most airports now have recycling initiatives. One of the earliest airports to undertake this was Zurich Airport, which introduced an airport-wide waste management concept in 1992. Other examples include concrete recycling at Jersey Airport to reuse cut grass instead of fertiliser at Stansted Airport, airline pillow recycling at Oakland Airport, and re-use of excavated soil at Dallas/Fort Worth airport. In Los Angeles in 2017, a pilot scheme was undertaken to recycle food waste into renewable natural gas, with the residual solids and liquids being made into reusable products such as soil amendments. At Seattle airport, the food waste is given to a food bank in the city. As at Calgary airport, other airports, including Canberra, recycle their water or collect rainwater in the toilets. Interestingly, Hong Kong Airport undertook a waste-handling survey of 27 airports and liaised with its home carriers. (Graham 2018)

It found that airports and airlines had different procedures for recycling, which hindered the efficiency of the whole recycling process, and policies have been developed to overcome this. It has also developed a three-pronged management approach to tackle

food waste at the airport, covering food waste recycling, converting waste cooking oil to biodiesel, and food donation. Phoenix Sky Harbor is another example of an airport that has been very active in accomplishing waste diversion goals while reducing costs. Some of its initiatives include a dedicated recycling programme, a construction waste programme and a recycling plan for runway friction rubber removal. (Graham 2018)

Energy management associated with heating, ventilation, air conditioning, and lighting is also very important. Many airports undertake energy audits and have effective building management systems to provide optimal control of such systems. With energy conservation, as with waste and water management, there are good financial reasons why airports should address these issues since environmental improvements may bring about considerable cost savings. Many airports have replaced terminal or parking ramp lights with LED fixtures. Paris CDG airport has replaced the gas boilers that it previously used. It now has a biomass plant that produces heat through the combustion of wood waste in the form of wood chips, reusing the ashes as agricultural fertiliser by the company providing the wood chips.

Meanwhile, some airports, including Vancouver, Chicago, San Francisco, Malta, Barcelona, Brisbane, Athens, Kuala Lumpur and Bologna, use solar energy –around 100 airports worldwide have solar installations. Others, such as La Palma airport in Spain, have wind power generators. (Graham 2018)

Sustainable waste management inevitably involves interaction with various stakeholders and companies that produce this waste, including airports, ground handling agencies, maintenance companies and retail outlets. It is common for airports to subcontract the collection and removal of waste to dedicated companies, especially in the case of hazardous materials such as asbestos, radioisotopes, oils and hydraulic fluids. (Budd, Budd, and Ison 2015)

While most waste comes from airlines, airport operators are usually responsible for waste management for all airport activities. Most individual companies, especially airlines, do not have sufficient space for waste management facilities. In addition, there are cost economies of scale to be gained by having recycling and other waste

management procedures. Improvements can often be achieved by evaluating airport treatment methods and the extent of waste reduction, reuse or recycling. With the single-use nature of most packaging, in-flight catering waste is recognized as a particular problem. Off-airport disposal methods, typically incineration and landfill, must also be considered. (Graham 2018)

Sustainable waste management practices generally include the provision of mixed recycling collection facilities to ensure, as far as possible, that waste is separated before collection. For example, there are increasing amounts of plastic bottles, sprays, perfumes and creams at airport security checkpoints due to practices restricting the amount of liquids passengers can carry in the cabin. In addition to traditional recycling points at Manchester and Luton Airport, clothing banks have been set up so that clothing and textiles discarded by passengers wishing to reduce the weight of their luggage can be donated to charity rather than sent to landfill. Several airports have established composting facilities for food waste on airport grounds. For example, 190 tonnes of food waste were composted at Stansted Airport in 2012. These practices have led to significant progress in the amount of recycling. At Newcastle Airport, 79% of all waste produced in 2012 was recycled rather than landfilled. The airport aims to recycle 100% of its waste by 2030. After the preferred waste reduction, reuse or recycling options are exhausted, in some cases, waste is converted into energy by burning. At Heathrow Airport, general waste is transferred to a nearby energy-from-waste facility to generate electricity. In 2010, 12,696 tons of waste were sent to the facility. Waste management represents an area where environmental and commercial objectives are increasingly aligned. Indeed, as the costs of sending waste to landfills increase, there is a commercial imperative for airports to improve their waste reduction, reuse and recycling initiatives. (Budd, Budd, and Ison 2015)

In recent years, increasing emphasis has been placed on incorporating energy efficiency regimes into designing and constructing new terminal buildings. However, airports with existing infrastructure face challenges in renewing and improving their technology. For example, at East Midlands Airport, airport operator Manchester Airports Group has installed an automatic electricity metering system that provides half-hourly energy consumption updates on the airport site for airport tenant companies. This system

allows for close monitoring of real-time energy usage by companies at the airport and helps the airport operator evaluate site-wide energy use patterns. In London Gatwick and Stansted, 'smart' control systems have been installed in heating and lighting systems, escalators and walkways to reduce energy consumption. Other airports have replaced their old lighting systems with more energy-efficient LEDs. At Manchester Airport, existing lights in car parks and terminal buildings have been replaced with LEDs. (Budd, Budd, and Ison 2015)

Since its operations in 1994, Kansai International Airport has strived to make a pollution-free airport a reality. Looking at the history of Kansai International Airport, it can be seen that it attaches importance to waste management by focusing on sustainable environmental management. The main goal of Kansai International Airport is to be an "environmentally advanced airport" that is both earth- and human-friendly. More importantly, the airport aims to be an increasingly pollution-free airport that co-exists with the local Kansai region. (Baxter, Srisaeng, and Wild 2018)

Combustible waste is burned in the airport's incinerator. The airport's incineration plant is designed with a fluidized bed furnace and is well-equipped with anti-pollution equipment. Flu gas treatment equipment includes a filter-type precipitator that uses catalysts to remove nitrogen oxides (NOX) and moisture-adjusted fly ash stabilizing equipment. Additionally, care has been taken to ensure the incinerator is compatible with the local environment. In addition, a garbage disposal has been installed, which significantly increases the incineration efficiency of the incinerator. (Baxter, Srisaeng, and Wild 2018)

### **3.5. APPLICATIONS RELATED TO WILDLIFE PROTECTION**

Historically, certain airport operators have had many practices regarding certain wildlife habitats, particularly during the construction a new airport or airport expansion. While the new Hong Kong Airport was built, a 1 km buffer zone was established to prevent the dolphins' sensitive hearing from being damaged during blasting operations. However, 3,000 new bat houses were established for Indiana bats at the Indianapolis Airport due to a new maintenance building that displaced bats. Airport expansion activities were halted at Perth Airport when a rare colony of western bog turtles was discovered. The deaths of four manatees below the runway at Miami Airport have forced the airport

operator to act to protect the endangered species. Badger dams at Manchester Airport had to be relocated, and a rare breed of lizard was protected while a second runway was built. At Oslo Gardermoen airport, a bridge had to be built to prevent the 1,000 deer migrating each year from entering the airport approach roads. The protected area may be affected by airport development. For example, there are cases where historic buildings are located within the area allocated for airport expansion. At Manchester and Copenhagen Airports, conservation areas have caused buildings to be moved to other locations. Airports can radically change the landscape by disrupting the ecosystem. To compensate for this, some airports have developed various applications.

An example is the 'green areas' project at Athens airport, which covers 6 hectares and consists of walking paths, playgrounds and cultivated areas. Detroit Airport has created a wetland, and Southwest Florida Airport has established a wilderness area. (Graham 2018)

It engages with various stakeholders, including government agencies, wildlife groups, and heating companies, to implement monitoring and evaluation programs to monitor and manage plant and animal species within the airport habitat. The area around Stansted Airport is famous for its wide variety of flora and fauna, including deer, brown hares, bee orchids, and the ancient settlement of Hatfield Forest. The airport is working with some landscape management experts and consultant environmentalists to develop strategies that include nature conservation and management of around 70 hectares of pasture as a dirt runway and taxiways close to the airport site of special ecological value. The airport has also developed a project to increase walking and cycling paths. A similar project has been carried out at East Midlands Airport. Here, with the help of volunteers, an 'airport path' was established as a walking and cycling path around the airport. While paying attention to the ecological impacts of airports, it is also important that airports balance these issues with the efficient and, most importantly, safe operation of the aircraft. This obligation comes to the fore with the bird problem and the threat of bird migration routes that can pose a significant danger to aircraft. Measures to improve biodiversity should not inadvertently attract birds (or other potentially dangerous wildlife) to the airport site. The airport also keeps detailed records of bird migration

routes to monitor bird behaviour and develop appropriate management plans for species. (Budd, Budd, and Ison 2015)



#### 4. CARBON EMISSION REDUCTION PRACTICES

The technologies developed will not be the only means to address environmental factors from airport construction and operations. The sustainability policies determined in the airports affect the life quality of the next generations. The international and national airport industry and relevant institutions have adopted more holistic sustainability approaches. By doing so, they aim to fully integrate economic viability, operational efficiency, liveability, natural resource conservation and social responsibility. Sustainable airports should set an example and be the leader in the transition of environmental ethics of the region that they belong to. (Oto and Çobanağlu 2012)

In parallel with the development of commercial activities, the demand for air transport, which stands out among the transport modes with its speed and safety advantage, has increased, and the capacity of air transport has grown. New airline companies are starting their activities while new airports are being built to meet the increasing air traffic. In addition to the economic gains it provides, airports cause environmental problems due to the fossil fuel use of aircraft and the activities at the airport. To reduce the negative environmental impacts of aviation activities, “DGCA developed Green Airport” projects and “Carbon-free Airport” projects were developed by GDSAA - General Directorate of State Airports Authority.

The airport sustainability concept in Turkey is relatively new, and Build Operate Transfer (BOT) has played an important role in its development. In Turkey, the airport industry is moving towards more holistic sustainability approaches to ensure the full integrity of economic viability, operational efficiency, liveability, natural resource conservation and social responsibility. Current sustainability trends at Turkish airports include the Green Airport Project by the Turkish Ministry of Transportation’s General Directorate of Civil Aviation (SHGM/ DGCA) and the Green Airport Manual. (Oto and Çobanağlu 2012)

Airports have the ability, tools and opportunities to invest in sustainable development to become sustainable by reducing carbon emissions, one of their biggest environmental impacts. In particular, renewable energy can be an alternative scenario to eliminate the dilemma between high growth drive and concern about environmental damage in air transportation. Renewable energy increases the options available for airports' energy

needs, reducing emissions and environmental footprint. Apart from this, airports are included in the Airport Carbon Accreditation Program, a global carbon management program, and try to establish a balance between carbon emission amounts and growing airline transportation, and even carry out sustainability studies with a zero-emission target.

#### **4.1. CARBON EMISSION REDUCTION PRACTICES IN THE WORLD**

A growing air transport industry is representative of several economic benefits, including increased global trade and the easy movement of people and freight across borders. In addition, the industry employs many people around the world. Despite the many economic and social benefits of the aviation sector, the sector also has negative effects that should not be ignored.

A growing air transport industry is representative of several economic benefits, including increased global trade and the easy movement of people and freight across borders. In addition, the industry employs approximately 65.5 million people worldwide. Despite the many economic and social benefits of the aviation sector, the sector also has negative effects that should not be ignored. The interdependence of aircraft technological systems, the global reach of the aviation transportation industry, and the uncertainty surrounding potential atmospheric impacts have made defining the relationship between aviation and environmental impact difficult. Air travel continues to experience the fastest growth of all transportation modes. Although the energy intensity of the aviation transportation system continues to decrease, fuel use and total emissions are increasing steadily. This trend, representing a conflict between growth and environmental impact, has motivated the aircraft manufacturing and airline industries, the scientific community, and governmental bodies to consider acceptable emissions reduction. (J. J. Lee et al. 2001)

Through a combination of quieter aircraft development and noise reduction operating procedures, most airports have managed to control most of the problems caused by aircraft noise. However, in recent years, aircraft emissions have emerged as a growing environmental threat. It is known that the constant emission of greenhouse gases is one of the causes of global climate change. This situation creates irreversible problems, such

as the destruction of the ecosystem. Companies must operate sustainably to minimize the sector's negative impacts and continue increasing its benefits to society.

The anthropogenic negative effects on the Earth's climate are one of the most important environmental issues the aviation industry has faced. Emissions from aircraft, both at ground level and at altitude, can give rise to numerous negative effects on air quality, climate and the ozone layer. The gases and particles emitted from aircraft engines can cause harmful effects in different stages of the flight, from the ground to higher altitudes. At ground level, where airports are involved, one of the adverse effects of aircraft emissions is the degradation of air quality, which may directly impact human health. According to the environmental reports and assessments, particulate matters, NO<sub>x</sub>, HC, SO<sub>x</sub>, and CO from aircraft engine emissions can affect air quality, health and welfare. Aviation-related emissions at the ground level and airport vicinities are not limited to aircraft emissions; ground support equipment is another contributor. Thus, this means that air pollution from airport ground-service vehicles and the airport surface access systems should be considered part of the environmental burden of the airports.(Sameh and Scavuzzi 2016)

#### **4.1.1. EMISSIONS**

Sharing responsibility for the global commons has long been a growing concern in the globalizing world economy. Since 1920, more than 140 international environmental agreements have been concluded to combat global environmental adverse factors. Many of these have constituted successful multinational efforts to protect globally valuable ecosystems and control some harmful emissions.(Rodoplu and Turan Erdoğan 2022)

Environmental pollution has reached a troublesome amount all over the world. Economic development, industrialization, and urbanization have caused an increase in greenhouse emissions. Thus, carbon dioxide and other toxic gases are released into the atmosphere, polluting the air and increasing its temperature. Moreover, this has become the reason for the depletion of the ozone layer, which significantly affects people's daily lives.(Sarfraz et al. 2021)

In the context of global greenhouse gas (GHG) emissions, the share of fossil carbon dioxide, CO<sub>2</sub>, dominates, and it has been continuously increasing throughout the period 1990–2015, from 32.8 to 49.1 Gt of CO<sub>2</sub> equivalent per year, with a total increase in total GHG emissions of about 50%. The world's largest CO<sub>2</sub> emitters are China, the United States, India, the EU28, Russia, and Japan, which together accounted for 51% of the population in 2018, 65% of global gross domestic production, 80% of total global consumption of fossil fuels, and emitted 67.5% of total global fossil CO<sub>2</sub>. (Cetković et al. 2021)

Lower prices and increased economic activity in China, Southeast Asia, and the Middle East are the key drivers for this growth. The number of jet aircraft in service and the total passenger kilometres flown are also expected to double in the next 20 years. (Takriti, Pavlenko, and Searle 2017)

#### **4.1.2. GREENHOUSE GAS EMISSIONS FROM AVIATION**

The rapid progress made in civil aviation infrastructure benefits the whole world, and airports, as the major infrastructure, inevitably leave more of a “carbon footprint”. By calculation, the global air transport industry contributes about 2% of the global total carbon emission, while airport activities take up about 5%. As people are more concerned about carbon emission reduction, eco-friendly airports have become the common goal of global airport development. (Li, Zhang, and Lei 2019)

For climate change, the primary concerns are emissions of CO<sub>2</sub>, NO<sub>x</sub> and nvPM. Also of concern are persistent contrails, which lead to cirrus clouds when the atmosphere is ice-supersaturated. A significant complication arises because the emissions (or their subsequent transformations) have different residence times in the atmosphere. They also have different radiative forcing values, measuring the associated heating or cooling effect. The combination of several factors determines the overall impact on global surface temperature over a given timescale. These factors are quantities emitted, residence time, radiative forcing, and the temperature response profile of a particular pollutant. CO<sub>2</sub> is of particular concern because of its exceptionally long residence time (thousands of years). The radiative forcing value for aircraft NO<sub>x</sub> per unit emission is now considered lower than the two previous Independent Expert NO<sub>x</sub> reviews, but it remains of concern. Although nvPM is implicated in cloud formation, the processes are

poorly understood. Contrails, leading to cirrus clouds and aircraft-induced cloudiness, have large RF impacts but are short-lived (hours). There is high confidence in the estimates of global warming due to CO<sub>2</sub>, whereas for all other emissions, there is a significant level of uncertainty that needs to be reduced. (ICAO 2019)

Other non-CO<sub>2</sub> factors, such as ozone, methane, water vapour, or aerosols, also affect global warming. Aircraft emit nitrogen oxides (NO<sub>x</sub>), which form ozone when emitted at cruise altitudes. Aircraft also trigger the formation of condensation trails, or contrails, which are suspected of enhancing the formation of cirrus clouds, which add to the overall global warming effect. These effects are estimated to be about two to four times greater than those of aviation's CO<sub>2</sub> alone. (ICAO 2019)

The contribution of jet fuel to the total energy consumption in transport is expected to increase from 11% to 14% in the next 20 years. Fuel combustion generates more than 99% of airline emissions, and the emissions from international aviation, which account for approximately 65% of global aviation fuel consumption, are expected to increase to 1.1–1.5 billion tonnes of CO<sub>2</sub> by 2035. (Takriti, Pavlenko, and Searle 2017)

Adverse human-caused impacts on the Earth's climate are one of the aviation industry's most significant environmental challenges. Emissions resulting from ground operation processes involving airports, greenhouse gases and particles emitted from aircraft engines during the entire navigation process directly affect human health as they deteriorate air quality.

Aviation-related emissions at the ground level and airport vicinities are not limited to aircraft emissions; ground support equipment is another contributor. Therefore, this means that air pollution from airport ground service vehicles and the airport surface access systems should be considered part of the environmental burden of the airports. (Sameh and Scavuzzi 2016)

While aviation efficiencies have steadily increased over the past several decades, demand has grown more rapidly than efficiency improvements, causing GHG emissions from these subsectors to continue to increase. (Mccollum, Gould, and Greene 2009)

Near-term, medium-term, and long-term mitigation options are available to slow the growth of aviation energy consumption and GHG emissions. (Mccollum, Gould, and Greene 2009)

These measures include improvements in aircraft technology, such as reducing propulsion efficiency, drag and structural weight; operational improvements, such as more efficient flight paths; and market-based measures.

A “green airline” is a relatively new concept and represents airline initiatives to support sustainable social and economic development without impacting the local and global environment. A “green airline” aims to provide the green society with a transport system that reduces its carbon footprint, uses renewable energy, and produces less carbon dioxide (CO<sub>2</sub>) emissions and other harmful pollutants. The concept of “greening” aviation firms, such as airlines, can be best linked to their emissions reduction into the atmosphere to the point where they achieve near carbon neutrality. Carbon neutrality means every ton of anthropogenic carbon dioxide (CO<sub>2</sub>) emitted is compensated with an equivalent amount of carbon dioxide (CO<sub>2</sub>) removed. Furthermore, adopting a green operations strategy by an airline is a combination of green operational actions undertaken to acknowledge green indicators. (Baxter 2021c)

As people become more concerned with reducing carbon emissions, environmentally friendly airports have become a common goal of global airport development. Some countries, regions and international organizations have implemented carbon emission reduction regulations and programs.

#### **4.1.3. REGULATIONS REGARDING CARBON EMISSIONS**

Aviation’s contribution to climate change is minor but still considerable. ICAO/CAEP’s initial estimate of the total volume of CO<sub>2</sub> emissions derived from the industry (both domestic and international) was 600 million tonnes in 2006. Aviation accounts for about 2% of total global CO<sub>2</sub> emissions and about 12% of the CO<sub>2</sub> emissions among all transportation sources. (Şahinkaya 2015)

The aviation sector is responsible for only 3% of the anthropogenic carbon emissions in the world. However, this transport mode – which demands 3-fold more energy per capita than other collective modes, such as railway and bus transportation – is

exclusively supplied by fossil fuels, and it has grown at an impressive rate of 7.5% per year in the last decade in the world. (Capaz 2021)

In line with the global aims to reduce Greenhouse Gas (GHG) emissions and the dependency on fossil fuels, the decarbonization of the aviation sector – typically based on cost-intensive projects with rigorous quality control – is challenging. (Capaz 2021)

Airports' carbon footprint is one of the crucial issues in terms of global warming. Airport Council International (ACI) owns the “Airport Carbon Accreditation” program. This program enables airports to implement carbon management processes. It consists of four different scheme levels. The entry point to the scheme recognizes that an airport is quantifying its carbon footprint. The overall aim of the scheme is to manage carbon emissions by managing energy during airport operations. (Şahinkaya 2015)

The carbon footprint of airports is considered the main subject of "Environmental Sustainability of Airports".

ICAO has set some ambitious goals for decarbonizing international flights in the competitive aviation industry market, which is highly dependent on fossil fuels subject to price volatility, while also reporting average growth rates over the last few years. In general, the ICAO's goals are as follows (Capaz 2021)

- Improve CO<sub>2</sub> efficiency by an average of 1.5% per year from 2009 until 2020;
- Achieve carbon-neutral growth by 2020;
- Reduce carbon emissions by 50% in 2050 compared to 2005 levels.

#### **4.1.3.1. EUROPEAN UNION EMISSIONS TRADING SYSTEM (EU ETS REGULATIONS)**

The European Union Emission Trading System is a milestone of the EU's policy to fight climate change, and it aims to reduce greenhouse gas emissions cost-effectively. It creates a market which provides carbon trade. EU ETS Regulations work on the “cap and trade” principle. A cap is set on the total amount of certain greenhouse gases that installations covered by the system can emit. The cap is reduced over time so that total emissions fall. Within the cap, companies receive or buy emission allowances, which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects worldwide. The limit on the total

number of allowances available ensures that they have a value, according to the European Commission (2018).

The EU ETS started in 2005 and includes European Union member states and European Economic Area countries such as Norway, Iceland and Liechtenstein. The system operates as a quota-free emissions trading system and covers the following main sectors:

- Energy Sector: Activities related to energy production, such as electricity generation and refineries.
- Industrial Sector: Energy-intensive industries such as iron and steel, cement, glass, ceramics and paper.
- Aviation Sector: For international flights.

The main principle of the EU ETS is to limit emission permits and make these permits transferable through trade. Participating businesses receive freely circulating emissions units over a specified period. Total emissions in the relevant sector are limited to the units of emissions that must be reduced to achieve a specified target. Businesses can sell excess emissions units or purchase missing emissions units.

This system aims to support efforts to reduce greenhouse gas emissions and promote emissions reduction. However, the amount of quota in the system, emission targets and other details may change over time. The EU ETS aims to drive more sustainable practices in various European industry sectors.

According to initial rules, each member state had to submit National Allocation Plans, which detailed a country-wide reduction target and a list of regulated installations. After the approval of these plans by the European Commission, installations received permits that could be traded. By the end of April each year, installations that hold too few permits to cover their emissions need to buy additional permits from the market or pay a penalty of €40 (2005 to 2007) or €100 (since 2008) for each ton of carbon they fall short.(Bayer and Aklin 2020)

The system supports stakeholders in the EU in finding cost-effective ways to reduce emissions. It is considered an important approach for the EU to reduce greenhouse gas emissions by 80-95% by 2050 compared to 1990. The European Union Emissions Trading System (EU ETS) is the cornerstone of European climate policy to combat climate

change. It aims to reduce greenhouse gas emissions cost-effectively by allowing relevant companies to trade emission permits.

The EU ETS operates in phases. From 2005 to 2007, the first phase was a pilot to get the system up and running. The second phase covered the Kyoto Protocol commitment period, 2008 to 2012. Finally, the third phase, which is currently ongoing, started in 2013 and will last until 2020. During the first phase, about 12,000 installations received permits to emit roughly 2.2 billion tons across the then 25 EU members, covering almost 50% of the EU's total emissions.(Bayer and Aklin 2020)

The fourth trading period from 2021 to 2030 will also further strengthen reduction targets and limit the use of international carbon credits.(Bayer and Aklin 2020)

Pollution quotas form the basis of emissions trading. Certain pollution quotas are given to facilities by the relevant government agency. Facilities that cause carbon dioxide emissions above their allocated quota are penalized 100 Euros for 1 ton of carbon dioxide. However, facilities within the scope of ETS can buy and sell emissions. (Algan 2011)

In other words, while ETS imposes fines on facilities that produce more greenhouse gases, it offers the right to trade those that use less.

Originally, almost all flights from or to EEA airports were planned to be subject to the EU ETS ("full scope"). However, in response to strong international opposition and to ease the ongoing CORSIA negotiations at the ICAO level, the EU's "stop the clock" decision eventually reduced the scheme's scope to intra-EEA traffic. The resulting "stop the clock" or "reduced scope" regime was originally planned to last until 2016 only. However, by regulation (EU) 2017/2392 and to allow for a review of the CORSIA implementation, the EU decided to maintain this framework until 31 December 2023. In case of no revision, the regulation would provide for a return to the original, full-scope regime from 2024 onwards.(Maertens et al. 2019)

The EU ETS started in 2005 and aimed to achieve overall emissions reductions cost-effectively by using tradeable emissions allowances to steer emissions reductions to sectors and businesses where they can be implemented at the lowest cost. The system covers over 12,000 energy and manufacturing plants in the EU. Since 2012, parts of the

aviation sector have been included in the EU ETS, meaning that affected airlines must have emission allowances covering their annual emissions—the aviation part of the EU ETS covers flights where both take-off and landing are within the EU. Initially, the EU planned to include all flights even if the take-off or landing point was outside the EU (referred to as full-scope). However, after protests from mainly the United States and China, the system was modified to a reduced scope. This 'stop-the-clock' approach is temporary, and if no new decision is made, 'full scope' will start in 2024. The allowances specifically for airlines are called European Union Aviation Allowances (EUAA). Airlines can purchase regular European Union Allowances (EUA) if they need additional allowances. The allowances issued for 2013–2020 correspond to 95% of 2008–2012 emissions. From 2021 onwards, there will be a linear annual reduction until 2064, when no additional EUAA allowances will be issued (the last EUA will be issued in 2057). The possibility of applying the 'full scope' of the EU ETS put pressure on ICAO, and in 2016, a decision was made by its 192 countries to introduce CORSIA, which aims to facilitate carbon-neutral growth for international aviation from 2020. (Larsson et al. 2019)

#### **4.1.3.2. KYOTO PROTOCOL**

The Kyoto Protocol is an agreement which is accepted internationally, and it is linked to the United Nations Framework Convention on Climate Change UNFCCC (1997). It aims to reduce carbon emissions as well as other agreements that are mentioned. The Kyoto Protocol was accepted by more than 150 countries in Kyoto, Japan, on 11 December 1997, but it went into operation on 16 February 2005. Kyoto Protocol (1997) aims to reduce emissions that:

- a. Improved technology
- b. Nation-created sinks
- c. Tradable permits for emissions

But sometimes, it is less expensive to buy carbon emission permits than to decrease emissions, and there is no credit for conservation, even though existing forests contain 40% of terrestrial carbon. (Başar 2018)

#### **4.1.3.3. CARBON OFFSETTING AND REDUCTION SCHEME IN INTERNATIONAL AVIATION (CORSIA)**

The International Civil Aviation Organization (ICAO) develops internationally harmonized standards and recommended practices and guidance policies to support a safe, secure and environmentally sustainable civil aviation sector. Environmental protection is one of ICAO's strategic objectives, and its work contributes to the UN's sustainable development goals and related supporting targets.

The preferred choice for regulating international activities like aviation is international policy instruments, of which a global carbon tax on jet fuel would probably be the most efficient. However, jet fuel for international aviation is exempt from taxes. The Chicago Convention on International Civil Aviation from 1944 is often incorrectly stated as generally forbidding the taxation of jet fuel. Still, it only prohibits taxing the fuel in the tanks of arriving aircraft. However, a resolution from ICAO (1993) states that '... the fuel, lubricants and other consumable technical supplies taken on board for consumption during the flight shall be furnished exempt from all customs and other duties ...'. Therefore, this can theoretically be changed, but most member states do not support this. ICAO has instead decided to implement a global scheme for carbon offsetting (CORSIA). (Larsson et al. 2019)

Almost 20 years after Kyoto, the 39th ICAO Assembly eventually adopted Resolution A39-3 on a formalized GMBM system in the form of the offsetting scheme CORSIA, aiming to support the goal of carbon-neutral growth in international aviation from 2020 onwards. (Maertens et al. 2019)

During the 39th ICAO Assembly in October 2016, 65 countries, including the United States, China and all EU countries, they were recognized that environmental protection is critically important and signed the International Aviation Program for voluntary participation in the Carbon Offsetting and Reduction Program between 2021 and 2026. The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) was created. CORSIA is a carbon offset scheme and the first global measure covering an entire industrial sector.

CORSIA is a global market-based measure system to offset international aviation emissions growth if in-sector measures—technological improvements, operational efficiency measures, and alternative aviation fuels—are insufficient to cap emissions.(Takriti, Pavlenko, and Searle 2017)

According to the CORSIA guidelines, the carbon offsetting requirements, calculated from the annual carbon emissions of aeroplane operators and their growth factor over the last few years, could be achieved by purchasing emission units (carbon credits) in the carbon market. Furthermore, the offsetting requirements can be discounted by GHG emission reductions from using sustainable aviation fuels (SAF), which have shown to be a strategic means of achieving carbon targets and reducing the sector’s dependency on fossil fuels. (Capaz 2021)

The scheme created by ICAO is a global compensation mechanism called CORSIA - Carbon Offsetting and Reduction Scheme in International Aviation. CORSIA aims to help address the annual increase in total CO<sub>2</sub> emissions from international civil aviation above the level set out for the year 2020. CORSIA has been adopted to complement a broader package of measures to help ICAO achieve its ambitious carbon-neutral growth target from 2020 and reduce net emissions from aviation by 50% compared to 2005 levels by 2050. CORSIA relies on using emission units in the carbon market to compensate for CO<sub>2</sub> emissions that cannot be reduced through technological and operational improvements or sustainable aviation fuels.(Kováčik, Lusiak, and Novák 2021)

The CORSIA approach compares total CO<sub>2</sub> emissions for a given year (from 2021 onwards) with a baseline CO<sub>2</sub> emission level, defined as the average of the 2019 and 2020 emissions from international aviation covered by CORSIA. In the coming years, any international CO<sub>2</sub> emissions from aviation covered by CORSIA that exceed the baseline will constitute compensation requirements. All States whose airlines operate international flights must develop an MRV monitoring, reporting and verification system for CO<sub>2</sub> emissions from international flights from 1 January 2019. The requirement to monitor, report and verify CO<sub>2</sub> emissions from international aviation is independent of the compensation requirements, and the data reported by the States will be used to calculate the CORSIA baseline and compensation claims for airlines.

From 1 January 2019, all carriers are required to report their CO<sub>2</sub> emissions annually. All airlines flying international routes must monitor, report and verify their CO<sub>2</sub> emissions.

CORSIA will be implemented in three phases, starting with the participation of States in the CORSIA compensation voluntarily (pilot phase and first phase), followed by the participation of all States except those exempted from compensation requirements as follows (Kováčik, Lusiak, and Novák 2021):

- pilot phase: from 2021 to 2023
- first phase: from 2024 to 2026
- second phase: from 2027 to 2035

Firstly, worldwide air transport is split into flights within and outside CORSIA's scope. The UNFCCC Paris Agreement covers domestic flight emissions and does not fall under CORSIA. Moreover, ICAO is only responsible for international air traffic. In addition, emissions from domestic flights, but also emissions from small operators (<10,000 t CO<sub>2</sub> p.a.), small aircraft (<5.7 t MTOM), and rotorcraft, and from humanitarian, medical, and firefighting operations do not fall under the scheme (Assembly Resolution A39-3). Military and governmental aviation are excluded as they are not subject to the Chicago Convention. (Maertens et al. 2019)

The COVID-19 pandemic has caused the world to experience unprecedented problems, including the implementation of CORSIA in 2020. CORSIA's sectoral baseline is defined as the average of total CO<sub>2</sub> emissions for 2019 and 2020 on the routes CORSIA calculates in a given year starting from 2021. Therefore, the expected reduction of CO<sub>2</sub> emissions by international aviation in 2020 due to the COVID-19 pandemic will reduce the CORSIA baseline relative to the non-COVID-19 plan, and it will not be possible to obtain accurate emissions measurements in 2020. The ICAO Council decided that 2020 emissions should not be used to protect airlines against undue economic burden on aircraft operators and that 2019 emissions should be used for 2020 emissions. (Wozny et al. 2022)

#### **4.1.4. BENEFITS OF REDUCING CARBON EMISSIONS AT AIRPORTS**

In the global aviation industry, passenger and air cargo services are provided within a value chain with the key stakeholders comprising aircraft manufacturers, leasing firms, airlines, airports, service providers for air traffic control, aircraft maintenance

organizations, flight catering providers, aircraft refuellers, ground handling agents, global distribution systems (GDS), travel agents, tour operators, and air freight forwarders. Airports play a fundamental role in the value of air transport by providing the critical infrastructure, such as passenger terminals and runways, necessary to facilitate passenger and air cargo movement. Accordingly, airports act as the critical interface between surface-based and air transport modes. Despite the significant social and economic benefits of air transport services, such services harm the environment. Noise, air and water pollution, and natural resource consumption at an airport all adversely impact the environment. In addressing their environmental impact concerns, airports increasingly try to become “green” or more environmentally friendly. A "green airport" has a minimal impact on the environment and endeavours to become a carbon-neutral facility in terms of carbon emissions, aiming to produce zero greenhouse gas emissions. (Baxter 2021b)

Airports, which provide the infrastructure for ground operations required for air transportation, are important stakeholders. Increasing demand for air transportation paves the way for growth in the aviation industry. This situation increases the need for airports and encourages the growth of existing airports or the construction of new ones. Airports serving more flights with increasing demands and capacity increases expose the environment to more carbon dioxide emissions, making it difficult to realize the concept of sustainable development. (Rodoplu and Turan Erdoğan 2022)

Today, planners take an environmentally friendly approach to airport designs. Airports are designed from an environmental perspective, considering ecological and natural life, energy consumption, climate change, noise, land use, wastewater, underground fuel tanks, anti-icing liquid and solid chemicals. Trying to reduce such environmental impacts while aiming for air transportation to be in a growth trend is the biggest challenge faced by aviation authorities. (Rodoplu and Turan Erdoğan 2022)

To prevent the negative environmental impacts arising from the activities of airports, one of the busiest transportation centres, and to control the situation, public awareness and regulatory practices of the government and local authorities are of great importance. (Rodoplu and Turan Erdoğan 2022)

Sustainable energy management practices are becoming more important for the increasing number of airports with high environmental impacts and extremely energy-intensive areas. In this context, many airports are turning to alternative energy sources to reduce environmental impacts, especially energy consumption. Solar energy, built in large areas with systems that can be easily adapted to airports, is the most widely used alternative energy source worldwide. (Rodoplu and Dağlı 2021)

Energy efficiency is a key issue for the energy policies of most industrialized countries due to its central role in economic, technological and social growth. Today, given the high need for energy resources, the importance of environmental sustainability, and the economic downturn, expectations for progress in energy efficiency are increasing. Energy efficiency is considered a fundamental element for achieving environmental goals, optimizing the expenditure required to meet energy requirements and achieving adequate levels of energy security. (Rodoplu and Dağlı 2021)

On the other hand, the energy consumption of the air transportation industry is increasing faster than that of other industries, which causes environmental pollution. (Rodoplu and Dağlı 2021)

Airports are extremely energy-intensive areas. Thus, this is due to the large buildings (both passenger terminals and non-passenger areas) equipped with heating and air-conditioning systems, the high-power demand for lighting and electric equipment, and the energy requirements from the many facilities within the airport precinct. Air conditioning systems represent a substantial portion of the airport's energy consumption. Around 70% of the energy consumed in airport terminal buildings is utilized for air conditioning, cooling and heat. This rate can be higher in countries with a cold climate. (Baxter, Srisaeng, and Wild 2019)

In addition to providing the electrical energy required for air transport operations, electrical energy is also required for airport buildings, aircraft hangers, and other airport facilities. Thus, energy management, which includes heating, ventilation, air conditioning, and lighting, is extremely critical for airports. (Baxter, Srisaeng, and Wild 2019)

Airports require a guaranteed, appropriately priced, and secure energy supply to meet peak demand from their service partners and passengers and optimise their operational capacity. Maintaining an ambient temperature and air quality within airport passenger terminals to ensure passenger comfort typically represents the most significant contribution to energy usage and management at most airports. To reduce their long-term operating costs and ensure that energy demand can be satisfied when it arises, airports focus on energy-conservation measures in terminal buildings' design (and operations). Some airports have also developed and operate their power-generation systems. Furthermore, airports often work closely with tenants, concessionaires, and service partners to reduce energy consumption by introducing low-energy equipment and systems. (Baxter, Wild, and Sabatini 2014)

Airport terminals are subject to frequent internal change and external growth in response to the increasing passenger volumes and the evolving nature of aircraft design. The ensuing increase in energy demand has turned them into very energy-intensive environments and one of our planet's greatest energy-consuming centres per square kilometre. The energy use is de-facto comparable to that of small cities. The typical electrical energy used in a major airport lies between 100 and 300 GWh/year, corresponding to the consumption of 30,000 to 100,000 households. Terminal buildings use large amounts of energy for lighting, heating, ventilation, air conditioning, and conveyance systems.(Kotopouleas and Nikolopoulou 2016)

The first step is to conduct an energy audit to understand how much energy is used and how the usage compares to that of similar buildings and other facilities to improve airport energy efficiency. An energy audit comprehensively evaluates a building or facility's electricity, water, gas and other services. Many airports undertake energy audits and have effective building management systems to ensure optimum control of such systems. To reduce long-term operating costs and ensure that energy demand is met as it arises, airports are now focusing more on energy-saving measures in the design (and operation) of terminal buildings.(Rodoplu and Dağlı 2021)

Renewable energy could be an alternative scenario to escape the dilemma between the urge for high growth and the concern about environmental damage in air transport. Renewable energy is defined as energy from a not-depleted source comprising common

sources such as solar, wind, geothermal, hydro, and some forms of biomass. The benefit of renewable energy is that it increases the options available to airports for their energy needs. Most airports buy electricity from a power provider, making energy use a major operating cost; thus, energy efficiency is a basic cost control measure. They also provide other advantages, i.e. producing fewer emissions and reducing the environmental footprint. In addition, installing renewable energy generation technologies on-site at an airport can lower the carbon footprint with minimal impact on airport operations (e.g., solar panels on rooftops). (Nam 2019)

The major areas of energy consumption at airports are illumination (lighting), steam, heating systems, cooling systems, climate control systems, and comfort provision systems. Airports must constantly supply power annually to sustain operations and satisfy key stakeholder requirements. New renewable technologies, such as solar and wind power, can be utilised to help satisfy airports' energy demand. The use of renewable energy resources has several advantages for airports. First, these systems tend to have a low impact, and second, they provide an alternative power source to operate the airport. Renewable energy sources also produce very little waste. Using solar power photovoltaic (PV) systems at airports appears to be the most successful way of decreasing airport ground emissions. (Baxter, Srisaeng, and Wild 2019)

#### **4.1.4.1. RENEWABLE ENERGY SOURCES:**

Renewable energy sources (RES) supply 14% of world energy demand. RES includes biomass, hydropower, geothermal, solar, wind and marine energies. Renewable energy is the primary, domestic and clean or inexhaustible energy resource. (Panwar, Kaushik, and Kothari 2011)

Renewable energy sources are those resources that can be used to produce energy repeatedly, e.g., solar energy, wind energy, biomass energy, geothermal energy, etc... They are also often called alternative energy sources.(Panwar, Kaushik, and Kothari 2011)

Renewable energy sources that meet domestic energy requirements have the potential to provide energy services with zero or almost zero emissions of both air pollutants and greenhouse gases.(Panwar, Kaushik, and Kothari 2011)

Renewable energy sources can be listed as follows:(Panwar, Kaushik, and Kothari 2011)

- Solar energy,
- Wind power,
- Hydraulic (hydroelectric) energy (Hydropower)
- Geothermal energy,
- Biomass energy (including biofuel energy),

#### **A) Wind power**

Wind energy is potentially a very useful source of renewable energy for airports, again because the land-rich nature of airports provides many feasible onsite locations. However, airport safeguarding regulations may limit the practical application of building wind turbines on or near airport land for reasons of both being a physical obstacle and radar interference. Micro-turbine devices might have more practicality. (Rowlings and Walker 2008)

For example, the British Civil Aviation Authority (CAA) dictates that it be notified of any planning application for a proposed wind turbine development within a 15 km radius of any airport in its jurisdiction so that it and the aerodrome can conduct investigations and analyse any potential interference. (Rowlings and Walker 2008)

The wind power plant seen in Figure 5 meets 2% of the energy needs at Boston Logan International Airport. This way, 13 thousand dollars are saved annually, and the initial investment cost is covered in 10 years. (Akyüz 2018)



Figure 5 - Wind power plant installed at Logan International Airport  
Source: (Akyüz 2018)

### **B) Hydraulic (hydroelectric) energy: (Hydropower)**

Hydropower, the capture of the energy of moving water, has three primary types: run-of-river, tidal and wave. A typical large hydroelectric scheme is impossible in an airport context unless the airport is located near a large body of water containing usable kinetic energy potential. However, smallscale run-of-river, or similar turbine-based schemes, may be relevant to airports near rivers or streams. (Rowlings and Walker 2008)

Tidal barrage systems are environmentally complex, given the need for structural alteration to the tidal area. Tidal stream turbine systems and wave systems do not have the same environmental complexities and have proven commercial ability. The Portuguese Pelamis project is reported as the world's first commercialisation of wave energy. (Rowlings and Walker 2008)

All hydropower generation options depend heavily on the individual airport's geographic location and right-of-access to the water deployment zone. Additionally, the environmental impact of developing a hydropower system near airports would make it unsuitable for most airport situations. Some Asian airports on reclaimed land surrounded by large ocean frontages could benefit from hydropower provided all environmental sustainability criteria were met. (Rowlings and Walker 2008)

### **C) Geothermal Energy**

Geothermal energy is the energy obtained from hot water and steam from the heat accumulated deep in the ground. Since the regions where airports are located must have certain geological structures (such as hot water reserves or hot rocks), geothermal energy is more difficult than other renewable energy sources. (Akyüz 2018)

Geothermal energy is used to heat and cool the new terminal building of Thessaloniki Airport. In this way, the annual energy savings are 13,150 MWh and 7,500 for heating and cooling, respectively. Thanks to a geothermal system installed at Paris Orly Airport in 2011, 70% of the heating needs of the airport terminal building are met. In this way, it saves 9,000 tons of CO2 emissions annually. (Akyüz 2018)

### **D) Biomass Energy**

Biomass derivatives such as biogas and liquid biofuels can be purchased onsite. Biodiesel can be used to power onsite transportation devices. For example, Munich Airport, with 20 million passengers per year, has developed into a medium-sized Airport Metropolis. (Rowlings and Walker 2008)

Biogas can be an alternative to natural gas, such as a combustion source for heating (or cooling) buildings and water. Solid biomass, such as food waste, can be harvested by an airport and recycled onsite as an energy source via gasification. Such a scheme could even be expanded to include the receipt of waste from surrounding areas. Biomass energy is well suited to airport applications, and numerous airports have successfully applied this technology. (Rowlings and Walker 2008)

London's Stansted airport has installed a 2MW woodchip boiler to provide biomass-supplied heating and hot water. The system was installed in 2008 and has been reported as performing above expectations. (Rowlings 2016)

At Heathrow Airport in London, the T2 energy centre is a combined heat and power plant (CHP) powered by biomass. The biomass fuel is sourced from sustainable forests within 150 kilometres of the airport. The system has a capacity of 10 MW (LC Energy, 2014). These systems are sustainable because they maintain a closed carbon cycle with no net increase of carbon to the atmosphere and no net depletion of resources if the harvested crop is replenished. (Rowlings 2016)

Another airport in England, East Midlands, plans to fuel a terminal boiler with biomass grown onsite. Twenty-six hectares of willow trees have been planted on the airport site. (Rowlings 2016)

Aéroports de Paris 2012 installed a 14MW wood-burning boiler at Charles de Gaulle airport. It supplies 25% of the airport's heating requirements and reduces CO<sub>2</sub> emissions by 18,000 tonnes annually. (Rowlings 2016)

### **E) Solar Energy**

Solar energy is obtained from the sun, and the incoming radiation can produce heat directly in electrical or thermal systems in the photovoltaic cell. From the sun to the world every year, approximately  $1.5 \times 10^{18}$  kWh /m<sup>2</sup> is given; This value is more than 10,000 times the annual energy consumption of humanity. This fact shows that as well

as being responsible for the survival of life on Earth, sunlight is an almost inexhaustible, renewable and clean source of energy. One of the ways to transform this energy is photovoltaic (PV) modules that can be used in buildings. (Akyüz 2018)

The construction of airports in large areas, the lack of large buildings and facilities that will form a shadow around, and the establishment of PV panels due to typical horizontal structures are very suitable places. On hot and sunny days, a high amount of energy is needed due to the intense energy demand of air conditioning systems in airport terminal buildings. There is a very strong correlation between the outdoor temperature and the usability of sunlight and electricity. Considering the architectural structures of the buildings and the area width that can be used, using solar energy systems in airports is one of the smartest solutions. Reflection of sunlight from the panels can affect the controller employees, cockpit and cabin team. However, studies have shown that the reflection effect of sunlight from solar panels is less dangerous than its reflection from existing surfaces. In the airports, when determining the location of solar panels, it is necessary to exclude places that will prevent, reflect or disrupt electromagnetic signals of radio navigation systems. In addition, the places where solar panels will be installed should align with the requirements of safety rules considering the operational areas of the aircraft. Energy demand at airports in hot and sunny regions can be met, especially by solar panels in the morning. However, the main problem at the airports is that the energy produced from solar panels in the evening cannot meet the burden requested by the airport. The most suitable method for solving this problem is using energy storage technologies with solar panels. (Akyüz 2018)

Cochin International Airport in India meets all its electrical energy needs from renewable solar energy. At Cochin International Airport, there are 46,150 solar panels with an installed power of 12MW on an area of approximately 4000 m<sup>2</sup>, all of which are in the apron area. This project costs 9.3 million dollars, and the power plant is thought to be amortised in 6 years. In addition, the energy required by the drip irrigation system used in agriculture is provided by these solar panels located at the airport and vegetable production is carried out (Figure 6). (D. Yılmaz and Korkmaz 2021)



**Figure 6 - Cochin International Airport solar power plant**  
Source: (Akyüz 2018)

The solar power plant installed on the roof of the San Diego Airport parking lot, Figure 7, is a different application for installing PV modules at airports. In this respect, different regions can be considered for installing airport solar energy systems. It is aimed to meet 13% of the energy demand of Terminals 1 and 2 with the solar energy system installed at San Diego Airport. In addition, it is planned to save 8 million dollars in total energy costs. (Akyüz 2018)



**Figure 7 -Solar power plant installed on the roof of the San Diego Airport parking lot**  
Source: (Akyüz 2018)

In addition, many airports have mandatory free spaces, called sound buffer zones, which are ideal locations for solar power plants. Airport areas often satisfy these constraints, so a growing number of airport authorities are installing or planning to install large surfaces of PV panels that can produce 20MWh or more. (Baxter, Srisaeng, and Wild 2019)

Other energy-saving measures at airports include installing LED lighting in floodlights, sky bridges, street lighting, car parks, taxiways and various areas within airport terminals. Some airports have also installed motion sensors on passenger airbridges. Other energy-saving measures include installing variable speed drive pumps for the airport's recycled water treatment plant and introducing a gas-fired hot water service (with recycled water supply) to serve the airport's new bathroom facilities. Electric buses are also widely used at airports for parking and ground transportation operations. Additionally, the change in travel mode for airport surface access is interesting. In recent years, the share of public transportation usage has increased remarkably. There are direct train services and bus service connections at the airports. This practice aims to reduce emission production by reducing vehicle use. Finally, one of the most important carbon reduction measures implemented by airports has been the electrification of airport support vehicles and ground services equipment (GSE). Electrification of ground services equipment and vehicles provides environmental benefits by helping to reduce harmful emissions. Airports are working closely with their key stakeholders to implement the electrification strategy across their vehicle and bus fleet and to ensure they adopt it for GSE and ground support vehicles. Additionally, airports are incorporating the infrastructure necessary to support the electrification of ground vehicles and ground handling equipment (GSE) into the planning and designing of new airport-related developments. (Baxter 2021a)

Several organizations and programmes have been established in the global air transport industry to assist airports in reducing their carbon emissions; such programmes aid airports in establishing systems to identify, monitor, and reduce sources of air pollution. For example, the Airport Carbon Accreditation Programme is an independent programme that enforces accreditation criteria for airports annually. (Baxter, Srisaeng, and Wild 2019)

## **4.2. EVALUATION OF CARBON EMISSION REDUCTION PRACTICES WITHIN THE SCOPE OF ENVIRONMENTAL SUSTAINABILITY AT ISTANBUL AIRPORT**

### **4.2.1. DIRECTORATE GENERAL OF CIVIL AVIATION (DGCA)**

The first aviation operations in Turkey were started just in two hangars and at a small airport in Sefaköy in 1912, which is currently near the Ataturk International Airport. Turkish Civil Aviation was founded institutionally through the Turkish Aircraft Community, founded in 1925 in line with the famous quote by Ataturk, "The future is in the skies". (Şahinkaya 2015)

The first Civil Aviation Transportation began with a small fleet covering only 5 aircraft in 1933 under Turkish Air Mails. State Airlines Operation Authority was commissioned to establish civil airlines and lead transportation activities in Turkey. Civil Aviation Department, which was founded under the organizational structure of the Ministry of Transport in 1954, aimed to protect our national interests and manage our international relations regularly. With the fast development of World Civil Aviation and the significant technological progress, it was reorganized as "Directorate General of Civil Aviation" in 1987. The Directorate General of Civil Aviation achieved its autonomy financially through Law Nr. 5431 and had its current management structure. (Şahinkaya 2015)

Today, the aviation operations held in Turkey are carried out per the Turkish Civil Aviation Act Nr.2920, the Administrative and Technical Regulations issued accordingly, and the Aviation Instructions. (Şahinkaya 2015)

### **4.2.2. GREEN AIRPORT PROJECT**

To eliminate damages generated by organizations during operational activities in airports, DGCA has started a systematic effort to reduce or mitigate these in terms of environmental and human health aspects. Companies must establish an environmental management system to achieve this goal, which aligns with standards and regulations. (Şahinkaya 2015)

This system has to be applicable, well documented, sustainable, convenient to standard, and have a proper inventory report that complies with the greenhouse gas criteria. After completing these requirements, the organization is given a Green Establishment

Certificate. When all the organizations inside the airport have that Green Establishment Certificate, the Green Airport Certificate will be given. (Şahinkaya 2015)

Organizations holding Green Establishment Certificates are subject to various discounts related to registration fees and other permission documents that DGCA takes. The current deduction amount is indicated in the DGCA fee list, which is valid for organizations with a Green Establishment certificate. (Şahinkaya 2015)

#### **4.2.3. ISTANBUL AIRPORT**

Istanbul Airport, the largest infrastructure project in the history of the Republic of Turkey and its first phase opened on October 29, 2018, serves its passengers at full capacity as of April 6, 2019. Covering an area of 76.5 million square meters, the new airport attracts attention as a global transfer centre among the Asia, Africa and Europe continents. (Deveci, Ciftci, and Akyurt 2020)

The effects of the new airport on the natural environment have been examined in detail in the Environmental and Social Impact Assessment Report prepared by the IGA. It has been stated that the principles of «prevention, mitigation and remediation» in the direction of the mitigation hierarchy are adopted in the impact assessment process, including identifying mitigation and control measures. The report prepared in this context emphasizes that the new airport will cause a significant increase in greenhouse gas emissions during construction and operation and that mitigation measures should be taken. Noise maps have been prepared for the new airport, population and settlement areas to be affected according to these maps are shown.(Bas, Eren, and Paköz 2018)

The project area is located in a region where the ecological diversity of Istanbul is the highest, with natural habitats, bird migration routes, endemic plant species, important natural and plant areas, and land and water ecosystems. For this reason, it is predicted that there will be adverse effects during construction and operation. An Environmental and Social Management Plan has been prepared to reduce the most negative impacts on natural resources (ENVIRON, 2015). This plan includes mitigation, monitoring and emergency steps. For example, to monitor migratory birds, a bird radar system was established before construction began, five bird scientists were employed, a bird

database was created, and a bird management program was started (IGA, 2018). On the other hand, the IGA has put into practice the Biodiversity Action Plan in 2015, so many actions have been taken to protect biodiversity. (Bas, Eren, and Paköz 2018)

The forest asset in the project area is another important consideration. It is emphasized that the INA Project will have two main effects on forestry: loss of tree/forest assets and loss of carbon capture capacity resulting from forest loss during land preparation for construction. It is mentioned in the report that this effect is negative and high, and it is needed for the reforestation plan (IGA, 2015). The IGA commits to planting 5 saplings for each tree cut to compensate for the loss of trees. At the same time, some of the trees were moved to other public spaces. (Bas, Eren, and Paköz 2018)

In Istanbul Airport, Waste collection bins are designed with 4 cells for packaging recycling, paper recycling, glass recycling and other wastes. The wastes accumulated in the recycling bins are often collected with wheeled vehicles during the day. The collected wastes are first accepted in special containers in the waste rooms at the terminal and subjected to pre-separation. The waste ready to be shipped is sent to the sorting facility suitable for their waste classes. Organic wastes are sent directly to the compost facility. (Özbay and Gokceviz 2022)

The waste generated at the airport is categorized as organic, recyclable, and domestic, according to the present waste management plan. (Özbay and Gokceviz 2022)

The main difference between airport and urban waste management is that the separation process is carried out more effectively at the source. Organic wastes separated at source in dining halls and catering are directly sent to the composting facility. Packaging and other recyclable materials collected in recycling bins are separated according to their types in the waste separation facility with a feeding capacity of 28 tons/h and then recycled by licensed companies. On the other hand, the waste separation facility separates domestic wastes into recyclable, flammable, and biodegradable categories. (Özbay and Gokceviz 2022)

With increasing awareness of responsibility, green building certification systems have been developed in many countries to evaluate the environmental performance of buildings so that they are environmentally friendly. Certification systems developed by

independent green building associations and some research institutions and evaluating sustainable buildings under various headings involve a long-term study period, from determining the location of the architectural project to the preparation of the project, from the construction process to post-construction energy efficiency impressions, and require many disciplines to work together. In this context, these systems largely lead to the creation of awareness in the perception of green buildings and the recognition of buildings that meet the basic sustainability criteria. (Görgülü and Çelik 2021)

The LEED certification method was created by sub-working committees of the American Green Building Council (USGBC) to measure and evaluate the sustainability performances of buildings with a scoring system, classify them and create a road map for sustainable buildings. USGBC states LEED's goals are to create universal measurement standards to define green buildings. These are stated as developing a holistic building design method, creating environmental leadership in the construction industry, encouraging green competition, and increasing consumer awareness about the benefits of green building. Istanbul New Airport Terminal Building is LEED certified. (Görgülü and Çelik 2021)

#### **4.2.4. EVALUATION OF CARBON EMISSION REDUCTION PRACTICES AT ISTANBUL AIRPORT**

Since its opening, Istanbul Airport has continued its energy and greenhouse gas management efforts. Activities that cause greenhouse gas emissions are reviewed regularly, and measurement and reduction activities are carried out per international standards. (IGA 2023)

In line with the IPCC 1.5°C targets, the 2050 Net Zero road map has been determined. It is among the airports committed to “Net Zero CO<sub>2</sub> emissions”. Within the scope of efforts to reduce carbon emissions, in addition to energy efficiency activities, it continues feasibility studies for the installation and use of zero-emission technologies. It continues afforestation activities that will create a carbon sink within the scope of practices and forward-looking plans. (IGA 2023)

Additionally, it continues to invest in renewable energy resources within its net zero target. A solar panel system with a capacity of 737 KW is installed in the parking lot. With

this investment, it is planned to meet 1.5% of İGA's annual electricity consumption. (İGA 2023)

- As of December 2020, İGA Airport has met the ACI Airports Carbon Accreditation (ACA) Program requirements and has been entitled to a carbon accreditation certificate.
- In 2022, due to the carbon footprint management and reduction efforts carried out within the sustainability policy framework, the certificate, which was Level 1 within the scope of the same program, could increase to Level 3 quickly.
- It received an (A-) score in the CDP Climate Change program, which shows how companies use natural resources and natural capital, how they affect the reproduction of limited resources with their activities, and how they manage their risks in this field.

**IN 2022;**

- According to the NET Zero road map prepared in line with the IPCC 1.5°C targets, it completed 2022 with -13 % less emissions.
- There was a -21% reduction in total emissions compared to the base year, 2019
- There was a -14% reduction in total energy consumption compared to the base year of 2019

Carbon management activities are carried out with procedures prepared per the Standard 14064-1 Calculation and Reporting of Greenhouse Gas Emissions and Removals at the Establishment Level. (İGA 2023)

The year 2019 is taken as a basis for the 2050 Net Zero Emission commitment, and there are reduction targets for Scope 1 and Scope 2 emissions on the way to 2050 (İGA 2023)

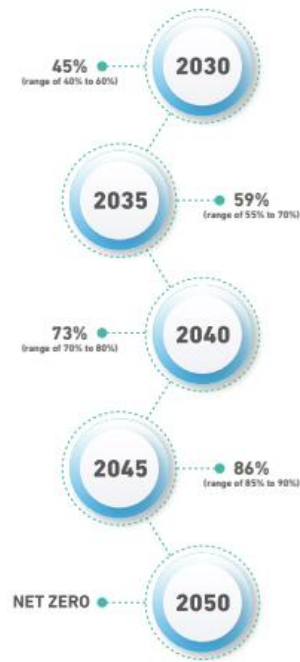


Figure 8 - Istanbul Airport's 2050 Net Zero Emission commitment  
Source: (IGA 2023)

### Scope 1 Emissions

It aims to reduce Scope 1 emissions by 45% in 2030, aligning with the 2050 Net Zero Emission target. (IGA 2023)

The main activities and practices implemented to achieve the goal are (IGA 2023)

- Mechanical system automation studies
- Building structure insulation activities
- IoT and energy efficiency data analysis applications
- Conversion to electric/hydrogen vehicles
- Route optimization of waste management vehicles
- Fuel conversions (Biodiesel fuel use)
- Increasing the amount of carbon sinks through afforestation activities in cooperation with the General Directorate of Forestry.
- It creates platforms encouraging employees through practices that increase employee awareness (ecodrone, energy efficiency activities, etc.).
- Preventing energy loss; eliminating idle energy use
- Energy efficiency practices in wastewater management and processes.
- Obtaining hot water from solar energy

**Mechanical Systems Automation Studies:**

Monitoring and controlling the buildings within the Terminal Building and External Buildings scope from the central automation system. Considering the outside air temperature and humidity, it tries to provide the most efficient conditions. (IGA 2023)

**Vehicle Conversions:** 5% of the vehicle fleet comprises electric vehicles.

Currently, 5 passenger vehicles and 31 work machines (platforms, pallet trucks and forklifts) are electric. In addition, 564 electric vehicles (electric bicycles, scooters, gingers, wheelchairs, buggies, etc.) belonging to İGA and other stakeholders are used in the terminal building. (IGA 2023)

The number of electric vehicle charging stations throughout Istanbul Airport is increasing daily. Currently, there are 6 DC charging stations with a capacity of 60 KW, 1 DC charging station with a capacity of 50 KW, 6 AC charging stations and 20 DC charging stations for electric Buggy vehicles located in the terminal building. (IGA 2023)

**Afforestation Works:** The ongoing afforestation works at Istanbul Airport are expected to be a significant carbon footprint sink in the medium and long term. The afforestation activities will create approximately 1,258,554 tons of CO<sub>2</sub> sinks for 25 years. (IGA 2023)

**Scope 2 Emissions**

It aims to reduce Scope 2 emissions by 45% in 2030, aligning with the 2050 Net Zero Emission target. (IGA 2023)

Main activities and practices implemented to achieve the goal (IGA 2023)

- Energy Management System Activities
- Lighting automation system
- IoT and Energy Efficiency Data Analysis Applications
- Green energy purchases (YEK-G)
- Installation of Solar Panels

**IoT and Energy Efficiency Applications:** Continuous monitoring of alarm/status information is provided by remote monitoring of all end points using Wireless IoT and Big Data. IoT technology will be an important tool on the path to net zero. (IGA 2023)

- Lift, Escalator, and Travelator (LET) Monitoring System
- Energy monitoring system
- Meter-reading System
- SCADA System
- Mechanical Automation System
- Lighting Automation System
- Chlorine Measurement System
- Heat and Humidity Monitoring System
- Automatic Landscape Irrigation Monitoring and Control System
- Drainage Pump Tracking System
- Wastewater Pumping Station Monitoring System
- Solid Waste Tracking and Route Optimization

**Solar Panel Installations:** Solar panel installations are among the clean energy sources evaluated to achieve the net zero target. Work continues on solar energy projects. (IGA 2023)

**Green Energy Purchases:** The YEK-G certificate is recognized by the ACI Carbon Accreditation Program. Therefore, purchasing renewable energy with the YEK-G certificate in line with the performance criteria in the 2050 NET Zero road map has an important place. (IGA 2023)

### **Scope 3 Emissions**

Efficiency activities, stakeholder auditing, training, and information activities carried out within the scope of the Stakeholder Management Plan serve to improve Scope 3 emissions. Scope 3 emissions are monitored per the ACI Carbon Accreditation Program Stakeholder Management Plan. (IGA 2023)

Examples of activities and practices that will benefit from reducing Scope 3 emissions (IGA 2023)

- Collaborating with Eurocontrol to conduct joint initiatives such as Additional Taxi Time and Additional AS-MA Time
- Implementation of A-SMGC Level 4 Follow the Greens integration studies
- APU restrictions for aircraft

- Optimizing the route and frequency of transportation provided by public transportation according to passenger density.

## **Zero Waste**

### **Solid Waste Management**

İGA is the first airport in Turkey to receive the Zero Waste Certificate. In this context, it separates all waste into recycling or recovery. (IGA 2023)

What is being done:

**Waste reduction:** First of all, efforts are made to minimize waste. It strives to spread Zero Waste awareness among its stakeholders. It regularly monitors the waste-related key performance indicators of all waste-related companies. It involves its stakeholders in waste reduction activities through projects, inspections and training. (IGA 2023)

**Collection:** With field operation teams, all airport 3rd party companies, tenants, public buildings and İGA's wastes in 5 categories (Paper-cardboard, Packaging, Glass, Organic, Domestic) and other non-hazardous and all hazardous wastes of İGA are collected for final return from the source. It provides 24/7 control by recording up to the point of recovery or disposal. (IGA 2023)

**Segregation:** The Waste Management System strives to recycle waste through source and semi-automatic separation practices. It strives to increase the current 34% recycling rate day by day. (IGA 2023)

It weighs all waste coming to the Solid Waste Collection and Separation Facility and separates it into a semi-automatic separation system. After weighing, other hazardous and non-hazardous wastes are stored in the Hazardous Waste Temporary Storage Area and designated stock areas and removed from the campus through contracted licensed recovery and/or disposal companies. It contributes to the circular economy by utilizing domestic waste in incineration facilities and organic (biodegradable) waste in bio-methanolisation and compost facilities. (IGA 2023)



Figure 9- Istanbul Airport's Recycling Table for 2021 – 2022

Source: (IGA 2023)

#### 4.2.5. USE OF RESOURCES

##### 4.2.5.1. WATER AND WASTEWATER MANAGEMENT & WATER SAFETY

It implements practices for the efficient use of water and recycling of water used within the scope of operations (IGA 2023)

- The wastewater generated from the operations is collected through the wastewater sewage infrastructure system and treated in the Domestic Advanced Biological Wastewater Treatment Facility with a capacity of 15 thousand m<sup>3</sup>/day. The water recovered from this system, where water quality is monitored through daily analysis, is used as landscape water. It provides 100% of its garden irrigation needs from recycled water. Thus, İGA meets 35% of its water consumption from recycled water. In addition, local plants that consume less water are used in the landscaping areas at the airport.
- Istanbul Airport prefers efficient batteries and reservoirs that consume less water.
- There are waste oil-water separation systems in locations planned as maintenance centres.

#### What was done in 2021-2022?

- The ISO 14046 Water Footprint Standard has verified the water footprint report.
- It received a (B) score in the CDP Water Security Program. It shows how companies use natural resources and natural capital, how they affect the

reproduction of limited resources with their activities, and how they manage their risks in this field.

- It has completed its R&D study on nitrogen and phosphorus recovery from aircraft wastewater and obtaining fertilizer as a by-product. Once production begins, it may be used in gardens and landscaping areas. (IGA 2023)

#### **4.2.5.2. ENERGY EFFICIENCY**

In line with the Energy Management Policy, which works integrated with the ISO 50001 Energy Management System, it analyzes the consumption of all systems, including greenhouse gas emission sources, with IoT sensors. It can track unusual consumptions and make improvements. Operational efficiency and energy efficiency can be achieved with follow-ups. IoT makes decisions that will enable us to use our energy more sustainably and efficiently by using the data collected by sensors and data from existing systems (LET, SCADA and Energy Measurement System Integrations). (IGA 2023)

SCADA (Energy Management System) ensures the provision, management, control and monitoring of uninterrupted energy throughout the airport. This system monitors and controls 106 main energy distribution points 24/7 via the central energy management system. It performs energy and efficiency analyzes with the data collected from the system. (IGA 2023)

#### **4.2.5.3. AUTOMATION SYSTEMS**

LET system for energy-saving use of escalators and walkways; It uses the DALI system for lighting automation and efficiency. With the DALI system, more than 110,000 lighting fixtures are constantly monitored, and their operating modes are centrally controlled. With the flight information system integration, the lighting of unused areas is automatically turned off. It provides maximum benefit from daylight with daylight sensors. (IGA 2023)

Istanbul Airport Terminal received the "LEED Gold" Certificate in May 2020, becoming the world's largest LEED Gold Certified building. (IGA 2023)

Additionally, with its equipment and fixtures, Istanbul Airport's energy-efficient façade design provides more than 22% energy savings compared to the base building defined in ASHRAE, which is accepted as an international standard. (IGA 2023)

Mechanical Automation System: It can perform automatic interventions on the equipment of the HVAC (heating-cooling-ventilation) system by collecting data 24/7 from 130,000 points with mechanical automation and analyzing the parameters of outdoor air, temperature and humidity. Thus, it provides efficiency in the natural gas consumed by heating systems and the electrical energy consumed by the cooling system. (IGA 2023)

The hot water needs are obtained from solar energy, and the solar energy systems installed for the hot water needs in auxiliary buildings are monitored through the mechanical automation system. Thus, efficiency in natural gas consumption is achieved by turning off boiler systems for hot water in the summer months. (IGA 2023)

**According to the news published in ACI on December 13, 2023**, IGA Istanbul Airport became the first airport in Turkey to receive Level 4 Transformation in Airport Carbon Accreditation. (Airport Carbon Accreditation 2023c)

Istanbul Airport, which joined the program in 2021, has developed a long-term target for the absolute reduction of carbon emissions in line with the IPCC's 1.5°C path, which aims to reach net zero carbon by 2050. (Airport Carbon Accreditation 2023c)

At Level 4, the airport's carbon management strategy is now fully aligned with the ambition of the Paris Agreement. In addition, IST needed to deliver a more detailed mapping of carbon emissions, including more sources from Scope 3. Level 4 requires airports to map those emissions and implement an effective Stakeholder Partnership Plan to drive third-party emissions reductions actively. (Airport Carbon Accreditation 2023c)

Remarkably, Istanbul Airport has recorded a 21% reduction in Scope 1 and 2 carbon emissions since 2019, advancing from Level 1 to Level 4 within Airport Carbon Accreditation. Its significant achievements in reducing its carbon footprint include meeting 35% of its water consumption needs through reclaimed water, implementing a Lighting Automation System, and installing solar panels to source all its electricity from renewable energy. Additionally, the airport initiated a 5,000-hectare afforestation project in 2019 as part of its sustainability pledge, planting 2,695,500 trees between 2019 and 2022. (Airport Carbon Accreditation 2023c)

Olivier Jankovec, Director General of ACI EUROPE, congratulated Istanbul Airport for its achievement and added: "Istanbul Airport was certified under the Airport Carbon Accreditation programme just two years ago, and their progress in reaching Level 4 from Level 1 has been remarkable. I commend the Istanbul Airport team for their efforts towards achieving net zero carbon emissions by 2050".(Airport Carbon Accreditation 2023c)

#### **4.3. EVALUATION OF ENVIRONMENTAL SUSTAINABILITY PRACTICES IN AIRPORTS AROUND THE WORLD WITHIN THE SCOPE OF CARBON EMISSIONS**

The industry's interest in ecological certification systems that indicate the companies' environmental commitment has grown recently. Similarly, the concerns of the aviation industry have recently been increasing. Today, for example, almost all air traffic control centres and airports have implemented environmental management systems that conform to UNE-EN ISO 14001.(Comendador, Valdés, and Lisker 2019)

Airports worldwide are increasingly more environmentally concerned, increasing their efforts to reduce aviation impacts by applying environmental management, certification systems, or other ecological rating systems to their infrastructures and operations. Especially relevant are the airports' efforts to manage and reduce their CO<sub>2</sub> emissions through Airport Carbon Accreditation, the efforts made by Eurocontrol to encourage collaborative environmental management or the increasing numbers of airports worldwide that get their terminals certified according to several world-recognized Green Building Rating Standards (GBRS).(Comendador, Valdés, and Lisker 2019)

Airports are at different points on the journey to becoming cleaner and more efficient. As the centre points of a complex web of aircraft movements, technical operations and surface access transport, airports can address their CO<sub>2</sub> emissions in various ways. These can include better insulation and energy efficiency, switching to green energy sources, investing in hybrid, electric or renewable gas-powered service vehicles, encouraging employees, passengers and visitors to use public transport, working with airlines and air traffic management to reduce runway taxiing times and implement green landing processes and much more. (Airport Carbon Accreditation 2023b)

Airports are committed to reducing carbon emissions from their operations, aiming to become carbon neutral. Airport Carbon Accreditation was developed by Airports Council International (ACI) Europe in 2009, and today, it is the only global carbon management standard for airports. The initiative's objective is to reduce carbon emissions and achieve best practices in carbon management from operations fully within the control of the airports, with the ultimate target of becoming carbon neutral. (Comendador, Valdés, and Lisker 2019)

Airports can participate in the programme at one of the four main progressively stringent levels of accreditation: 1. Mapping; 2. Reduction; 3. Optimisation; and 4. Transformation. In addition, airports at levels 3 and 4 can choose to offset their residual emissions, thereby achieving levels 3+ (Neutrality) and 4+ (Transition), respectively. (Airport Carbon Accreditation 2023b)

In 2020, Level 4 (Transformation) and 4+ (Transition) were added to the Airport Carbon Accreditation programme to align it with the objectives of the Paris Agreement to limit the increase of global average temperature to 2°C above pre-industrial levels and aim not to exceed 1.5°C. Levels 4 and 4+ have been introduced as an interim step towards the long-term goal of supporting airports in achieving net zero carbon emissions. Level 4 and 4+ will encourage airports to reduce their emissions per the latest scientific and political developments and meet growing public and stakeholder expectations. (Airport Carbon Accreditation 2023b)

Expanding on its remarkable history and acknowledging the necessity for constant enhancement, the Airport Carbon Accreditation programme has introduced Level 5, the highest achievement within the programme. Airports can now validate their efforts in maintaining a Net Zero carbon balance for Scopes 1 and 2 while also addressing Scope 3 emissions, showcasing their commitment to a sustainable future for the aviation sector. (Airport Carbon Accreditation 2023b)

Eurocontrol promotes the Collaborative Environmental Management (CEM) process to formalize collaboration among the core operational stakeholders at airports and minimize the environmental impact of their combined operations. Therefore, this is facilitated by setting out generic, high-level requirements and recommended practices

and establishing CEM working arrangements in a pragmatic protocol to suit local needs and capabilities.(Comendador, Valdés, and Lisker 2019)

Individuals and international regulatory bodies' push force for climate action incentivize airline groups to react and adjust their long-term strategies for sustainable development. Research and development already have shown an indication of optimism for the emissions of aviation groups. In December 2020, Lufthansa Cargo carried out the world's first eco-friendly flight using sustainable aviation fuel for its Boeing 777F cargo aircraft between Frankfurt, Germany and Shanghai, China. Emission intensity is a factor which airlines could minimize by technologically advancing the aeroplane fleet in use. During 2020 in Europe, Wizz Air had the lowest carbon dioxide emission intensity amongst other airlines globally, with 57 grams of CO<sub>2</sub> per revenue passenger kilometre (RPK).

On the other hand, Lufthansa emitted roughly 92 grams of carbon dioxide per revenue passenger kilometre in the same period. Considering the global carbon emission goals determined by the 2015 Paris Conference, airline groups still lag behind ideal levels of CO<sub>2</sub> emissions. (Statista 2023)

At the ATAG Global Sustainable Aviation Forum taking place at COP28, Olivier Jankovec, Director General of ACI EUROPE, unveiled the programme's latest and most ambitious yet development: a new accreditation level - Level 5 - certifying airports for (Airport Carbon Accreditation 2023a)

- Reaching and maintaining a net zero carbon balance for emissions under their control (Scope 1 and 2) and
- Extending mapping, influencing and reporting requirements for all other emissions (Scope 3).

The introduction of Level 5 builds on the trajectory of evolution set by the introduction of Levels 4 and 4+ in 2020. These earlier levels already certify airports for following a CO<sub>2</sub> emissions reduction pathway aligned with the objective of the Paris Agreement to limit global warming by 1.5°C/2°C.(Airport Carbon Accreditation 2023a)

Level 5 thus recognises the ultimate achievement and maturity in airport carbon management, based on the following requirements:(Airport Carbon Accreditation 2023a)

- Extensive carbon reduction in absolute terms: To achieve Level 5, airports must reach and maintain  $\geq 90\%$  absolute CO<sub>2</sub> emissions reductions in Scope 1 and 2 in alignment with the ISO Net Zero Guidelines and commit to achieving net zero in Scope 3 by 2050 or sooner.
- Investment in carbon removal: Any residual emissions need to be removed from the atmosphere through investment in credible carbon removal projects. To guide airports in this endeavour, ACI has analysed the carbon removal options available and outlined the most effective removal strategies in the updated edition of the Airport Carbon Accreditation Offset Guidance Document.
- Establishment of a Carbon Management Plan: Level 5 accredited airports need to outline detailed steps to achieve their emissions reduction targets as part of their Carbon Management Plan.
- Extended carbon footprint: Airports need to submit a verified carbon footprint for Scope 1 and 2 (direct and indirect emissions under the airport's control) and all relevant categories of Scope 3 (indirect emissions outside of the airport's control) as per the requirements of the GHG Protocol Scope 3 Guidance, notably covering all significant upstream and downstream activities from third parties - including airlines. Following successful accreditation, Level 5 airports must submit their verified carbon footprint calculations annually.
- Establishment of a Stakeholder Partnership Plan: Underpinning airports' commitment to net zero in Scope 3, Level 5 accreditation requires the setup of a Stakeholder Partnership Plan, engaging with the entire airport ecosystem at a much deeper level and actively driving third parties towards delivering emissions reductions themselves. The plan needs to include regular milestones to gauge progress.

At the official COP28 side-event, it was announced that ten airports have already secured Level 5 accreditation as part of the pilot programme that took place in 2023,

testing the feasibility and rigorousness of the new framework. Global pioneers included:(Airport Carbon Accreditation 2023a)

- The Royal Schiphol Group operates Amsterdam Airport Schiphol, Eindhoven and Rotterdam-The Hague airports in the Netherlands.
- Beja, Madeira and Ponta Delgada airports in Portugal, operated by ANA
- Christchurch International Airport Ltd operates Christchurch Airport in New Zealand.
- Göteborg Landvetter and Malmö airports in Sweden, operated by Swedavia.
- Toulon-Hyères airport in France, operated by VINCI Airports

## **5. CONCLUSIONS**

This dissertation investigates the airport's environmental sustainability practices and Istanbul's new airport case study. This final chapter reviews the research contributions of this dissertation and discusses directions for future research.

### **5.1. FINAL CONSIDERATIONS**

International air transportation, which provides economic development and fast and easy accessibility at different spatial levels, has grown rapidly. International air transportation activities constitute the most important building blocks of a country's socio-cultural and economic system. A growing air transport industry is representative of several economic benefits, including increased global trade and the easier movement of people and freight across borders. Air transportation, important for carrying out economic and social activities, affects people's quality of life and living standards in different countries. It provides numerous economic, social, technological, political, cultural, and military benefits.

While the benefits provided by the aviation industry to people have increased steadily in recent years, demand has grown faster, causing the expansion of airports and thus increasing the environmental problems arising from the sector. In response to this situation, many airports worldwide have made environmental regulations.

Noise measurements are made for noise management, and some regions impose restrictions on night flights. Regarding wastewater management, airports use a rainwater collection system and groundwater boreholes to collect the terminal's wastewater. For waste and energy management, grass clippings are reused instead of fertilizer at the airport, and food waste is recycled, which is used to produce methane gas converted into electricity. In addition, solar panels are installed for energy management, while many airports have wind generators. To reduce energy consumption, 'smart' control systems are installed in heating and lighting systems, escalators and walkways at airports, and old lighting systems are replaced with more energy-efficient LEDs. Some regulations have also been made to protect wildlife at airports. The bat house was established due to a new maintenance building that displaced bats.

Additionally, there are cases where historic buildings are located within the area allocated for expanding airports. For this reason, protected airport areas have caused the buildings to be moved to other places. Air pollution management includes replacing existing ground handling equipment with more fuel-efficient or low-emission vehicles, and programs such as employee travel plans, car-sharing clubs and travel passes are also offered to encourage reduced vehicle use among employees.

Airports worldwide receive LEED certification in line with the zero-emission target, use sustainable aviation fuel, and improve their technologies.

Airports are increasingly trying to become more environmentally friendly, eliminating environmental impact concerns. This situation led to the emergence of the green airport project. A “green airport” is an airport that has a minimal impact on the environment and strives to be a carbon-neutral facility in terms of carbon emissions, intending to produce zero greenhouse gas emissions. Green Airport aims to implement an environmentally friendly policy by reducing its carbon footprint, using renewable energy, and producing less CO<sub>2</sub> and other harmful pollutants. Turkish airports are also trying to implement an environmentally friendly policy and are trying to receive the title of green organization by DGCA. In this direction, some initiatives have been taken by airline companies in our country to reduce the amount of carbon emissions, and the first use of sustainable aviation fuel in Turkey has been realized.

The first Sustainable Aviation Fuel (SAF) flight in Türkiye occurred on February 2, 2022, from iGA Istanbul Airport to Paris CDG Airport, operated by Turkish Airlines (THY) flight number 1823.

Various applications are being developed and implemented at airports worldwide, thus trying to reduce carbon emissions. Airports are actively working to combat climate change with a net zero carbon target. Airports worldwide are parties to various regulatory bodies that apply environmental management and certification systems to their infrastructure and operations. Airports’ efforts to manage and reduce CO<sub>2</sub> emissions through Airport Carbon Accreditation are important in minimizing environmental negative impacts and preventing pollution within the life cycle framework.

Environmental sustainability studies at Istanbul Airport in Turkey are extremely comprehensive when the literature is examined. At Istanbul Airport, work is carried out in line with the principle of sustainability at every stage, from design to construction and from the construction period to the operation process. Istanbul Airport fulfils the ISO 14064 Greenhouse Gas Calculation and Verification Management System Standard requirements and the Airport Carbon Accreditation program for measuring and reporting greenhouse gas emissions. The airport effectively identifies the sources of greenhouse gas emissions thanks to the greenhouse gas management system that works with the ISO 50001 Energy Management System.

Istanbul Airport became the first airport in Turkey to receive Level 4 Transformation in Airport Carbon Accreditation.

Notably, Istanbul Airport has progressed from Level 1 to Level 4 within the scope of Airport Carbon Accreditation, recording a 21% reduction in Scope 1 and Scope 2 carbon emissions since 2019.

Intensive work must be done within the airport for Airport Carbon Accreditation Level 4 + Transition and Level 5.

For Istanbul Airport to reach the Level 4+ 'Transition' stage of Carbon Accreditation, it must compensate for its remaining carbon emissions through offsetting.

At this stage, it must meet all the requirements of 'Transformation'. It must offset remaining Scope 1 and 2 carbon emissions and emissions from staff business travel using internationally accepted offsets.

In addition, Istanbul Airport must collaborate with its entire ecosystem, including employees, suppliers, business partners, airlines, other companies, and third parties active on the airport site, to significantly contribute to reducing emissions in line with broader Net Zero commitments. Regular monitoring and evaluation are essential to measure progress and ensure transparency.

In addition, Istanbul Airport should submit a verified carbon footprint for Scope 1 and 2 emissions and all relevant Scope 3 emission categories under the requirements of the Greenhouse Gas Protocol Scope 3 Guidelines.

It should achieve and maintain absolute CO<sub>2</sub> emissions reductions of over 90% in Scopes 1 and 2 and commit to Net Zero by 2050 or sooner in Scope 3.

It should implement reliable carbon removals for residual emissions.

It should develop a Carbon Management Plan (CMP) that outlines steps to achieve emissions targets.

It should develop a Stakeholder Partnership Plan to achieve Net Zero for Scope 3 emissions by engaging with the value chain and encouraging third parties at the airport to self-deliver emissions reductions with regular milestones in line with their sector's Net Zero frameworks and commitments.

Incorporating sustainability into the airport master planning process is expensive for most organisations. This process can consume even more resources for small and medium-sized organizations. In addition, a significant amount of finance is invested in implementing a successful project. Obtaining subject matter experts to oversee projects and continue the monitoring process after implementation may also incur additional costs. Since the planning and reporting of studies is not a legal requirement, it can be ignored. It is open to discussion that industry stakeholders interested in carrying out sustainability-oriented practices in our country should adopt different approaches to identify and implement sustainable airport improvement projects.

## **5.2. LIMITATIONS**

The findings of this study must be seen considering some limitations. The time available to study the research problem and to measure change over time was constrained; this impacted the final document, and it needs extended future study to answer this research problem.

## **5.3. FUTURE RESEARCH**

While the airport environmental sustainability practices with the Istanbul new airport case study proposed in this dissertation provide a high-level guideline to future research, the research contributions suggest many more specific open questions and directions. The remainder of this section will lay out some of these more immediately accessible avenues for future research:

1. The social, economic, and environmental impacts of airport sustainability. A Systematic Literature Review
2. A Correlation Study of Airport sustainable Initiatives with the sustainable development goals (SDG).
3. Environmental sustainability framework at airports.



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