ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

ASSESSMENT OF ENVIRONMENTAL SUSTAINABILITY FOR AN EXISTING AIRPORT

M.Sc. THESIS

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Environmental Science and Engineering Programme

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To my family,

FOREWORD

I would like to thank you my supervisor Prof.Dr. Fatoş Germirli Babuna for her great help, guidance and encouragement during thesis.

This thesis is dedicated to my husband, Onur Şahinkaya and my parents Gülderen Akşit and Fazıl Akşit for their support. Their trust helped me to focus and succeed on my study. I am greatful to my supervisor and my family.

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ABBREVIATIONS

ACERT	**:**	Airport Carbon and Emissions Reporting Tool
ACI	**:**	Airports Council International
AYEDAS	**:**	Istanbul Anatolian Side Electricity Distribution Company
CAEP	**:**	Committee on Aviation Environmental Protection
DGCA	**:**	Directorate General of Civil Aviation
EIA	**:**	Environmental Impact Assessment
EPA	**:**	Environmental Protection Agency
FAA	**:**	Federal Aviation Administration
GWP	**:**	Global Warming Potential
IATA	**:**	International Air Transport Association
ICAO	**:**	International Civil Aviation Organisation
IETT	**:**	Istanbul Electric Tramway And Tunnel Establishments
IMM	**:**	Istanbul Metropolitian Municipality
IGDAS	**:**	Istanbul Gas Distribution Industry and Trade Incorporated Company
ISKI	**:**	Istanbul Water and Sewerage Administration
MAHB	**:**	Malaysia Airports Holdings Berhad
NGO	**:**	Non-governmental organizations
NRDC	**:**	National Resources Defence Council
SEI	**:**	Stockholm Environment Institute
WBCSD	**:**	World Business Council for Sustainable Development
WCED	**:**	World Commission on Environment and Development
WRI	**:**	World Resources Institute
WWAP	**:**	World Water Assessment Programme

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ASSESSMENT OF ENVIRONMENTAL SUSTAINABILITY FOR AN EXISTING AIRPORT

SUMMARY

Sustainable growth is a concept that emerged in the Brundtland Report prepared by the World Commission on Environment and Development, in 1987. The term defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

In practice, sustainable growth means giving importance to environmental protection as it envisages creating the conditions for long-term economic development. At a conference held in Denmark in 1995, it was emphasized to secure community health and struggle with social exclusion. With the Treaty of Amsterdam in 1997, sustainable growth was accepted as one of the main targets of the European Union.

Sustainability can be described as undertaking economic activities while at the same time considering environmental issues and social balance. For sustainable growth companies must assume social and environmental responsibility. They are also required to add these mechanisms to their business and decision-making processes.

The national sustainability practices in the transportation system are providing an important contribution to national sustainable growth. The aviation sector is by far the most improved among other modes of transportation. Aviation has a different position in terms of creating a variety of services compared to other transportation systems.

The importance of sustainability in the aviation industry is increasing day by day due to the rapid growth of the sector. On the one hand international political factors while on the other rising fuel consumption, due to the dramatically increasing number of aircrafts used, along with fluctuating oil prices have affected airlines in recent years.

The aviation industry has been one of the leading sectors in our country and in the world in terms of sustainability. Both the noise generated by aircraft engines and the use of fuel have decreased over the years. Researchers illustrate that several items can still be improved upon, such as reducing up to 80% of harmful gas emissions as well as noise levels over the next 25 years.

All business enterprises in airports that are serving as the sector's main component are influenced by external developments and internal dynamics. Sustainable development should be treated as a natural part of corporate responsibility, including the owners of such business enterprises, the managers and all of the workers respectively.

The environmental impacts of the aviation industry not only come from aircrafts, but also from airports and their supporting infrastructure. Thus, environmentally sustainable airports must be considered as an inseparable part of sustainable aviation systems. In this context, the objective of this study is to evaluate an existing airport in terms of its carbon footprint and to put forth recommendations on developing the environmental sustainability of the facility. For this purpose, Sabiha Gokcen International Airport, located in Istanbul is investigated. According to 2014 data, more than 23.5 million passengers are used the airport and about 185,400 flights are realized annually. The amount of waste and wastewater generation and information on their management/treatment practices, energy requirement for buildings (heating and cooling), fuel consumption of airplanes, fuel requirement for air-side vehicles and shuttles used for employee transportation, the amount of used deicer are gathered for 2012,2013 and 2014. The mentioned information is fed to ACERT v3.1 calculation tool to obtain the carbon footprint of the facility. Currently a 2nd runway is under construction. This runway will be completed in 2017. Due to this elevation in capacity greenhouse emissions are estimated to increase three fold. To tackle with this recommendation that develop the sustainability of the airport are presented.

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ÖZET

Sürdürülebilir büyüme, 1987 yılında Dünya Çevre ve Kalkınma Komisyonu'nun hazırladığı Ortak Geleceğimiz Raporu'nda ortaya çıkmış bir kavramdır. Raporda, ekonomik kalkınmanın çevreye zarar vermeden sağlanması gerektiğine dikkat çekilmektedir. Sürdürülebilirlik kavramı, doğal kaynakların verimli kullanılması, atıkların azaltılması, kaynakların geri dönüşümünün sağlanması ve kaynakların gelecek nesillerin ihtiyaçlarına cevap verecek şekilde korunması esaslarına dayanmaktadır. Sürdürülebilir büyüme tüm kaynakların yönetimine ilişkin ekonomik, finansal ve endüstriyel boyutları olan oldukça kapsamlı bir süreçtir.

Uygulamada ise sürdürülebilir büyüme, çevrenin korunmasına önem vermek suretiyle uzun vadeli bir ekonomik kalkınmanın koşullarını oluşturmayı öngörmektedir. 1995 yılında Danimarka'da gerçekleştirilen sürdürülebilir büyüme konferansı, toplumsal dışlanmayla mücadele edilmesi ve kamu sağlığının korunmasının önemini vurgulamıştır. Amsterdam Antlaşmasıyla birlikte sürdürülebilir büyüme, Avrupa Birliği'nin hedefleri arasında yer almıştır.

Ekonomik beklentilerin ve faaliyetlerin çevresel ve sosyal bir denge içinde bulunmasına sürdürülebilirlik denmektedir. Bir diğer deyişle sürdürülebilir büyüme, şirketlerin sosyal ve çevresel sorumluluklarının da olması, şirketlerin tüm iş süreçleri ve karar alma mekanizmalarına bu sosyal ve çevresel sorumlulukları dahil etmesi esasına dayanır.

Sürdürülebilirlik bir anlamda toplumun yapılandırılmasıdır. Bu sayede ekonomik, sosyal ve çevresel amaçlar arasında güzel bir denge yaratılmaktadır. İşletmeler için bu kavram, devamlılığı olan ekonomik büyümeyi, kurumsal itibarı, müşteri ilişkilerini ve ürünlerin ve sunulan hizmet kalitesini kapsamaktadır.

Kurumsal sürdürülebilirliğin oluşturulması için her işletmenin ekonomik, sosyal ve çevresel süreçlerde denge kurması ve optimum düzeyde her üç boyutla ilgili çabalarında başarılı olması gerekmektedir. İşletmeler karlılık ve verimlilik açısından hedeflerine yönelik çaba harcarken doğal kaynaklar ve toplumsal sorumluluk gibi alanları da göz önünde bulundurmalıdır. Ancak birbirinden farklı her üç boyutta da iyi uygulamalar gerçekleştirdiği takdirde sürdürülebilir işletme yolunda ilerleme kaydedilecektir. Benzer şekilde, sürdürülebilir kentler için de ilgili unsurların dikkate alınması gerektiği aşikardır.

İngilizce "sustainable development" kavramının çevirisi olan "sürdürülebilir gelişme", Kent Bilim Terimleri Sözlüğü'nde, "çevre değerlerinin ve doğal kaynakların savurganlığa yol açamayacak biçimde akılcı yöntemlerle, bugünkü ve gelecek kuşakların hak ve yararları da gözönünde bulundurularak kullanılması ilkesi ve bu bağlamda ekonomik gelişmenin sağlanmasını amaçlayan çevreci dünya görüşü" biçiminde açıklanmaktadır.

Ulusal sürdürülebilirlik uygulamalarında ise ulaşım sistemleri ulusal sürdürülebilir büyümeye önemli katkılar sağlamaktadır. Ulaşım sistemleri içinde havacılık sektörü çeşitli hizmet alanları yaratması ve diğer ulaşım sistemlerinin bütünselliği açısından farklı bir konuma sahiptir.
Sektörün ana faaliyet alanları havacılık endüstrisi, havayolu işleticileri, hava meydanları ve onların tedarikçilerdir. Ulusal değer yaratma kaynakları arasında yer alan hava meydanlarının yarattığı sosyal, ekonomik ve çevresel boyutlar kentsel, bölgesel ve ulusal sürdürülebilir büyümeyi doğrudan doğruya etkilemektedir. Ek olarak, havayolu taşımacılığındaki iş modellerinin değişmesi, trafik yoğunluğunun artmasına neden olmaktadır. Talebin karşılanabilmesi için hava meydanları fiziki anlamda zorlanmaktadır. Fiziksel gelişim ve değişim ihtiyacı, hava meydanı işletmelerinin tüm faaliyetlerini sürdürülebilirlik açısından ele almalarını ihtiyacını gündeme getirmektedir.

Sektörün hızlı büyümesi sebebiyle havacılık endüstrisinde sürdürülebilirliğin önemi giderek artmaktadır. Bir yanda havayollarının artan uçak sayısına bağlı olarak harcanan yakıt miktarı diğer yanda uluslararası politik faktörler, son dönemde yaşanan değişken petrol fiyatları ve petrol sağlayacılarının yaşadığı anlaşmazlıklar gibi faktörler havayolu maliyetlerini etkilemektedir.

Havacılık endüstrisi ülkemizde ve dünyada sürdürülebilirlik konusunda öncü sektörlerden biri olmuştur. Uçak motorlarının yarattığı gürültü düzeyi yıllar içinde azalmış, uçakların yakıt kullanımı düşürülmüştür. Araştırmalar önümüzdeki 25 yıl içinde gürültü düzeyi ve zararlı gaz salınımlarının %80 oranında azaltılabileceğini ortaya koymaktadır.

Havacılık sektörü aynı zamanda diğer ulaştırma sektörleri içerisinde e-dönüşümün öncüsüdür. Yalnız uçak bileti değil, bakım dokümanlarında da kâğıt israfı en düşük seviyeye çekilmiştir. Ancak, uçakların rotaları, bekleme süreleri, havalimanlarınd yer hizmetlerinde kaybedilen zamanlar, trafik kontrollerinin yetersizliği halâ çözüm bekleyen sorunlar olarak karşımıza çıkmaktadır.

Sürdürülebilirlik alanında kaydedilen gelişmelere ve ar-ge çalışmalarına rağmen fosil yakıt kullanımı artmakta ve havacılıkta CO_2 emisyonları beklenen düzeye çekilememektedir. Mevcut şartları iyileştirme çalışmalarının yanında, yeni nesil yakıt araştırmaları ve uygulama çalışmaları devam etmektedir.

Havacılık sektörü ülkemizde ileri teknolojinin öncülüğü yapmaktadır. Bu yüzden de sektör, çevreci ve yeşil örgütlerin sıkı takibindedir. Yeşil havalimanı konsepti Türkiye'de hedefler doğrultusunda uygulanmakta olup, günümüzde havalimanları için adeta bir prestij meselesi halini almıştır.

Sektörün ana bileşenlerinden hava meydanlarında hizmet veren tüm işletmeler, dış kaynaklı gelişmeler ve iç dinamiklerin etkisi altındadır. Hava meydanlarındaki kurum ve kuruluşların sahipleri, hissedarları, yöneticileri ve tüm çalışanları açısından sürdürülebilir büyüme, işlerinin doğal bir parçası ve kurumsal sorumluluk olarak ele alınmak durumundadır.

Bireylere sağlıklı ve iyi bir çevrede yaşam bırakmak amacıyla doğal kaynakları sorumluluk bilinciyle kullanmak, çevreyi korumak için standartlar geliştirmek, ilgili standartlara ve yasal düzenlemelere uymak gerekmektedir. Havalimanlarının çevre kalitesi ile ilgili bilgiler yayınlayıp kamuoyu ile paylaşması yapılması gereken sürdürülebilirlik çalışmalarına örnek teşkil etmektedir.

1. INTRODUCTION

1.1 Importance of the study

The concept of sustainability is a wide approach. Most human activities cause environmental problems. To solve these problems completely, it is not enough to think only of current conditions and time. It is necessary to find causes and get exact solutions for both today and the future. The concept of sustainability becomes important at this point. According to United States Environmental Protection Agency (EPA), sustainability is “Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. To pursue sustainability is to create and maintain the conditions under which humans and nature can exist in productive harmony to support present and future generations” (Environmental Protection Agency (EPA) 2015).

The organizing principle for sustainability is sustainable development which is defined in the Brundtland Report of the World Commission on Environment and Development (WCED) (Brundtland Report 1987) as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- the concept of '**needs**', in particular the essential needs of the world's poor, to which overriding priority should be given; and
- the idea of **limitations** imposed by the state of technology and social organization on the environment's ability to meet present and future needs.”

Sustainable development leans on three pillars which are economic, social and environmental (Sustainable Development Knowledge Platform 2005). It is necessary to focus on all pillars to find sustainable solutions. Definitions of the three pillars are as follows:

- Economic Sustainability: The ability of an economy to support a defined level of economic production indefinitely.

- Social Sustainability: The ability of a social system, such as a country, family, or organization, to function at a defined level of social well being and harmony indefinitely.

- Environmental Sustainability: the ability of the environment to support a defined level of environmental quality and natural resource extraction rates indefinitely (Thwink 2015)

Aviation is one of the most important transportation modes and that importance increases constantly. According to the International Air Transport Association (IATA), global passenger traffic has increased 5.9% from 2013 to 2014. The annual growth rate of 2013-2014 was above the 10- year average growth rate of 5.6 and the annual growth rate of 2012-2013 which was 5.2% (IACA Press Release No.5 2015). The increase in air traffic shows the growth of demand in air travel.

The growth in demand is a sign of how important it is to be sustainable in the aviation industry. Significant amounts of fossil fuels are consumed and the growing problems of greenhouse gas emissions and climate change are contributed to by the aviation sector. The environmental, social and economic impacts of the aviation industry not only come from aircrafts but also from airports and their supporting infrastructure, such as maintenance and servicing of the aircraft, freight distribution and terminal facilities (Whitlegg and Cambridge 2004).
Thus, a possible direction for the future is to maintain a sustainable infrastructure for air travel, starting with airports. Airports are one of the important parts in aviation as they are the starting and ending point of air travel, as well as a place for organizing all related actions. In this study the existing Sabiha Gökçen International Airport, is observed as a point of environmental sustainability.

1.2 Objective of the Study

The objective of this study is to evaluate an existing airport in terms of its carbon footprint and to put forward recommendations on developing the sustainability of the facility.

1.3 Scope of the study

Chapter 2 covers a literature review of the study. First, aviation and sustainability were examined. Environmental effects of airports were clarified and how to reduce these effects were briefly stated. Second, international aviation organizations were introduced to see who they are and what they are doing for airport sustainability. Then, a Turkish aviation and sustainability project named Green Airport was defined. After this briefing, greenhouse gases and their effects were explored. Carbon footprints and their importance were remarked.

Chapter 3 encloses materials and methods of carbon footprint calculation. Calculation approaches were explained. Brief information about Sabiha Gökçen International Airport (SAW) was also given in this chapter.

In results and discussion, chapter 4, Carbon Footprint of SAW was calculated in accordance with materials and methods expressed at the beginning of this chapter. Evaluation of the results, forseen carbon footprint of SAW after completion of 2nd runway, alternative solutions to decrease emission amounts were performed.

2. LITERATURE SURVEY

2.1 Aviation and Sustainability

As distinct from other industry, air transport bringing people, businesses and communities together. And, it provides global transportation by rapidly and safely moving passengers and goods worldwide.

Air transport's benefit is not limited with those involved in the flight itself, the aircraft manufacturers, the airlines and the airports are some that makes the benefits of air transport reach far beyond it. Aviation is a major economic driver from the businesses producing the goods transported in the cargo hold, to all those working in the areas of the tourism industry that air transport makes possible. But, aviation expands day by day and increases responsibility to ensure that its environmental impact is kept a minimum.

When other indsutry and transportation means are compared with aviation, it seems that the contribution of aviation to climate change is lower than others. (See: Figure 2.1, Figure 2.2 and Figure 2.3)

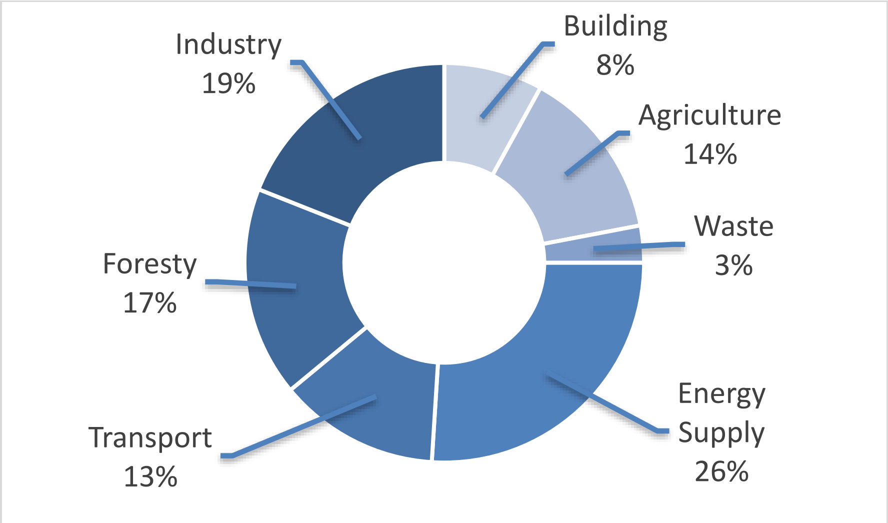

Figure 2. 1 : Global Greenhouse Gasses by Section, 2004 (IPCC)

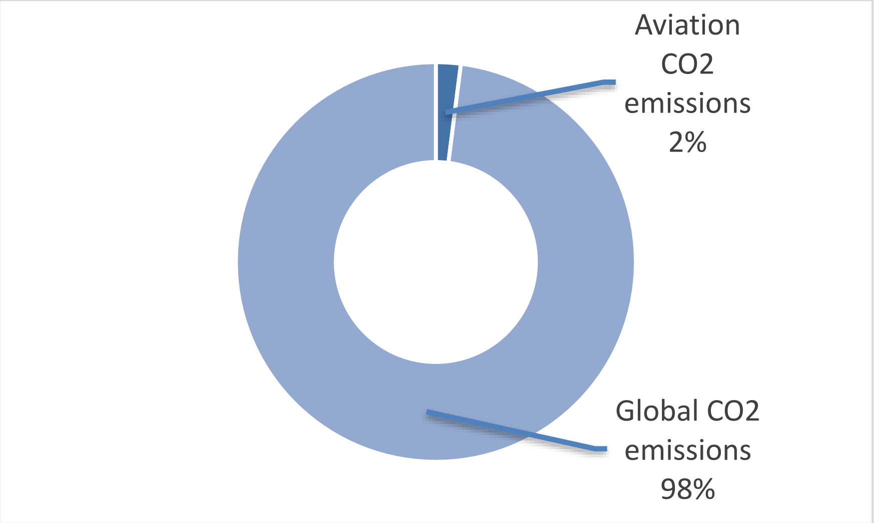

Figure 2. 2 : Part of Aviation, Global CO_2 emissions

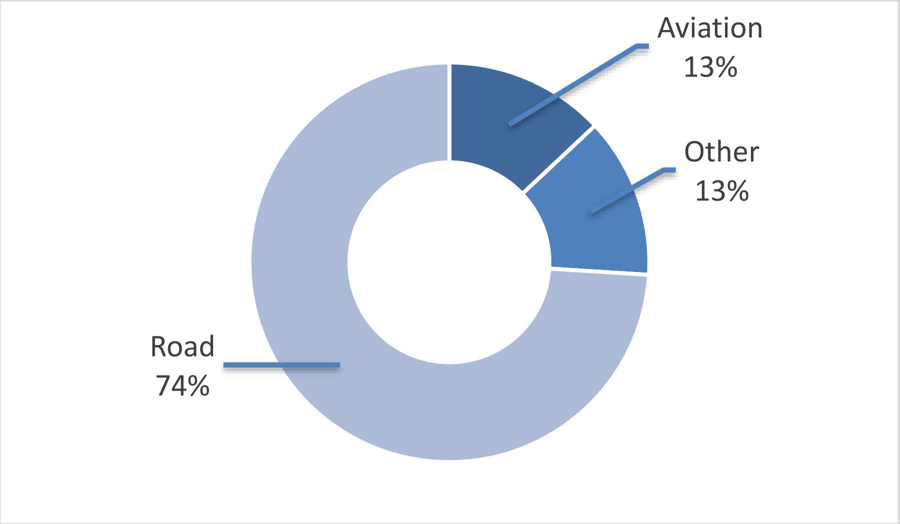

Figure 2. 3 : Global CO_2 emissions per transport (%)

At the local, regional and global levels, the environmental impact of aviation is wide-renging and significant by mostly focusing on noise (local) and climate change (global). Because of great growth rate in aviation, technological progress cannot keep up with the growth. Stockholm Environment Institute was expressed how big impact of aviation as “Aviation is responsible for 1-2 per cent of anthropogenic greenhouse gas emissions but these gases are injected at relatively high levels in the atmosphere and have a radiative forcing impact of 3. This means that the emissions are approximately three times more damaging in terms of climate change than if they had been emitted at ground level. Aviation is expected to account for up to 15 per cent of the total contribution to climate change by 2050.” in a Policy Paper, “Aviation and Sustainability”.

The world’s airlines burn 205 million tonnes of aviation fuel (kerosene) (OECD, 2002) a year and produce 300 million tonnes of greenhouse gases (IEA, 2002).

Aircraft, airports and supporting infrastructure such as maintenance and servicing of the aircraft, freight distribution and terminal facilities such as shopping malls are factors of the environmental, social and economical impacts of the aviation. And, a number of impacts are associated with the operation of airports.

Firstly, a significant amount of land is required to build the runways, terminals, car parks, services areas and transport networks. Airports are typically located on the outskirts of the cities near to the countryside, and as more and more capacity is required to meet demand for aviation more land is used, encroaching further on the countryside with the direct loss of important habitats and possible reduction in biodiversity. Furthermore, losses could be caused by the pollution emanating from the airport including the waste generated by millions of passenger movements and by the airport employees’ commute. In addition, airport operations such as the maintenance and servicing contribute to local air quality and surface water pollution. For example, during freezing weather aircraft need de-icing fluid, part of which ends up washed into local water sources. (Whitlegg & Cambridge, 2004)

2.2 International Aviation Organizations

2.2.1 International Air Transport Association (IATA)

The International Air Transport Association (IATA) is the trade association for the world’s airlines, representing approximately 85% of total air traffic. It supports different areas of aviation activity and promotes to formulate global policies on critical aviation issues (The International Air Transport Association (IATA), 2015).

Protecting environment is one of IATA’s top priorities as airlines are working to reduce their climate change impacts with the help of IATA (The International Air Transport Association (IATA), 2015).

Acccording to a report published by the IATA aviation is responsible for the following:

- 2% of global carbon dioxide (CO2) emissions
- 12% of CO2 emissions from all transport sources, compared to 74% from road transport
- 3 % of the total man-made contribution to climate change

From the early days of jet aircraft, aviation has significantly improved its performance in terms of environment. Since the 1960s, fuel efficiency has improved by almost 70% per passenger km, today's aircraft are 75% quieter compared to airplanes manufactured 50 years ago, and levels of carbon monoxide fell by 50% and unburned hydrocarbons and smoke by almost 90% (The International Air Transport Association (IATA), 2015).

Sustainable growth means for the aviation sector to meet today's needs without consuming the resources available that future generations will search for. The industry is aware of its environmental impacts as well as its effect to climate change.

Considerable amount of efforts is already done to decrease the environmental impacts of aviation. IATA supports this kind of research, development, and the commercial activities that meets necessary sustainability standards.

In 2009, the aviation industry collectively agreed to set of sector-specific climate change targets for the first time in the world. These targets are:

- 1.5% fuel efficiency improvement from 2009 until 2020
- Carbon neutral growth from 2020
- A 50% reduction in carbon emissions by 2050 relative to a 2005 baseline (International Air Transport Association, 2015)

2.2.2 International Civil Aviation Association (ICAO)

The International Civil Aviation Organization (ICAO) is a UN specialized agency, established in the USA in 1944 to run the administration and governance of the Convention on International Civil Aviation (International Civil Aviation Organisation (ICAO), 2015).

ICAO consider improving the environmental performance of aviation very seriously. The Organization developed a lot of standards, policies and guidance materials for the application of integrated measures related with aircraft noise and engine emissions. These works include proper organization of air traffic, sufficient airport and land-use planning, and the use of market-based options (International Civil Aviation Organisation (ICAO), 2015).

As a result, airline operations that today can be 70% more efficient than in the 1970s (International Civil Aviation Organisation (ICAO), 2015).

In 2004, ICAO stated three major environmental goals which adressed:

- limit or decrease the number of people affected by high levels of aircraft noise;
- limit or decrease the impact of aviation emissions on quality of air; and
- limit or decrease the impact of aviation greenhouse gas emissions on the global climate.

Strategic Objectives which was adopted by The ICAO Council gives high priority environmental protection matters (International Civil Aviation Organisation (ICAO), 2015).

ICAO's activities in the environment field are mainly focused on those problems regarding aircraft noise and the impact of aircraft engine emissions (International Civil Aviation Organisation (ICAO), 2015).

Majority of this work is undertaken through the ICAO Council's Committee on Aviation Environmental Protection (CAEP), which consists of Members and Observers from the USA, from both intergovernmental and non-governmental organizations representing a wide participation of aviation industry. Besides, ICAO has close relations with other UN policy-making bodies that have expressed an interest in civil aviation (International Civil Aviation Organisation (ICAO), 2015).

Aviation Environmental Protection (CAEP) is a technical committee of the ICAO Council and commits most of the Organization’s work in this area. It is the international forum of expertise for the study and development of proposals to limit the harmful impacts of aviation on the environment. Each proposal in CAEP is being analyzed according to four criteria: technical feasibility; environmental benefit; economic reasonableness and in terms of the interrelationship between measures. The

ICAO Council reviews and applies the CAEP recommendations and then sending reports to the ICAO Assembly, where the main policies on aviation environmental protection are determined and converted into Assembly Resolutions. At the same time, the ICAO publishes studies, reports, manuals on the subject of aviation and environment (International Civil Aviation Organisation (ICAO), 2015).

Annexes of International Civil Aviation Standards are given in Table 2.1. Annex consist of 18 parts from which the 16th is the standard of environmental protection for civil aviation (International Civil Aviation Organisation (ICAO), 2015).

Table 2. 1 : Annexes of International Civil Aviation (ICAO, 2001)

Annex 1 Personnel Licensing
Annex 2 Rules of the Air
Annex 3 Meteorological Service for International Air Navigation
Annex 4 Aeronautical Charts
Annex 5 Units of Measurement to be Used in Air and Ground Operations
Annex 6 Operation of Aircraft
Annex 7 Aircraft Nationality and Registration Marks
Annex 8 Airworthiness of Aircraft
Annex 9 Facilitation
Annex 10 Aeronautical Telecommunications
Annex 11 Air Traffic Services
Annex 12 Search and Rescue
Annex 13 Aircraft Accident and Incident Investigation
Annex 14 Aerodromes
Annex 15 Aeronautical Information Services
Annex 16 Environmental Protection
Annex 17 Security: Safeguarding International Civil Aviation Against Acts of Unlawful Interference
Annex 18 The Safe Transport of Dangerous Goods by Air

Similir to IATA, ICAO has researches on alternative jet fuels. Jet fuels that are currently are a combination of complex hydrocarbons, and the specific composition varies within broad performance specification limits. Nevertheless, typically they have components of 60% paraffin’s, 20% naphthenic, and 20% aromatics. The naphthenes and aromatics have a higher carbon to hydrogen ratio than the paraffins, which enables them to have a greater volumetric efficiency. However, they also include compounds which may result the release of particulate matter in the engine exhaust – which is one of the parts of increasing environmental concern (Dagget, et al., 2007)

2.2.3 European Civil Aviation Conference (ECAC)

The European Civil Aviation Conference founded in 1955 to combine civil policies and practices amongst its Member States as an intergovernmental organisation. It also promotes understanding on these policy issues between its members and other countries (Europena Civil Aviation Conference, 2015).

ECAC's mission is the promotion of the lasting development of a safe, efficient and sustainable European air transport network (Europena Civil Aviation Conference, 2015).

ECAC works closely and in collaboration with other regional organisations and individual Contracting States of ICAO, including the United States, on a variety of civil aviation issues of common interest by training activities in the security, safety and environmental fields (Europena Civil Aviation Conference, 2015).

ECAC also conducts international workshops, seminars and training events regularly (Europena Civil Aviation Conference, 2015).

2.2.4 Federal Aviation Administration (FAA)

The Federal Aviation Administration (FAA) is the national aviation authority of the United States. It has authority to manage all aspects of American civil aviation. The agency adopted its current name in 1966 when it became a part of the U.S. Department of Transportation. The FAA's major roles are the following:

- To regulate U.S. commercial space transportation
- To Encourage and develop civil aeronautics, including new aviation technologies
- To regulate civil aviation in terms of promoting safety
- To develop and operate a system of air traffic control and navigation for both civil and military aircraft
- To conduct researches and develop the National Airspace System and civil aeronautics

- To develop and carry out programs to control noise created by engines and other environmental effects of civil aviation

Like to other aviation organisations, FAA is also working on environmental issues. These studies are mainly based on aircraft noise and bird strikes (Federal Aviation Administration, 2015)

2.2.5 Airports Council International (ACI)

The Airports Council International is the only global trade representative of the world’s airports. ACI represents airports interests with governments and international organizations such as ICAO. Established in 1991, its mission is to develops standards, policies and recommended practices for airports (Airports Council International (ACI), 2015).

Table 2.2 compares international aviation organizations with their environmental goals (Özdemir, 2013).

Table 2. 2 : Summary of international aviation organizations in terms of environmental goals

Organization	Activity Site	Environmental Goals
IATA	Global organization of Air Transport	Monitoring, assessing and responding to environmental developments, policies and regulations Advising the Board of Governors, the Director General and other relevant IATA bodies on environmental matters
ICAO	A convention on International Civil Aviation, works closely with other UN bodies	Focuses primarily on aircraft noise and the effect of GHG on global environment.
ECAC	Strongly related to International Civil Aviation Organization (ICAO), Council of Europe, European Union, EUROCONTROL and the Joint Aviation Authorities (JAA)	Focuses primarily on noise, local and global emissions.
FAA	Regulating U.S. commercial space transportation	Focuses on air quality, climate change, noise, wildlife management

2.3 Turkish Aviation

2.3.1 Directorate General of Civil Aviation (DGCA)

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

The first Civil Aviation Transportation was begun with small sized fleet covering only 5 aircraft in 1933 under the name of Turkish Air Mails. State Airlines Operation Authority were commissioned in order to establish civil airlines, and to 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 to manage our international relations on regular basis. With the fast development of World Civil Aviation and the significant progress in the technology, it was reorganized as "Directorate General of Civil Aviation" in 1987. The Directorate General of Civil Aviation achieved its autonomy financially through the Law Nr. 5431 and had its current management structure (Directorate General of Civil Aviation (DGCA), 2015).

Today, the aviation operations held in Turkey are carried out in accordance with the Turkish Civil Aviation Act Nr.2920 and the Administrative and Technical Regulations issued accordingly and the Aviation Instructions. (Directorate General of Civil Aviation (DGCA), 2015)

2.3.2 Green Airport Project

In order to eliminate damages generated by organizations during the operational acitivities in airports, DGCA has started a systematic effort to reduce or mitigate these in terms of environmental and human health aspects.

To achieve this goal, it is required from companies that they must establish an Environmental Management System which is in line with standards and regulations.

This system has to be applicable, well documented, sustainable and also should be convenient to standard and a proper inventory report that complies with the greenhouse gases criteria's.

After completion of these requirements, the organization is given a Green Establishment Certificate. When all of the organizations inside the airport have that Green Establishment Certificate, then the Green Airport Certificate would be given.

Organizations which held Green Establishment Certificate are subject to various discounts related with registration fee and other permission documents which is taken by DGCA. The current deduction amount is indicated in DGCA fee list which is valid for the organizations having Green Establishment certificate (Directorate General of Civil Aviation (DGCA), 2015).

2.4 Greenhouse Gases and Carbon Footprint

While the Earth absorbs some of the energy that receives from the sun and radiates the rest back to space, greenhouse gases hold some of the energy radiated from the Earth and trap it in the atmosphere. Therefore, these gases act as a blanket actually, making the Earth's surface more warm than it otherwise would be. This "greenhouse effect" cycle occurs naturally, but human activities in the past century increased the amount of greenhouse gases in the atmosphere extensively, causing the atmosphere to trap more heat and this resulted several changes in the Earth's climate (Environmental Protection Agency (EPA), 2015).

The major greenhouse gases emitted into the atmosphere through human activities are carbon dioxide, methane, nitrous oxide, and fluorinated gases. Some of these gases are produced almost totally by human activities; while others come from a different combination of natural sources.

The majority of greenhouse gases can remain in the atmosphere for decades after being released. They become globally mixed in the lower atmosphere, reflecting contributions from emissions generated by various sources worldwide.

The effect of one particular greenhouse gas depend on a range of factors. One factor is the duration of time that the gas remains in the atmosphere. Another factor is each gas's individual ability to absorb energy. By considering both of these factors, scientists calculate a gas's potential on global warming, in comparison with an equivalent mass of carbon dioxide (Environmental Protection Agency (EPA), 2015).

2.4.1 Types of Greenhouse Gases

Water vapour: The primary greenhouse gas is water vapour (H_2O), which is responsible for about 70% of the natural greenhouse effect. In the atmosphere, water molecules hold the heat which the earth radiates and then re-radiate into all directions with a result of warming earth's surface, before it is finally radiated back to space. Water vapour in the atmosphere is part of the hydrologic cycle, described as a loop that circulating water from the oceans and land to the atmosphere and back again in terms of evaporation and transpiration, condensation and precipitation.

Human activities do not make any contribution of water vapour to the atmosphere but warmer air has the capacity of captivating much more moisture, therefore increasing temperatures further intensify climate change (European Commission, 2015).

Carbon dioxide: The main contributor to the humankind greenhouse effect is carbon dioxide (CO_2). For a global perspective, it accounts for over 60% of the greenhouse gas effect. In well developed countries, CO_2 makes up more than 80% of greenhouse gas emissions.

There is a finite amount of carbon on earth, which, like water, is part of a cycle – the carbon cycle. This is a very complex system in which carbon moves through the atmosphere, the terrestrial biosphere and oceans.

Like water, carbon has also that it moves through atmosphere, the terrestrial biosphere and oceans which is more complicated compared to water. Plants absorb CO_2 from the atmosphere during the process of photosynthesis. They use the carbon to build their tissue, and they release it back to the atmosphere when they die. The bodies of humans and animals also contain carbon.

Fossil fuels also contain a lot of carbon as remains of dead plants and animals formed over millions of years under a certain condition.

Billions of tonnes of carbon are exchanged each year between the atmosphere, the oceans and land vegetation as a form of natural process. Carbon dioxide levels in the atmosphere seems to changed less than 10% during the 10,000 years before the Industrial Revolution. Since 1800, however, concentrations have gone up by almostt

30% as massive amounts of fossil fuels are used to produce energy. Humans emitting more than 25 billion tonnes of CO2 into the atmosphere each year recently. European researchers founded that current concentrations of CO_2 in the atmosphere are higher now than at any time during the last 650,000 years. CO_2 can stay in the atmosphere more than 50 years up to 200 years due to how it is recycled back in to the land or the oceans (European Commission, 2015).

Methane: Methane is the second-most important greenhouse gas for the enhanced greenhouse effect. Since the beginning of the Industrial Revolution, methane concentration in the atmosphere have doubled. Methane contributed some 20% to the enhancement of the greenhouse gas effect. In industrialised countries, methane holds nearly for 15% of greenhouse gas emissions. Methane is produced predominantly by bacteria that feed on organic material where lacks oxygen. Manmade emissions account the majority but it can be emitted from a variety of natural and human-influenced sources as well. Wetlands, termites, and oceans are examples of natural sources. The mining and burning of fossil fuels, livestock husbandry, rice cultivation and landfills are sources of human-influence. Methane traps heat 23 times more effective at that than CO_2 in the atmosphere. By contrast, its lifetime is shorter, between 10 and 15 years (European Commission, 2015).

Nitrous oxide: Nitrous oxide (N_2O) is produced naturally from oceans, rainforests and by bacterias in soils. Human-influenced sources are nitrogen-based fertilisers, fossil fuel combustion and industrial chemical production using nitrogen, for example, sewage treatment. N_2O accounts for 6% of greenhouse gas emissions in industrialised countries. Nitrous oxide is one of greenhouse gases whose molecules absorb heat trying to release to space like CO_2 and methane. N_2O is 310 times more effective than CO_2 as means of absorbing heat. After the beginning of the Industrial Revolution, nitrous oxide concentrations in the atmosphere have increased by approximately 16% and contributed 4 to 6% to the enhancement of the greenhouse gas effect.

Fluorinated greenhouse gases: These greenhouse gases that do not occur naturally, produced by man for industrial purposes. Their rate of greenhouse gas emissions from industrialised countries is around 1.5%. However, they are so powerful which they can trap heat up to 22,000 times more effectively than CO_2 at the same time they can stay in the atmosphere for thousands of years (European Commission, 2015).

Hydrofluorocarbons (HFCs) are used in cooling and refrigeration, including air conditioning; sulphur hexafluoride (SF_6) is used in the electronics industry; and perfluorocarbons (PFCs), which are emitted during the manufacture of aluminium are examples of fluorinated greenhouse gases. Among them, the most known of these gases are chlorofluorocarbons (CFCs), which are not only fluorinated greenhouse gases, but also it depletes the ozone layer. These gases are being phased out under the 1987 Montreal Protocol on Ozone Depleting Substances (European Commission, 2015).

2.4.2 The Greenhouse Gas Protocol Initiative

The Greenhouse Gas Protocol Initiative is a multi-stakeholder partnership of businesses, non-governmental organizations (NGOs), governments, and others got together by the World Resources Institute (WRI), and the World Business Council for Sustainable Development (WBCSD). The Initiative's mission is to prepare internationally accepted greenhouse gas (GHG) accounting and reporting standards for business and to promote their wide use (Greenhouse Gas Protocol, 2015).

The GHG Protocol Initiative comprises two separate but linked standards:

• GHG Protocol Corporate Accounting and Reporting Standard (this document, provides a step-by-step guide for companies for the purpose quantifying and reporting their GHG emissions)

• GHG Protocol Project Quantification Standard (in preparation; a guide for quantifying reductions from GHG mitigation projects)

This study is focuses on calculation of CO_2 footprint for Sabiha Gökçen International Airport based on abovementioned two standards for quantifying and reporting purposes.

2.4.3 Aviation In Relation To Greenhosuse Gases and Sustainability

Aviation has experienced a fast expansion as the world economy has grown in the last 10 years. Passenger and freight movements by air transportation is on the increase which making air travel the fastest growing sector amongst the other transportation modes. It is also believed that air transport getting safer over the years is the safest in the world compared the highways or sea transportation. Managing the global air transportation system to requires continuous economic and social benefits, while at the same time mitigating environmental impacts, is a big challenge. The system is vast, complex, and multi-disciplinary and involves a lot of stakeholders with different agendas. As a result, sustainable development of the system depends crucially on the delivery to policymakers understanding of the processes and interactions between the key system elements in terms of environmental, social and economic impacts. It is an urgent to establish a model that the contributions of aviation at local and global levels in order to assess aviation policies to be pursued in the future to have stable condition between these impacts (Reynolds, 2007).

Estimates suggest that millions of people are seriously affected by side effects of aviation. Economic vitality and security are 2 main constraints of rising environmental quality. This means that environmental constraints may border on the growth of air transportation system in the 21st century ((ICAO), 2007).

Aviation's contribution to climate change is minor but it is still considerable. ICAO/CAEP's initial estimate about the total volume of CO_2 emissions derived from the industry (both domestic and international) is in the range of 600 million tonnes in 2006. At present, aviation accounts for about 2% of total global CO_2 emissions and about 12% of the CO_2 emissions among all transportation sources ((ICAO) I. C., 2010).

Aircraft engines produce almost same emissions that emissions produced by fossil fuel combustion. However, the majority of these emissions are released directly into the upper troposphere and lower stratospheres. Therefore, it creates a different impact on atmospheric composition, as shown in Figure 2.4. At present, it is really hard to quantify and the estimate the impact of these gases when emitted and formed in such way ((ICAO) I. C., 2010).

Carbon footprint of airports is one of the crucial issues in terms of global warming. Airport Council International (ACI) is the owner of 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 the airport operation (International Civil Aviation Organisation (ICAO), 2015).

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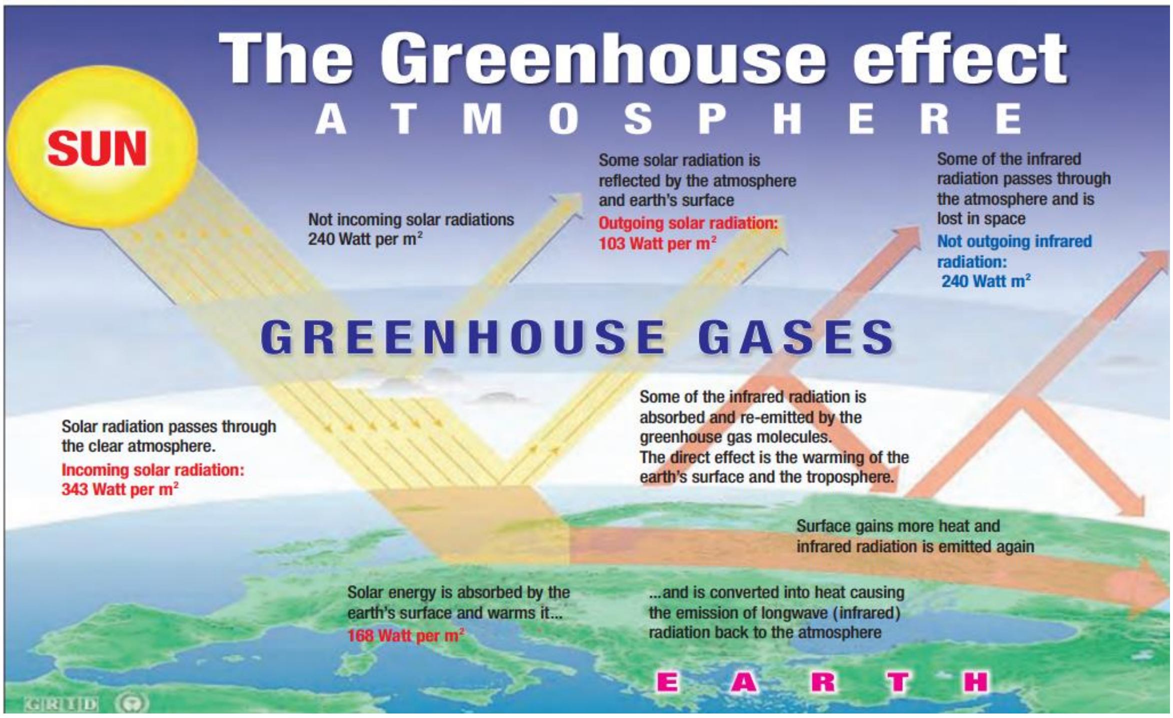

Figure 2. 4 : The greenhouse effect on the atmosphere (IPCC Fourth Assessment Report)

Carbon footprint of the airports is considered as the main subject of "Environmental Sustainability of the Airports". Sustainability is a concept which consists of environmental, social and economic pillars.

Sustainable development seeks to secure the well-being of present and future generations by creating a balance among social, economic and environmental objectives. The three pillars of sustainable development are especially relevant to the international aviation sector as means of safe and efficient transportation, is globally recognized as a crucial component of the global economy and universal social progress (ICAO, 2015) .

In environmental terms, air transport sector is able to reduce its environmental impact by continually improving its fuel consumption, reducing noise and introducing new, more sustainable technologies.

3. MATERIALS AND METHODS

3.1 Carbon Footprint Calculations

To calculate carbon footprint, it is important to identify company operations and emissions. For this identification, imaginary lines called as boundaries are formed. These boundaries are Organizational and Operational Boundaries and they encompass the emissions to include in a company's Greenhouse Gas inventory (Greenhouse Gas Protocol, 2015).

3.1.1 Setting Organizational Boundiries

Organizational boundaries help to determine which company operations to include. It is important to set them because some companies have complex business structure like subsidiaries, joint ventures and franchises. Also, it derives to measure emissions consistenly throughout company.

To set organizational boundaries, it is necessary to combine emissions data from separate operations and this is called as consolidation approach. Consolidation approach based on two approaches which are equity share and control.

Equity share is a percentage of ownership and accounts for emissions according to the company's equity share in the operations. This approach is independent from financial or operational control. For example, there is a company and it has ownership in Factoy A and Factor B. In Factory A, company owns 50% of equity share and in Factory B, it owns 85% equity share. If Factory A releases 1,000 tonnes CO_2 per year this accounts as 500 tonnes per year for the company. Same logic applies for Factory B as well. If Factory B releases 1,000 tonnes CO_2 per year, this accounts as 850 tonnes per year for the company.

Control approach defines as financial and operational control. A hundred percent of emissions from operations under company's control accounts in this approach. Equity share is not in consideration for control approach. As it defined, control approach devides two; Financial Control and Operational Control.

Financial Control is the ability to direct an operations's financial and operational policies. To determine, corporate voting rights and financial accounting status are considered. Operational Control is authority to introduce and implement operating policies. Ownership of operating permit is considered to determine operational control. Both in financial and operational control 100% of the emissions from each operation under control account. But in Financial Control, if there is a joint, percentage of this joint is important (Greenhouse Gas Protocol, 2015).

Summary of consolidation approaches are given in Table 3.1.

Table 3. 1 : Summary of Consolidation Approaches

APPROACH	DEFINITION	GHG ACCOUNTING
EQUITY SHARE	Percent ownership	% owned
FINANCIAL CONTROL	Directs financial policies to gain economic benefits	If yes: 100% If no: 0% If joint: % owned
OPERATIONAL CONTROL	Authority to introduce and implement operating policies	If yes: 100% If no: 0%

3.1.2 Setting Operational Boundiries

After a company has determined its organizational boundaries in terms of the operations that it owns or controls, it then sets its operational boundaries. Operational Boundaries determine which emissions sources to include and how to categorize these emissions. Importance of operational boundaries are to avoid double counting, to provide more useful information to stakeholders and to help manage GHG risks and opportunities along value chain.

There are some steps to set operational boundaries which are;

1. Identifying emissions associated with operations
2. Classifying emissions as direct or indirect
3. Categorizing the "scope" of emissions

In the light of above steps, operations and emissions from these operations should be listed. Afterwards, sources should be identified as direct or indirect emissions. Direct GHG emissions are emissions from sources that are owned or controlled by the company. And, Indirect GHG emissions are emissions that are a consequence of the activities of the company but occur at sources owned or controlled by another company.

Organizational and operational boundaries are in relationship, because classification of direct and indirect emissions is dependent on the consolidation approach (equity share or control) selected for setting the organizational boundary.

Last but not least, emissions should be categorized to scopes. Three scopes are defined to help delineate direct and indirect emission sources.

Scope 1 emissions are direct sourced emissions. They are sourced from a company owns or controls. For instance, generation of electricitiy, heat or steam or physical or chemical processing or transportation of materials, products, waste and employees or fugitive emissions. As long as company owns/controls the source, they are direct emission and define as Scope 1 emissions. Otherwise, the emissions classified as indirect sources which are Scope 2 and Scope 3 emissions. Scope 2 emissions are the indirect emissions that occur when the electricity, heat, steam, or cooling that your company purchases and consumes is generated at a source not owned or controlled by the company. All other indirect emissions are Scope 3 emissions. In other word, Scope 3 emissions are a consequence of the activities of the company, but occur from sources not owned or controlled by the company. Some examples of scope 3 activities are extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services.

An operational boundary defines the scope of direct and indirect emissions for operations that fall within a company's established organizational boundary. The operational boundary (scope 1, scope 2, scope 3) is decided at the corporate level after setting the organizational boundary. Figure 3.1 illustrates company's organizational and operational boundaries (Greenhouse Gas Protocol, 2015).

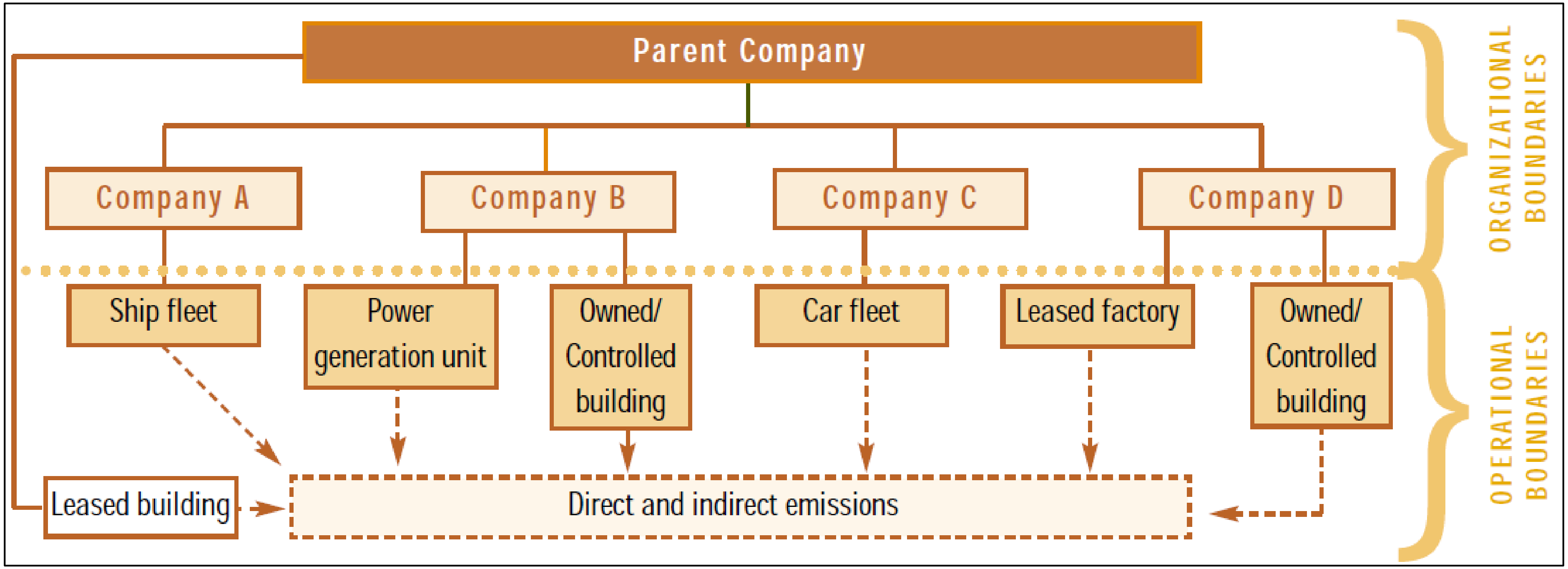

Figure 3. 1 : Organizational and operational boundaries of a company

3.2 Identifying and Calculating Emissions

To conclude with accurate results, there are steps to follow for identifying and calculating emissions;

1. Identify Sources
2. Select Calculation Approach
3. Collect Data and Choose Emissions Factors
4. Apply Calculation Tools

As a first step to calculate emissions, identfying the source is required. GHG emissions typically occur from Stationary combustion, Mobile combustion, Process emissions, Fugitive emissions. Stationary combustion is fuel combustions in stationary equipment. Boilers, furnaces, burners, turbines, heaters, incinerators, engines flares are some examples to stationary combustion. Combustions of fuels in transportation devices are defined as mobile combustions. For instance; automobiles, trucks, buses, trains, airplanes, boats, ships, bargers, vessels are mobile combustions sources. Process emissions are from physical and chemical processes such as CO_2 from calcinations step in cement manufacturing, or CO_2 from catalytic cracking in petrochemical processing, or PFC emissions from aluminum smelting. Intentional and unintentional releases are fugitive emissions. Equipment leaks from joints, seals, packing, gaskets, or coal piles, wastewater treatment, pits, cooling towers, gas processing facilities are some cases that define as fugitive emissions. After identifying emission sources, it is necessary to classify scopes of emissions as Scope 1, 2 and 3.

Furthermore, calculation approach should be selected. There are three types of calculation approach: direct measurement, stoichimetric calculation and estimate emissions. Direct measurent requires monitoring of GHG concentration and flow rate. Stoichiometric calculation is a measurement that observes which elements enter and leave the system. Most common approach is estimate emissions. In this approach, activity dat multiply by appropriate emission factor.

Activity Data x Emission Factor = tonnes of Emissions

Tonnes of Emissions x *Global Warming Potential (GWP)* = Carbon Dioxide Equvalent (CO_2e) of Emissions

Activity data is a data on an activity resulting in emissions. To illustrate, use of electricity, distance of travel or use of gasoline. Through purchasing records, metered consumptions and distances activity data could be find and include into calculations.

Each activity has different emission factor. Emission factors can be obtained from GHG Protocol in calculation tools or IPCC or Government Agencies or sector specific sources such as International Petroleum Indsutry, International Aluminum Institute etc. Emission factors convert acivity data to emission values. They presented in specific units such as kilogram of CO_2 per air kilometer traveled, pounds of CO_2 per kWh of electricity and kilograms of CO_2 per liter of petrol/gasoline. It is important to make sure units' match and use most recent available ones while maintaining consistency.

Global Warming Potential (GWP) is a measure of how much a greenhouse gas contributes to global warming relative to CO_2. GWP converts tonnes of GHG to tonnes of carbon dioxide equivalent (CO_2e) to calculate total emissions using a common unit. Higher GWP means more warming capacity. According to IPCC Assessment Reports, SF_6 has highest GWP value than other greenhouse gases. From highest to lowest; SF_6, PFCs, HFCs, N_2O, CH_4, CO_2.

Briefly, calculation methodology is given at the below. For correct calculations, there are tools. Tools generally differ according to the sectors which allows a good sourcing for emission factors (Greenhouse Gas Protocol, 2015).

3.3 Sabiha Gokcen Internatıonal Airport

3.3.1 Who is Sabiha Gökçen?

On March 22nd of 1913, Sabiha Gökçen was born in Bursa. She was sixth child of Mr. Mustafa İzzet and Mrs. Hayriye. Mustafa Kemal Atatürk founder of Republic of Turkey adopted her after the death of her parents. Atatürk gave her the surname of "Gökçen".

Figure 3. 2 : Sabiha Gökçen

Sabiha Gökçen studied at Çankaya Primary School and Istanbul Üsküdar College for Girls. In 1935, she enrolled in Civil Aviation School “Türk Kuşu” (Turkish Bird) of Turkish Aeronautical Association. Reward of High Gliding brevet was given to her in Ankara. She finished her education of gliding in Crimea, Russia. She was accepted to Eskişehir Military Aviation School in 1936 and she was entitled as “The First Female Combat Pilot”. As the first female pilot of the Tuskish Aeronautical Association “9 number of Jeweled Medal” was granded to her in 1937.

Sabiha Gökçen also awarded with International Aviation Federation Gold Medal in 1991. In 1996, she became the first female aviator of the 20 aviators who put their stamps on world aviation history in Eagles Meeting in America.

March 22nd of 2001, Sabiha Gökçen rested in peace. (HEAŞ Airport Management & Aeronautical Industries Inc., 2016)

3.3.2 History

Sabiha Gökçen Airport was established as the first stage of 6 main elements of Technocity, which would be developed as a “Center of Perfection” within the framework of “Advanced Technology Industrial Park and Airport Project” (İTEP) prepared by Undersecretariat for Defense Industries.

In 1987, "Advanced Technology Industrial Park and Airport Project" (İTEP) was decided to be established in Pendik, Kurtköy with the decision of Defense Industry Executive Committee. When Sabiha Gökçen International Airport was first established, it started its operations with the capacity of 90-thousand-ton Cargo, annual 3 million international and 500.000 domestic passengers. Sabiha Gökçen Airport was established in Istanbul Anatolian side as the first stage of ITEP Project.

Management of Sabiha Gökçen Airport, of which profit would be used in projects concerning the development of technological infrastructure of our country's defense industry and provision of Turkish Armed Forces' needs, was decided to be given to a public capital based joint stock company that will be active within Turkish Commercial Code. As of 27 January 2000, Airport Management and Aviation Industries Inc. (HEAŞ) started to manage the airport with the 96,4% capital share of Undersecretariat for Defense Industries.

HEAŞ, which was established on 27th January 2000 with the partnership of Undersecretariat for Defense Industries (SSM), being in the first place, TUSAŞ Aerospace Industries Inc. (TAI), Turkish Armed Forces Foundation (TSKGV), Turkish Air Association (THK), ASELSAN Electronics Industry and Trade Inc. (ASELSAN), and Air Electronic Industry and Trade Inc. (HAVELSAN) has continued its activities as a 3-partner company since 25.12.2014 when TAI, ASELSAN and HAVELSAN transferred their HEAŞ shares to TSKGV.

Sabiha Gökçen Airport, which was opened to traffic on 8 January 2001 and became first privately operated airport of Turkey and Anatolian side of Istanbul, has become the airport that reflects high technology of 2000s to safety and customer satisfaction and increases passenger capacity in each passing year.

HEAŞ transformed Sabiha Gökçen into an "airport brand" where 4 million passengers of annual 47 thousand passengers are hosted and assigned Management of Ground services, Fuel, Terminal and Warehouses to İSG (Istanbul Sabiha Gökçen International Airport Investment Development and Operation Inc.) which is established by consortium of Limak-GMR-Malaysia Airports as of 1 May 2008 as a result of a tender in July 2007.

Along with rulemaking, organization and inspection activities that being an airport authority brings; HEAŞ also provides electricity-water-gas-heating-cooling services of the airport, aviation information processing activities, VIP services, safety and inspection of gates to the airside activities. It also keeps movement area (runway-apron-taxiway), air information management, fire-plane crash-wreck rescue, first aid and health, navigation devices active for 24 hours. (HEAŞ Airport Management & Aeronautical Industries Inc., 2016)

3.3.3 Organizations

3.3.3.1 Istanbul Sabiha Gökçen International Airport Investment Development and Operation Inc. (ISG)

Istanbul Sabiha Gökçen International Airport Investment Development and Operation Inc. (ISG), is a company founded in partnership by Limak Holding (LIMAK), GMR Infrastructure Limited (GMR), and Malaysia Airports Holdings Berhad (MAHB). As of May 1st of 2008, ISG has 20 years' operation rights of Istanbul Sabiha Gökçen International Airport. Management of the terminal buildings, car park, ground handling, cargo and aircraft refueling operations, the airport hotel and CIP facilities are ISG's control points. LIMAK and GMR transferred its sharws to MAHB at 2014. (Istanbul Sabiha Gokcen International Airport (ISG), 2016).

3.3.3.2 myTechnic

myTECHNIC was founded in 2008 and became a part of Hainan Group Co. Limited (HNA) as of November 2010. It is world's first Lean Greenfield MRO, and located at Sabiha Gokcen International Airport (SAW) on the Asian side of Istanbul, Turkey. myTECHNIC provides MRO service options ranging from wide/narrow body airframe maintenance to engine overhaul and aircraft painting. Built-up are of myTECHNIC hangar is 60,000 square-meter. Hangar beams with 3-floor desing on 15,400 square-meters of bay area. It includes 24,800 square-meters of shop, office and storage area. The facility also encompasses 6,000 square-meters of engine shop are (MyTechnic, 2016).

Figure 3. 3 : View of myTECHNIC

3.3.3.3 HABOM

HABOM is Turkish Airlines’ maintenance centre at Sabiha Gökçen International Airport. HABOM has the capacity to work on 11 single-aisle aircraft simultaneously as well as three long-haul airframes. Part of the hangar for long-haul aircraft has been designed to include a paint shop. There will be stations for servicing auxiliary power units, landing-gear assemblies and other components. (Flight Global, 2014)

3.3.3.4 Pratt & Whitney THY Technic

Pratt & Whitney's Turkish Engine Center is a joint venture between Pratt & Whitney and Turkish Technic. This engine center specializes in CFM56® and V2500® engine overhaul and repair. It is established in 2009 and located at Istanbul’s Sabiha Gökçen International Airport. More than 150 engine overhauls have been performed by Pratt& Whitnet THY Technis (Pratt & Whitney, 2015)

3.3.3.5 Airlines

Numerous airlines give service at Sabiha Gökçen International Airport which are AnadoluJet, Pegasus, SunExpress, Türk Airlines, Germanwings, AirArabia, Emirates, Air Serbia, transavia, flynas, Corendon, Qatar Airways, Wizz Air, Azerbaijan Airlines, Borajet, Flydubai, AtlasGlobal.

Rapid increase in air travel is also seen in SAW and this creates a huge need especially in Istanbul. Annual passenger and flight numbers by years are shown in Table 3.2 and 3.3 and Figure 3.4 displays the increase of passenger and flight numbers.

Table 3. 2 : Annual Number of Passengers

YEARS	NUMBER OF DOMESTIC PASSENGERS	NUMBER OF INTERNATIONAL PASSENGER	TOTAL NUMBER OF PASSENGER
2001	11.924	35.453	47.377
2002	2.975	127.302	130.277
2003	2.826	154.346	157.172
2004	10.323	235.278	245.601
2005	559.824	459.922	1.019.746
2006	2.153.561	762.893	2.916.454
2007	2.563.283	1.228.342	3.791.625
2008	2.789.743	1.568.967	4.358.710
2009	4.547.945	2.092.285	6.640.230
2010	7.665.021	3.933.005	11.598.026
2011	9.117.049	4.571.964	13.689.013
2012	9.762.757	5.045.827	14.808.584
2013	12.029.430	6.813.358	18.842.788
2014	15.028.244	8.603.620	23.631.864

Table 3. 3 : Annual Number of Flights

YEARS	NUMBER OF DOMESTIC FLIGHTS	NUMBER OF INTERNATIONAL FLIGHTS	TOTAL NUMBER OF FLIGHTS
2004	920	5.273	6.193
2005	5.843	8.789	14.632
2006	20.374	11.939	32.313
2007	23.813	15.944	39.757
2008	25.747	19.009	44.756
2009	37.655	22.975	60.630
2010	64.692	41.272	105.964
2011	74.888	43.555	118.443
2012	75.452	49.752	125.204
2013	89.985	59.349	149.334
2014	112.798	72.612	185.410

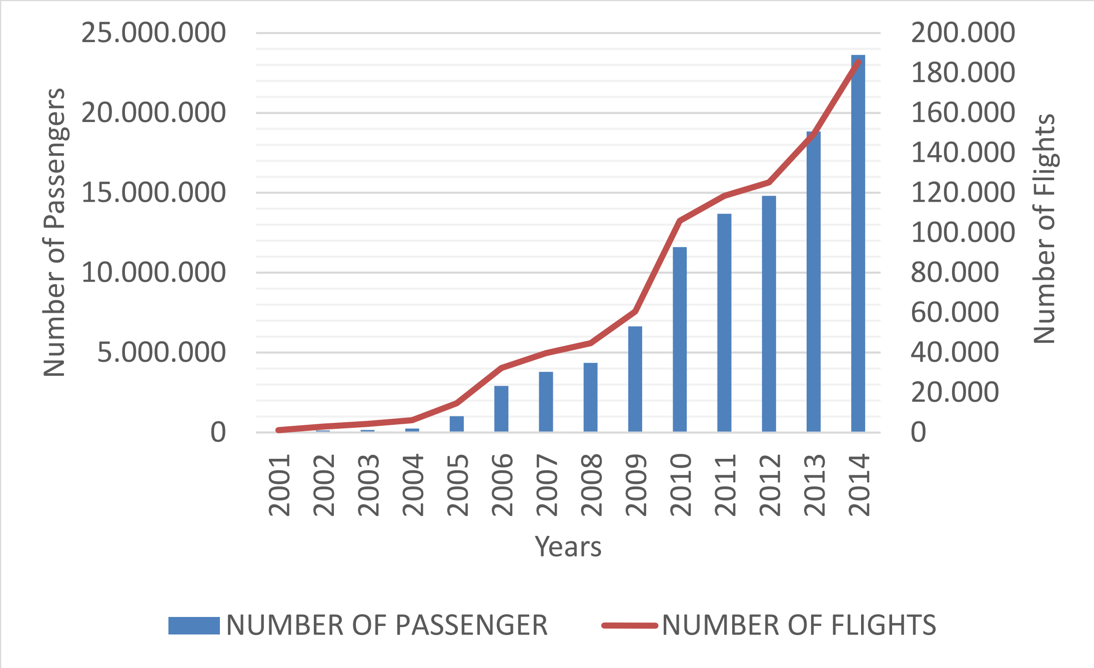

Figure 3. 4 : Passenger and Flight Numbers by Years

3.3.4 Transportation

Sabiha Gökçen International Airport is the second biggest airport in Istanbul, Turkey with passenger capactiy of 25 million per year. It was opened to air traffic on January 8th of 2001 and Turkey's first privately operated airport. By located in Anatolia side of Istanbul, Sabiha Gökçen International Airport gains importance. It is 40 km away from Kadıköy, 12 km away from Pendik and 50 km away from Taksim. It has a really convenient traffic in terms of transportation with its 1.5 km connection to TEM motorway and 5 km connection road to E-5 highway (Airport Management and Aviation Industries Inc. (HEAŞ), 2015).

There are several options to reach airport. Private car, taxis, rent-a-car, public bus, private bus (Havaş and Havataş), sea bus and train are the ways to access airport. Sea bus and train are not directly connected to airport. They are switched lines.

Figure 3. 5 : General view of Sabiha Gökçen Airport

Shuttle service runs for the employers. Employers who work in day shift have 8 shuttle services to Üsküdar, Kadıköy, Bostancı, Uydukent, Uğur Mumcu, Gebze, Libadiye and Çekmeköy districts. Day shift shuttles service 44 times monthly.

Table 3. 4 : Day Shift Shuttle Service Details

	Destination	Shift	Daily Number of Service	Round-Trip (km)	Monthly Total Number of Services	Monthly Total Distance (km)
1	Üsküdar	Daily	2	80	44	3520
2	Kadıköy	Daily	2	70	44	3080
3	Bostancı	Daily	2	60	44	2640
4	Uydukent	Daily	2	20	44	880
5	Uğur Mumcu	Daily	2	50	44	2200
6	Gebze	Daily	2	70	44	3080
7	Libadiye	Daily	2	80	44	3520
8	Çekmeköy	Daily	2	70	44	3080

For night shift employers, there are 9 shuttle services. Shuttles service to Üsküdar, Kadıköy, Bostancı, Uydukent, Uğur Mumcu, Gebze, Libadiya, Aydos and Tuzla districts with monthly total as 120 times.

Table 3. 5 : Night Shift Shuttle Service Details

	Destination	Shift	Daily Number of Service	Round-Trip (km)	Monthly Total Number of Services	Monthly Total Distance (km)
1	Üsküdar	Night	4	90	120	10800
2	Kadıköy	Night	4	80	120	9600
3	Bostancı	Night	4	70	120	8400
4	Uydukent	Night	4	20	120	2400
5	Uğur Mumcu	Night	4	60	120	7200
6	Gebze	Night	4	70	120	8400
7	Libadiye	Night	4	90	120	10800
8	Aydos	Night	4	60	120	7200
9	Tuzla	Night	4	80	120	9600

Day shift shuttles monthly travel 22,000 km, and night shift shuttles trip 74,400 km totally. Figure 3.6 shows total distance travelled by day and night shift shuttles.

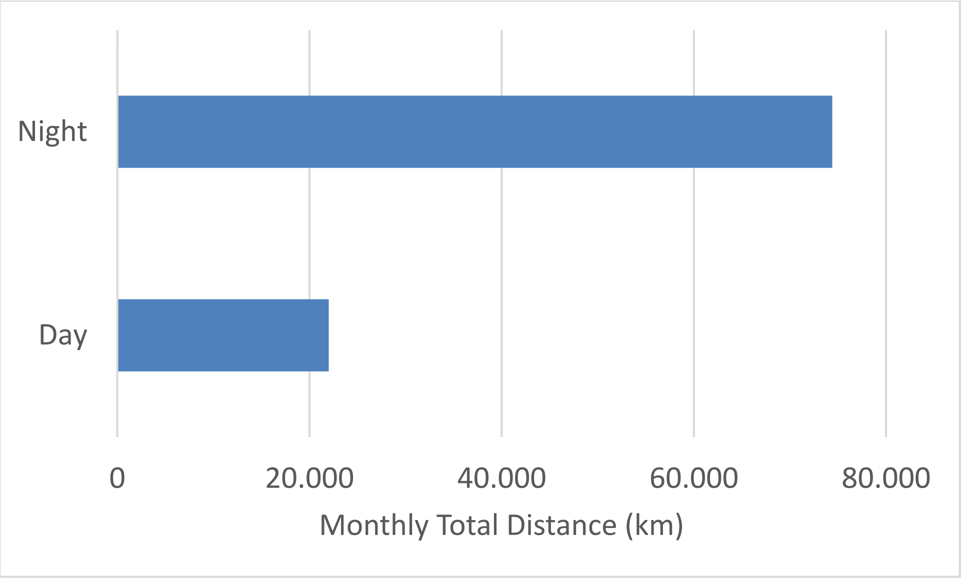

Figure 3. 6 : Day and Night Shift Monthly Total Distances

3.3.5 Utilities

Sabiha Gökçen Airport has 1 runway, 4 apron, taxiways, tower, enterance control building, domestic and international terminal building, cargo terminal, hangar, custom house, fuel site, wastewater treatment plant, baggage handling and control system, fire station, police building, regulator building, power center, heating and cooling plant and solid waste collecting and separation center (Detam, 2013). General information about SAW is summarized in Table 3.6.

Table 3. 6 : General Information of Sabiha Gökçen Airport

City	Istanbul
Starting Date of Operation	2001
Airport Status	Civil
ICAO Code:	LTFJ
IATA	SAW
Traffic Type	Domestic and International
Geographical Coordinates	405354N-291833E (WGS-84)

3.3.5.1 Water Management

Sabiha Gökçen Airpot provides water from Istanbul Water and Sewage Administration (İSKİ) who gives potable water service to around 14 million people (Istanbul Water and Sewerage Administration (ISKI), 2015). According to data from HEAŞ, last 3 years' annual average consumption of water is 319.596 m3. Table 3.7 shows each year's water consumption amounts.

Table 3. 7 : Water Consumption Amount

YEAR	WATER CONSUMPTION (m3)
2012	259.978,00
2013	288.186,00
2014	410.624,00

The airport includes on-site wastewater treatment plant. The wastewater of all units in the airport is treated at on-site plant located on 7500 m2 area. Treatment plant's daily capacity is 1000 m3.

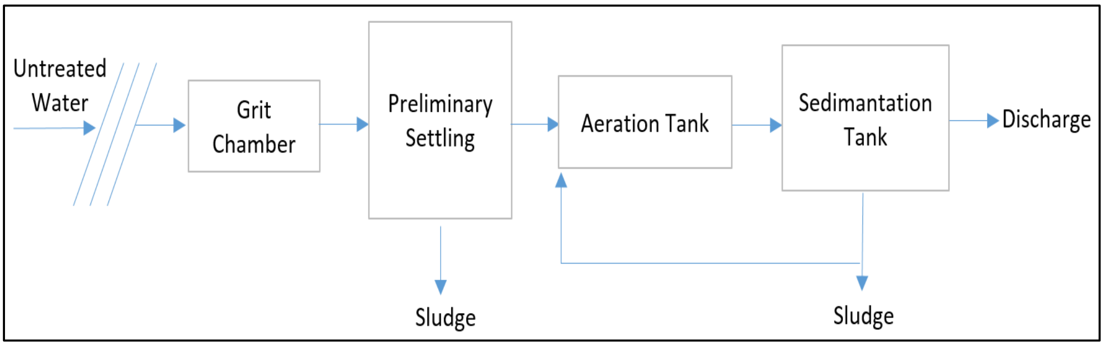

Figure 3. 7 : Process Diagram of Wastewater Treatment Plant

Process diagram of wastwater treatment plant is shown in Figure 3.7. Effluent reached the treatment plant firstly passes through the grit chamber, then goes through the following steps preliminary settling and aeration tank, and seperates to two sedimantation tanks. As a final step, treated wastewater is disinfected and used for irrigation.

Separate collection of white, grey and black water is not existed in any section of airport. However, hundred percent of the treated water reuse for irrigation of green areas.

SAW recycles 100% of its wastewater inside the airport. Treated water fully used in irrigation. The data obtained from HEAŞ instructs that treated water is not enough for irrigation. To supply more water, storm water collection system could be built to airport. By collecting rainwater, more water could be obtained for irrigation purpose.

3.3.5.2 Heating and Cooling

Within the structure of airport, there is a trigeneration system which is under control of ISG. Trigeneration use natural gas to produce electricity, heating and cooling for terminal building. Natural gas is supplied from Istanbul Gas Distribution Industry and Trade Inc. (İGDAŞ).

In the airport, there are two heating plants; one is under control of ISG another one is under control of HEAŞ. Both heating plants use natural gas. Consumption of natural gas given in Table 3.8. ISG's natural gas consumption amount does not contain natural gas consumption amount for trigeneration. Trigeneration's natural gas consumption amounts could not be obtained.

Table 3. 8 : Natural Gas Consumption

Year	Natural Gas Consumption (Kwh) By Heaş	Natural Gas Consumption (Kwh) By Isg	Total Natural Gas Consumption (Kwh)
2012	6,614,629	4,644,235	11,258,864
2013	7,233,636	3,439,513	10,673,149
2014	7,577,854	3,558,406	11,136,260

3.3.5.3 Purchased Electricity

Sabiha Gökçen International Airport purchases electricity from Istanbul Anatolian Side Electricity Distribution Co. (AYEDAŞ) which supplies electricity to approximately 4.7 million people living in the Anatolian Side of Istanbul (Istanbul Anatolian Side Electricity Distribution Co. (AYEDAŞ), 2016).

According to the data obtained from HEAŞ, electricity consumption amount is summarized for 2012, 2013 and 2014. As it seen from the Table 3.9, electricity consumption amount increases every year.

Table 3. 9 : Electricity Consumption By Years

YEAR	ELECTRICITY CONSUMPTION (kWh)
2012	16.657.570,27 kwh
2013	18.508.411,42 kwh
2014	20.564.901,57 kwh

3.3.5.4 Fuel Consumption

Under the contract between HEAŞ and ISG, 2012 model cars give services in the airport. The fuel use is not only used by airside vehicles; it is also consumed for employee transportation by shuttles. Gasoline and diesel are fuel types used. Fuel consumption amounts for 2012, 2013 and 2014 are shown in Table 3.10.

Table 3. 10 : Fuel Consumption Amounts for Airside Vehicles and Shuttles for Employees'

	Gasoline	Diesel
2012	14,622.20 lt.	1,333,160.14 lt.
2013	16,807.12 lt.	1,481,289.05 lt.
2014	18,268.61 lt.	1,559,251.63 lt.

Shuttles for employee transportation uses diesel fuel. As it given under Transportation title of this Chapter, montly total distance travelled by shuttles are 96,400 km which is equal to 1,156,800 km. If average fuel consumption is assumed as 0.06 liter per kilometer by shuttles, total diesel consumption amount for shuttles will be found as 69,408 liters. It is assumed that number of employee shuttle services for 2012, 2013 and 2014 and its travelled distance remain same. As a result, it is predicted that airside vehicles' diesel comsuption amounts would be 1,263,752.14 liters for 2012, 1,411,881.05 liters for 2013 and 1,489,843.63 liters for 2014.

Jet A1 is the fuel type used by aircrafts. SAW includes a storage for Jet A1 and total usage amount is listed in Table 3.11 which for 2012, 2013 and 2014.

Table 3. 11 : Jet A1 Fuel Consumption Amounts

	Jet A1
2012	278,679 lt.
2013	398,679 lt.
2014	492,649 lt.

3.3.5.5 Waste Management

Each facility inside the airport is responsible for its own waste. Only municipal waste is sent to waste collection area of HEAŞ which is responsible to send municipal waste to municipality. Municipal waste amount could not be obtained.
National Resources Defence Council (NRDC) stated that the average amount of waste generated through terminal public areas, retail and restaurant tenants, and airlines is 1,28 pounds per passenger which is equal to 0,58 kg (Atkin, Hershkowitz, & Hoover, 2006). In the light of this information, SAW's waste generation for 2012 to 2014 is calculated as Table 3.12.

Table 3. 12 : Waste Generation of SAW

Years	**Waste Generation**
2012	8.598 tonnes
2013	10.940 tonnes
2014	13.721 tonnes

According to findings of NRDC, waste composition of airports is 20% compostable, 26% nonrecyclable and 54% packing waste (Atkin, Hershkowitz, & Hoover, 2006). Therefore, Table 3.13 is constituted.

Table 3. 13 : Waste Composition of SAW

	Compostables (tonnes)	**Nonrecyclables (tonnes)**	**Packing Waste (tonnes)**	**Total Amount of Waste (tonnes)**
2012	1,720	2,235	4,643	8.598
2013	2,188	2,844	5,908	10.940
2014	2,744	3,567	7,409	13.721

3.3.5.6 Construction of 2^{nd} Runway

In May 5^{th} of 2015, contract of Construction of 2^{nd} Runway Project of Sabiha Gökçen Airport is signed. With this project, capacity of the airport will increase and new facilities will be constructed; such as two aprons, taxiways, tower, and fire department. Also, with new junctions and tunnels transportation to the airport will get easier. The project will satisfy the need of capacity increase (Detam, 2013).

4. RESULTS AND DISCUSSION

4.1 Carbon Footprint Of Sabiha Gökçen International Airport

4.1.1 Organizational Boundaries

SAW contain various companies within itself. To define organizational boundary of SAW, operational control approach was chosen. It is important to determine which companies and activities to include calculations.

Difficulties on data collection make hard to calculate all companies' carbon footprint in the airport. Because of this difficulty, terminal building and common facilities inside the airport are taken account for calculations. As it described previously, HEAŞ responsible for common facilities such as wastewater treatment plant, heating center, wast collection area etc. and ISG responsible for terminal building under supervision of HEAŞ. For the calculations, data obtained from HEAŞ which includes data for ISG as well was used.

4.1.2 Operational Boundaries

4.1.2.1 Identifying Emissions Associated With Operations

According to determined organizational boundry, emission sources associated with operations were detected. Airside vehicles, employee transport, heating plant, wastewater process, purchased electricity, employee vehicles, visitor vehicles, ground access system, generators and aircrafts are some of the main emission sources of SAW.

4.1.2.2 Classifying Emissions As Direct or Indirect

Direct emissions are from sources owned or controlled by the reporting company and indirect emissions are consequence of activities of the reporting company but occur at sources owned or controlled by another company. Hereunder definitions of direct and indirect emissions, sources are segregated.

Direct sources of SAW are airside vehicles, employee transport, and wastewater process. Indirect sources are purchased electricity and natural gas, aircrafts, visitor and employee vehicles, and ground access to airport.

4.1.2.3 Categorizing the "Scope" of Emissions

Direct sources are Scope 1 emissions which are from company owns and controls such as generation of electricity, heat or steam, physical or chemical processing, transportation of materials, products, waste and employees.

Indirect sources are separated to Scope 2 and Scope 3 emissions. Scope 2 emissions are purchased electricity, steam, heating and cooling. And, Scope 3 emissions are all other indirect emissions such as transport in vehicles not owned/controlled by the company, and energy consumed during customer use of company products. Hence, Table 4.1 was emerged in line with this objective.

Table 4. 1 : Summary of Operational Boundries of SAW

Entity	Source	Activity	Type of Source	Scope
HEAŞ	Airport	Fuel consumption by Airside Vehicles, Employee Shuttles	Direct	1
HEAŞ	Airport	WasteWater Processing	Direct	1
HEAŞ	Airport	Deicer Usage (Glycol)	Direct	1
HEAŞ & ISG	Airport	Purchased Natural Gas	Indirect	2
HEAŞ & ISG	Airport	Purchased Electricity	Indirect	2
Airlines	Tenant	Fuel Consumption by Aircraft	Indirect	3
Employees	Airport	Employee Vehicles	Indirect	3
Public	Tenant	Visitor Vehicles	Indirect	3
Public	Ground Access	Cars, taxi	Indirect	3
Public	Ground Access	Bus, shuttles	Indirect	3

4.1.3 Calculation of Carbon Footprint

4.1.3.1 Carbon Footprint of 2012, 2013 and 2014

For years of 2012, 2013 and 2014, data collected to calculate Carbon Footprint of SAW Collected data was given under Utilities title of Chapter 3 and summarised in Table 4.2.

Table 4. 2 : Summary of 2012, 2013 and 2014 Data

	2012	**2013**	**2014**
Passenger Number	14,808,584	18,842,788	23,631,864
Flight Number	125,204	149,334	185,410
Electricity Consumption	16,657,570.27 kwh	18,508,411.42 kwh	20,564,901.57 kwh
Solid Waste Generation	8,598 tonnes	10,940 tonnes	13,721 tonnes
Water Consumption	259,978 m3	288,186 m3	410,624 m3
Jet A1 Fuel Consumption	278,679 liters	398,679 liters	492,649 liters
Gasoline Fuel Consumption by Airside Vehicles	14,622 liters	16,807 liters	18,269 liters
Diesel Consumption by Airside Vehicles	1,263,752.14 liters	1,411,881.05 liters	1,489,843.63 liters
Diesel Fuel Consumption by Employee Shuttles	69,408 liters	69,408 liters	69,408 liters
Natural Gas Consumption[1]	11,258,864 kWh	10,673,149 kWh	11,136,260 kWh
Deicing Agent Usage (Glycol)	10,167.25 tonne	12,126.74 tonne	15,056.31 tonne

Estimate emissions which is a calculating approach with a method that multiply activity data by appropriate emission factor was selected.

Activity Data	x	Emission Factor	=	tonnes of Emissions
Tonnes of Emissions	x	*Global Warming Potential (GWP)*	=	Carbon Dioxide Equivalent (CO_2e) of Emissions

[1] Natural Gas consumption amount for ISG's Trigeneration Unit is not included.

Global Warming Potential (GWP) is a measure of how much greenhouse gas contributes to global warming relative to CO_2. IPCC-2006 indicated GWP for GHG as Table 4.3 (IPCC, 2016)

Table 4. 3 : Global Warming Potential Values

Green House Gas	Global Warming Potential
CO_2	1
CH_4	21
N_2O	310
HFCs	140 - 11,700
PFCs	6,500 - 9,200
SF_6	23,900

Airport Carbon and Emissions Reporting Tool (ACERT), is preapared by Airports Council International (ACI) to calculate greenhouse gas emissions inventory. It is an Excel spreadsheet and especial for airports. To calculate accurate carbon footprint of SAW, ACERT v3.1 calculation tool was used.

During the calculations some assumptions were made. Glycol usage could not be obtained from HEAŞ, so glycol consumption amount was calculated by flight number, de-icing amount for one plane, and number of snow day. One commercial plane needs around 1900-3800 liter de-icer (Detam, 2013). It was assumed that annually 10-day snows in Istanbul. From each year's flight number, daily number of flight was calculated.

Sample calculation for de-icing:

185,140 is total number of fligt for 2014

185,140 / 365 = 508 flight / day

10 snow day * 508 flight / day * 3,800 liters = 19,302,958.90-liter max. glycol usage

10 snow day * 508 flight / day * 1,900 liters = 9,651,479.45-liter min. glycol usage

Average of minimum and maximum glycol usage was accepted as glycol usage amount which is 14,477,219.18 liters for sample calculation. Clariant which is a deicer with a CAS number 57-55-6 is used in the SAW. According to MSDS, density of deicer is 1.04 g/cm^3. This means that 14,477,291.18-liter glycol usage is equal to 15,056.31 tonne.

For 2012 and 2013, same calculation is applied, and 10,167.25 tonne for 2012 and 12,126.74 tonne for 2013 were found. (See Table 4.4 for summary of glycol consumptions)

Table 4. 4 : Summary of Glycol Consumption Calculations

	Flight Number	Flight Day	Max. (liter)	Min. (liter)	Ave. (liter)	Ave. (tonne)
2012	125,204	343	13,034,936.99	6,517,468.49	9,776,202.74	10,167.25
2013	149,334	409	15,547,101.37	7,773,550.68	11,660,326.03	12,126.74
2014	185,410	508	19,302,958.90	9,651,479.45	14,477,219.18	15,056.31

Another assumption was made for the calculation of waste generation. National Resources Defence Council (NRDC) stated that the average amount of waste generated through terminal public areas, retail and restaurant tenants, and airlines is 1.28 pounds per passenger which is equal to 0.58 kg (Atkin, Hershkowitz, & Hoover, 2006). In light of this information, waste generation calculated as Table 3.12.

Each years' data was entered to ACERT v3.1 calculation tool and separately calculated. Scope 1 emissions which are sourced by and under control of HEAŞ resulted as Table 4.5, 4.6 and 4.7.

Table 4. 5 : Scope 1 Emissions for 2012

			Greenhouse Gases (tonnes)			
Source		**Scope**	**CO_2**	**CH_4**	**N_2O**	**CO_{2e}**
Airport	Airside Vehicles and Employee Shuttles	1	3,584	0.1460	0.1976	3,648
Airport	Glycol Usage	1	8,603.6	-	-	8,603.6
Airport	Wastewater Processing	1	0.0	28	0	591.4
Subtotal	**Airport Scope 1**		**12,187**	**28**	**0**	**12,843**

Table 4. 6 : Scope 1 Emissions for 2013

			Greenhouse Gases (tonnes)			
Source		**Scope**	**CO_2**	**CH_4**	**N_2O**	**CO_{2e}**
Airport	Airside Vehicles and Employee Shuttles	1	3,983	0.1625	0.2196	4,055
Airport	Glycol Usage	1	10,261.7	-	-	10,261.7
Airport	Wastewater Processing	1	0.0	35	0	743.9
Subtotal	**Airport Scope 1**		**14,245**	**36**	**0**	**15,060**

Table 4. 7 : Scope 1 Emissions for 2014

			Greenhouse Gases (tonnes)			
Source		**Scope**	**CO_2**	**CH_4**	**N_2O**	**CO_{2e}**
Airport	Airside Vehicles and Employee Shuttles	1	4,194	0.1713	0.2313	4,269
Airport	Glycol Usage	1	10,940.2	-	-	10,940.2
Airport	Wastewater Processing	1	0.0	44	0	924.9
Subtotal	**Airport Scope 1**		**15,134**	**44**	**0**	**16,135**

Scope 1 emission results show that there is a rapid increase by years in the amount of CO_2 emissions. Main source of Scope 1 emissions is glycol usage in the airport which was added to calculation by making assumption as 10 snow day for each year. Second main source of CO_2 emissions is fuel consumption of airside vehicles and employee shuttles. Fuel consumption amounts which are diesel and gasoline were entered to calculate airside vehicles’ and employee shuttles’ emissions. Processing of wastewater is another source of Scope 1 emissions and it is less than glycol usage and airside vehicles & employee shuttles.

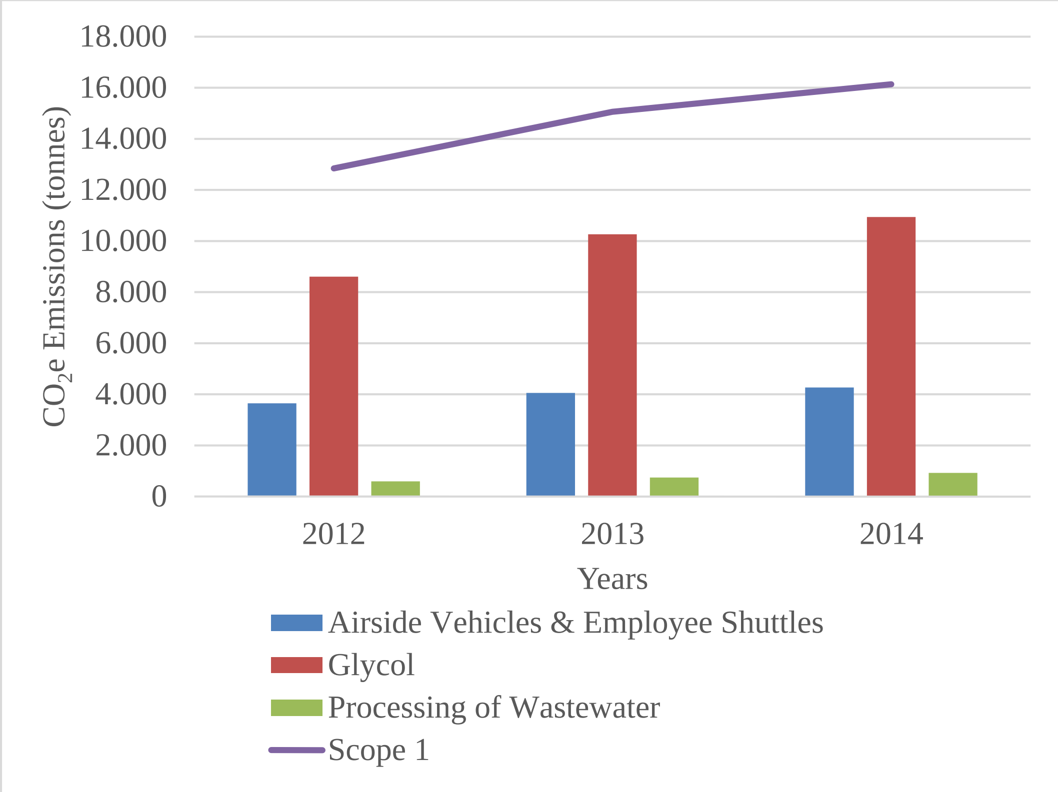

Figure 4. 1 : Comparison of Scope 1 Emissions by Years

Comparison of emission amounts shows that glycol usage causes much more emissions than airside vehicles & employee shuttles and process of waste and wastewater (See Figure 4.1). Therefore, it is important to use more environmentally friendly de-icing product or recycle deicer to decrease affect of glycol.

Scope 2 emissions which were summarized in Table 4.8 show purchased electricity and natural gas effect as an emission source. When Scope 2 is comparied with Scope 1, it is appeared that Scope 2 causes less amount of CO_2 emissions than Scope 1.

Electricity purchasing results more emissions than natural gas purchasing. And, it is also seen that Scope 2 emissions remains each year. Even purchased electricity and natural gas are indirect sources, HEAŞ has control on them and amounts can be reduced. For example, to achieve less amount for electricity purchased, renewable energy sources can be applied to generate power, or consumption can be lowered by using energy efficient lighting and equipment.

Table 4. 8 : Scope 2 Emissions for 2012, 2013 and 2014

	Source		Scope	Greenhouse Gases (tonnes) CO_2	CH_4	N_2O	CO_{2e}
2012	Airport	Electricity purchased	2	7,656			7,656
		Natural Gas purchased		2,274	0.0405	0.0041	2,276
	Total			**9,929**	**0**	**0**	**9,932**
2013	Airport	Electricity purchased	2	8,506			8,506
		Natural Gas purchased		2,155	0.0384	0.0038	2,157
	Total			**10,662**	**0**	**0**	**10,664**
2014	Airport	Electricity purchased	2	9,452			9,452
		Natural Gas purchased		2,249	0.0401	0.0040	2,251
	Total			**11,700**	**0**	**0**	**11,703**

Scope 3 emissions are indirect emissions. They are not sourced or controlled by HEAŞ or ISG. Table 4.9, 4.10 and 4.11 are scope 3 emissions of SAW by years. Calculations made by some assumptions and also by data obtained from HEAŞ.

Average trip distance is accepted as 40 km which is a distance from airport to city center.

HEAŞ informed that number of airport operator employees are around 320 and number of tenant employess are around 1000. Percentage of passengers taking connecting flights and percentage of passengers travelling on public transport were accepted as 30% for each and %40 reaches airport by their own vehicles. Vehiles used by staff/visitors/passenger were considered as 84% via car, 5% via truck/SUV/Light duty vehicle, 1% via motocycle, and 10% via bus/train/bicycle/walk.

Number of tenants at airport is around 40 and it was assumed that average daily visitors or deliveries to each tenant is 10.

Percentage of different fuel types were considered as 10% for gasoline and 90% for diesel cars and 15% for gasoline and 85% for diesel light duty vehicles.

According to Istanbul Electric Tramway and Tunnel Establishments (IETT), there are 12 bus route for SAW and as a total buses give service 306 times daily (Istanbul Electric Tramway and Tunnel Establishments (IETT), 2016). It was accepted that one-way distance of each bus is around 40 km. It was considered that 10% of buses use gasoline and 90% of buses use diesel fuel. Also, there is a hotel inside the airport and shuttles give service to reach the terminal. It was assumed that 20 times a day they service is given and one-way distance is around 5 km. For fuel usage, same percentage amounts with buses is taken account which are 10 % for gasoline, and 90% for diesel fuel. These assumptions and data were applied to all years.

Table 4. 9 : Scope 3 Emissions of 2012

			Greenhouse Gases (tonnes)			
Source		**Scope**	**CO_2**	**CH_4**	**N_2O**	**CO_{2e}**
Tenant	Aircraft (fuel consumption)	3	707	-	-	707
Tenant	Staff/visitor Vehicles	3	6,541	0.3149	0.5256	6,710
Airport	Employee Vehicles	3	1,490	0.0791	0.1193	1,529
Tenant/off-site/Staff Sub-total						**8,946**
Ground Access	Cars, taxi	3	66,343	3.04	5.34	68,063
	Bus, hotel shuttle	3	13,863	0.36	1.12	14,218
	Rail	3	-	-	-	-
Public Sub-total						**82,282**
Airport Scope 3			**88,944**	**4**	**7**	**91,228**

Table 4. 10 : Scope 3 Emissions of 2013

			Greenhouse Gases (tonnes)			
Source		**Scope**	**CO_2**	**CH_4**	**N_2O**	**CO_{2e}**
Tenant	Aircraft (fuel consumption)	3	1,011	-	-	1,011
Tenant	Staff/visitor Vehicles	3	6,541	0.3149	0.5256	6,710
Airport	Employee Vehicles	3	1,490	0.0791	0.1193	1,529
Tenant/off-site/Staff Sub-total						**9,250**
Ground Access	Cars, taxi	3	84,417	3.87	6.80	86,605
	Bus, hotel shuttle	3	13,863	0.36	1.12	14,218
	Rail	3	-	-	-	-
Public Sub-total						**100,824**
Airport Scope 3			**107,321**	**5**	**9**	**110,074**

Table 4. 11 : Scope 3 Emissions of 2014

Source		Scope	Greenhouse Gases (tonnes)			
			CO_2	CH_4	N_2O	CO_{2e}
Tenant	Aircraft (fuel consumption)	3	1,249	-	-	1,249
Tenant	Staff/visitor Vehicles	3	6,541	0.3149	0.5256	6,710
Airport	Employee Vehicles	3	1,490	0.0791	0.1193	1,529
Tenant/off-site/Staff Sub-total						**9,488**
Ground Access	Cars, taxi	3	105,872	4.85	8.53	108,617
	Bus, hotel shuttle	3	13,863	0.36	1.12	14,218
	Rail	3	-	-	-	-
Public Sub-total						**122,816**
Airport Scope 3			**129,015**	**6**	**10**	**132,324**

In brief, Table 4.12 compiles Scope 1, Scope 2, Scope 3 and total CO_2 emission amounts for 2012, 2013 and 2014 in tonnes of CO_2 equivalent.

Table 4. 12 : Overall CO_2e Emissions by Years

	2012	2013	2014
Scope 1 emissions	12,843 tonnes	15,060 tonnes	16,135 tonnes
Scope 2 emissions	9,932 tonnes	10,664 tonnes	11,703 tonnes
Scope 3 emissions	91,228 tonnes	110,074 tonnes	132,324 tonnes
Total CO2 emissions	114,002 tonnes	135,798 tonnes	160,161 tonnes

The graph, Figure 4.2, illustrastes that CO2 emissions has risen dramatically over the years (2012-2014).

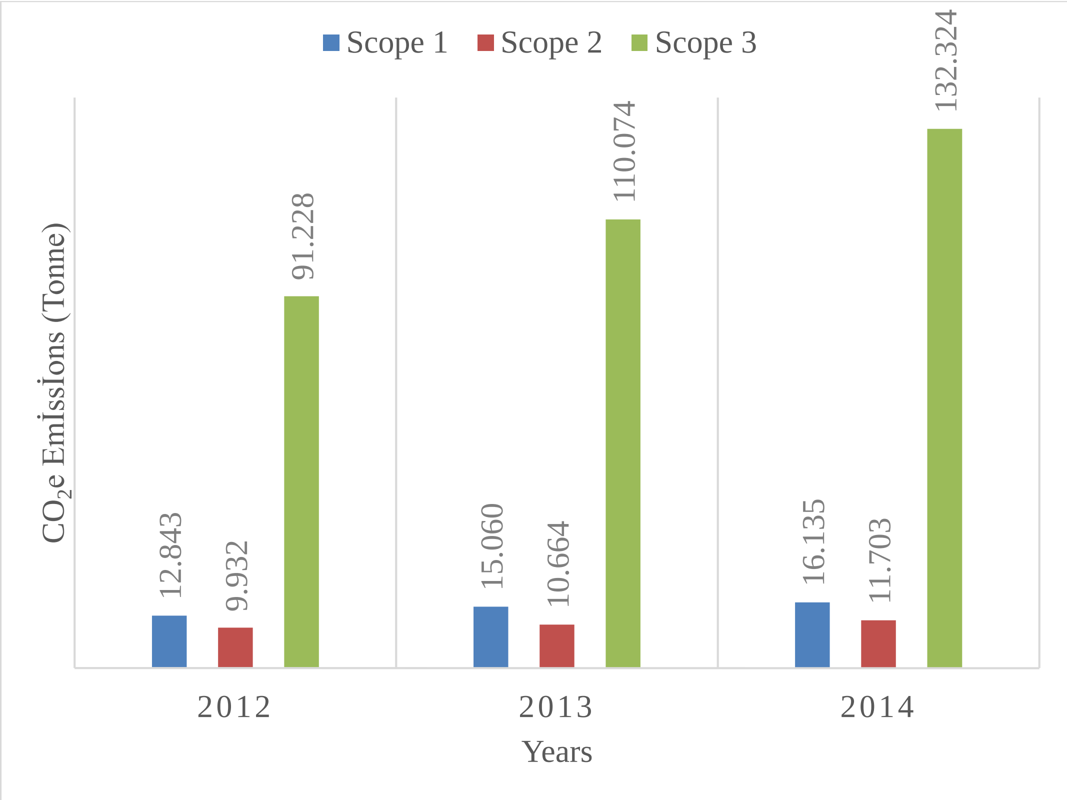

Figure 4. 2 : CO_2 Emissions by Years

4.1.3.2 Carbon Footprint After Completion of 2nd Runway

According to SAW 2nd Runway Environmental Impact Assessment (EIA) Report, construction of 2nd Runway will complete and provide service at 2017. Expected daily passenger number will be 194.444, flight number will be 556.830 and number of employee will be 2000 in the terminal (Detam, 2013). To calculate carbon footprint after completion of 2nd runway, it was assumed that all utilities will remain same. And, 2014 was selected as a base year. According to data obtained from EIA Report, forseen consumption amounts were calculated as Table 4.13.

Table 4. 13 : Foreseen Consumption Amounts

	Consumption Amounts	Calculation Based On
Electricity Consumption	61,761,248.64 kwh	Passenger
Waste Generation	41,206 tonnes	Passenger
Water Consumption	1,233,201 m3	Passenger
Jet A1 Fuel Consumption	1,479,541 liters	Flight
Gasoline Consumption	54,865 liters	Passenger
Diesel Consumption	4,682,800 liters	Passenger
Shuttle	7,155,000 km	Employee
Natural Gas Consumption	33,444,815 kWh	Passenger
Deicing	45,217.65 tonnes	Flight

Foreseen consumption amounts entered to ACERT v3.1 calculation tool and expected emission amounts were calculated as Table 4.14.

Table 4. 14 : Forseen Emission Amounts

			Greenhouse Gases (tonnes)			
Source		**Scope**	**CO_2**	**CH_4**	**N_2O**	**CO_{2e}**
Airport	Airside Vehicles, Shuttles	1	12,596	0.5146	0.6947	12,822
Airport	Glycol	1	38,263.5			38,263.5
Airport	Process (Waste/Water)	1	0.0	132	0	2,763.7
Subtotal	**Airport Scope 1**		**50,859**	**132**	**1**	**53,849**
Airport	Electricity purchased	2	28,385			28,385
Airport	Heat Purchase	2	6,754	0.1204	0.0120	6,760
Subtotal	**Airport Scope 2**		**35,139**	**0**	**0**	**35,146**
Airport Operator Sub-total						**88,995**
Tenant	Aircraft (from total fuel)	3	3,750	-		3,750
Tenant	Staff/visitor Vehicles	3	11,197	0.5621	0.8985	11,487
Airport	Employee Vehicles	3	9,312	0.4945	0.7457	9,554
Tenant/off-site/Staff Sub-total						**24,791**
Ground Access	Cars, taxi	3	317,958	14.58	25.61	326,203
	Bus, shuttles	3	13,863	0.36	1.12	14,218
Public Sub-total						**340,421**
Subtotal	**Airport Scope 3**		**356,080**	**16**	**28**	**365,212**
TOTAL CO_2e emissions (tonnes)			**442,079**	**148**	**29**	**454,207**

Figure 4.3 shows comparison of Scope 1 and Scope 2 Emission for expected CO_2 emissionsand based year (2014). As it seen from the graph, emissions for Scope 1 and 2 will be redoubling.

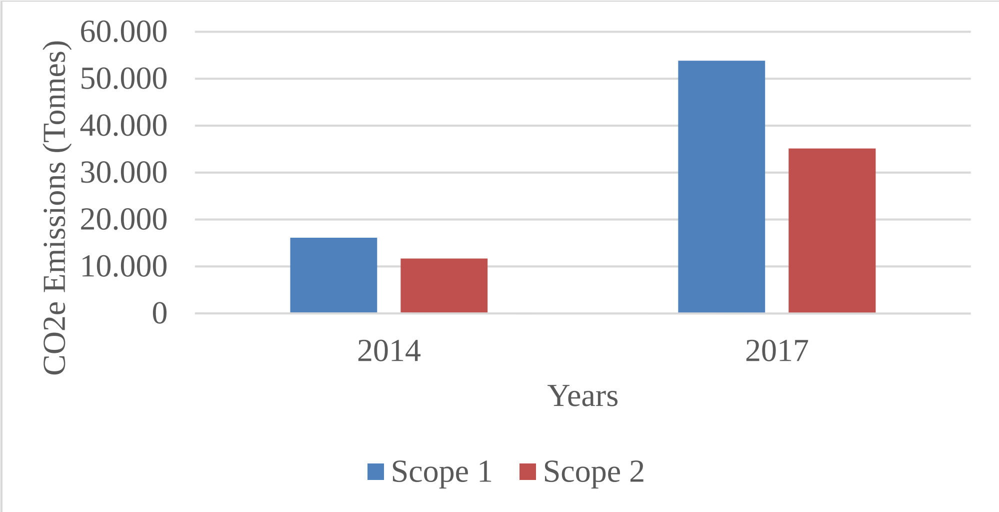

Figure 4. 3 : Comparison of Scope 1 and Scope 2 Emissions for Expected CO_2 Emissions and Based Year

Table 4.15 shows that after the completion of 2^{nd} runway, CO_2 emissions will show great extent. Each sources within Scope 1&2 emissions estimated to increase 3 times more than based year. And, this will be cause due to the capacity increase. To decrease this upcoming effect, environmentally friendly equipments and materials should be used for new portion of the airport and sustainability plans should be shcemed and applied.

Table 4. 15 : Expected Emission Amounts Compared to Based Year

	Expected CO_2 Emission Amounts	**Based Year CO_2 Emission Amounts (2014)**
Scope 1	53,849 tonnes	16.135 tonnes
Scope 2	35,146 tonnes	11,703 tonnes
Scope 3	365,212 tonnes	132,324 tonnes
Total	**454,207 tonnes**	**160,161 tonnes**

4.2 General Evaluation for 2012, 2013 and 2014 Carbon Emissions

Airport, tenants and public are emission sources of SAW. Depending on their activities, they are direct and indirect sources. Calculations show that public sources are dominant. Figure 4.4 demostrates percentage distribution of emission sources based on average value of 2012, 2013 and 2014.

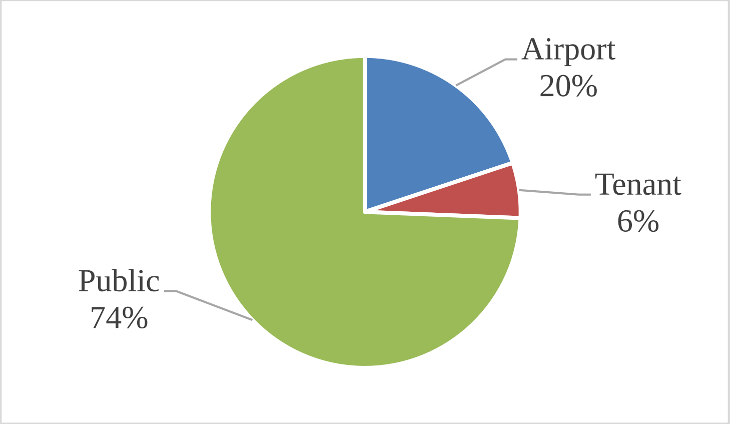

Figure 4. 4 : Percentage Distribution of Average Emission Sources for 2012-2013-2014

Scope 3 emissions are not controllable sources. Activities of scope 1 and scope 2 can be reduced by alternative solutions and correct management. As it mentioned previously, airside vehicles, employee shuttles, glycol usage, processing of wastewater on site, purchased electricity and purchased natural gas are SAW's manageable actitivities. Percentage distribution of these activities as to total of controllable sources is shown in Figure 4.5.

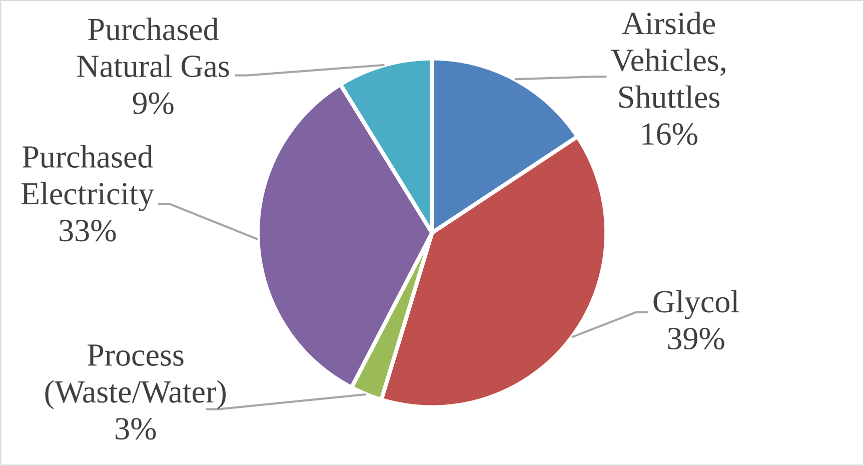

Figure 4. 5 : Percentage Distribution of Average Scope 1 and Scope 2 Emissions for 2012, 2013 and 2014

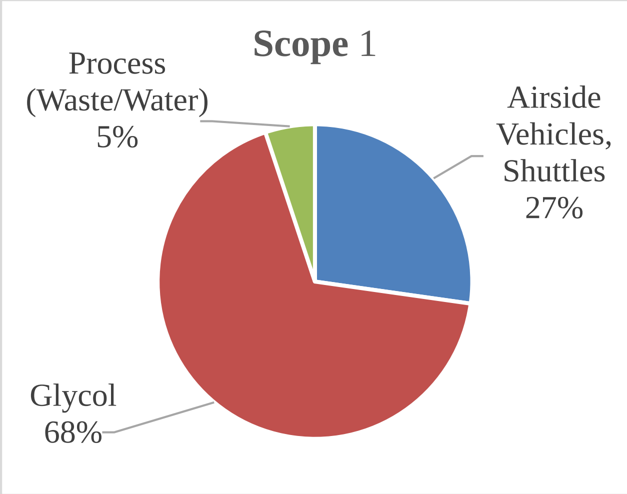

Figure 4. 6 : Percentage Distribution of CO_2e within Scope 1 Activities

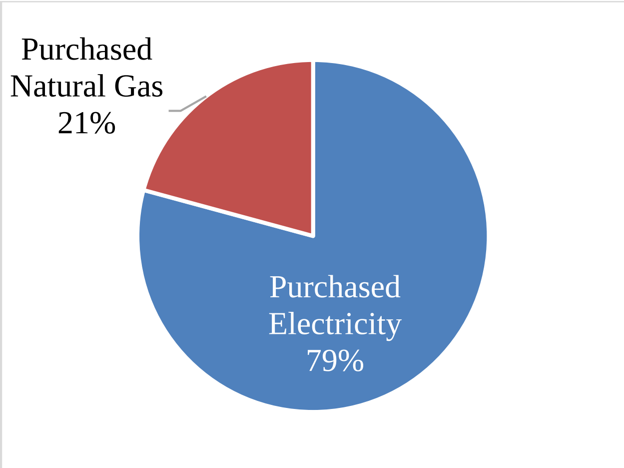

Figure 4. 7 : Percentage Distribution of CO_2e within Scope 2 Activities

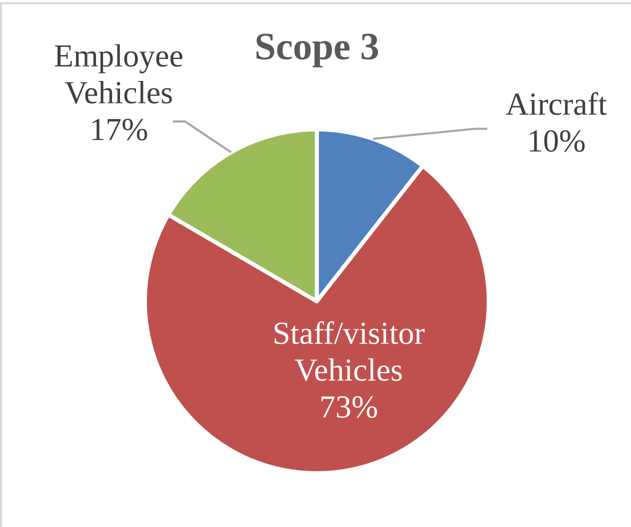

Figure 4. 8 : Percentage Distribution of CO_2e within Scope 3 Activities

For years 2012, 2013 and 2014, average usage of glycol is computed and percentage amount is found as %68 for glycol, %27 for airside vehicles and shuttles, and %5 for process of waste and water within Scope 1 activities. Glycol consumption amount which was found by assumptions is the main source of Scope 1 activities according to calculations (See Figure 4.6).

Same way applied to Scope 2 emission sources for finding percentage distribution. Purchased electricity has higher emission amount than purchased natural gas. Purchased electricity is %79 and purchased natural gas is %21 of Scope 2 emisions (See Figure 4.7).

Based on suppositions, Scope 3 emissions amount are estimated. Identical method of the below is applied to find average amounts and percentage distribution. In accordance with the result, staff and visitor vehicles cause most emissions compared to other Scope 3 sources. %73 of Scope 3 emissions are staff and visitor vehicles. Employee vehicles produce %17 and aircrafts generate %10 of Scope 3 emissions (See Figure 4.8). These emission sources are not manageable. But, they may respond to environmental arrengements such as rising amount of public transportation.

4.3 Suggestions And Solutions

4.3.1 Scope 1 Emission: Airside Vehicles & Employee Shuttles

Airside vehicles and employee shuttles are second rank Scope 1 emission. At 2014 4,269 tonnes CO_2e, at 2013 4,055 tonnes CO_2e and at 2012 3,648 tonnes CO_2e emission released. To decrease amount of emissions from airside vehicles and employee shuttles, alternative way was searched.

Through research, electric car found as a solution. Electric cars release zero CO_2 emissions while in use, but power source during the manufacturing electric cars matters. Electric cars have higher manufacturing emissions than normal cars. The fuel to manufacture electric car takes important role in total life time emission of electric car and there are various types of fuel mix such as coal based, fossil heavy, broad mix, fossil light and low carbon. Even manufacturing of electric car releases high emissions; life time emission of electric cars is lower than normal cars. (Buekers, Holderbeke, Bierkens, & Panis, 2014)

2014 values were selected for benchmarking, and following calculations were made.

Fuel consumption amounts for airside vehicles and employee shuttles at 2014:

- Gasoline : 18,269 liters
- Diesel : 1,559,252 liters

Total Fuel Consumption Amount:

18,269 liters + 1,559,252 liters = 1,577,521 liters

Average fuel consumption was assumed as 0,06 liters per kilometer.

Total travelled length at 2014:

1,577,521 liter / 0,06 liters/km = 26,292,017 km

For electric cars' electricity consumption Renault Fluence Elctric Car is taken as an example. It consumes 140 Wh/km (Renault, 2011).

26,292,017 km x 140 Wh/km x 0,001 kWh/Wh = 3,680,882 kWh electricity is consumed totally for 2014. This consumption amount is equal to 1,691 tonnes CO_2e which is less than 4,269 tonnes CO_2e. If electric car prefered rather than diesel or gasoline cars, total emission from airside vehicles and shuttles would be lower.

4.3.2 Scope 1 Emission: Deicer

The deicer consists of three components which are glycol, additives and water, and it is a very important issue for airports as a common procedure in colder-weather. Usually for existing ice removal or protect against ice reformation, deicing activity is implemented. It is necessary to manage dicer application, because impact of deicers can be very dangerous. After deicing, disposal requires attention. Wastewater treatment, recycling and dispersal to the environment are essential steps of disposaling. However, not every airport recycles deicer. SAW do not have a collecting system for deicer. Most airports who receive snow oftenly, drains deicer with wastewater and send it to wastewater treatment plant or recycle deicer onsite/offsite the airport (See Figure 4.9) (Johnson, 2011).

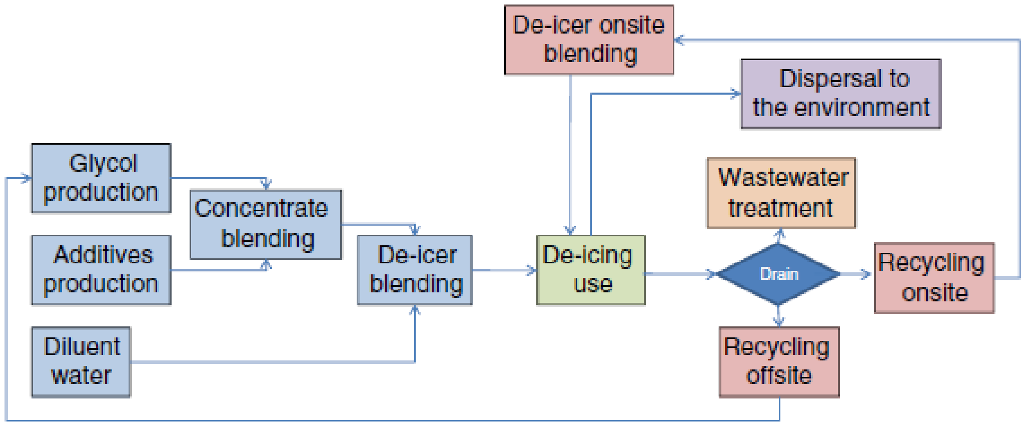

Figure 4. 9 : The life-cycle of aircraft de-icing

Recycling of deicer reduces airport's carbon footprint. To illustrate, deicer product company named as Clarinat which is also used by SAW, built off-site recycling plant for aircraft de-icer in Oslo International Airport (reprocessing 60-70% of deicer fluid) similar to Zurich Airport. Munich Airport is another example for recycling deicer. Munich Airport has on-site recycling plant. Process of recycling the deicer is follow these steps; deicer is captured by drains under the de-icing platforms; it is treated, then concentrated with 60-65% Mono-Proplene Glycol (MPG); and as a final step this concentrate is purified to commercial specificatins for virgin MPG. The recycling reduces life-cycle emissions of de-icing about 0.4 tonnes of CO_2e per ton of saved glycol (Clariant, 2011). If SAW had a similar recycling plant at 2014 and reprocessed 65% of the aircraft de-icer fluid similar to Oslo International Airport, SAW would have been reduced by 3,916.98 tonnes CO_2e emissions over the life-cycle of de-icing.

Another method to cut down glycol emissions is to use bio deicer. Bio deicers have the same chemical composition as propylene glycol, $C_3O_2H_8$ and reduce carbon footprint. For instance, a bio deicer called as Susterra has cradle to gate footprint as 2.18 kg CO_2e/kg Susterra. MPG has 4.06 kg CO_2e/ kg convetionale propylene glycol. Sustterra's footprint nearly half of the MPG' footprint (Johnson, 2011).

4.3.3 Scope 1 Emission: Process (Waste/Water)

Under airport control, %100 of wastewater treated on site. This information was used in the calculations and for wastewater process 591.4 tonnes CO_2e in 2012, 743.9 tonnes CO_2e in 2013 and 924.9 tonnes CO_2e emissions in 2014 were released. Waste to landfill calculation is not available in ACERT v3.1 that used during calculations. Therefore, waste to landfill could not be included to the calculations and effect of waste to landfill could not be observed.

However, on site composting was calculated to be examined the effect. Values of 2014 is used for calculations. As it mentioned in Waste Management Section of Chapter 3, total amount of compostable waste was 2,744 tonnes in 2014. This value entered to ACERT v3.1 and total emission of composting is calculated as 1,086.6 tonnes CO_2e.

4.3.4 Scope 2 Emission: Purchased Electricity

Purchased electricity is the highest emission source of Scope 3 emissions. To reduce amount of release from purchased electricity renewable energy sources could be alternative solution. Solar Panel System which is one of the renewable energy source is examined as an alternative.

Solar Panel Systems have applications in various fields; airports are one of them. As an example, Cochin International Airport located in in the Southern State of Kerala, Cochin, India is the first airport in the world run completely on solar power. 46,150 solar panels laid on 45 acres' area which is equal to 182,108,539 square meters. (Cochin International Airport, 2015)

There are also similiar systems located in Turkey. Teknopark Istanbul Solar Energy Plant located in Pendik, Istanbul is one of them. Averagely, 598,000 kWh energy per year is generated by this plant and total installed power is 46 kW (Enerji Atlası, n.d.). Each panel has 240 W power and there are 190 units of solar panels (Elektrik Haber, 2014).

Another example is Antalya International Airport. The power of solar panels is 250 kWp, and 962 units laid on free land inside the airport. Yingli Solar panels were used and total annual energy production capacity is 372,470 kWh. This project is Turkey's first airport solar panel system project. By the project, it is aspected to decrease 115,838 kg CO_2 emission (Başarı Hikayesi Antalya Uluslararası Havalimanı, 2016)

Antalya International Airport project data used for the calculations that will show the results of solar panel system application to SAW. Yearly sunshine duration for Istanbul is 2,446 hours and for Antalya it is 3,011 hours (GNS Solar, 2016). It is assumed as same solar panel system with Antalya Int. Airport is applied to SAW.

In Antalya International Airport's solar panel system;

372,470 kWh/year / 962 units = 387.183 kWh/year per solar panel unit is generated as energy. This amount is for sunshine duration of 3,011 hours.

In Istanbul same panel will generate;

387.183 kWh/year x 2,446 hours / 3,011 hours = 314.53 kWh/year per unit

According to 2014 electrcity consumption amount, to cover all electricity

20,564,901.57 kWh / 314.53 kWh/unit = ~65,383 units is needed.

One panel needs around 1.6 square meter area, so 65.383 units will need at least 104,612.80 m^2 area which is a huge amount of land. On the other hand, by laying 10,000 units which will take 16,000 square meter area will cover 3,145,298.91 kWh electricity which is about %15 of electricity consumption of 2014 and purchased electricity's total emission would be 1,446 tonnes Co_2e less (amount calculated by ACERT v3.1). Even laying less amount of solar panel system, some portion of electricity consumption can be lowered.

4.3.5 Scope 3 Emission: Ground Access

Calculations show that the main emission source of SAW is ground access to airport. Ground access is publicly sourced emissions which are cars, taxi, bus, hotel shuttles and rail service used by passengers to access airport. As it explained in Chapter 3 Materials and Methods, Transportation Section, there are several ways to reach airport, but public transportation is limited. There is 12 public bus runs to SAW. However, there is no directly connected train service to airport. According to Istanbul Metropolitan Municipality (IMM), there 2 upcoming subway project. One is Sabiha

Gökçen Int. Airport – Kurtköy which will be tendered before 2019 and another one is Sabiha Gökçen Int. Airport – Pendik which is under construction. Both lines 7 km long (Istanbul Metropolitian Municipality (IMM), 2016). The case subway construction is completed is analyzed.

2014 is selected for observation. It is assumed that in 2014 both subway routes were running. For train movements, following data is entered to ACERT v3.1

- Total number of round trips/day: Every half and hour and train runs for 12 hours a day which is equal 24 times a day for one route. There are two routes so total number is 48.
- One-way Distance: Distance from airport to nearest stations entered as 7 km.
- Typical Train Speed: Average speed of a sub-way train is accepted as 60 km/h
- Days per Year: 365 days a year
- Electricified Trains (%): 100 %

It is also assumed that preference of travelling on Public Transport is increased from 30% to 90%. Output showed that ground access decreased from 122,835 tonnes CO_2e to 30,214 tonnes CO_2e.

4.4 Conclusion

The conclusions obtained from this study that deals with the assessment of sustainability for Sabiha Gökçen International Airport is outlined below.

The total number of passengers annually used the airport increased drastically from 2001 to 2014. This number that was 47,377 in 2001, is find out to reach 23,631,864 in 2014. A similar rise in annual total number of flights from 6,193 (2004) to 185,410 (2014) is observed.

The total CO2e emissions arising from the airport is calculated to be 114,002 tonnes CO_2e, 135,798 tonnes CO_2e and 160,161 tonnes CO_2e for 2012, 2013 and 2014, respectively. The mentioned amounts indicate a 41 % increase from 2012 to 2014.

According to 2012, 2013 and 2014 data, Scope 3 emissions (that are indirect emissions generated due to a consequence of the activities of the company, but occur from sources not owned or controlled by the company, such as ground access and aircraft fuel consumption) has the highest share within all CO2e emissions. After Scope 3, Scope 1 emissions that consist of fuel usage by airside vehicles and employee shuttles, deicer usage and waste/wastewater management, are observed to be the highest contributor to CO2e emissions.

Scope 1 emissions are the most important ones as these constitute the directly controllable group. Among all Scope 1 emissions, deicer usage is the highest contributor, where after fuel usage by airside vehicles and employee shuttles come. Calculations based on year 2014 show that 6.83% of the scope 1 emissions arise from deicer usage, 2,67 % from fuel usage by airside vehicles and employee shuttles and finally 0.58% from waste management.

For deicing purposes an agent composed of glycol is used. According to 2014 data usage of this agent as deicer is calculated to generate 10,940 tons CO2e. The application of recycling deicer is evaluated to reduce this contribution by 36%, resulting in 7,023.22 tons CO2e emissions.

Fossil fuel usage for airside vehicles and employee shuttles results in generation of 4,269 tons CO_2e in 2014. When electric cars and minibuses are used for this purpose, it is possible to completely diminish CO2e emissions from fossil fuel usage. However, it must be noted that electric vehicle manufacturing results in more CO2e emissions than cars working with fossil fuels. On the other hand, lifetime CO2e emissions of electric cars are lower than the other cars.

Scope 2 emissions arise from indirect sources, i.e. electricity purchasing. The CO_2e emissions generated by Scope 2 activities show that 9,932 tonnes CO_2e, 10,664 tonnes CO_2e and 11,703 tonnes CO_2e emissions for years 2012, 2013 and 2015, respectively. Scope 2 emissions compose 7.31% of the total emissions for 2014. In order to reduce this amount, it is recommended to construct solar panel systems. When 16,000 m^2 area is covered with solar panels, it is calculated that 15 % of the total electricity is supplied, resulting in 1,446 tonnes CO_2e reduction for 2014.

Scope 3 activities cover ground access to airport. It is evaluated that when the current level of public transportation used by 30 % of the people is increased to cover 90 % of the people, the CO2e emissions will be decreased from 122,835 tons to 30,214 tons resulting in a 75% reduction. With the usage of metro system, that will be opened in 2019 it is expected to get this result.

In 2017, a 2nd runway will be in service. Together with it two aprons, new taxiways, a new tower and a fire station will be opened. The effect of this enlargement is evaluated to increase CO2e emissions from 160,161 tons to 454,207 tons. However, with the recommendations mentioned (usage of electric cars for employee shuttles, usage of an environmentally friendly deicer, construction of solar panels, metro services...... etc.) to reduce the CO_2e emissions, it is possible to lower the greenhouse gas emissions by 62%.

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