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List of Contributors

DELHI INDIRA GANDHI INTERNATIONAL AIRPORT | GMR

JET AIRWAYS

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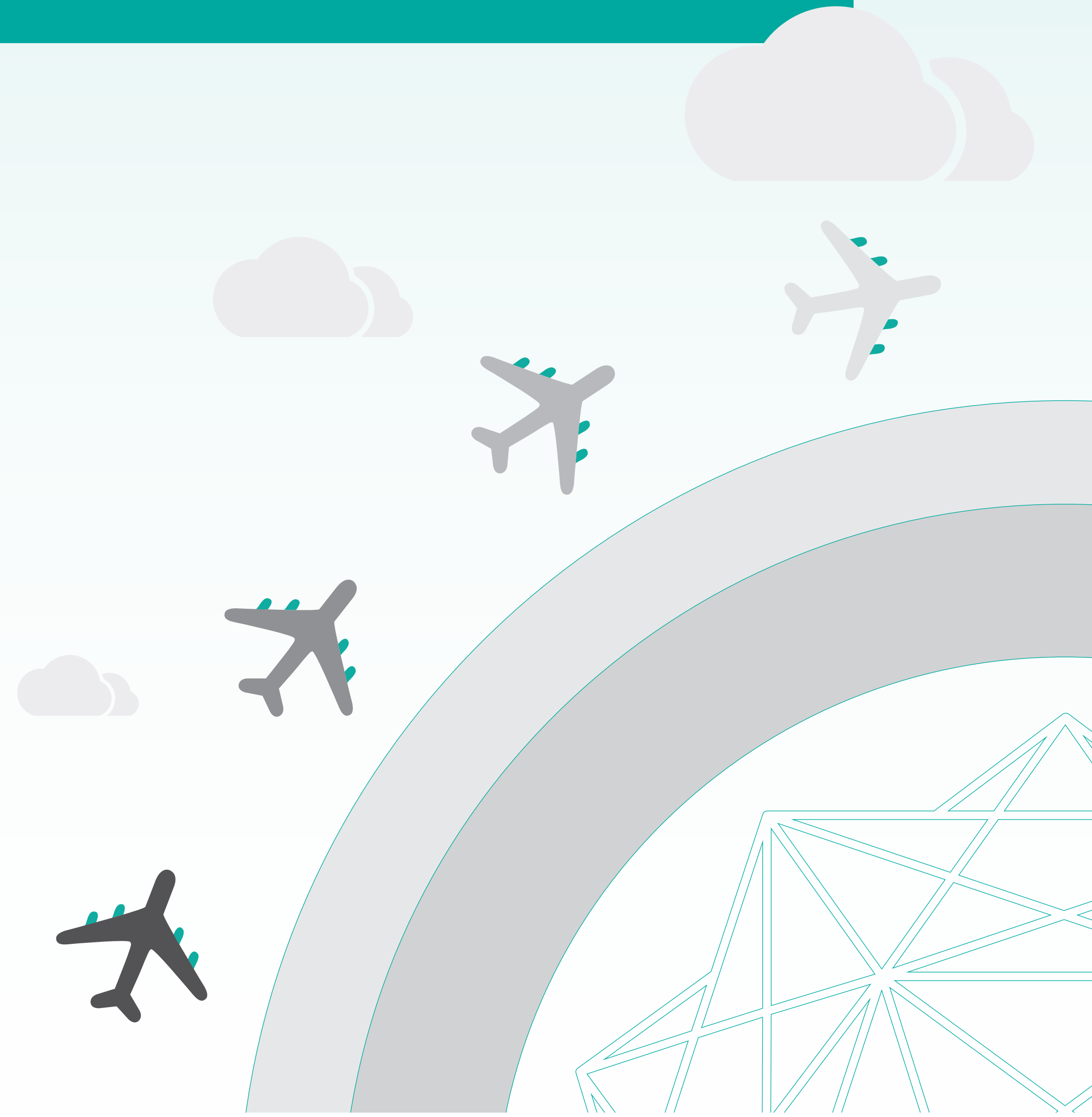
INDIA GHG PROGRAM

Promoting profitable, sustainable and competitive businesses.

Aviation Best Practices: Climate Change & Emission Reductions 2015



DELHI INDIRA GANDHI INTERNATIONAL AIRPORT | GMR

FOREWORD

Companies today are progressively addressing climate risks in their operations, services, products and supply chains. A variety of sectors including energy-intensive ones such as chemicals, iron and steel, and power are developing strategies to improve energy efficiency and are adopting lower-carbon technologies in processes and operating methods. Most of these companies are acting alone on climate initiatives. There are no second thoughts that acting in silos is insufficient to transform a sector in its environmental and carbon disclosure actions if we are to keep the global temperatures below the 2 degree Celsius trajectory.

The aviation sector is a major economic sector for India. By 2020, India's airports would be handling 336 million domestic and 85 million international passengers with projected investment to the tune of USD 120 billion. Controlling aviation's emission growth is a challenging task, but it is crucial given the size of the sector's emissions. To address this need, in 2010, at the 37th International Civil Aviation Organisation (ICAO) Assembly, governments have set ambitious goals to improve fuel efficiency by 2 percent per year and make international aviation's growth from 2020 onwards "carbon-neutral".

The Aviation Sector report intends to lay the roadmap for the sector to transition to a low-carbon business model. This report, an initiative led by the Delhi International Airport Limited (DIAL), proactively collaborated with the Jet Airways, Air Traffic Controller (ATC) of Airport Authority of India and supported by the India GHG Program builds a framework for the measurement and mitigation of carbon emissions. It also highlights, how cost-effective measures are available to further reduce emissions from aviation, mainly by more efficient fuel usage and harmonised air traffic management systems.

The report underscores the India GHG Program's emphasis on peer engagement, industry specific benchmarking and sectoral best practices. This multi-stakeholder approach is a wider attempt by DIAL and the India GHG Program for decarbonising the aviation sector, by adopting common standards for measuring, reporting and verifying emissions data using best practice protocols. We hope the report encourages other business associations and sectors to set emission reduction targets and implement corresponding action plans. We believe this report will address the need for coordinated policies and harmonised efforts to reduce emissions and stay in line with a 2 degree Celsius pathway suggested by the International Civil Aviation Organisation (ICAO).

The next 15 years are critical to the global climate. A business-as-usual approach will lead to investments in high carbon assets and make it increasingly more expensive to shift towards a low carbon economy. Businesses, particularly, will face serious risk as a result of the changing climate. This report comes at an opportune time for businesses to become the drivers of change by investing in greater energy and resource efficiency as a first step, thus laying the blueprint for future economic growth while also tackling the risk of climate change.

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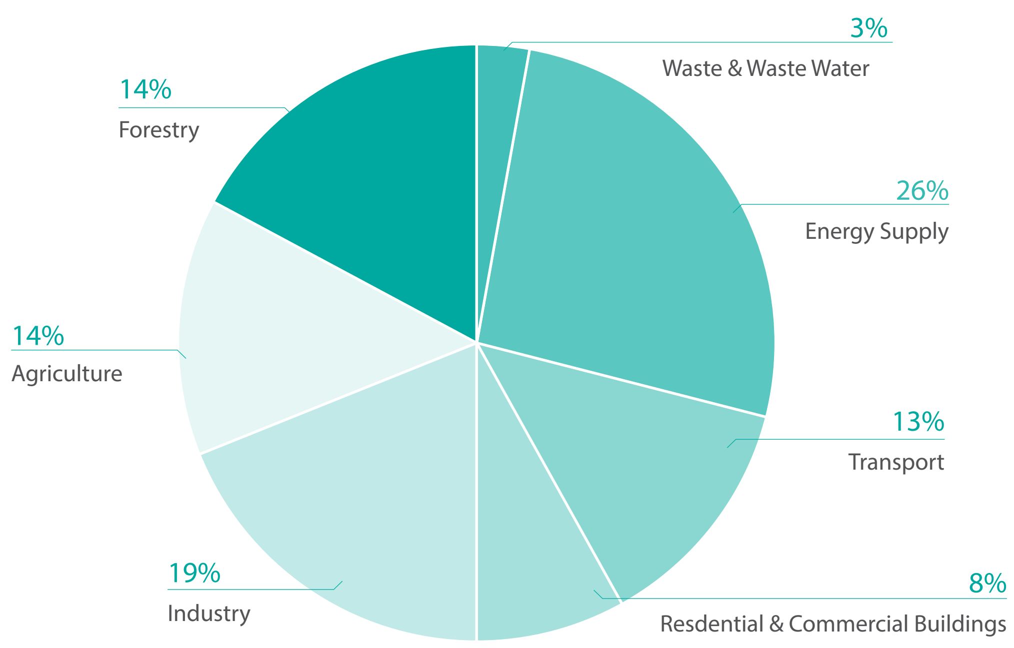
1. INTRODUCTION:

Stabilizing the global climate is the greatest challenge of the 21st century. Temperatures have exceeded global annual averages for 38 consecutive years. The impacts are being felt all around the world. It is evident from scientific information and corroborations that anthropogenic activities carried out across the world is the main source for increase in Greenhouse (GHG) gases in the atmosphere, which are primarily responsible for the changes in climate. These human led activities include fossil fuel combustion in power plants, GHG released by various manufacturing and service industries, energy supply, transportations etc. Other factors such as changes in land use pattern, use of ozone depletion substances also contribute, both separately and in conjunction with other factors towards affecting climate, microclimate, and measures of climate variables.

Climate change has environmental, social, political and economic repercussions which needs a united approach across the world. In the future, individuals and businesses will face challenges never seen before, if climate change impacts are not understood and are not incorporated as key objectives in strategic planning when creating national and international developmental roadmaps. It is important for every business unit to reassess its business sustainability initiatives and to consider climate change mitigation measures as one of the key organisational objectives from a social, environmental and business point of view.

1.1 GLOBAL TRANSPORTATION GHG EMISSION:

Civil aviation is one of the world's fastest growing transport businesses. Scheduled aviation traffic (revenue passenger-km, RPK) has grown at an average annual rate of 3.8 percent between 2001 and 2005, and is currently growing at 5.9 percent per year as reported by Kahn Ribeiro, S. et al, [1]. The GHG emission by different sectors as reported by Intergovernmental Panel on Climate Change (IPCC, 2007), is presented in Figure 1[2]. It shows that the contribution of transportation sector is 13 percent of the total anthropogenic emissions of which 13 percent is represented by the Aviation sector.

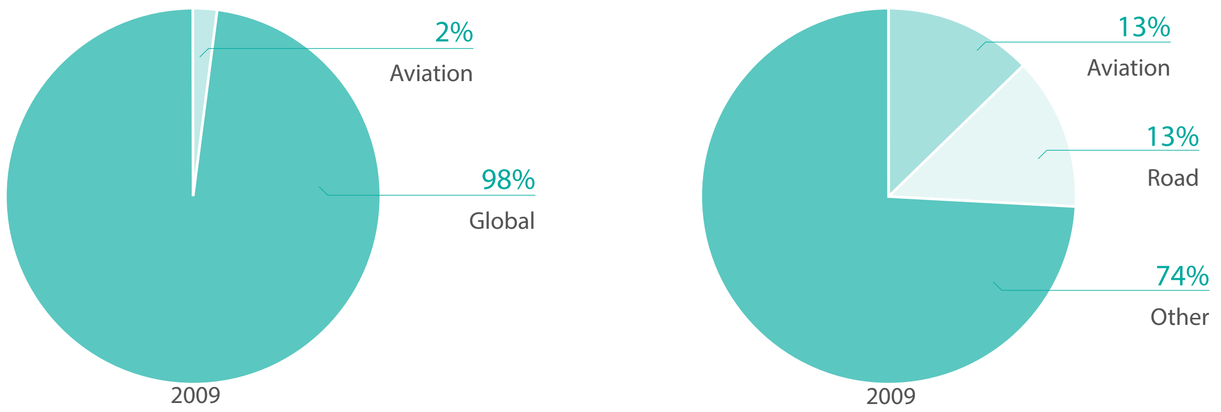


GHG Emission by Sectors, 2004
(fig:1)

1.2. GLOBAL AVIATION GHG EMISSION:

The majority GHG emissions from Civil Aviation are from aircraft operations, which are responsible for the greenhouse gases such as Carbon Dioxide (CO_2) and Water Vapour (H_2O). Other GHG emissions are nitrous oxide (NO) and nitrogen dioxide (NO_2) (which together are termed NO_x), sulfur oxides (SO_x), and soot. The climate impacts of these gases and particles at a higher altitude, due to aircraft movement are more complex to quantify than the normal GHG estimation by conventional stoichiometry method in terms of CO_2 and CO_2 equivalent.

Aviation currently accounts for 2 percent of global emissions from human activity as reported by IPCC, 2007 [3]. International aviation accounts for 60% of the total aviation emission as reported in ICAO Environmental Report, 2013 [4]. Within the transportation sector the contribution of aviation emission is 13 percent (Figure 2) [8]. As aviation grows to meet increasing demand, the IPCC has forecasted that by 2050, the contribution of aviation emission in total anthropogenic emission could rise to 3 percent [5].



Global Anthropogenic GHG Emission in 2009 (IPCC 2007)
(fig:2)

1.2.1. SOME FACTS ON AVIATION AND CLIMATE CHANGE [9]:

- In 2013, flights worldwide produced 705 million tonnes of CO_2; globally, human activities produced over 36 billion tonnes of CO_2 (ATAG)
- Air transport has reduced its fuel use and CO_2 emissions per passenger kilometer by well over 70% compared to the 1960s (IEA)
- While traffic increased by 4.7% between 2012 and 2013, in the same period CO_2 emissions only increased by 1.5% (IATA)
- Between 1990 and 2009, the energy efficiency of air transport improved by 29.8%, compared to 16.4% for cars, 13.3% for trucks and light vehicles, and 5.2% for rail (EEA)

2. AVIATION BODIES & GHG MANAGEMENT STRATEGIES:

Globally Aviation is managed by the International Civil Aviation Organisation ICAO, a UN specialized body created in 1944 upon the signing of the Convention on International Civil Aviation (Chicago Convention). ICAO works with the Convention's 191 Member States, and global aviation organisations to develop International Standards and Recommended Practices (SARPs), which states reference when developing their legally-enforceable national civil aviation regulations [10].
Other Aviation bodies such as International Air Transport Association (IATA), Airports Council International (ACI), are global trade representatives of airlines and airports respectively and work in collaboration with each other and their members to create sustainable aviation. [11], [12].

2.1. Initiatives by International Civil Aviation Organisation (ICAO):

ICAO has continued to develop policies, standards, guidelines and tools that facilitate the development of a range of measures to help design and implement action plans [10]. Progress has been achieved on all related elements, including technical Standards, operational initiatives, sustainable alternative fuels, and market-based measures (MBMs). Aviation industry organisations have further committed to reduce net air transport CO_2 emissions by 2050 to half of what they were in 2005.

ICAO's collective global aspirational goal is improving annual fuel efficiency by 2 percent, while stabilizing global CO_2 emissions at 2020 levels. Though contentious, there is precedent - due to focus on performance improvements in the past 50 years, aircraft have become 80 percent more energy efficient and 75 percent quieter.

The 38th Session of the ICAO Assembly, held from 24 September to 4 October 2013, adopted Resolution A38-18: Consolidated statement of continuing ICAO policies and practices related to environmental protection– Climate change. Resolution A38-18 reflects the determination of ICAO's Member States to provide continued leadership to international civil aviation for limiting or reducing its emissions which includes:

- Reaffirmation of collective global aspirational goals for the international aviation sector, namely improving fuel efficiency by 2 percent per year and maintaining same net CO_2 emissions 2020 onwards.
- Maintenance and enhancement of appropriate standards, methodologies and mechanisms to measure/estimate, monitor and verify global greenhouse gas (GHG) emissions from international aviation.
- Development of a global CO_2 Emissions Standard for aircraft, with an aim to adopt it the ICAO Council in 2016.
- Maintenance and update of air traffic management (ATM) improvements and other operational measures to reduce emissions, along with continued development of tools to assess their benefits.
- Coordinated national policy actions to accelerate appropriate development, deployment, and use of sustainable alternative fuels for aviation.
- Voluntary preparation and update of States' action plans on CO_2 emissions reduction activities, to be submitted to ICAO by June 2015, and to be made publically available.
- Enhancement of ICAO strategy for capacity building and assistance, including support for the development and update of States' action plans, as well as the mechanisms to facilitate access to financial resources.

2.1. A few key aspects for the States:

a) Consider policies to encourage introduction of more fuel efficient aircrafts in the market;

b) Accelerate investments on research and development, to bring more efficient technology into the market by 2020;

c) Accelerate the development and implementation of fuel efficient routings and procedures to reduce aviation emissions;

d) Accelerate efforts to achieve environmental benefits through the application of technologies that improve the efficiency of air navigation. Work with ICAO to bring these benefits to all regions and States, taking into account the Aviation System Block Upgrades (ASBUs) strategy;

e) Reduce legal, security, economic and other institutional barriers to enable implementation of the new ATM operating concepts for environmentally efficient use of airspace;

f) Consider measures to support research and development , as well as processing technology and feedstock production, in order to decrease costs and support scale-up of sustainable production pathways up to commercial scale, taking into account the sustainable development of States;

g) Recognize existing approaches to assess sustainability of all alternative fuels in general;

h) Work together with ICAO and other relevant international bodies, to exchange information and best practices, including on the sustainability of alternative fuels for aviation;

2.2. Initiatives by International Air Transport Association (IATA):

International Air Transport Association (IATA) recognizes the need to address the global challenge of climate change and have adopted a set of ambitious targets to mitigate CO2 emissions within air transport [6]:

Fuel Efficiency	Emission Reduction	Carbon-Neutral Growth
Average improvement of 1.5% per year from 2009 to 2020	Reduction in net aviation CO2 emissions of 50% by 2050, relative to 2005	Cap on net aviation CO2 emissions from 2020

2.2.1. A multi-faceted approach: the four-pillar strategy

IATA is determined to be part of the solution but insists, that in order to achieve these targets, a strong commitment is required from all stakeholders working together on the four pillars of the aviation industry strategy:

- Improved technology
- Efficient aircraft operations
- Infrastructure improvements
- Single global market-based measure

2.3. Initiatives by Airport Council International (ACI):

Airports are the interface between aviation and ground transportation. The Indian aviation industry is working with the ICAO towards a global framework to address global aircraft emissions. ACI is also working with its airport members to address aircraft emissions at airports from landing to take-off, including auxiliary power units (APU), taxiing, queuing and congestion. Airports also need to address non-aviation emissions from ground support equipment (GSE), fleet vehicles, power and heating plants, and ground access vehicles (GAV) [7].

ACI supports the joint aviation industry position on - a global sectoral approach for addressing aircraft emissions, 1.5 percent average improvement in efficiency on an annual basis , carbon neutral growth from 2020 and a 50 percent carbon reduction (relative to 2005 levels) by 2050. These aviation targets refer only to emissions from aircraft - in-flight and on ground, taxiing and auxiliary power units (APU).

ACI encourages its members to set goals on both GHG emissions sources within their control and those in the control of stakeholders which they can influence. For the airport's direct (scope 1) and indirect energy emission (scope 2), the ultimate target is for the airport to become carbon neutral. Carbon neutral status can be achieved by reducing emissions as much as practicable, and purchasing carbon offset credits for the remaining emissions. Purchased offset credits must comply with international standards and be fully verified.

Airports can attain recognition for their achievements in carbon management with the Airport Carbon Accreditation (ACA) Programmes which recognizes four levels of emission management

Footprint measurement	Carbon management towards a reduced carbon footprint	Third party (stakeholder's) engagement in carbon footprint reduction	Carbon neutrality for direct emissions by offsetting
Mapping	Reduction	Optimization	Neutrality

ACI will continue to take actions in collaboration with airport and aviation industries to minimize emissions within their control, and will continue to support the development of technologies and design strategies that will help to reduce aircraft emissions globally.

Overall, the transition from goals to executable action by stakeholders in a collaborative manner can help the industry achieve the end goal of a sustainable international aviation sector. This will be supported by the development of sustainable alternative fuels; continued deployment of new technology for aircraft and operational improvements; accelerating the transformation of global air traffic management performance; working with partners to develop a global CO2 standard for new aircraft; working with partners to design and implement a global market-based measure for international aviation; and working together to further efforts for capacity building across the world.

3. INDIA'S CLIMATE CHANGE PLANS:

India occupies almost 2.3 percent of the world's land area - it is the 7th largest country in the world - but holds nearly 18 percent of the world's population. In order to achieve a sustainable development that simultaneously advances, economic and environmental objectives and also reduces the impacts of climate change, government of India came up with National Action Plan for Climate Change (NAPCC) during 2008 which is guided by the following principles [13]:

• Protecting the poor and vulnerable sections of society through an inclusive and sustainable, development strategy which is sensitive to climate change.

• Achieving national growth objectives through a qualitative change in direction that enhances ecological sustainability, leading to further mitigation of greenhouse gas emissions.

• Devising efficient and cost-effective strategies for end use Demand Side Management.

• Deploying appropriate technologies for both adaptation and mitigation of greenhouse gasses emissions extensively as well as at an accelerated pace.

• Engineering new and innovative forms of market, regulatory and voluntary mechanisms to promote sustainable development.

• Effecting implementation of programmes through unique linkages, including civil society and local government institutions and through public private partnership.

• Welcoming international cooperation on research, development, sharing and transfer of technologies, enabled by additional funding and a global Intellectual Property Rights (IPR) regime that facilitates technology transfer to developing countries under the UNFCCC.

3.1. The National Action Plan on Climate Change:

The National Action Plan on Climate Change identifies measures that promote our development Objective, while also yielding co-benefits for addressing climate change effectively [13]. The focus is on promoting understanding of climate change, adaptation and mitigation, energy efficiency and natural resource conservation measures. The NAPCC consist of eight "National Missions" representing multi-pronged, long-term, integrated strategies for achieving key goals in the context of climate change.

The Missions' are :

National Mission for Sustainable Agriculture (NMSA)	National Mission for Enhanced Energy Efficiency (NMEEE)	National Mission for a Green India (GIM)	National Mission on Sustainable Habitat (NMSH)
National Mission for Sustaining the Himalayan Ecosystem (NMSHE)	National Mission on Strategic Knowledge for Climate Change (NMSKCC)	National Solar Mission (NSM)	National Water Mission (NWM)

3.2. India's Policy Structure Relevant to GHG Mitigation

India has in place, a detailed policy, regulatory, and legislative structure that relates strongly to GHG mitigation. Some key policy measures initiated by Government of India towards GHG mitigation are presented in Table1.

Table 1: Key policy measures related to GHG mitigation in India

Promotion of energy efficiency in all sectors
• Introduction of labeling program for appliances • Energy conservation building code • Energy audits of large industrial consumers • Promotion of energy saving devices • Promoting energy efficiency in the residential and commercial sector • Efficient transmission and distribution
Emphasis on mass transport
• Clean air initiatives
Emphasis on renewables including biofuels plantations
• Promotion of biofuels • Solar based power generation • R&D collaboration, technology transfer, and capacity building • Management of municipal solid waste (MSW) • Biomass based power generation technologies • Wind energy
Accelerated development of nuclear and hydropower for clean energy
Focused R&D on several clean energy related technologies
• Sector specific technological options • Cross-cutting technological options • Fuel switch and natural gas based power plants • Energy-efficient buildings and building components • Development of energy efficient windows • Development of low-cost insulation material • Development of simulation software to predict the energy used in buildings • Energy efficient appliances • Development of energy-efficient ceiling fans • Development of very-low-energy-consuming circuits for stand-by power • Development of low-cost light-emitting diode • (LED)-based lamps for space lighting

3.3. Initiatives of Indian Aviation:

Aviation industry, though a small contributor, is aggressively working to minimize its adverse impact on the environment. India represents a growing aviation market with more than 100 airports that during the fiscal year 2013-2014 handled around 170 million passengers.

Major scheduled passenger airlines operate more than 400 aircraft. The industry represents around 1.5 percent of India's GDP and supports 9 million jobs. The country ranks 9th in the global civil aviation market [14]. It is expected that domestic and international passenger traffic will continue to grow at rates of 12 percent and 8 percent respectively and that India will become the 3rd largest aviation market in the world by 2020.

India's fast growing aviation industry has begun taking proactive actions to address the environmental issues. Directorate General of Civil Aviation (DGCA) has issued various environmental guidelines for its stakeholders especially related to emissions from aircraft. In order to have a sustainable aviation industry, following measures have been taken by DGCA: stakeholders have been advised to establish Environment Cell in their organisations and to develop their carbon footprint. Airlines have been advised to - retrofit existing aircrafts; adopt aggressive fuel efficiency method; explore possibility of using biofuels; fix winglets & riblets; minimize dead weights on board; improve load factors; adhere to maintenance schedules; select the appropriate aircraft for a particular route; improve taxing and parking procedures and others.

Given India's commitment to environmental improvements, the DGCA maps the CO2 emissions of Indian aviation regularly and reports it in a comprehensive manner [14].

Aviation Infrastructure and Airspace improvements play important roles in GHG reductions. Airports that have Precision Approach, Full Approach Lighting System (ALS) and Runway Visual Range (RVR) Instrument will see more efficient operations and a significant reduction in emissions. Advanced State Meteorological Forecasts will also support operational efficiency and associated emission reductions by helping in the implementation of proper operational plans.
Further, efficient utilization of airspace is a very important element in operational efficiency of airlines and airports. Limited restrictions on airspace will reduce the distance travelled by aircrafts and yield significant savings in fuel and associated emission.

A combination of the above factors will reduce delays and diversion, and will consequently discourage airlines from carrying additional fuel. Additional fuel carriage leads to additional fuel burn, payload curtailment and carbon emission. Improving the above mentioned factors will help in reducing operational cost and improve operational efficiencies of entire aviation networks.

3.3.1. Initiatives of Airline:

Indian airlines play an important role in overall aviation emissions reductions. They already operate modern, fuel-efficient aircraft (e.g. Boeing 787 Dreamliner, Airbus 320/B737 NG with sharklets/winglets) that result in significant fuel savings. At the same time, they have been changing the mode of operations to further reduce their emissions.

To ensure sustainability airlines have to focus more on operational efficiency through improved flight planning, aircraft weight reduction, single-engine taxi procedures, minimal use of Auxiliary Power Units, etc. which can lead to emissions reductions and cost savings. Airlines can also participate in carbon offsetting initiatives, such as the IATA's relevant program and collaborate with other aviation stakeholders on promoting the adoption of biofuels. IATA's program brings standardization to the process and makes it possible for airlines of any size to easily introduce a credible and independently validated offset program.

Some of the initiatives taken by Indian airline operators towards GHG reductions [15] are given below:

Developing green and efficient office buildings

Developing weight reduction measures by selection of
- Cabin equipment
- Catering services
- Manuals and reading materials
- Extra fuel on board

Adhere to proper maintenance of aircraft

Adopt more efficient operational procedures, by:
- Minimum usage of APU
- Optimum flap setting during takeoff and landings
- PBN procedures and constant descent approach
- Usage of idle reverse thrust while landings
- Proper flight planning system
- Prior information about congestion at arriving airport
- One engine off during taxiing
- Engine off while waiting for takeoff

3.3.2. Initiatives of Airport:

Since airports represent a nodal point of aviation activities, such as airline flights, passenger/public access, and third party operations (e.g., ground handling, catering, fuelling), it shall play key role in establishing guidelines for emission reductions. Airports can contribute to the reduction of aircraft emissions through more efficient use and planning of airport infrastructure and operations. Close cooperation between airports, airlines, air traffic control and the public authorities will also help in reducing aviation emissions.

As of 2015, several Indian airports have obtained Green Building certifications i.e. LEED certifications (Leadership in Energy and Environment Design) and have adopted other measures as well, such as the use energy efficient systems, operating environment friendly vehicles, etc. Further, Indian airports such as Delhi, Hyderabad, Bangalore & Mumbai has been participating in Airport Carbon Accreditation program, an initiative by the ACI for carbon reduction. These airports have established carbon footprints and have taken additional measures to reduce emission by adopting green design principles, renewable energy development and energy efficiency initiatives etc.

Delhi Airport is one of the founding members of the India Greenhouse Gas Program (IGHGP), an initiative by CII, TERI & WRI, to support organisations to map and reduce Greenhouse Gases from various sectors. Delhi Airport is working closely with the partner organisations to establish possible GHGs reduction measures in its aviation functions.

Some of the initiatives taken by Indian airport operators towards GHG reductions are given below:

Initiatives taken by Indian airport operators towards GHG reductions are given below:

- Green infrastructures concepts
- Airport Collaborative Decision Making (A-CDM)
- Energy Efficiency Measures for Terminal Buildings
- Integrated Building Management System (IBMS) for energy efficiency
- Renewable/Green Energy Generations
- LEDs at Buildings & Airport Ground Lightings networks
- UPS system for Airport Ground Lightings networks
- Bridge Mounted Equipment's (BMEs): FEGP & PCAs Supply
- Fuel Hydrant systems
- CNG Vehicle Operation & Fueling Station
- Electrical Tugs & Buggies
- Multimodal Connectivity (Road & Metro)
- Environment Management System (ISO 14001) & Green House Gas Reporting System (ISO 14064) & Energy Management System (ISO 50001)
- Airport Carbon Accreditation Programs
- Landscaping & Tree Plantations

Some Initiatives of Delhi Airport towards GHG mitigation:

a) Leadership in Energy and Environmental Design (LEED):

Delhi Airport is the first airport in the world to have achieved LEED Gold rating for its green infrastructure. Terminal 3 at IGIA (T3) has been designed to be a model for passenger-friendly and environmentally responsible airport facilities. Using daylight has been a primary focus of the terminal's design.
The Integration of LEED criteria from concept to operation in Terminal 3 and its ancillary infrastructures and using environment friendly green airport operation by right site selection, master planning, design & verification, commissioning, operation of Terminal 3 have resulted in achieving a GOLD rating from Indian Green Building Council (IGBC).
The salient features of LEED Gold certified T3 building are-

- Energy-efficient infrastructure and technology adoption.
- Water efficient Air Conditioning, plumbing & irrigation.
- Reduction in pollution & waste due to construction activity by effective site & waste management.
- Provision for eco-friendly vehicles.
- Rain water harvesting & reuse of treated waste water.
- Use of no Chlro-Fluro Carbons based refrigerants.

b) GreenCo Gold Certificate by CII:

The GreenCo framework assesses the environmental performance of an organisation in eight environment related parameters that is Energy Efficiency, Water Conservation, GHG emission, Renewable Energy, Waste Management, Material conservation and Recycling, Green Supply Chain and Innovations.
Delhi Airport adopted this framework as a part of its sustainable airport initiatives. Delhi Airport is the "First Airport in India" to achieve the prestigious "GreenCo Gold rating" for its environmental excellence in the field of energy and environment. Besides this, Delhi Airport was also awarded "the best practices award in Renewable Energy and GHG Management" for its exemplary achievements over the years in these fields. The key aspects of GreenCo Framework are-

- Business Excellence
- Commitment of Top Managements
- Holistic Approach on all Aspects
- Integrating with many Quality Tools
- All level Workforce Engagements
- Stakeholders Engagements
- Integrated System, Result & Impact Assessment

c) Clean Development Mechanism (CDM):

Energy Efficiency Measures implemented in Terminal 3 has been registered with UNFCCC (United Nations Framework Convention on Climate Change) as Clean Development Mechanism (CDM), with effect from 26 July 2013. Delhi Airport is the first airport in the world that achieved CDM registration with the United Nations Framework Convention on Climate Change (UNFCCC). The components of the CDM project are-

- Energy efficient chillers
- VFD's in Secondary Pumps and CT Fans
- Tempered Cooling system
- Low U- Value Building Envelope and Roof
- VVFD and Radar sensor based Travellators & Escalators

d) Promotion of Renewable Energy:

DIAL has installed 2.14 MW Solar plant at IGI Airport and is the first airport in India having mega solar power plant at airside premises. This measure has been taken to promote renewable energy use and reduce associate emission and also to support National Climate Change Action Plan. DIAL is also in the process of setting up another 5.71 MW solar plant in the airside area. Once completed the total contribution of electricity, from the Solar PV plant is expected to be more than 11million kWh of electricity, which will be 9 percent more, than current consumption of electricity at DIAL.

- The First of its kind MW scale Airport Solar project in India : 2.14 MW
- Location : South of Runway 11/29 beyond drain
- Usage : Internal usage
- Generation at : 11KV
- Make: Canadian Solar
- Type of solar panel : Crystalline PV panels
- Energy generation (2014): 3.2 million unit

e) Environment Management System & Green House Gas Reporting

Delhi Airport's Environment Management System (EMS) is certified as per ISO 14001:2004 since 2009. EMS provides an organized and formal approach towards managing environmental aspects and its impacts. Delhi Airport is also certified under ISO 14064:2011 for its GHG emission inventory and management. DIAL has achieved Level 3 (Optimization of GHG Emission) accreditation by Airport Council International (ACI) for the IGI Airport.

f) Energy Management System (EnMS):

Delhi Airport is certified for Energy Management System (ISO 50001:2011). Delhi Airport is the first Airport in the world to be certified for ISO 50001:2011 Energy Management system. With the adoption of EnMS ISO 50001:2011 systems, Delhi Airport is mandated to have all its processes well mapped, regularly reviewed and constantly improved to meet Delhi Airport's Energy Management and Environment Management Policies. This helps in significant carbon emission reduction from airport function.

g) Fixed Electrical Ground Power (FEGP) & Pre Conditioned Air (PCA)

Fixed Electrical Ground Power (FEGP) units prevent the use of Auxiliary Power Unit (APU) resulting in reduced emissions from fuel combustion and related noise from aircraft APU.

Aircrafts, on ground require electrical energy (115 volts at 400 Hz) for operating their control systems and other internal components. There are 78 stands at T3 of Delhi Airport equipped with FEGP & Pre Conditioned systems and other internal components. There are 78 stands at T3 of Delhi Airport equipped with FEGP & Pre Conditioned Air (PCA) units which significantly supports in green building initiative at IGI Airport. A PCA unit helps in delivering conditioned air to the aircraft without any fuel combustion. The PCA is connected to hose reels over a telescope pipe. Aircraft using FEGP on ground instead of APU would benefit in reducing significant emission, especially since emissions would multiply more than 400 times for a short haul consuming more than 100 liters/ hour and 600 times for long haul aircraft which would consume more than 250 liters/hour of aviation turbine fuel for APU to run.

Some of the other GHG mitigation activities being implemented at Delhi Airport are-

Multimodal Connectivity
Delhi Airport Collaborative Decision Making (DA-CDM)
Fixed Ground Power Unit (FGPU) and Conditioned air supply facility at T3 Terminal.
Dedicated CNG filling station inside the airport
Energy efficient advanced STP and WTP
Fixed Electrical Ground Power (FEGP) & Pre Conditioned Air (PCA)
Integrated Building Management System
Rainwater Harvesting
Battery operated vehicles for Terminal buildings
Regular air quality monitoring around airport
Regular vehicles pollution check
Carpool network website for employees
Fuel Hydrant systems
Landscaping & Tree Plantation
Greenhouse Gas (GHG) Inventory

3.3.3. Initiatives of Air Navigation Services:

India has launched the Future India Air Navigation System (FIANS) initiative, which is based on projects in the fields of communication, air navigation and surveillance. Improvements in the efficient of Air Navigation Services (ANS) provide an important opportunity for CO2 emissions reduction, but also for increased capacity and improved safety. Indicative projects include implementation of Performance Based Navigation (PBN), use of Automatic Dependent Surveillance-Broadcast (ADS-B), harmonization with international systems, human resources development and training, etc. A PBN roadmap has been developed and several projects have already been launched. Implementation of PBN procedures has helped in reducing Flight distance (Great Circle Distance), Flight time, Fuel consumed during flight and Quantum of carbon dioxide emission.

In 2011, the Indian Ocean Strategic Partnership to Reduce Emissions (INSPIRE) was launched. This project represents a partnership between the Airports Authority of India (AAI), Air services Australia, Dubai Airports, airlines, and many other organisations, "dedicated to improve the efficiency and sustainability of aviation." Relevant initiatives include the development of operational procedures, technologies and best practices, establishment of performance indicators, development of systematic processes, and communication

efficiency and sustainability of aviation." Relevant initiatives include the development of operational procedures, technologies and best practices, establishment of performance indicators, development of systematic processes, and communication initiatives.

A number of test flights have been conducted, and project partners have established recommended procedures, practices and services that are environmentally beneficial. On 13th July, 2015, the GAGAN (The GPS aided geo augmented air navigation or GPS and geo-augmented air navigation system) is an implementation of a regional satellite-based augmentation system (SBAS) facility launched by the Indian government. It is a system to improve the accuracy of a GNSS receiver by providing reference signals). This will also help all the stakeholders in achieving emission reduction objective in aviation sectors.

4. GHG ACCOUNTING AND AVIATION BUSINESS FUNCTION:

GHG accounting is a procedure to map, quantify, monitor and control GHG emissions generated from a business process or organisational activity. The total GHGs emitted by an organisation is also referred to as carbon footprint of the organisation, generally expressed in CO_2 equivalent. In general it is used as strategic indicator for fuel and energy consumption associated with the business products or services. It gives a basis for understanding and managing climate change impacts of business activities. The purpose of GHG accounting is to support organisation to monitor relevant, complete, consistent, accurate and transparent data to study the consumption & emission patterns and effects of aviation on climate change and its environment & economic impacts.

Aviation industry can be broadly categorized into four business functions as given below:

Aircraft Operation	Air Navigation Services (ANS)
Airport Operation	Ground Support Service

4.1. Drivers of GHG accounting:

The responsibility to reduce aviation related emissions lies with every aviation business function and the various authorities of center and states. Some of the key drivers of GHG accounting are:

GHG Management

- Enhance Environmental and Economic Performance of the business functions
- Mitigate possible risk associated with business due to climate change
- Enhance Process efficiency and Optimize resource utilization & sustainability
- Supporting National Climate Change Action Plans
- Comply with the requirements of various national authorities and international bodies.
- Enhance the credibility, consistency and transparency of GHG quantification, monitoring and reporting, including GHG project emission reductions and removal enhancements,
- Facilitate the development and implementation of an organization's GHG management strategies and plans.

4.2. Process Mapping and Key Performance Indicators (KPI):

The aviation business is an integration of number of processes linked with one another and it leads to emission of GHGs from various stages of the process. However the complexity of GHG management in aviation business increases as the ownership of the processes and sources of emission lies with different stakeholders.

Breaking down the entire process involved in aviation business will enable a better GHG management and will help in creating efficient reduction opportunities. To assess the performance of each stage of the business processes relevant KPIs may be assigned. Approaches to assigning a KPI vary substantially from sector to sector, and also from process to process within a sector. Some business units will have relatively simple processes and products whose impacts are easy to monitor. In such sectors, the task of defining, which emissions to include and which products and/or processes to benchmark, can be relatively straightforward. In other cases, the task can be much more difficult. Aviation sector includes lots of processes whose complexity varies from simple to moderate, with the additional burden of multiple ownerships. Assigning a KPI in terms of GHG emission in aviation sector must therefore be made specific to the output of the processes with respect to its emission load as a benchmark.

Process Mapping of Aviation Function:

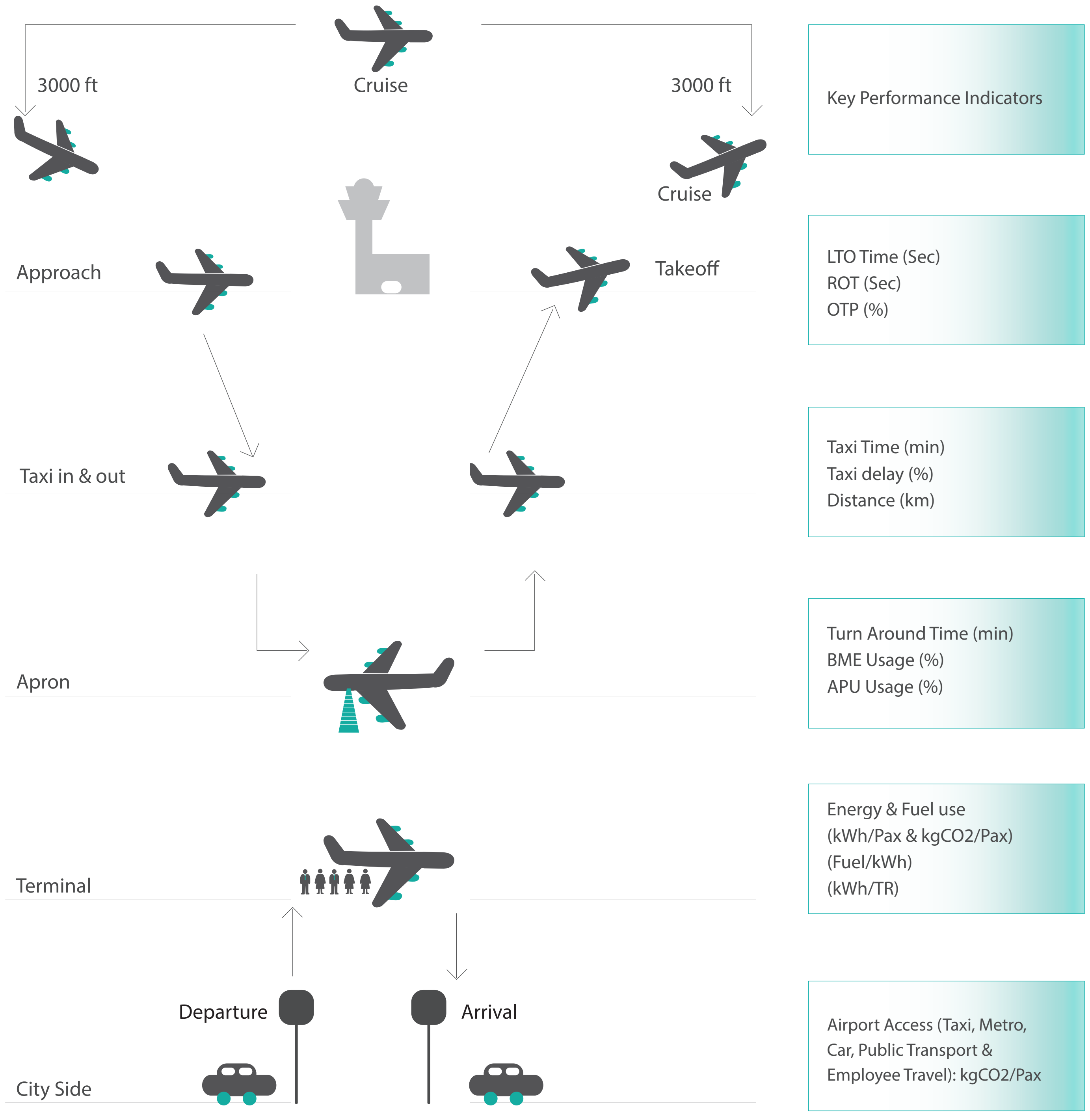
The pictorial representation (Figure 3) indicates the various aviation activities, sources of emission, its functions & ownerships. This will help all aviation stakeholders to establish possible GHG management system and emission reduction strategies in their businesses.

Activity	Landing	Taxiway	Apron, Terminal & City Side	Taxiway	Take Off
Source of emssion	ATF & Electricity	ATF & Electricity	ATF, Electricity, Diesel, Petrol & CNG & Waste Disposal	ATF & Electricity	ATF & Electricity
Function	Engine combustion Lighting & HVAC	Engine combustion Lighting & HVAC	Engine combustion, FEBP & PCA Lighting & HVAC Vehicles & Equipment, DG sets, Waste Disposal & Spills	Engine combustion Lighting & HVAC	Engine combustion Lighting & HVAC
Process Owenr	ATC & Airlines	ATC & Airlines & Airport	ATC & Airlines & Airport Ground Support services	ATC & Airlines & Airport	ATC & Airlines

Process Mapping of Aviation Function
(fig 3)

Key Performance Indicators (KPIs) of various phases:

The pictorial representation (Figure 4) indicates the various aviation activities, its functions & possible key performance indicators to the owner of all aviation stakeholders to establish possible GHG management system and emission reduction strategies in their businesses.

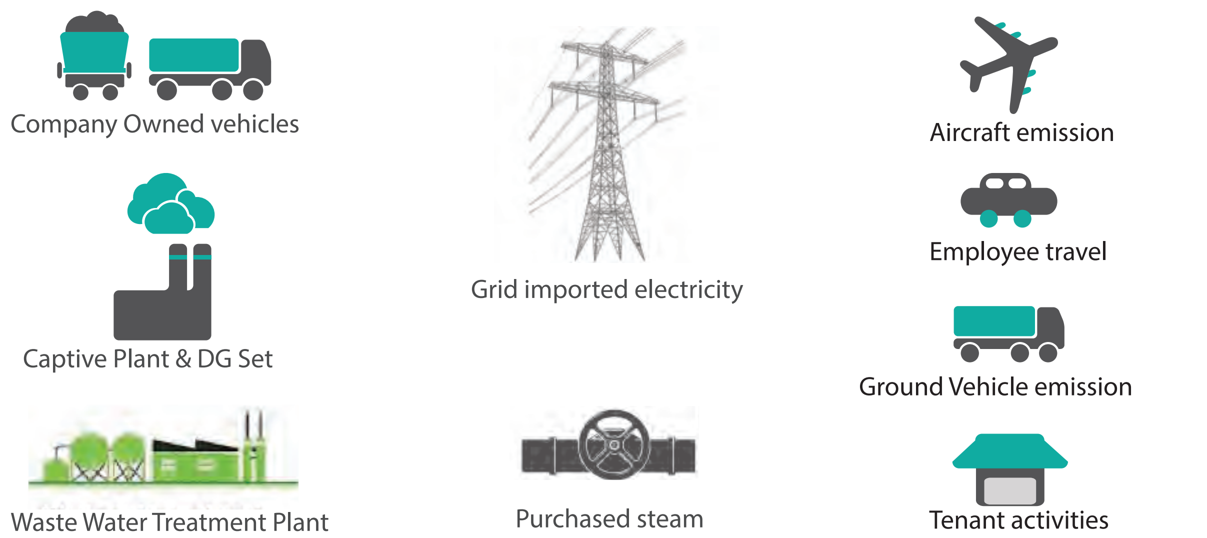


KPIs of Aviation Function
(fig 4)

4.3. GHG Scoping:

Based upon the ownership of the activities and functions, the sources of GHG emission, the boundary and responsibilities are categorized as various scopes such as Scope 1(emission from self-owned sources), Scope 2 (indirect emission due energy purchase) and Scope 3 (emission sources having indirect control). The definitions as per ISO 14064 are given below with pictorial representations. .

Scope 1 (Direct greenhouse gas emission)	Scope 2 (Energy indirect greenhouse gas emission)	Scope 3 (Other indirect greenhouse gas emission)
GHG emission from greenhouse gas sources owned or controlled by the organization. This can include emissions from combustion in boilers, power generation facilities and fleet vehicles. In the case of renewable fuel sources, such as wood waste, wood pellets, the net GHG emissions should be considered.	GHG emission from the generation of imported electricity, heat or steam consumed by the organization It includes GHG emissions from the off-site generation of electricity (and heating or cooling), purchased by the operator.	GHG emission, other than energy, indirect GHG emissions, which are consequence of an organization's activities, but arise from greenhouse gas sources that are owned or controlled by other organizations Examples include aircraft emissions, emissions from airline and other tenant activities, and ground transport vehicles not owned and controlled by the airport operator.



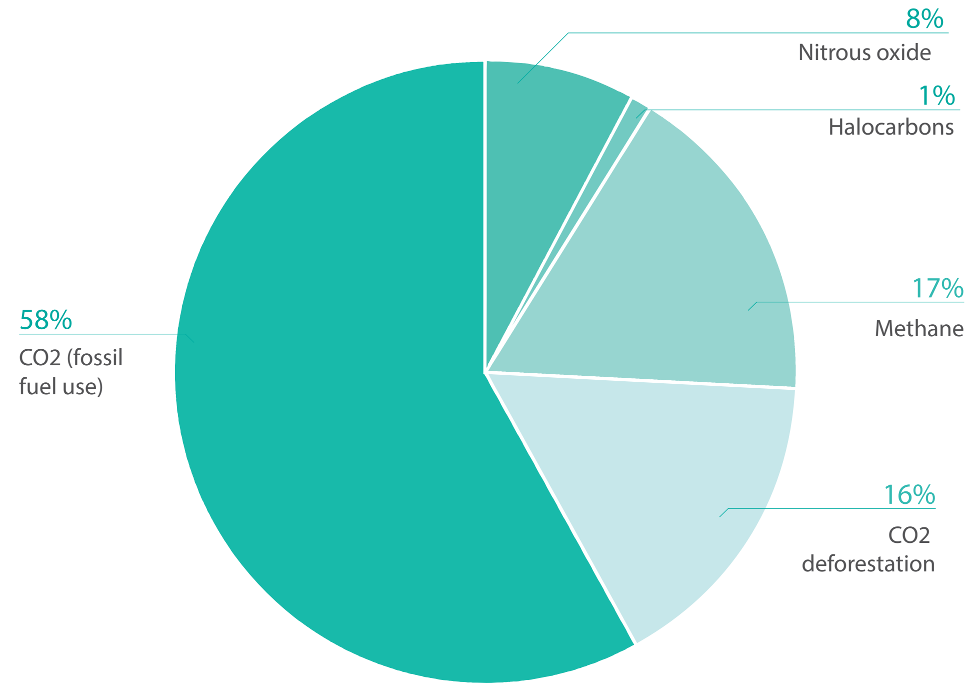
The GHG management ownerships for major aviation stakeholders is presented in Table 2 as Scope 1, 2 & 3

Table 2: The GHG management ownerships for major aviation stakeholders

Sources of emission	Process Owners Scopes			
	Airport operator	Airlines	Ground Support Services	Air Navigation
Self-owned Vehicles	1	1	1	1
Power Plant in Airport	1	3	3	3
DG set	1	3	3	3
Airport maintenance	1	3	3	3
Fire practice	1	3	3	3
Bird Chasing	1	3	3	3
Waste disposed on-site	1	3	3	3
Ground Support Equipment	1	3	3	3
Electricity Used by Self	2	2	2	2
APU	3	1	3	3
Aircraft and engine maintenance	3	1	3	3
Aircraft main engines	3	1	3	3
Construction Activities	3	3	3	3
Corporate Travel	3	3	3	3
Rail traffic	3	3	3	3
Waste disposed of off-site	3	3	3	3
Landside Road traffic/ Ground Access Vehicles (GAV)	3	3	3	3
Airside vehicle traffic (3rd Patty owned)	3	3	3	3
Electricity Used by others	3	3	3	3

4.4. Emission Estimation :

Greenhouse gases arise mostly due to the use of fuel combustion products and by-products. CO2 and CH4 are major GHGs as per quantity, but other by-product gases are also emitted during combustion process. A breakup of global human GHG emission by gases (IPCC, 2007), are shown below.



Global human emission by gases (IPCC, 2007) (fig:5)

There is a range of fuel burning activities within aviation that lead to GHG emission, including fuel combustion by the aircraft, ground support equipment, airside vehicles, landside vehicles, engine and APU testing and operation, power/heating/cooling plant and fire training etc.

• The fuel consumption and emissions from aircraft engine is dependent on the fuel type, aircraft type, aircraft payload, engine type, engine load, flying altitude and aircraft operational fuel efficiency which is associated with approach & takeoff, cursing, taxing, apron operation, ATC functions & ground support service functions at airport.

• The emission from ground vehicles for various ground service equipment depends on fuel type, vehicle type, engine type and distance travelled and its operational efficiency associated with airlines, airports and ATC functions.

• The emissions due to energy consumption at terminal function are based on the mechanical & electrical elements of infrastructures, building envelops & HVAC systems and airport terminal operational efficiency and its association with airlines, ATC functions & ground support service units.

• The emission due to airport access by passengers and other commuters are based on the fuel type, vehicle type, engine type and distance travelled and its operational efficiency, associated taxi, metro, personal car, public transport & employee travel service providers and multimodal connectivity's provided by the state government to the airport.

4.4.1. Emission Calculation {for Units as Mass (in kg) or for Units as Volume (in kl)}

Calculation Procedure Fuel Consumption (Self Owned/Controlled):
Emission CO_{2e} (kg) = Fuel consumed (kl) x Fuel Emission Factor (kg of CO_{2e}./kl of fuel)

Calculation Procedure for Electricity Consumption:
Emission CO_{2e} (kg) = Electricity Consumed (MWh) x Grid Emission Factor (Kg of CO_{2e}./MWh)

CO_{2e}: Carbon dioxide equivalency is a quantity that describes, for a given mixture and amount of greenhouse gas, the amount of CO_2 that would have the same global warming potential (GWP), when measured over a specified timescale (generally, 100 years). Carbon dioxide equivalency thus reflects the time-integrated radiative forcing of a quantity of emissions or rate of greenhouse gas emission—a flow into the atmosphere—rather than the instantaneous value of the radiative forcing of the stock (concentration) of greenhouse gases in the atmosphere described by CO_{2e}.

Calculation Procedure for Other Aviation Emission Sources:

g) Emission due to passengers' and other commuters access to airport:

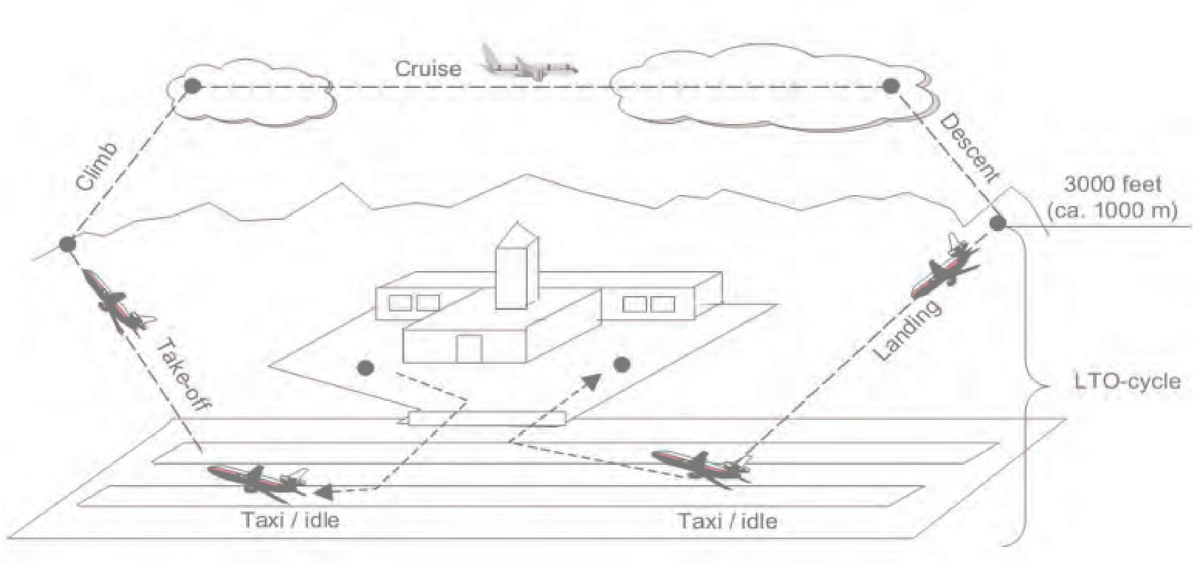
The passenger and other commuter's access to airport can be estimated by using a random sample survey. The survey can provide information on passenger number and their mode of travel and distance during the survey period. The total shares obtained for each mode of travel can be further extrapolated for the all passengers and commuters to the airport in a year. The mode of travel can be a personal car, taxi, public transport, metro/train etc. The boundary to the passenger's access depends upon the city circle radius (in terms of distance) and can be represented as per city boundary and major influence. It may vary between 20-60 km depends upon the airport connectivity and catchment area. Emission estimation methods for various modes of transportation are presented in Table 3.

Mode of transport	Estimation Method
Metro/Train	Distance (km)× Emission Factor (kgCO2/(Pax×km))× Pax
Taxi	(Fuel/km)×Distance× Emission Factor (kgCO2/kl)×Pax/(Pax/ Vehicle)
Public Transport (Bus)	Distance × Emission Factor (kgCO2/Pax×km)×Pax
Personal Car (Petrol)	(Fuel/km)× Distance × Emission Factor (kgCO2/kl)× Pax/(Pax/ Vehicle)
Personal Car (Diesel)	(Fuel/km)× Distance × Emission Factor (kgCO2/kl)× Pax/(Pax/ Vehicle)
Personal Car (CNG)	(Fuel/km)× Distance × Emission Factor (kgCO2/t)× Pax/(Pax/ Vehicle)

h) Emission of Aircraft Engine:

The emission from aircraft main engine occurs during two activities-
1. Emission due to LTO cycle and
2. Emission during cruise

Both the above two steps are presented in Figure 6.



Standard Flying Cycle (Source: IPCC, 2007)
(fig.5)

LTO Emission:

As per the definition provided by the ICAO (1993), landing and take-off cycles include all activities near the airport, that take place below a height of 3000 ft (914 m). This therefore includes taxi-in and -out, take-off, climb-out and approach-landing.

Emission dirung LTO Cycle=
[{Fuel consumption rate in approach (kg/sec)(starting from 3000 ft)×Time taken for approach (starting from 3000 ft)} (sec)+{Fuel consumption rate in Taxi (kg/sec)×Timetaken for taxi (min)} + {Fuel consumption rate in take off (from runway to 3000 ft) (kg/sec)×Time taken for takeoff} (min) + {Fuel consumption rate in climb out (kg/sec) × Time taken for climb out] (min) ×ATF emission factor (Kg of CO2/Kg of ATF)

One can also calculate LTO emission by referring to the LTO emission factors suggested by ICAO (Table B-1, Doc 9889, Airport Quality Manual) [16]. Example of LTO CO2 estimation by this method is presented in Table 4.

Table 4: LTO emission factor by aircraft

Aircraft Type	LTO Emisssions factors/airplane/kg/LTO/aircraft					
	CO_2	HC	NOx	CO	SO_2	Fuel consumption (kg/LTO/aircraft)
A319	2 310	0.59	8.73	6.35	0.73	730
A320	2 440	0.57	9.01	6.19	0.77	770
737-100/200	2 740	4.51	6.74	16.04	0.87	870
747-400	10 240	2.25	42.88	26.72	3.24	3 240
777-200/300	8 100	0.66	52.81	12.76	2.56	2 560

Cruise Emission:

Cruise is defined as all activities that take place at altitudes above 3000 feet (1000 m). No upper limit of altitude is given. Cruise, in the inventory methodology, includes climb to cruise altitude, cruise, and descent from cruise altitudes.

The cruise emissions will be dependent on the length of the flight (among other variables). The fuel used in the cruise phase is estimated as total fuel use minus fuel used in the LTO phase of the flight. This is performed for domestic and international aviation separately. The estimated fuel use is to be multiplied with emission factors in order to estimate the emissions.

Emission dirung Cruise (kg)=[{Fuel consumption from flight to or from airport (kg) }×ATF emission factor (3.15 kg/kg of ATF) - LTO Emission

i) Emission in APU use:

An auxiliary power unit (APU) is a small gas-turbine engine coupled to an electrical generator and is used to provide electrical and pneumatic power to aircraft systems when required. It is normally mounted in the tail cone of the aircraft, behind the rear pressure bulkhead, and runs on fuel fed from the main fuel tanks [17].

APU Emission (kg) = AUP Fuel Burn (kg/ APU event) × No. of AUP Events × ATF Emission Factor

Values representative of APU emissions for each aircraft operation [16]:

Aircraft group	Unit	Short-haul	Long-haul
Duration of APU operation	min	45	75
Fuel burn	kg	80	300
NO_x emissions	gm	700	2400
HC emissions	gm	30	160
CO emissions	gm	310	210
PM_{10} emissions	gm	25	40

Emission during Engine Testing of Aircrafts:

Emission during engine testing=
Fuel flow during testing (kg/second) × Duration of testing (second)× Emission factor of ATF (kgCO^2/kg of fuel).

k) Emission Due to Employee Travel:

i. Travel by air:

ICAO has developed a methodology to calculate the carbon dioxide emissions from air travel for use in offset program. The ICAO Carbon Emissions Calculator allows passengers to estimate the emissions attributed to their air travel. The methodology applies the best publicly available industry data to account for various

to account for various factors such as aircraft types, route specific data, passenger load factors and cargo carried. The tool is available in http://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx.

ii. Travel by road:
For estimation of emission due to employee travel by road, is estimated as follows-

$$\text{Total emission} = \frac{\text{Distance travelled in km}}{\text{Vehilce Mileage } \left(\frac{km}{kl}\right)} \times \text{Emission factor of fuel } \left(\frac{tCO_2}{kl}\right)$$

4.4.2. Grid Emission Factor for Electricity Consumption

The grid emission factor, which is used to calculate emission from electricity consumption in India is provided by Central Electricity Authority (CEA) [17]. The grid emission factors as provided by CEA, over the years are presented in Table 6.

Table 6: Grid Emission Factor for Electricity Consumption (India)

Grids	Year (tCO2)				
	2009-10	20010-11	20011-12	20012-13	20013-14
NEWNE	0.82	0.80	0.79	0.82	0.82
South	0.75	0.75	0.75	0.84	0.84
India	0.81	0.79	0.78	0.83	0.83

4.4.3. Fuel Emission Factors

The emission factors of different fuel types as suggested by DEFRA guidelines are presented in Table 7 [18].

4.5. Sample GHG Calculation & Inventory:

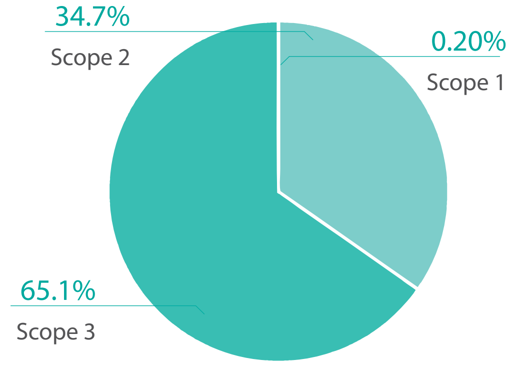
GHG estimation of some of the aviation function is demonstrated with representative of fuel consumption. For emission factor values as suggested by DEFRA have been used.
Airport Emissions:
The various emission sources of airport have been mentioned in Table 2, under section 4.3 of this report. The major sources of emission are vehicular and DG set emission (scope 1), emission due to electricity consumption (scope 2) and LTO emission, emission due to APU use, emission to passenger travel to the airport and emission due to airport staff travel (scope 3). Out of all the three scopes, the scope 3 emission is highest for an airport, followed by scope 2 and scope 1. A sample format for GHG inventory is presented in Table 8 and scope wise GHG emission (sample) of airport is presented in Figure 7.

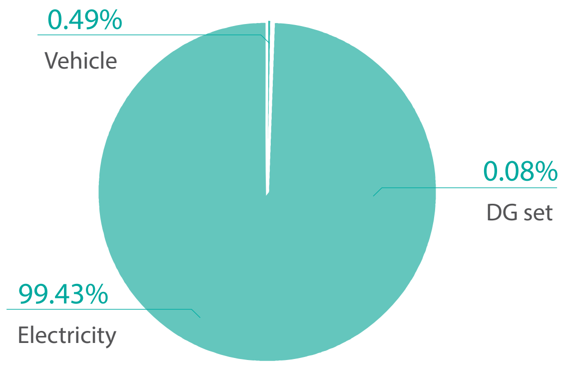
Table 7: Fuel Emission Factors

Fuel Type	Units	GHGs: CO_2 kg CO_2 /tonn	CH_4 kg CO_2e /tonn	N_2O kg CO_2e /tonn	Total Direct GHG kg CO_2e /tonn
Mass basis					
Aviation Spirit	tonne	3127.9	32.1	31.0	3191.1
Aviation Turbine Fuel		3149.7	1.5	31.0	3182.2
Burning Oil		3149.7	6.7	8.6	3165.0
CNG		2702.0	4.0	1.6	2707.6
Coal (industrial)		2339.0	1.4	42.7	2383.1
Coal (electricity generation)		2238.3	0.4	19.5	2258.2
Coal (domestic)5		2506.3	329.7	37.8	2873.8
Coking Coal		2955.4	30.4	70.7	3056.4
Diesel (100% mineral diesel)		3164.3	1.5	22.0	3067.2
Fuel Oil		3212.5	2.8	13.0	3187.8
Gas Oil		3190.0	3.5	334.1	3228.3
LNG		2702.0	4.0	1.6	3527.6
Lubricants		3171.1	1.9	8.5	2707.6
Naphtha		3131.3	2.7	8.0	3181.5
Other Petroleum Gas		2621.4	3.3	69.3	3142.1
Petrol (100% mineral petrol)		3135.0	4.6	8.9	2694.0
Petroleum Coke		3089.9	2.3	70.3	3050.4
Volume basis					
Aviation Spirit	litre	2.2121	0.0227	0.0219	2.2568
Aviation Turbine Fuel		2.5218	0.0012	0.0248	2.5478
Burning Oil		2.5299	0.0054	0.0069	2.5421
CNG		0.4728	0.0007	0.0003	0.4738
Diesel (100% mineral diesel)		2.6480	0.0012	0.0184	2.6676
Gas Oil		2.7667	0.0030	0.2898	3.0595
LNG		1.2226	0.0018	0.0007	1.2251
LPG		1.4884	0.0010	0.0023	1.4918
Petrol (100% mineral petrol)		2.3018	0.0034	0.0065	2.3117
Natural Gas	cubic metre	2.0154	0.0030	0.0012	2.0196

Table 8: Sample GHG emission report

Scope	Activity	Sources	Unit	Quantity Year (a)	EF (b)	Unit	Emisssion (tCO_2) (a×b)	5 of total emission
Scope 1	vehicles	Diesel	Kl	267	2.648		707	0.20%
		Petrol	KL	51	2.301		117	
		CNG	Tonn	22	2.702		59	
	DG Set airport	Diesel	Kl	56	2.648	tCO2/kl	148	
Scope 2	Electricity in Airport	Electricity	MWh	220000	0.82	tCO2/MWh	180400	34.7%z
Scope 3	APU	(ATF)	tonn	11475	3.15	tCO2/kL	36148	65.1%
	LTO	(ATF)	tonn	95843	3.15	tCO2/kL	301906	
Total Emission							519486	





Scope wise GHG emission share for Airport
(fig 7)

4.6. Various Opportunities for GHG Reduction:

Operational Measures
Reduce emission by improving operational efficinecy

- Implement Airport Collaborative decision making
- Reduce delays in each stages of a process
- Proactive approach instead of reactive approach

Technological Measures
Reduce emissions through the implementation of technical devices

- Efficient Building Infrastructure
- Efficient HVAC system
- Efficient Lighting system
- Deployment of Renewable energy
- Promotion of less emission intensive fuel

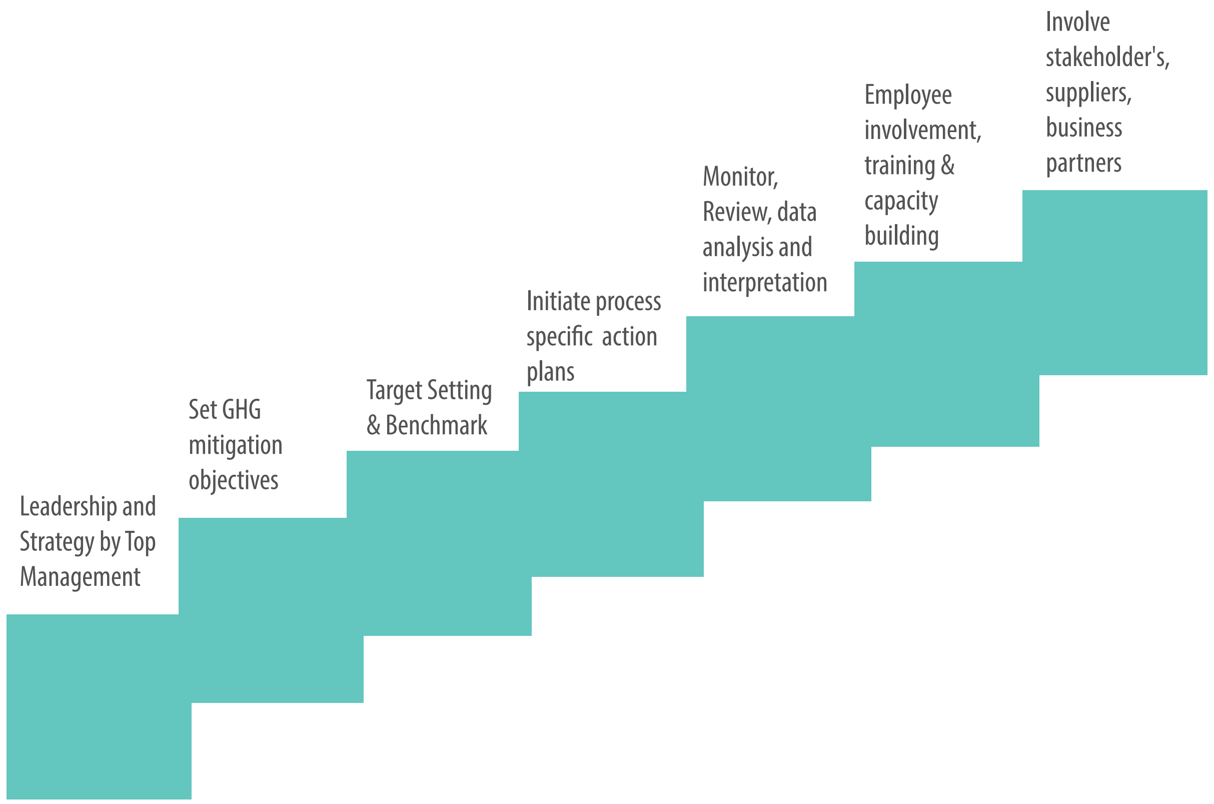
Economic Measures
Influence emission levels through providing economic incentives

- Purchase green certificates/RECs
- Purchase Carbon Credits

4.7. Evaluation Criteria for GHG Mitigation Initiatives:

- Technological feasibility
- Financial feasibility (IRR, NPV)
- Environment friendliness
- Risk and barrier analysis
- Gestation period
- Contribution to brand image

4.8 GHG Reduction Roadmap:



5. GHG REDUCTION BEST PRACTICES:

5.1. Best Practices for Airport:

Green Building Integration

Green Buildings are environmentally responsible and resource-efficient throughout the building's life-cycle, from Siting to Design, Construction, Operation, Maintenance, Renovation, and Demolition. Green Infrastructures have the processes, fittings and building elements with high efficiency, using minimum natural resources and have the required pollution prevention technologies & functions to reduce the building impacts on human health and the environment during the building's lifecycle. Implementing green infrastructure concepts during expansion of existing airports and/or construction of new airports and its allied infrastructures will benefit the environment and the society on water quality and its availability, air quality, emissions, waste, soil characteristic and noise levels in and around airport.

Terminal 3 of Delhi Airport is a LEED Gold certified green building and it is the first airport in the world to have achieved LEED Gold Certificate. Terminal 3 of IGIA has been designed to be a model for passenger-friendly and environmentally responsible airport facility. The integration of LEED concept in the construction of Terminal 3 has led to significant saving in natural resources (energy, water), materials, more use of recyclable and eco-friendly products

Energy Management System (ISO 50001:2011):

Benefits of ISO 50001

- Reduce energy cost for the organization via a structured approach of managing energy consumption trend.
- Increased knowledge of equipment efficiencies.
- Informed decision-making processes from system design to operation
- Increased energy awareness among employees at all levels.
- Structured approach to the Right First Time methodologies
- Improved brand image and confidence building with stakeholders and customer
- Minimization of risk associated with continuous supply of energy to the organization.
- Improved operational efficiencies and maintenance practices
- Reduced greenhouse-gas (GHG) emissions and carbon footprint.

DIAL is certified for Energy Management System (ISO 50001:2011). DIAL is the First Airport in the world to be certified for ISO 50001:2011 Energy Management system. With the adoption of EnMS ISO 50001:2011 systems, DIAL is mandated to have all its processes well mapped, regularly reviewed and constantly improved to meet DIAL Energy Management and Environment Management Policies. This has helped in significant reduction of per pax energy consumption at IGI Airport over the years.

Develop On/off-site Renewable/ Green Energy Generations


2.14 MW Solar PV plant in Delhi Airport

Key Drivers of Renewable Energy

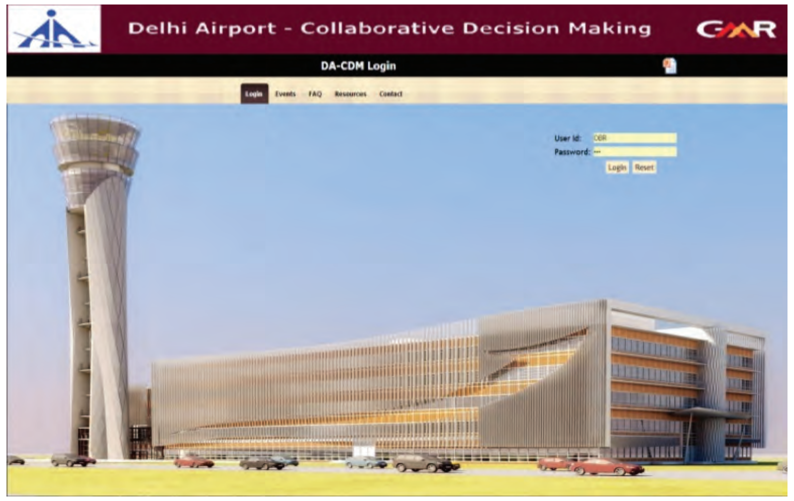
- Energy security concerns
- Increasing cost competitiveness
- Government support and policy changes
- Distributed electricity demand
- Climate Change and environmental issues associated with conventional fuels
- Foreign investment policy
- Vast untapped potential of RE resources.

DIAL has Installed 2.14 MW Solar PV (On-Site) in its airside premises. DIAL is the first airport in the country to have MW size solar PV at airside corridor. DIAL is also in the process of adding another 5.7 MW solar PV to the existing 2.14 MW by 2016. Besides solar PV plant, DIAL has also installed solar street lights and solar water heating systems to meet hot water demand at IGIA.

Implement Airport Collaborative Decision Making (A-CDM):

Airport Collaborative Decision Making is the concept and a tool which aims at improving Air Traffic Flow and Capacity Management (ATFCM) at airports by reducing delays, improving the predictability of aircraft events, planning and optimizing the utilization of infrastructures and natural resources.

A-CDM encompasses the en-route time, the approach of a flight, the turnaround and the departure. Airport CDM Information sharing requires that shared information is available through a common system, connected via proper interfacing to all partners' systems and database. This common system is the main infrastructure, which is known as the A-CDM Platform. This platform has interfaces with the Airport Operations Data Base, ATC systems and with airlines/GHAs to facilitate entry of targeted time, estimated time and actual time for different events during aircraft approach, landing, and taxi, take off time.



- Improved predictability of events
- Improved On-Time Performance (OTP)
- Reduce ground movement and cost savings on fuels and vehicles
- Optimize and enhance use of ground handling resources
- Optimize use of stands, gates, terminals and Reduced apron and taxiway congestion
- Optimize the use of airport infrastructure and reduced congestion
- Significant fuel and GHG emission reduction.

5.2. Best Practices for Airlines:

What Makes a Perfect Flight?
For Airlines, addressing external influences on gate-to-gate traffic flow, from one airport to another the followings are important for fuel efficiency and emission reduction [19]:

- Efficient ground movements (for aircraft and passengers)
- Optimized flight profiles
- Unrestricted climbs
- Optimum cruise levels
- Uninterrupted descents
- Maximizing aircraft capabilities while Minimizing ATC intervention
- Predictable departure and landing events

At the Gate:

To have high fuel efficiency and emission reduction the airline should emphasis at the Gate:

- Fuel loaded optimized for the flight
- Maximized use of ground power and conditioned air by BMEs instead of AUP use
- Coordinated optimum time to start APU
- Departure slot coordinated
- Aircraft ready on-time
- Departure according to a CDM plan.

Auxiliary power unit (APU)
• APU costs 30 to 50 times more than ground power
• A 1-minute delay in each APU start adds up to major fuel savings (2000 to 4000 kg per year).

Taxi-Out

To have high fuel efficiency and emission reduction, the airline should emphasis on Co-ordinated surface movement during taxi out. Variations to the plan coordinated through ATC permits pilot to:

- Plan for APU / Engine start-up
- From pushback to the runway, ATC "keeps traffic moving" (up to 30kts)
- CDM plan - shortest route to runway
- ATC updates on take-off sequence
- Allows pilots to complete pre-take off tasks - reducing runway occupancy

Aircraft engines are optimized for flight
•Each 1 min taxi burns 3-10kg fuel
•An A340 can save 140kg fuel by taxiing for 8 min with one engine off

Approaching the Runway

To have high fuel efficiency and emission reduction, the airline should emphasis while approaching Runway:

- Rolling take-off avoids intermediate stop
- No delay on runway
- Departure priority
- Intersection take-offs when possible
- Runway direction linked to flight route

Runway Selection
•Savings per movement also improves overall airport throughput
•Each minute of flight in the 'wrong-direction' equals 9 minutes of taxi fuel burn

Take-Off

To have a high fuel efficient and emission reduction, the airline should emphasis while take-off:

- Unrestricted climb to cruise
- No intermediate level-off
- Optimum FMS climb-out speed
- After meeting low altitude regulatory speeds
- CI determines

The Need for speed
•A 20kt speed increase for A340 from 280kt to 300kt will result in a 135kg saving.
•Fuel consumption at take-off and missed approach is about three times higher than in arrival

Departures

To have a high fuel efficient and emission reduction, the airline should emphasis while take-off:

- Optimally designed (RNP/RNAV) departures reduce Standard Instrument Departure (SID) time & distance required
- Flight avoid noise sensitive areas
- Flown with high precision of track and time accuracy

•An RNAV SID design can reduce ground tracks by 7 nautical miles or more
•Noise sensitive areas can be easily avoided

Climbing to Cruise Altitude

To have a high fuel efficient and emission reduction, the airline should emphasis while take-off:

- Aircraft is allowed to climb using its optimum climb profile
- Coordination with military authorities allows co-use of W-105 allowing optimum climb track
- Flight is allowed to use flex routing vs. prescribed entry into the NATS

Optimum altitudes
•Reroutes add time and fuel burn
•Flying 4000ft below optimum increases fuel burn ~350kg per hour
•A 15min hold at FL350 vs. FL150 saves ~128kg.

En-route & Holding

After 4 hours, the aircraft is 24,000kg lighter and should climb to a higher optimum altitude

- ATC slows flight while the aircraft is still at a fuel efficient cruising altitude.

Descent

To have a high fuel efficient and emission reduction, the airline should emphasis while descending:

- Continuous Descent
- ATC clearance to descend at Pilot's Discretion
- FMS / Flight Idle to incorporate:
- Cost Index Speed
- Rate of descent
- Accurate time predictions at gate

Continuous descent arrival / approach results in:
•10% less fuel
•40% less noise
•Saves 50-200 kg fuel
•150 - 640kg less CO_2

Approach:

To have a high fuel efficient and emission reduction, the airline should emphasis while Descent the RNAV / RNP Approach than Visual Approach, it helps in:

- More direct approach
- Improved safety
- Reduced fuel burn / emissions
- Less noise
- Save up to 15 mins per approach over ground-based STAR
- Fewer WX diversions (lower mins)

• 30% of the global airspace belongs to military
• Air routes developed over 50 years are little changed

Landing:

To have high fuel efficiency and emission reduction, the airline should emphasis while landing the Low Noise Low Drag Approach, it helps in:

- Full use of runway available fuel saving technique
- High-speed taxiway exit
- Runway assigned close to gate to minimize taxi

A go-around can cost ~4000kg in fuel and an additional 15 minutes of air-time

Taxi-In

To have a high fuel efficiency and emission reduction, airlines should emphasis while taxi-in:

- Vacate runway via high speed taxiway is included in landing clearance
- Advance gate information allows the pilot to plan for fuel savings techniques such as partial main engine shutdown prior to arrival on stand

However, the Perfect Flight can be flown with:

- A Collaborative Approach to Air Traffic Services
- Efficient Ground Movements
- CI Speeds / Direct Departures
- Flying at Optimum Altitude / Airspeed
- Flex Routes (wherever possible)

National Airspace Management Plans (civil / military)

- Continuous (Pilot Discretion) Descents
- Optimum Holding (airspeed / altitude)
- RNP / Visual Arrivals

Delhi Airport

There are two approaches to mitigating aircraft emissions for airport operations [20]. The first approach involves improvement in the technology of engines, aircraft design, fuel, etc. The second approach is related to modifying airport operations to help in emission reduction without involving any changes to current engine technology or aircraft design and include the following:

Decreasing Taxi-out time: Operational changes that reduce aircraft idling and taxi time directly reduce pollutant emissions. A possible option is "dispatch towing". High-speed tugs can be used to move aircraft between the terminal gate and runway more efficiently. Such tugs have already been tested successfully and are being used by many airlines.

Reducing Power Output during Taxi: Another way of reducing aircraft emission, is by the judicious use of aircraft engines, in taxi mode. Fuel burn and emissions can potentially be reduced if all aircrafts were to taxi out using only a subset of their engines. This translates to using one engine for twin-engine aircraft, and is therefore referred to as single engine taxiing. This not only reduces emissions but allows other engines to operate more efficiently (i.e. at higher RPMs) resulting in lower consumption of fuel and less HC and CO emissions. Globally many airports already encourage this practice.

For Single Engine Taxing Procedure: Shutting down an engine during taxi-in and taxi-out operations should be planned in advance and accomplished as early as possible during the taxi phase to obtain the maximum reduction of fuel burn and environmental benefit.

5.3. Best Practices for Air Traffic Service:

The concept of continuous decent operation (CDO) was implemented at IGIA, New Delhi since 2011 for noise abatement procedures. Since November 2013, the implementation of CDO gained further momentum, to enhance operational efficiency by fuel saving, reduced carbon emission & reduced aircraft noise. Since then, CDOs are being initiated by ATC Delhi, from en-route phase i.e. top of descent, during lean traffic and from terminal airspace i.e. from intermediate levels to TDZ during moderate traffic. The record of CDOs performed is being kept by ATM. Airlines and their fuel management departments are being encouraged to give their fuel saving by e-mail.

Delhi ATC is handling about 1000 movement in a day. On an average, Delhi initiates CDO to about 10-15 percent arrivals, resulting in fuel savings- as reported by airlines - up to about 200 kgs maximum. There have been instances when up to 80 flights landing at Delhi during night were given CDO, resulting into huge savings of fuel and corresponding Carbon Emissions. These percentages are likely to go up to 20-25 percent after implementation of C-ATFM.

Delhi Airport

Some other initiatives being implemented by ATC are:

Mixed Mode of Operations of Parallel/ Near Parallel Runways: Resulted in enhancement of airport capacity. Holdings in air as well as on the ground have reduced drastically.

Three Runway Operations at IGI Airport: It facilitate departures and arrivals, nearer to the terminal resulting in less taxi timings which means saving of fuel and less carbon emissions.

40 NM Longitudinal Enroute Separation (in place of 80 NM/ 10 minutes) on Routes W20/ R460-R594-M890: Enabling the aircraft to fly at optimum level as per load thereby resulting in fuel savings.

RNAV – 5 City Pair Routes between Delhi and Mumbai: Direct Routing with 50 NM Enroute Separation (in place of 80 NM/ 10 minutes): Enabling the aircraft to fly at optimum level as per load thereby resulting in fuel savings.

Continuous Descent/ Climb Operations: Delivers benefits like reduction to fuel burn, gaseous emissions and noise impact.

DA-CDM Process: Improved overall efficiency of the operation by reducing delays which results in reduction of carbon emission and noise pollution. The process has also enhanced predictability and optimized the use of ground handling resources.

Arrival Manager and Issuance of Estimated Touch down Time: Better enroute planning, absorption of delay, if any.

Flexible Use of Airspace and Conditional Routes through Restricted Defense Airfields: Better utilization of Airspace through Mutual coordination between Airports Authority of India and India Air Force. Aircrafts to fly shorter route; resulting in less flying time hence reducing fuel consumption.

5.4. Best Practices for Ground Service Providers:

• The agency should ensure that adequate awareness training is carried out for ground-crews to ensure that they are aware of the importance and benefits of using ground-based power and air supplies.

• Early reporting of the non-availability of ground-based systems by Ground Handling Agent's crews should be encouraged to ensure that availability levels and confidence in the use of the systems are kept high.

• Have standard Into-Plane Fuelling Procedures: simplified and logically sequenced step-by step approach to aircraft refueling for fuel conservation and emission reduction.

• Monthly monitoring of fuel consumption and energy consumption followed by analysis and corrective actions will benefit in emission reduction.

• Keeping on-time preventive maintenance programs for equipment will benefit in emission reduction.

•Use of electric driven vehicle and baggage trolley.

• Adopting green infrastructures and renewable energy developments (e.g. solar)

• Monitoring and regulating idle running of vehicles to avoid carbon emissions.

• Consolidated operations working area to reduce additional footprint of vehicles/equipment.

Delhi Airport

5.5. Best Practices for all Aviation Stakeholder: Employee & Stakeholders Engagement & Capacity Building:

Greenhouse Gas (GHG) Collaborative Management Programs at each airport incorporate roles and responsibility of all stakeholders is an important steps for aviation sector to reduce overall GHG emission in India. Collaborative Management Programs will help all stakeholders have a common understanding of the scope, objective and target. It will also help in identifying and imparting various capacity building initiatives for its stakeholders. This will bring an active measure and control across the aviation business stakeholders to incorporated emission reduction and sustainable environment programs.

Collaborative Management Programs will give an opportunity to discuss and express the best practices adopted in their business function for emission reduction and measures adopted to enhance the co-operation between stakeholders on emission reduction initiatives at each airport. The programs should be focused on improving process parameters, infrastructural needs (for energy and environmental improvement) and attitude (to enhance cleanliness at airport, culture for focusing environmental friendly measures). Stakeholder engagement programs also facilitate ongoing dialogue and corporation between stakeholders with the aim of reducing emissions.

The key stakeholders who are responsible for the majority of the airport's scope 3 emission includes airlines, ground handling agencies, local transport operators, passengers, tenants, and staffs. The engagement plans should aims to:

• Raise Awareness

• Develop understating between stakeholders and identify key stakeholders

• Build support and indicate the possible change required for process, infrastructural and attitude improvements.

• Develop effective working partnership with common goals of emission reduction and with responsibilities accounted.

• Explore the possibilities of extending the collaboration on investment project for possible emission reduction.

6. SUMMARY

As a part of India Greenhouse Gas Program (IGHGP) together with founding members (CII, TERI and WRI), Delhi Airport presents this knowledge sharing document "Aviation Greenhouse Gas (GHG) Reduction: Best Practices & Perspectives" to all aviation stakeholder and organisations to map, reduce and optimize Greenhouse Gases from its various functions.

This document highlights the literatures and information related to climate change and its mitigation measure and estimation procedures suggested by various agencies and authorities with best practices adapted by aviation stakeholders on the objective of knowledge sharing. This report, an initiative led by the Delhi International Airport Limited (DIAL), proactively collaborated with the Jet Airways, Air Traffic Controller (ATC) of Airport Authority of India and supported by the India GHG Program builds a framework for measurement and mitigation of carbon emissions. It also highlights how cost-effective measures are available for further reducing emissions from aviation, mainly from more efficient fuel usage and harmonized air traffic management systems.

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ACKNOWLEDGEMENT

We would like to thank the partners of India GHG Program, (CII, TERI and WRI) for providing us the opportunity to come up with the report titled "Aviation Greenhouse Gas (GHG) Reduction Best Practices & Perspectives" for knowledge sharing together with the partners involved for this document.

We would also like to thank our stakeholder's Air Traffic Controls (ATC), Palam of Airport Authority of India and Airlines & Ground Service Providers for their valuable inputs.

DISCLAIMER

While every care has been taken in writing this report, IIndia GHG Program and founding member (M/s Delhi International Airport (P) Limited) and supporting organisations accept no claim for compensation with respect to any wrong, abbreviated, omitted or incorrectly inserted content in the report. The report is only an attempt to put down the best practices followed in the aviation sector only for the purpose of enhancing knowledge and awareness.

The report has been compiled based upon the publicly available data, technical expertise of the authors for the purpose of enhancing knowledge and awareness.

The report is open for stakeholder consultation and you are invited to share your views and comments to :
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Published By:
India GHG Pogram
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LIST OF ABBREVIATIONS

AAI	Airports Authority of India
A-CDM	Airport Collaborative Decision Making
ACI	Airports Council International
ADS-B	Automatic Dependent Surveillance-Broadcast
ALS	Approach Lighting System
ANS	Air Navigation Services
APU	Auxiliary Power Units
ASBU	Aviation System Block Upgrade
ATC	Air Traffic Control
ATFCM	Air Traffic Flow and Capacity Management
ATM	Air Traffic Movement
BME	Bridge Mounted Equipment
CDM	Clean Development Mechanism
CII	Confederation of Indian Industry
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO2	Carbon Dioxide
DEFRA	Department for Environment, Food & Rural Affairs
DG	Diesel Generator
DGCA	Directorate General of Civil Aviation
DIAL	Delhi International Airport (P) Limited
EMS	Environment Management System
EnMS	Energy Management System
FIANS	Future India Air Navigation System
FEGP	Fixed Electrical Ground Power
GAGAN	GPS Aided Geo Augmented Navigation
GAV	Ground Access Vehicles
GHA	Ground Handling Agent
GHG	Green House Gases
GIM	National Mission for a Green India
GNSS	Global Navigation Satellite System
GSE	Ground Support Equipment
HC	Hydro Carbon
HVAC	Heating Ventilation and Air Conditioning
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IGBC	Indian Green Building Council
IGHGP	India Greenhouse Gas Program
IGIA	Indira Gandhi International Airport
INSPIRE	Indian Ocean Strategic Partnership to Reduce Emissions
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual Property Rights
ISO	International Organisation for Standards
kWh	Kilo Watt Hour
KPI	Key Performance Indicators
LEED	Leadership in Energy and Environment Design
LNG	Liquid Natural Gas
LPG	Liquid Petroleum Gas
LTO	Landing Take Off
MW	Mega Watt
MWh	Mega Watt Hour
NAPCC	National Action Plan for Climate Change
NEWNE	North East West and North-East
NMEEE	National Mission for Enhanced Energy Efficiency
NMSA	National Mission for Sustainable Agriculture
NMSH	National Mission on Sustainable Habitat
NMSHE	National Mission for Sustaining the Himalayan Ecosystem
NMSKCC	National Mission on Strategic Knowledge for Climate Change
NO	Nitrous Oxide
NO2	Nitrogen Dioxide
NSM	National Solar Mission
NWM	National Water Mission
OTP	On Time Performance
PBN	Performance Based Navigation
PCA	Pre-Conditioned Air
PM	Particulate Matter
PV	Photo Voltaic
RNP	Required Navigation Performance
ROT	Rate of Turn
RPK	Revenue Passenger-km
RVR	Runway Visual Range
SBAS	Satellite-Based Augmentation System
SO2	Sulfur Dioxide
TERI	The Energy Resources Institute
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
VFD	Variable Frequency Drive
WRI	World Resources Institute