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Air Transport and Energy Efficiency



Safe, Clean, Affordable
TRANSPORT



BOMBARDIER



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ABBREVIATIONS

A-CDM	Airport Collaborative Decision Making
ACI	Airports Council International
AEA	Association of European Airlines
AfDB	African Development Bank
AGD	Aviation Global Deal Group
ANSP	Air Navigation Service Provider
APD	Air Passenger Duty (United Kingdom)
APM	Automated People Movers
APU	Aircraft Auxiliary Power Unit
ASPIRE	Asia and South Pacific Initiative to Reduce Emissions
ASTM	American Society for Testing and Materials
ATC	Air Traffic Control
ATF	Advanced Turbofan
ATM	Air Traffic Management
BMS	Building Management System
BTL	Biomass-to-Liquid
CAAFI	Commercial Aviation Alternative Fuels Initiative
CAEP	Committee on Aviation Environmental Protection (ICAO)
CBDR	Common But Differentiated Responsibilities
CDA	Continuous Descent Approach
CDM	Clean Development Mechanism
CDO	Continuous Descent Operations
CDP	Carbon Disclosure Project
CER	Certified Emissions Reductions
CFD	Computational Fluid Dynamics
CICERO	Center for International Climate and Environmental Research at the University of Oslo
CIF	Climate Investment Funds
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
COP16	Conferences of the in Parties in Cancun, Mexico, 2010 (UNFCCC)
CUSS	Common Use Self Service
EPNdB	Effective Perceived Noise decibels

ETS	Emissions Trading Scheme
EU	European Union
FAA	United States Federal Aviation Administration
FAB	Functional Airspace Blocks
FDI	Foreign Direct Investments
FEGP	Fixed Electrical Ground Power
GAP	Global Approach Proposal
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gases
GIACC	Group on International Aviation and Climate Change
GNSS	Global Navigation Satellite Systems
GRI	Global Reporting Initiative
GSE	Ground Support Equipment
GTF	Geared Turbofan
GTL	Gas-to-Liquids
HVAC	Heating, Ventilating, and Air Conditioning
IAE	International Energy Agency
IATA	International Air Transport Association
IBRD	International Bank for Reconstruction and Development
ICAO	International Civil Aviation Organization
IDA	International Development Association
IFC	International Finance Corporation
IPCC	United Nations Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
Kg	Kilogram
Km	Kilometer
KPA	Key Performance Areas
KW	Kilowatt
KWh	Kilowatt hour
LCA	Life Cycle Cost Analysis
LCC	Low-Cost Carrier
LED	Light-Emitting Diode
LPG	Liquid Petroleum Gas
LTO	Landing and Take-off
Mb/d	Million barrels per day
MBM	Market-Based Measure

Mtoe	Metric tons
MW	Megawatt
NextGen	Next Generation Air Transportation System
O&M	Operations & Maintenance
OECD	Organisation for Economic Co-operation and Development
PCA	Pre-Conditioned Air
PKP	Passenger-Kilometers Performed
QABP	Qatar Advanced Biofuel Platform
QP	Qatar Petroleum
QSTP	Qatar Science & Technology Park
R&D	Research and Development
REDD	Reducing Emissions from Deforestation and Forest Degradation
RNP	Required Navigation Performance
RPK	Revenue Passenger Kilometers
RVSM	Reduced Vertical Separation Minimum
RVSM	Reduced Vertical Separation Minima
SEB	Skandinaviska Enskilda Banken
SES	Single European Sky
SESAR	Single European Sky ATM Research programme
TMA	Terminal Maneuvering Area
UHB	Ultra-High Bypass Ratio
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNREDD	United Nations Reducing Emissions from Deforestation and Forest Degradation Project
UNWTO	World Tourism Organization
US\$	United States Dollar
VOC	Volatile Organic Compound
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

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EXECUTIVE SUMMARY

The air transport sector is enjoying an optimistic growth rate while at the same time eliciting growing concern, due to its environmental impact and its vulnerability with respect to energy security. These issues have put the sector at the forefront of the tide in achieving energy efficiency. Efforts have been made on every front to improve efficiency through better technology, optimized operation, as well as energy-saving infrastructure.

What is the low-hanging fruit that the air transport sector can reach in terms of energy efficiency? What are the policy makers' and private sector's roles in achieving energy efficiency in air transport? These are the issues that this report would like to address in this energy- and finance-constrained economy.

This report includes five chapters. Chapter 1 will introduce the air transport energy consumption outlook though the analysis of the growth of air services as well as consumption of fossil fuel-based energy. Chapter 2 will discuss air transport's impact on the environment and the response and actions from the air transport sector. Chapter 3 will detail potential energy efficiency gains in aircraft design, air service operation, as well as infrastructure design. The role of the government and private sector in fostering and supporting those energy efficiency gains will also be discussed. Chapter 4 will enumerate policy options for countries with respect to air transport energy efficiency, focusing on fiscal measures. Finally, Chapter 5 presents an analysis of support and financing measures that can be taken by the World Bank and its member countries.

This report compiles a maximum of information on the proposed issues culled from existing research as well as from open sources provided by partner organizations and industry. It aims to guide the air transport industry, policy makers, and development institutions on where to focus their investments or support in developing and emerging markets in order to address the energy and climate change challenges ahead.

INTRODUCTION

Air transport's role of providing rapid and intercontinental connections has made it an essential economic and social conduit throughout the world. In 2010, the air transport industry transported approximately 4.8 billion passengers, roughly 30 percent of the world's population when counted on a round-trip basis. Nearly 43.3 million tons of freight are transported by air worldwide, up from 30.4 million in 2000, which account for nearly 40 percent of all goods by value. Many developing countries today depend heavily on air cargo for their exports as other modes of transportation are unreliable or non-existent.

In addition to its unique role in transportation, the air transport industry generates roughly 5.5 million direct jobs globally (airlines employ 4.7 million people and the civil aerospace sector about 780,000). Its direct contribution to the global economy was around US\$425 billion in 2007. Air transport has an even greater indirect and induced effect on the industry's supply chain, which includes suppliers (for example, off-site suppliers of fuel, food and beverages, and construction services), manufacturers (such as computers and retail), and business services (call centers, accountants, lawyers, and financial services, etc.). The induced effect is generated by the spending of direct and indirect employees on such items as food and beverages, recreation, transport, clothing, and household goods. It is estimated that the indirect impact of the sector in 2007 represented 6.4 million jobs, with a global contribution to GDP of US\$490 billion. The induced effect of the air transport sector generated another 3 million jobs and contributed US\$229 billion to global GDP. Overall, in 2007, the air transport sector was a global industry with about 15 million jobs that accounted for over US\$1,144 billion of global GDP (ATAG 2008).

With this optimistic growth rate, by the same token, the air transport industry now faces a fresh set of challenges. According to the International Energy Agency (IEA), aviation used 246 million tons of oil equivalents (Mtoe) of energy in 2006, which represented 11 percent of all transport energy used. Aviation's energy usage is expected to triple to about 750 Mtoe by 2050, according to the IEA's baseline scenario; as a result, aviation would account for 19 percent of all energy used (IEA 2009). The growing demand in energy along with rising fuel costs is endangering air transport's optimistic outlook. Traditionally, fuel costs were less than 15 percent of airline operational costs; however, they have risen substantially since 2003. Fuel costs rose to around 33 percent in 2008 and exceeded 40 percent for carriers with lower labor costs (IATA 2008). In addition, the industry's impact on the environment is

increasingly becoming a source of concern. Initially, noise was the central issue. In recent years, however, concerns have focused more on addressing aviation's impact on greenhouse gas emissions. Though it only contributes 2 percent of overall global CO₂ emissions today (IPCC 2007), the rapid growth of air transport over the past few decades has led to the adoption of new tradable carbon rights rules in Europe, while similar legislation¹ is being considered in the United States.

The air transport industry consists of an aviation sector and a civil aerospace sector. The aviation sector includes airlines (passengers, cargo, general aviation), airports and related services (civil airports, handling and catering, freight services, aircraft maintenance, fueling, retail), and providers of air navigation services. The civil aerospace sector develops and manufactures airframes, engines, and equipment and performs offsite maintenance. Historically, technology enhancement in airframe and engine design, air traffic control, and airport operation, etc. has improved fuel efficiency in the air transport sector over the years. Trends in improving efficiency levels have shown that aircraft entering today's fleet are around 80 percent more fuel-efficient than they were in the 1960s (International Coordinating Council of Aerospace Industries Associations). These efficiency levels have been achieved with step changes in design—such as the introduction of turbofan engines with increasingly high bypass ratios—coupled with year-on-year “incremental” improvements to engine design and operation.

In the mid-1970s, fuel conservation was further enhanced with the development of flight management systems that automatically set the most efficient cruise speed and engine power settings based on fuel and other operational costs involved (Intergovernmental Panel on Climate Change). More recently, airlines have undertaken a range of operational, maintenance and planning procedures to ensure that their current technology aircraft are flying to their optimal levels of efficiency.

¹ Lieberman-Warner Climate Security Act of 2008.

Fuel efficiency gains since the early jet age

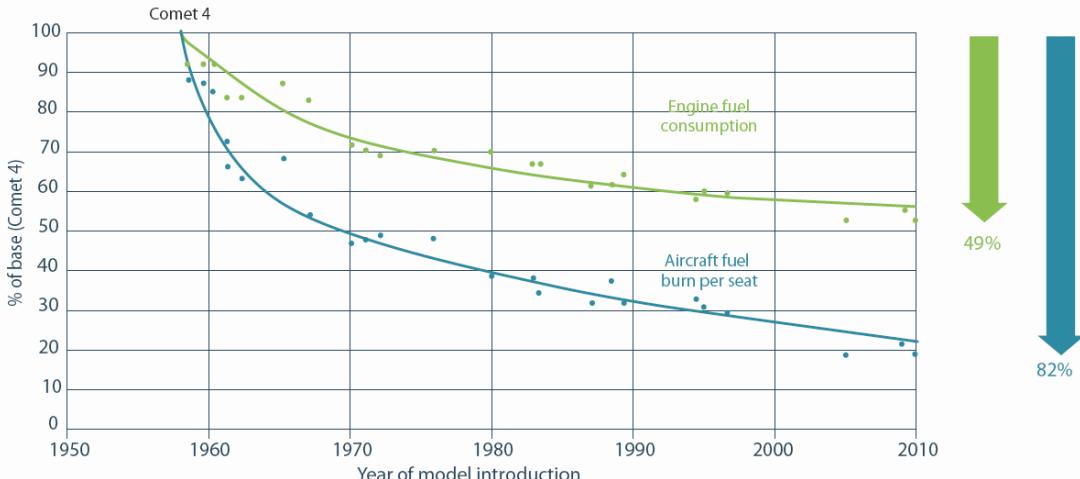


FIGURE 1 - FUEL EFFICIENCY GAINS SINCE THE EARLY JET AGE

The world's most widely used jet aircraft is the Boeing 737. The first commercial version, the Boeing 737-100, took to the skies for the first time in 1967 and could carry 124 passengers over 2,775 km with a total payload of 12,701 kg. A recent version, the 737-800, can carry 48 percent more passengers, travel 119 percent farther with a 67 percent increase in payload, while burning 23 percent less fuel—or 48 percent less fuel on a per-seat basis (Aerospace Technical Publications International). The latest generation Airbus A320 is approximately 40 percent less expensive—and more fuel-efficient—to operate than the aircraft it replaced (Airbus 2008). In fact, Airbus spends US\$265 million per annum on research and development in an effort to further improve the efficiency of the A320 family of aircraft. In the coming years, additional enhancements will be made to narrow body aircraft efficiency in the Boeing and Airbus models, along with new developments from Bombardier (the CSeries) and Embraer's E-Jet family.

The link between energy use and environment is obvious as each ton of fuel translates into approximately 3.15 tons of CO₂ emissions (ATAG 2010). Aviation emissions of greenhouse gas included 810 million tons of CO₂ in 2006, which represents 12 percent of all transport CO₂ emissions. The Organization for Economic Cooperation and Development (OECD) forecasts that CO₂ emissions from air transport will grow to 23 percent of all transportation CO₂ emissions by 2050 if no measures are taken (Anming Zhang 2009).

Improving energy efficiency results in tremendous energy savings, as well as a reduction in costs, while at the same time reducing greenhouse gas emissions. This report investigates measures that the air transport industry and governments can take to improve energy efficiency and mitigate greenhouse gas emissions. Its objective is to identify areas in which

to finance air transport efficiency measures and to provide guidance to the World Bank and other development banks with a similar project focus. Another goal of this report is to provide a balanced overview of the various elements that will be needed to ensure the most efficient use of energy in the air transport sector—the key condition for its sustainable development.

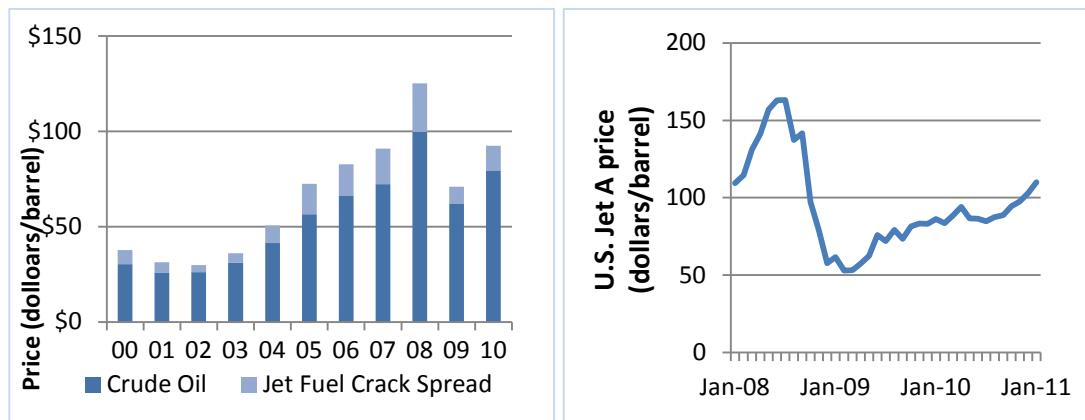
Inputs submitted by over twenty air transport sector partners provided the background for this report and are listed in the acknowledgements. The objective was to allow each entity to freely and independently share its knowledge, views and technical insights on effective measures that will help to tackle most effectively the challenges ahead.

1 ENERGY CONSUMPTION OUTLOOK AND AIR TRANSPORT

1.1 OUTLOOK OF CONSUMPTION OF FOSSIL FUELS-BASED ENERGY

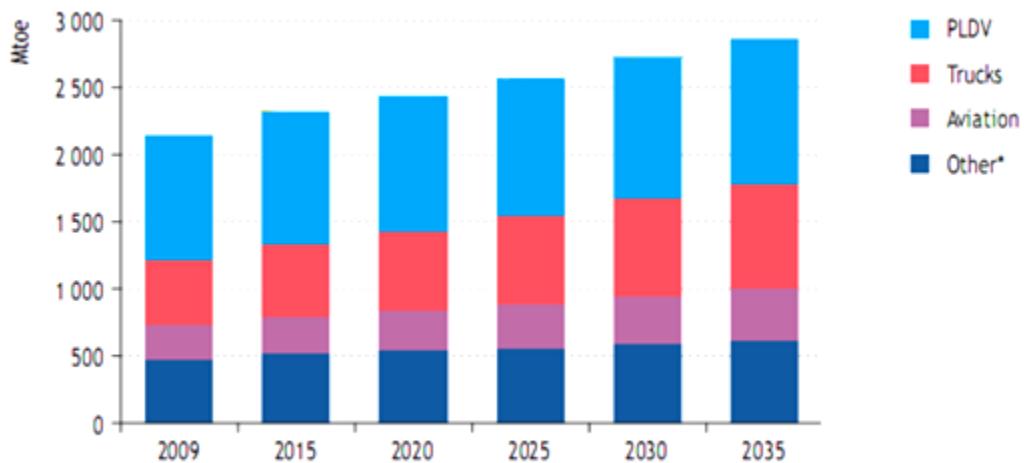
According to the IEA, even if governments take actions to meet the commitments they have made in an effort to tackle climate change and energy insecurity, global energy consumption is still projected to increase by 36 percent from 2008 to 2035, rising from currently 12,300 Mtoe to 16,750 Mtoe. Nevertheless, annual growth is anticipated to slow progressively, from 1.4 percent per year during the 2008 to 2020 period to 0.9 percent per year between 2020 and 2035, as those government measures take effect. The primary energy demand will come from developing and emerging countries where economies and populations enjoy a higher growth rate. The OECD countries' share of global primary energy demand has already declined from 61 percent in 1973 to 44 percent in 2008 and is expected to fall further to 33 percent in 2035 (International Energy Agency 2010).

During the 2008 to 2035 period, the IEA foresees that fossil fuels (oil, coal and natural gas) will continue to be the mainstay of global energy consumption. Oil will remain the dominant fuel, with demand increasing from 85 million barrels per day (mb/d) in 2008 to 99 mb/d in 2035. The increase in price pressures on international markets, the cost of carbon emissions, and government policies and incentives to achieve energy efficiency will motivate global energy consumption to switch to low-carbon energy sources and help to restrain demand growth for fossil fuels. As a result, the share of fossil fuels in global energy consumption is expected to drop from 33 percent in 2008 to 28 percent in 2035.



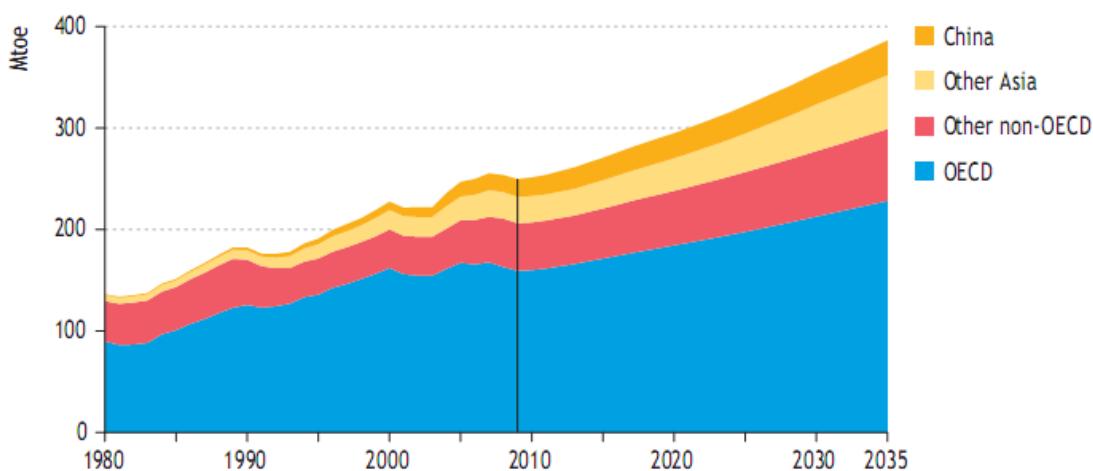
**FIGURE 2 - TREND OF FUEL PRICE
(ENERGY INFORMATION ADMINISTRATION)**

The growing economies in emerging countries result in the rapid increase in demand for energy due to greater car ownership, a growing road and railway network, and an ever more complex trade logistics system. The demand for jet fuel and aviation gasoline in the air transport sector is projected to reach 14 percent of the total fuel demand in transportation in 2035, compared to 12 percent in 2009. For OECD countries, the air transport sector is currently the only major sector with significant growth in demand for oil. China is considered to be the largest country in terms of aviation fuel demand growth, with an annual demand increase projected at 2.6 percent.



*Includes other road, rail, pipelines, navigation and non-specified.

**FIGURE 3 - TRANSPORT OIL CONSUMPTION BY TYPE
(INTERNATIONAL ENERGY AGENCY 2010)**



**FIGURE 4 - AVIATION OIL CONSUMPTION BY REGION
(INTERNATIONAL ENERGY AGENCY 2010)**

**TABLE 1 - SHARES OF RENEWABLE ENERGY BY SECTOR AND REGION
BASED ON THE IEA'S NEW POLICY SCENARIO²
(INTERNATIONAL ENERGY AGENCY 2010)**

	Electricity		Heat		Biofuels			
	2008	2035	2008	2035	2008	2035	2008	2035
OECD	17%	33%	11%	23%	3%	12%	0%	3%
Europe	21%	44%	12%	25%	3%	12%	0%	0%
United States	9%	25%	10%	25%	4%	15%	0%	4%
Japan	10%	19%	3%	7%	0%	1%	0%	4%
Australia/ New Zealand	15%	31%	18%	41%	0%	2%	0%	0%
Non-OECD	21%	31%	9%	12%	2%	6%	0%	0%
China	17%	27%	1%	5%	1%	4%	0%	0%
India	16%	26%	24%	19%	0%	6%	n.a.	n.a.
Other Asia	16%	31%	11%	15%	1%	4%	0%	0%
Brazil	84%	75%	47%	50%	21%	41%	0%	3%
Other Latin America	52%	65%	13%	15%	0%	5%	0%	0%
Russia	16%	28%	5%	5%	0%	2%	0%	0%
Middle East	1%	16%	1%	3%	0%	0%	0%	0%
Africa	16%	39%	31%	37%	0%	2%	0%	0%
World	19%	32%	10%	16%	3%	8%	0%	1%
European Union	17%	41%	13%	26%	3%	14%	0%	0%

Note: Electricity = share of renewables in total electricity generation; heat = share of renewables for heat in total demand for heat; biofuels = share of biofuels used in road transport in total road transport and share of biofuels used in aviation in total aviation fuel.

Compared to measures taken by governments worldwide with respect to other modes of transport, commitments to reduce energy use in the air transport sector have been rather limited. It is estimated that the global consumption of aviation oil will increase by more than 50 percent in 2035 compared to its 2008 level. Nevertheless, the aviation industry made significant efforts to improve energy efficiency in various aspects, especially by making efficiency gains in airframe and

² The new policy scenario expects G20 countries to enact policies to support commitments and plans that they have announced publicly, including national pledges to reduce greenhouse gas emissions and plans to phase out fossil-energy subsidies, even where the measures to implement these commitments have yet to be identified or announced.

engine design, by introducing measures in air traffic control, and by improving airport operations. Furthermore, the industry is also engaged in researching and developing alternative fuels for aviation. The industry expects that by 2020 biofuels for aviation will make up 15 percent of global aviation fuel consumption, and 30 percent by 2030. Nevertheless, it is commonly accepted that the most immediate means to address climate change and energy security in the air transport industry is the improvement of energy efficiency.

1.2 GROWTH OF AIR SERVICES (ICAO 2010)

1.2.1 HISTORIC AIR TRAVEL GROWTH

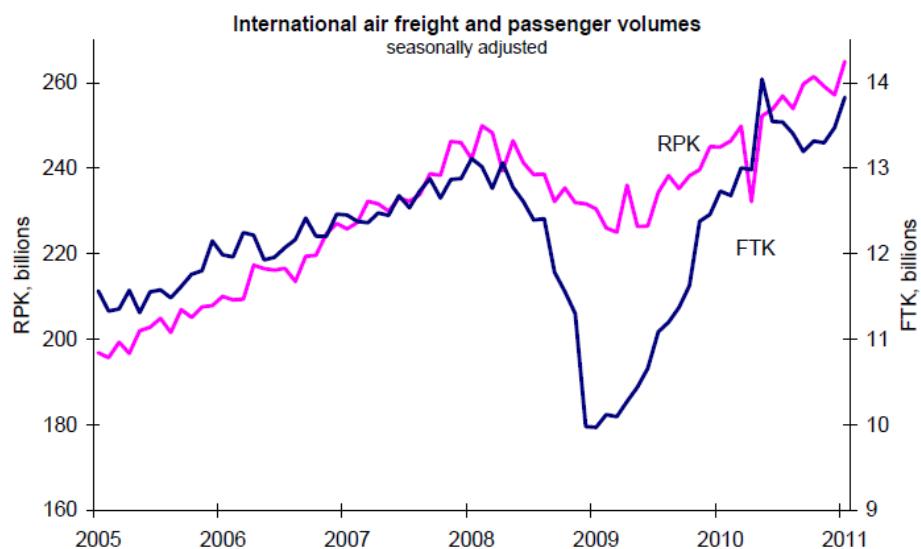
According to the ICAO's statistics, the world's airlines carried about 4.8 billion passengers and 38 million tons of freight on scheduled services in 2009. Total scheduled traffic, measured in ton-kilometers performed, grew at an average annual rate of 4.4 percent between 1989 and 2009. During this period, thanks to strong economic growth, air service liberalization and the entry of low cost carriers into many markets, the airline industry has grown significantly.

**TABLE 2 - TRENDS IN TOTAL SCHEDULED AIR TRAFFIC (1979-2009)
(ICAO 2009)**

	Average annual growth (percent)		
	1979-1989	1989-1999	1999-2009
Passenger-kilometers performed	5.3	4.7	4.3
Freight ton-kilometers performed	7.4	6.6	2.6
Mail ton-kilometers performed	4.0	1.2	-2.7
Total ton-kilometers performed	5.8	5.2	3.7

However, the severe financial crisis of 2008 and global economic recession of 2009 hit the air transport industry hard. Airlines globally lost US\$9.9 billion in 2009, passenger traffic fell 2.1 percent, cargo dropped 9.8 percent, and industry revenue fell by 15 percent to US\$479 billion. The recovery that followed remains generally sluggish in the United States and in Europe, which is also affecting the economies of

many developing countries that initially were not hit as hard. Despite this, air transportation has rebounded in most emerging markets. The strongest growth in traffic was experienced in Asia and the Middle East. Latin America and Africa were much less affected by the crisis and continue to experience a steady development.



**FIGURE 5 - INTERNATIONAL AIR FREIGHT AND PASSENGER VOLUMES
(IATA 2011)**

1.2.2 FACTORS THAT AFFECT AIR TRAVEL GROWTH

Economic growth and falling ticket prices expressed in real terms are the main drivers of air traffic growth. While economic growth is largely determined outside the industry, airfares reflect many factors that are determined mostly by the airline industry environment.

Over the previous five decades, better aerospace technology has allowed airlines to increase their management efficiencies, thereby enabling them to lower their costs. The result is that the passengers were the greatest beneficiaries of these technical improvements, enjoying lower fares for air transportation. In parallel, liberalization of aviation markets, resulting in increased airline competition, has ensured that customers benefit from lower airline costs through lower ticket prices. A decrease in fares has encouraged people of all incomes to travel more, resulting in a significant growth in air travel demand, substantially larger than what economic growth alone

would have created. As a consequence, airlines have adapted their business models. So-called low-cost carriers (LCCs) started operating flights to airports that were underserved by the incumbents, building on their competitive advantage and offering attractive low air fares. Nevertheless, while regional airlines continued to operate short haul routes, mainly as a feeder for the hub and spoke network of a large airline, the legacy carriers reacted to LCCs by lowering their fares and by adopting many of the LCCs' attributes. This shift has subsequently blurred the distinction between the business models of LCC and legacy airlines.

A more liberalized regulatory environment provides a stimulus to the growth of commercial aviation. However, in many instances this puts pressure on the current aviation infrastructure, challenges the states' capabilities for conducting effective regulatory safety oversight, and continuously pressures airlines' operating yields due to heightened competition. In addition, the environmental impact of the industry has become the prime public concern in certain parts of the world. On the other hand, profit margins of commercial airlines have, over the past decade, consistently been too small to adequately compensate the shareholders. Despite continuous optimism to become profitable, most airlines have in fact performed poorly for investors. The average operating margin between 1999 and 2009 ranged from 3.8 percent to 4 percent, which is insufficient to cover overheads and generate a profit—a necessity to attract new capital. Intense price competition under liberalized regimes, sometimes aggressively fueled by LCCs, coupled with increasing and widespread use by consumers of low fares found by internet search engines, have further contributed to the reduced earnings.

On the cost side, the inherent volatility of fuel prices will most likely continue to cause short-term changes in operating costs. In early 2008, the crude oil price was, on average, US\$80 per barrel, before peaking in July 2008 at US\$147 but ending the year at around US\$40. In 2008, fuel accounted for about 30 percent of total airline operating expenses. That year, fuel price hedging led to strong profits for certain carriers, which enabled some to offset operational losses in their core business. However, the spike in oil prices generally resulted in large losses for most carriers.

**TABLE 3 - DEVELOPMENTS IN SELECTED ELEMENTS OF AIRLINE
PRODUCTIVITY (1979-2009) (ICAO 2009)**

	1979	1989	1999	2009
Passenger load factor	66	68	69	76
Aircraft utilization (hours per aircraft per year)	2,068	2,193	2,770	3,502
Average aircraft capacity	149	181	171	166

Increased competition resulting from continued liberalization, along with the impact the economic downturn of 2009, have pushed airlines to maximize utilization of their assets, as shown in Table 3. Higher load factors, resulting from better capacity management, helped airlines to maintain revenues while average ticket prices fell continuously. Higher aircraft utilization was possible thanks to improved aircraft reliability and versatility, and the reduction of the average aircraft capacity starting in 1989 can be attributed to the introduction of regional jets as well as to the extended range of short-haul aircraft. Nevertheless, despite continued poor profitability within the industry, ICAO's traffic forecasts assume that growing demand for air travel will ensure that the airline industry has continued access to capital markets, which is necessary for the renewal of operational assets among airlines.

1.2.3 AIR TRAFFIC FORECASTS

Several organizations and institutes perform air traffic forecasts on a regular basis. Many apply quite complex models with various assumptions. The ICAO forecast methodology uses a sophisticated set of econometric models, combined with industry knowledge at a global and regional level. The forecasts consider both quantitative relationships, such as the impact of economic growth on traffic, and insights about the factors driving growth in each geographical market. The latter, due to their qualitative nature, cannot be factored into the models. In this forecast, the world is divided into nine forecasting regions defining 53 route groups (36 international markets, 8 intra-region market and 9 domestic markets), with an additional non-scheduled segment. ICAO produces forecasts of revenue passenger-

kilometers through to 2030 extended to the 2040 horizon, which is increasingly required for long-term environmental analysis.

The future growth of air traffic will depend on economic development and on the technological advances that will allow further reduction in the cost of air travel. In addition, market liberalization has greatly stimulated air traffic growth in the past and will most likely continue to do so. Nevertheless, during the initial phases of liberalization growth rates are generally at their strongest, after which they stabilize on a standard level when the market has absorbed the changes created by new entrants. According to economic forecasters, annual economic growth between 2010 and 2030, expressed in terms of percent change in Gross Domestic Product (GDP), will range from 2 percent in North Asia to 6.9 percent in China. The developed economies of North America, Japan and Western Europe will experience slow growth because of the economic maturity of their aging labor forces. Developing regions in Asia, Latin America, Eastern Europe, and Africa will most likely see strong and sustained growth. As a result, world GDP is expected to grow on average at 4 percent per year, when expressed in real terms and calculated on the basis of purchasing power parity.

The ICAO forecast for the current top ten markets in terms of passenger-kilometers performed (PKP) is featured in Figure 6. Domestic services in North America will grow at the lowest rate of any of the top ten markets. However, this market's great magnitude, which is the result of a large and prosperous economy and the longest post-liberalization period stimulating growth over decades, will most likely preserve its leadership through 2030. Domestic air services in China will benefit from the very high growth rates resulting from economic development. Finally, the large scale of Western European air traffic and continued growth in Eastern Europe will define the Intra-European market, which will be the third largest in 2030. Based on these forecasts, ICAO is deriving both regional passenger forecasts for its statistical regions (as shown in Figure 7) and aircraft movement forecasts.

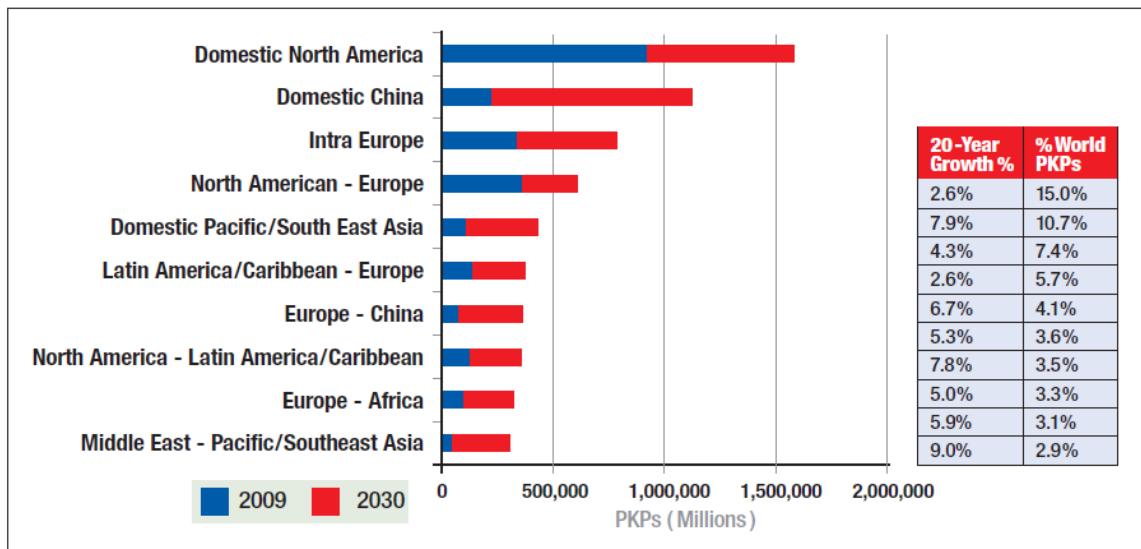


FIGURE 6 - TOP 10 TRAFFIC FLOWS IN 2030 (ICAO 2010)

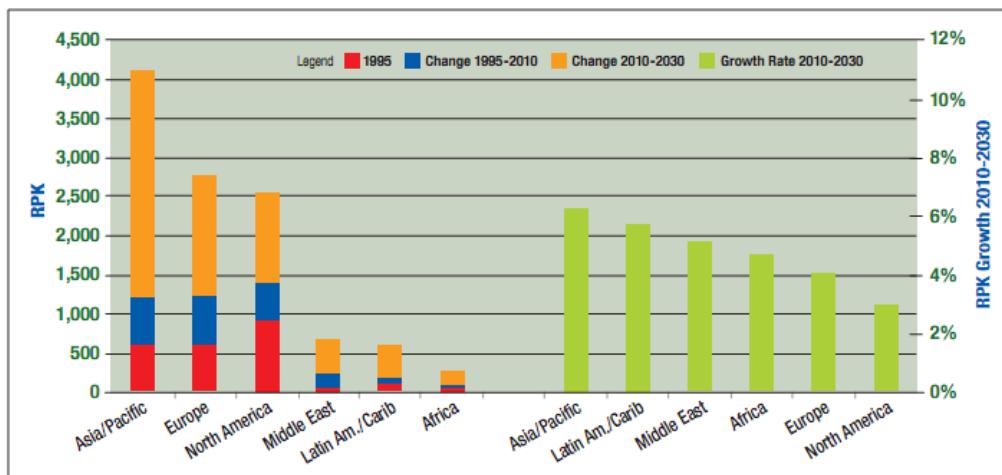


Figure 2: ICAO Passenger Traffic Forecasts by ICAO Statistical Region.

FIGURE 7 - ICAO PASSENGER TRAFFIC FORECAST
BY ICAO STATISTICAL REGION (ICAO 2010)

Air traffic will grow at rates set by, but larger than, GDP growth in all regions of the world. The growth that will be captured by Asian/Pacific airlines will generally reflect the expansion of civil aviation in China, India and Southeast Asia. The airlines domiciled in the Middle East, Latin America and Africa will also experience strong growth, although their current, comparatively small market sizes will result in a limited overall traffic increase.

Similar air traffic forecasts have been made by the airline industry. It is generally agreed that the regained growth of the world economy in 2010 will support the recovery of the airline industry; furthermore, a strong upturn in demand is expected in the Asia-Pacific region and in the Middle East. Boeing's latest market outlook, for example, predicts a 5.3 percent annual growth of world passenger traffic over the next two decades, while Airbus and Embraer predict this figure to be at 4.8 percent and 4.9 percent respectively. One-third of global air traffic currently passes through the Asia-Pacific region, and the growth of this traffic is forecasted at 43 percent by 2029. The demand for new aircraft by air carriers has also increased, but remains somewhat plagued by the uncertainty of fuel prices. This uncertainty, combined with global environmental concerns regarding aviation, will affect activity in the more established markets, such as North America and Europe, which will in turn foster the introduction of more fuel-efficient aircraft. Aircraft manufacturers forecast a demand for new aircraft ranging from 26,900 (Airbus) to 33,500 (Boeing) new planes by 2030, which represents a market of between US\$3.3 trillion (Airbus) and US\$4.06 trillion (Boeing).

Airplanes in service 2010 and 2030			Demand by size 2011 to 2030		
Size	2010	2030	Size	New airplanes	Value (\$B)
Large	770	1,140	Large	820	270
Twin aisle	3,640	8,570	Twin aisle	7,330	1,770
Single aisle	12,100	27,750	Single aisle	23,370	1,950
Regional jets	2,900	2,070	Regional jets	1,980	70
Total	19,410	39,530	Total	33,500	4,060

**Current Market Outlook
2011–2030**



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**FIGURE 8 - BOEING CURRENT MARKET OUTLOOK
2011-2030**

2 AIR TRANSPORT AND THE ENVIRONMENT

2.1 AIR TRANSPORT AND CLIMATE CHANGE

Aviation has always caused environmental concerns. Initially, the focus of concern was on aviation noise and, for decades now, the industry has been working to reduce noise. According to Boeing and Airbus, aircraft are on average 50 percent quieter today than they were 10 years ago. It is estimated that the noise footprint of each new generation of aircraft is at least 15 percent lower than that of replaced aircraft.

In recent years, the impact of aviation greenhouse gas emissions on the environment has been of increasing concern. Aviation produces approximately 2 percent of global Carbon Dioxide (CO₂) emissions, according to the United Nations Intergovernmental Panel on Climate Change (IPCC 2007). Given the strong growth rate that aviation has enjoyed and will continue to enjoy in the future, as was discussed in the previous chapter, these concerns are justified.

Four kinds of gases make up the main emissions from aviation: carbon dioxide (around 70 percent of total emissions), water vapor (around 30 percent), nitrogen oxide and sulfur oxide (less than one percent). In 2006, aviation emitted 810 million tons of CO₂, which represents 12 percent of all transport CO₂ emissions that year. The OECD forecasts that air transport CO₂ emissions will grow to 23 percent of transportation CO₂ emissions by 2050 if no measures are taken (Anming Zhang 2009).

The water vapor trails (contrails) created by aircraft may also have an impact on the environment, but research is inconclusive about whether these have a net warming or cooling effect on the earth. Under some meteorological conditions they can remain in the atmosphere and form cirrus clouds, which may have an effect on climate change. For example, some research suggests these clouds may have different cooling and warming effects, depending on whether flights occur during the day or night. This type of research can identify whether there are any potential

benefits to altering operational behavior. More work is being done in this area and the aviation industry is assisting with research into the effects of contrails on climate change, including putting high-altitude atmospheric testing equipment on some passenger aircraft (Air Transport Action Group).



**FIGURE 9 - CIRRUS CLOUDS AND VAPOR TRAILS
(AIR TRANSPORT ACTION GROUP)³**

Emissions from aircraft change at different flight stages. Roughly 10 percent of aircraft emissions are produced during airport ground level operations and at landing and takeoff, except hydrocarbons and CO. The major emissions from aircraft occur at higher altitudes (Federal Aviation Administration 2005). Research has suggested that aviation's impact on climate change is far greater due to aircraft emissions of other greenhouse gases, such as NO_x, CH₄ and H₂O.⁴

Apart from aircraft, airport access vehicles and ground support vehicles are also sources of aviation-related greenhouse gas emissions. Such vehicles include traffic to and from the airport, ground equipment that services aircraft, and shuttle buses and vans serving passengers. Other emissions sources at the airport include auxiliary power units providing electricity and air conditioning to aircraft parked at airport terminal gates, stationary airport power sources, and construction equipment operating at the airport.

³ The evidence of vapor trails' impact on climate change is inconclusive. The aviation industry is assisting in further research to fully understand their effects.

⁴ This statement is based on research that increasingly indicates that the impact on the climate of NO_x and water vapor is significant, especially in the high altitudes of the stratosphere at 10 km above the earth's surface due to its radioactive forcing, which is considered to have two to four times the effect of CO₂ alone.

The aviation industry is taking measures to mitigate its impact on climate change and the IPCC estimates that aviation's total contribution of greenhouse gas emissions would likely rise to 5 percent (with a worst case scenario of 15 percent) by 2050. This estimation of aviation's impact will also depend on the success of other sectors to mitigate their own emissions.

2.2 RESPONSE FROM THE AIR TRANSPORT SECTOR

Given growing public concern regarding air transport's impact on the environment, regulators around the world are under pressure to regulate the sector. Several multilateral and unilateral measures have been announced or are in preparation. The Kyoto Protocol, which was ratified by over 180 countries, only addresses domestic flights.⁵ The Protocol, however, calls upon the International Civil Aviation Organization (ICAO) to develop mechanisms with its Contracting States aimed at limiting and reducing GHG emissions from international flights. ICAO had already worked on various technological and operational measures to reduce emissions, but it did not pursue the development of a new global legal and market-based mechanism to reduce GHG emissions (International Civil Aviation Organization 2004). Instead, in 2004 ICAO developed a template for voluntary agreements between aviation industries and public organizations, and collected and shared information on voluntary actions to reduce aviation GHG emissions by Contracting States and various stakeholders in 2007. At the 36th session of the ICAO Assembly in September 2007, a report on voluntary emissions trading for aviation was presented by ICAO's Committee on Aviation Environmental Protection; it was adopted by the Assembly only as recommended guidelines.⁶ Nevertheless, the 36th Session of the Assembly requested that the ICAO Council form the Group on

⁵ The Kyoto Protocol is a protocol to the United Nations Framework Convention on Climate Change, an international environmental treaty concluded at the United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil, from June 3–14, 1992. The treaty intends to achieve a "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." See *Protocol to the United Nations Framework on Climate Change*, December 11, 1997, 1869 U.N.T.S. 299 (entered into force February 16, 2005) [Kyoto Protocol]. While national targets for the reduction of GHG emissions cover almost all sectors of economic activity, they exclude emissions from international aviation because of the difficulty in allocating them to specific countries.

⁶ The guidelines urge the adoption of voluntary emissions trading schemes that take the form of a Memorandum of Understanding entered into by government and industry. See *Template and Guidance on Voluntary Measures*. ICAO Air Transport Bureau (ATB). Online: http://www.icao.int/icao/en/env/Caep_Template.pdf. Accessed on March 8, 2011.

International Aviation and Climate Change (GIACC), which would be mandated to develop concrete proposals to the United Nations Framework Convention on Climate Change (UNFCCC). The Assembly also requested that ICAO convene a High-level Meeting at which GIACC would present its recommendations for consideration (ICAO 2009).

The High-level Meeting on International Aviation and Climate Change was held in Montreal, Canada, from October 7 to 9, 2009. GIACC recommended a global goal of 2 percent annual improvement in fuel efficiency of the international civil aviation in-service fleet, which would lead to a cumulative improvement of 13 percent in the short term (2010 to 2012), 26 percent in the medium term (2013 to 2020) and about 60 percent in the long term (2021 to 2050), from a 2005 base level. It also proposed establishing concrete objectives for carbon-neutral growth in the medium term and carbon emissions reduction in the long term, and presented a project to develop a framework for market-based measures in international aviation (International Civil Aviation Organization 2009). However, the meeting did not reach a consensus on the proposed measures, but rather ended with a declaration that went beyond the airline industry's self-proclaimed goal of a 1.5 percent fuel efficiency gain per annum. It set a goal of achieving an annual average fuel efficiency improvement of 2 percent until 2020, with the aspiration to do the same in the long term, from 2021 to 2050. In addition, the declaration announced plans to create a market-based mechanism to lower emissions and a comprehensive reporting system to track emissions, which should be reported to the UNFCCC (International Civil Aviation Organization 2009). Nevertheless, next to fuel efficiency improvements, ICAO further encouraged wider discussions on the development of alternative fuel technologies and the promotion of the use of sustainable alternative fuels, including biofuels, in aviation.

ICAO held its 37th Assembly from September 28 to October 8, 2010. Despite ICAO's strong efforts to develop a common and concrete resolution on measures addressing climate change, the Assembly fell short in reaching this objective. A few influential and vocal Contracting States opposed any concrete measures that were perceived to hamper their economic growth by limiting further rapid development of their respective air transport sectors. The pending inclusion of the aviation sector in Europe's Emissions Trading Scheme (EU-ETS) also moved a step closer to

completion. However, the scheme's effectiveness became weaker due to European concessions at the talks, which also dampened hope of achieving credible global measures to cut aviation's climate impact in the foreseeable future. The final resolution passed by this year's Assembly did not contain strong language on mutual agreement. The Assembly solidified and reiterated the goals initiated at the 36th Assembly in 2007, which includes a global target of improving aviation fuel efficiency by 2 percent each year until 2050, a framework for development and deployment of aviation alternative fuels, and a target to create a carbon dioxide standard for aircraft by 2013.

The first concrete multilateral measures to address aviation as an emitter of GHG were prepared by the European Commission and were issued in November 2008 through Directive 2008/101/EC, which modifies the existing Emission Trading System (ETS) of the EU to include aviation activities. Under this directive, all flights (with some exceptions made for government flights, military flights, etc.) that arrive at or depart from airports within the European Union (EU) will be subject to market-based measures to reduce or compensate for the emissions of GHG. Carriers will be given allowances, which are based on their past levels of emissions. In 2012, the number of allowances will equal 97 percent of historical CO₂-emissions (the average between 2004 and 2006), and in 2013 the number of allowances will be reduced to 95 percent of historical emissions. Further reductions will be decided for each subsequent period. Starting in 2012, 15 percent of total allowances will be auctioned to carriers and three percent will be reserved for entrant airlines, while incumbents will receive 82 percent of permits gratuitously based on historical operations. The percentage of permits auctioned may be increased as part of the general review of this Directive (European Parliament and the Council of the European Union 2008).

Each carrier, whether European or foreign, will be administered by one EU Member State. The exact number of allowances to be given for free to each carrier depends on the carrier's revenue ton-kilometer (RTK) data two years prior. In 2012, for example, carriers will be awarded free permits based on their 2010 RTK data. Each year, the EU publishes a benchmark in units of allowances per ton-kilometer that is used to calculate how many free allowances each carrier will receive that year.

Carriers that exceed their allotted allowances must either purchase allowances from other ETS participants, purchase approved emission-reduction credits, or pay a fine.

Given these realities, IATA announced at its Annual General Meeting in June 2009 the industry's commitment to significantly reducing CO₂ emissions (IATA 2009). IATA, which counts over 230 member airlines, represents 93 percent of scheduled international air traffic and includes all of the world's leading passenger and cargo carriers, declared that it will implement a three-step approach: (i) a 1.5 percent average annual improvement in fuel efficiency from 2010 to 2020; (ii) carbon-neutral growth after 2020; and (iii) a 50 percent absolute reduction in CO₂ emissions by 2050, compared to levels in 2005. The declared pathway to reach these ambitious goals is based on IATA's Four Pillar Strategy (International Air Transport Association 2009):

- **First Pillar: Technology**

Of the four pillars, technology has by far the best prospects for reducing aviation emissions. The industry is making great advances in technology such as: revolutionary new aircraft designs; new composite lightweight materials; radical new engine advances; and the development of sustainable alternative jet fuels that could reduce CO₂ emissions by 80 percent, on a full carbon life-cycle basis. The sector is primarily focusing on biofuels from second generation sources such as algae. These fuels can be produced sustainably to minimize impacts on food crops and fresh water usage. Tests flights have clearly demonstrated that the use of biofuel from these sources as "drop-in" fuels is safe and technically sound. Biofuels can be blended with existing jet fuel in increasing quantities as they become available.

- **Second Pillar: Operations**

Improved operational practices, including reduced auxiliary power unit usage, more efficient flight procedures, and weight reduction measures, could achieve further reductions in CO₂ emissions.

- **Third Pillar: Infrastructure**

Infrastructure improvements present a major opportunity for CO₂ reductions in the near term. Initial estimates by the IPCC indicated 12 percent inefficiency in global air transport infrastructure. Since then, 4 percent efficiencies have

already been achieved. Full implementation of more efficient air traffic management and airport infrastructure could provide substantial emissions reductions through the implementation of measures such as the Single European Sky and the Next Generation Air Traffic Management system in the United States.

- **Fourth Pillar: Economic Measures**

While efforts from the first three pillars will go a long way to achieving the goal of carbon-neutral growth from 2020, the aviation sector will need to turn to the fourth pillar—positive economic measures, such as carbon offset programs—to close the gap.

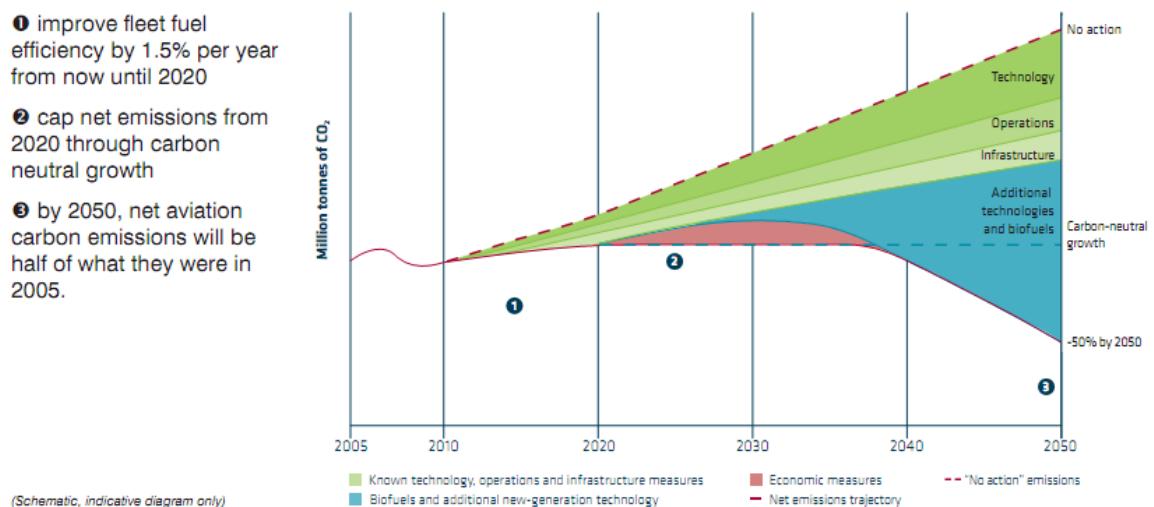


FIGURE 10 - EMISSIONS REDUCTION ROADMAP (ATAG 2010)

IATA's objective to achieve carbon-neutral growth after 2020 depends on several measures. 12,000 new aircraft will need to enter service in this period, at a cost of US\$1.3 trillion to airlines. Furthermore, some infrastructure and air traffic management efficiency improvements are dependent on direct government investments over which the industry has little visibility and control. IATA estimates the reduction of CO₂ emissions by fleet renewal at 600 million tons by 2030, while biofuels would reduce these emissions by 150 million tons. Other measures, such as

operational improvements, more adequate infrastructure, and improved engine and airframe technologies, would contribute a reduction of another 70 million tons (IATA2009).

3 ENERGY EFFICIENCY IN AIR TRANSPORT

3.1 TECHNOLOGICAL EFFICIENCY GAIN POTENTIAL

Improving the fuel efficiency of aircraft has been a priority since the onset of aviation. As shown in Figure 1, aircraft fuel efficiency has improved by over 80 percent since the dawn of the jet age. This improvement has been the result of concentrated R&D investment across the globe in aeronautical technologies. An underlying motivation for this investment has been the simple fact that the useful payload of an airplane represents only a small fraction of its initial weight. Therefore, relatively small improvements in airframe weight, drag, or engine efficiency can deliver large improvements in economic value, such as increased payload or range. Indeed, a rule of thumb is that each new airplane model should be 10 to 15 percent more economical to operate than its predecessor—an observation that illuminates the enormous reduction in airfares over the past five decades. There is a consensus that this rate of improvement can continue for the next few decades, assuming R&D investment continues as it has.

Quantifying the details as to how future technologies will improve aircraft efficiency is a complicated task because a modern aircraft is a tightly integrated system consisting not just of wings and a fuselage but many complex subsystems, such as engines, electrics, hydraulics, avionic, and environmental control. Each of these, in turn, consists of many separate technologies and components. The true value that a particular new technology may bring is dependent not just on the individual merits of that technology, but on how well that new technology integrates into a particular aircraft. Nevertheless the following sections give brief overviews of some emerging technologies. These are grouped into categories that contribute to improving weight, aerodynamic drag, subsystems, and engines.

3.1.1 AIRCRAFT DESIGN

The aircraft is designed for airline operations in an environment that depends upon the available infrastructure and its anticipated evolutions (Air Traffic Management "ATM," airport capabilities, etc.). The proper aircraft integration into this evolving environment is essential. The infrastructure and airspace operation must therefore be developed in close coordination between aircraft manufacturers, air traffic management system designers and airports, in order to enable the aircraft to be operated in the most efficient way throughout its life.

Technological improvements are possible on the airframe, on the engines, and on the systems. The integration of the different technological elements into the aircraft is key and needs to be taken into account as soon as possible during the aircraft design process. It is essential to mention, however, that the different improvements to the aircraft generate a global benefit that, given the interactions between them all, will generally not be as high as the sum of the individual benefits of each technology. Major technological breakthroughs have been made by aircraft manufacturers to deliver environmental benefits, with the progressive integration of new materials and systems, allowing significant weight reduction and aerodynamic improvements.

Reducing Aircraft Weight

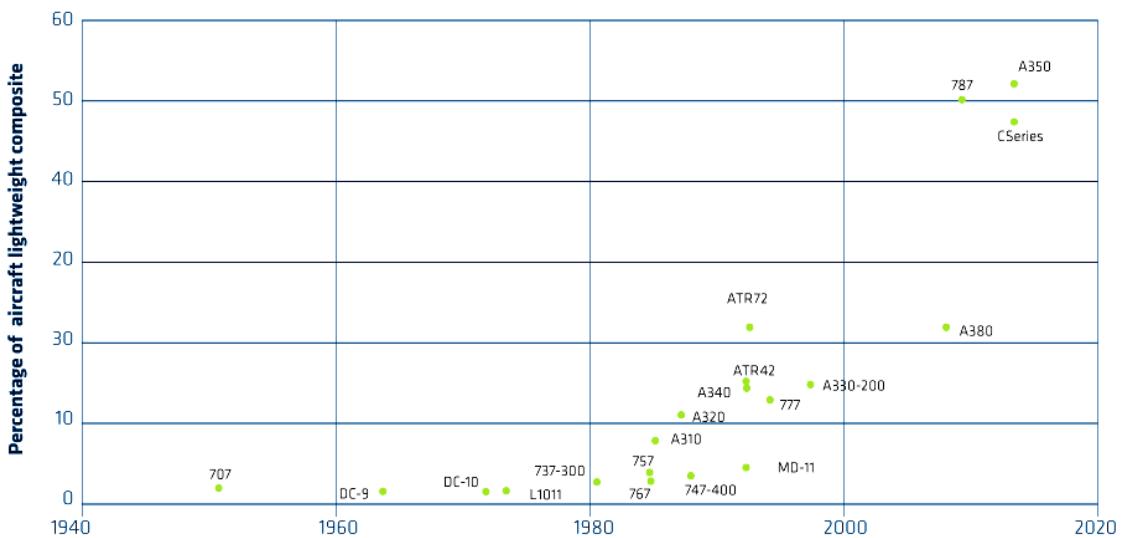
Utilizing lightweight materials and weight reduction of non-essential components leads to substantial decreases in fuel use. The weight of the airframe is about 50 percent of an aircraft's total weight. The use of advanced lighter and stronger materials in the structural components of airframe, such as aluminum alloy, titanium alloy, and composite materials, can decrease airframe weight, thus reducing fuel burn and associated CO₂ emissions.

Also, new manufacturing techniques such as laser or friction welding are being introduced to reduce the number of rivets and local reinforcements necessary, hence reducing the weight of the aircraft. Weight reduction efforts include several measures:

Lighter components: Other parts of the aircraft are also reducing weight. Lighter carbon brakes are now available as alternatives to steel brakes; they provide a weight savings of at least 250 kg per aircraft.⁷ There are also new, lighter and more efficient technologies available to power and control the braking system. The electric braking systems, which are lighter and easier to monitor than hydraulic or pneumatic systems, are now entering the market.⁸ Mastering the huge forces involved in slowing down a large aircraft as it lands can provide other benefits to the overall aviation system, such as an automated “brake-to-vacate” system, which combines satellite positioning with the on-board airport database and flight-control management system. The pilot selects a runway exit point and the system manages the braking process to ensure that the aircraft reaches the chosen exit point at the optimal speed, having factored in runway and weather conditions. This ensures that exactly the right force is applied to the brakes, thereby increasing their operational life as well as minimizing runway occupancy time and allows up to 15 percent more departures to be scheduled.

New materials and structural weight saving: The last few decades have seen a steady rise in the amount of ‘composite’ materials used in the airframe of aircraft. These have added strength but lowered the overall weight of the aircraft. The use of

FIGURE 11 - PERCENTAGE OF AIRCRAFT LIGHTWEIGHT COMPOSITE (ATAG 2010)



⁷ Goodrich. <http://ir.goodrich.com/phoenix.zhtml?c=60759&p=irol-newsArticle&highlight=&ID=1402116>

⁸ Bombardier. <http://www.bombardier.com/en/corporate/media-centre/press-releases/details?docID=0901260d8005a7da>

composites in one new aircraft has generated a weight savings of 20 percent over traditional aluminum alloys (Boeing). A composite material typically consists of relatively strong, stiff fibers in a tough resin matrix. The fibers are set into resin to form sheets, which are laid on top of each other, bonded, then heated in a large oven or “autoclave.” The main materials used in aerospace composite structures are carbon- and glass-fiber-reinforced plastic. They have several advantages over traditional aluminum alloys. As carbon composites are, in general, only 60 percent of the density of aluminum, they provide a much better strength-to-weight ratio than metals, sometimes by as much as 20 percent. They can also be formed into more complex shapes than their metallic counterparts, reducing the number of fuselage parts and the need for fasteners and joints.

Optimizing Subsystems: Aircraft have complex arrangements of systems with networks of electrical wires, pneumatic cables and air conditioning, among others. While the demands on these systems grow with every new aircraft type—for example, the recent addition of personal seat-back televisions has added hundreds of meters of wiring to an aircraft—there is a growing and contradictory requirement to reduce the weight of these systems while increasing their performance and reliability levels. However, new information technology advances are allowing reduced wiring for in-flight entertainment and even wireless systems are in development. In older aircraft, the control surfaces such as the flaps and slats on the wings and the rudder and ailerons used to be controlled mechanically from the cockpit through cables or heavy, hydraulically-powered systems. Since the 1980s, these have been replaced with lighter and more powerful electrical systems that are electronically-controlled “fly-by-wire” management systems. Other improvements in the design and weight of the individual motors that control all of those surfaces have further reduced the weight of the systems on board an aircraft.

Reducing Aerodynamic Drag

An aircraft’s aerodynamic drag in flight has to be overcome by engine thrust. The lower the aerodynamic drag, the lower the thrust required to overcome it, leading to lower fuel burn and CO₂ emissions. Thanks to increased simulation and calculation capacities, knowledge and understanding of aerodynamic behavior has significantly improved over the last few decades, allowing more effective aerodynamic

optimization. This has resulted in what may appear to be only subtle refinements in shape, but the sum of these refinements deliver considerable drag reduction. Perhaps the most obvious change has been the evolution in wing tip shape, from simple tips through the 1970s to small winglets in the 1980s and to large winglets or sharklets today. On aircraft such as those belonging to the A320 family, sharklets can reduce fuel burn by over 3 percent.

In addition to the above refinements, several technologies now in the research phase may further reduce aerodynamic drag. Various laminar flow approaches are being assessed to establish their robustness in service and impact on maintenance. The principle new technologies are:

Film surface grooves: feature an adhesive-backed film with micro-grooves placed on the outer surfaces of the wings and the fuselage of the aircraft. Such grooves are estimated to reduce total aerodynamic drag and thus fuel burn by up to 1.6 percent. Significant concerns, however, exist as to durability over time, due to contamination in operation from dust, insects and other small particles; and

Natural & Hybrid laminar flow technology: hybrid laminar flow technology (replacing turbulent air flow) integrates several approaches to maintain laminar flow. This technology may have greater potential than surface grooves but at the cost of increased complexity.

Although both the surface grooves (riblets) and the laminar flow technology (hybrid or natural) target increased laminarity, the latter has a significantly higher drag reduction potential.

Improving Engine Performance

The area that has contributed most to improving aircraft fuel consumption over the past decades is engine technology, as evidenced in Figure 1. In addition to reducing fuel burn, the technology advances in propulsion have improved engine reliability by more than a factor of 100, while increasing the mean time between overhaul by a factor 5 or more. Each new generation of engine has delivered a step improvement in efficiency of 5 to 15 percent. This fuel burn gain has been accompanied by significant reductions in noise and emissions as well. In addition to contributing to the improvement of local air quality, reducing fuel burn reduces climatic impact

since each kilogram of fuel burned generates over three kilograms of CO₂.

Engine enhancements have improved both the efficiency at which fuel energy is turned into power (so-called thermodynamic efficiency) and the efficiency with which the engine power propels the airplane (propulsive efficiency). In brief, the former requires increased compression ratios, improved aerodynamics, and better cooling. The latter needs larger fans or propellers. Both are highly dependent on lighter weight and higher temperature materials to realize practical designs. In all cases, a fuel consumption benefit is traded with engine weight and life in order to optimize for specific applications. Tightly integrated design is the key to a successful engine. Close integration of the engine with the airframe is needed as well to ensure that engine gains translate in to aircraft level benefits. The gains in engine performance over the decades reflect very large technology investments made by nations and manufacturers. If this level of investment continues as currently planned, then engine performance should continue to increase over the next few decades.

The last few years have been exciting for the engine community because of the promise of new engine architectures that combine technologies in new ways in order to generate value. Some examples of new engine architectures currently under development are:

Advanced Turbofan (ATF): Recent advances in long-range, high bypass ratio engines (high OPR and bypass >10) are now being applied to next generation propulsion for smaller thrust-class engines planned for entry into service in 2015 - 2018 within the A320 NEO family and the COMAC 919. Enabling technologies include advanced aerodynamics, new hot-section materials suites, expanded composites usage, highly optimized turbines, advanced combustor concepts, and improved integration. One innovative variant under study is the contra-rotating turbofan. This approach uses a contra-rotating two-stage fan to reduce both noise and fuel consumption at a given fan diameter.

Ultra-High Bypass Ratio (UHB) Ducted Propulsor: The ultra-high BPR ducted propulsor is enabled by Geared Turbofan (GTF) technology. The ultra-high BPR ducted propulsor engines use fan drive gear systems, low weight fans, and advanced nacelles technology to enable higher propulsive efficiencies and lower fuel burn

than traditional direct drive turbofans. Fan pressure ratios for UHB ducted propulsor engines are in the range of 1.2 to 1.5, significantly lower than for direct-drive fan architectures, with improved propulsive efficiency and lower noise. Bypass ratios for UHB ducted propulsor engines are in the range of 12 now, growing to between 15 and 20 in the future. The first engines to enter service will deliver about a 15 percent reduction in fuel burn compared to current engines with significantly lower noise levels as well. Entry into service for the Pratt & Whitney GTF™ is planned on the Bombardier CSeries in 2013, the MRJ in 2014, and A320 NEO family and Irkut MS-21 in 2015.

Open Rotor: Open rotor engines, also known as high speed turboprops, have a very high bypass ratio and propulsive efficiency, which are enabled by removing the outer nacelle to permit much larger propulsor diameters to reduce fuel burn. The large diameter rotors come with aircraft configuration challenges and at some cost in flight speed capability and noise. These engines may have single or dual contra-rotating props depending upon the aircraft configuration. Best estimates are that these will not be ready for entry into service before 2025. The optimal flight speeds for such aircraft are not yet well established but lie between current turboprops (Mach 0.55-0.65) and current turbofans (Mach 0.78-0.85).

Conclusion on Aircraft Design Technologies

The goal to drive down the cost of air travel while reducing environmental impact can only be met by advancing technology. This technology is aimed at reducing fuel burn, CO₂ emissions, other harmful emissions, and noise. Increasing attention is also being placed on other life cycle environmental impacts, such as manufacture and disposal. The technologies mentioned here are only a few examples of concepts being explored. There is no “one technology solution fits all.” The best design depends strongly on the aircraft mission and the market niche at which it is aimed. The quantitative value of new technologies can only be accurately judged during the complex process of aircraft design optimization.

For over 100 years, innovation has been at the root of the aviation business, and it still is. In this industry, “business as usual” simply means that market forces push aviation to the limits of what new technologies can provide. Aviation has always selected the schemes that appear to bring the most value to its customers. The

aviation business model, characterized by its huge upfront investments, small quantities, and long operating life, requires new aircraft to be in the production phase for many years. To succeed, new aircraft must utilize the best technologies available at the time of development or risk rapid obsolescence. A market failure is a multibillion dollar mistake. This is a business that rewards thoughtful innovation.

Examples of aircraft design improvement of selected manufactures are listed in Annex 1.

3.1.2 OPERATIONAL EFFICIENCY

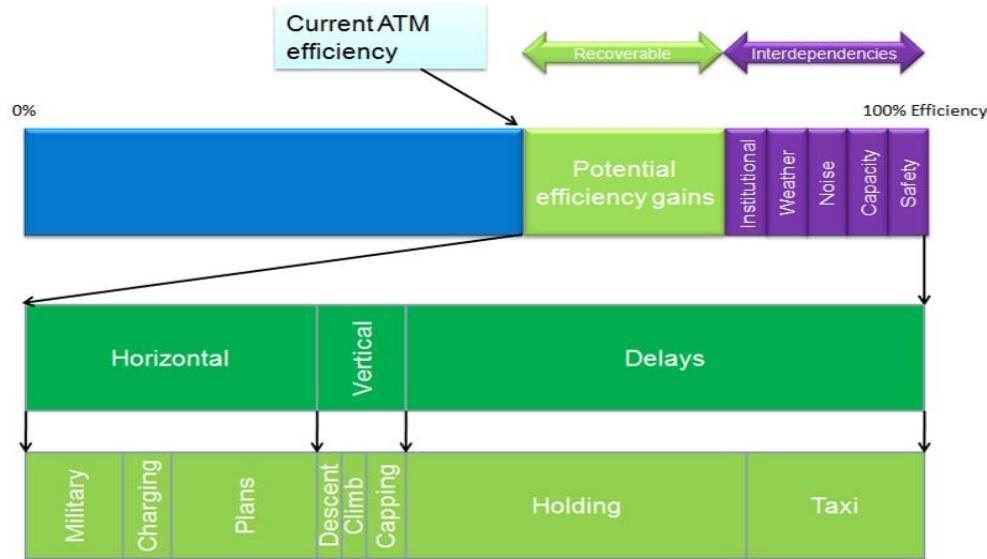
Aircraft are not the only parts of the air transport system contributing to greenhouse gas emissions. The operations of ground service vehicles, terminal buildings and construction of runways all produce emissions.

In the Air

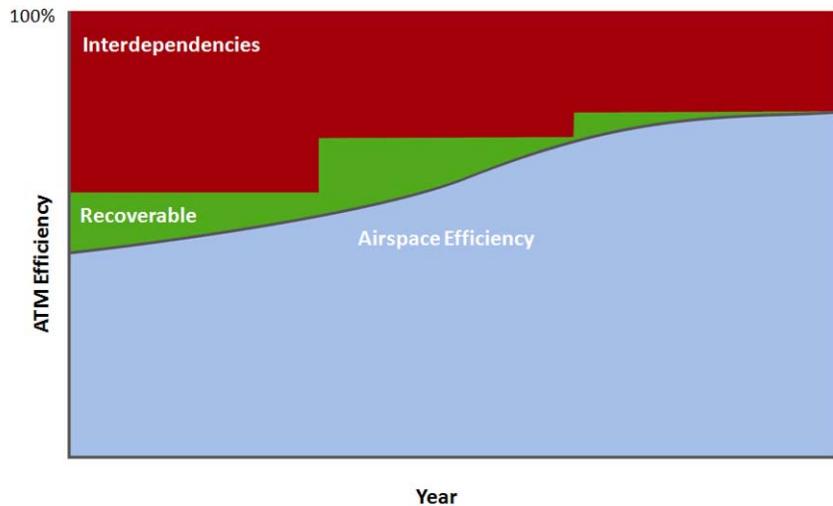
It is estimated that up to 8 percent of all aviation fuel is wasted as a result of the inefficient routes aircraft are forced to fly. Air traffic management (ATM) improvements provide the greatest short-term opportunities to improve the environmental and fuel-efficient performance of the air transportation system. However, ATM efficiency will decrease significantly with increased congestion brought about by forecast traffic growth unless there is a corresponding increase in airport and airspace capacity. Short-term ATM improvements in efficiency for 2012 are expected to be offset by the growth in congestion caused by the projected increase in aircraft movements. If the industry was to continue with the existing operational environment then the current level of global ATM efficiency will decrease as additional traffic increases congestion. A 100-percent efficient ATM system would enable aircraft to fly point to point using the fuel-optimum route between airports at all times. Inefficiencies are introduced into the system when less than optimal routes are flown; there are a number of reasons why this may be the case. Some of the inefficiency may be recovered by changing practices, but some will remain to enable the ATM system to cope with a number of interdependencies, such as:

- *Safety* - aircraft will deviate from the optimum route in order to ensure adequate separation between them and other nearby aircraft.

- *Weather* - to ensure safe and smooth flights, adverse weather systems may need to be avoided.
- *Capacity* - to accommodate capacity limitations either at the airport or within airspace, aircraft may be required to hold prior to arrival, or wait on the ground prior to departure. ATM has influence over the optimization of available civil airspace capacity, whereas it has no control over airport capacity but is able to influence how it is accommodated. When traffic demand approaches available capacity, congestion increases, reducing efficiency as discussed above.
- *Noise* - to reduce noise impact on the ground, aircraft operations around the airfield are subject to noise abatement procedures that may reduce noise but may cause the aircraft to fly a less efficient route or accept sub-optimal altitudes.
- *Airline Practices* – flight planning systems need to have the flexibility to benefit from more optimal routes that may be available.
- *Military* - civil aircraft generally must route around military airspace zones and other types of restricted airspace, increasing fuel burn. Air navigation service providers (ANSP) can actively seek cooperation from the military to implement and optimize the Flexible Use of Airspace.
- *Institutional* - aircraft may take less than optimal routes due to fragmented airspace. Different regions/countries may have different operating procedures, charging mechanisms and require specific hand-over protocols that may lead to less than optimum fuel-efficient routing. These may be resolved by political will.

**FIGURE 12 - ATM EFFICIENCY CATEGORIZATION**

As a result of these interdependencies, illustrated conceptually in Figure 12, it is not possible to reach 100 percent efficiency. Efficiency gains may be achieved by improving routings and ATM practices, but also by reducing the effect of interdependencies illustrated in Figure 13.

**FIGURE 13 - INTERDEPENDENCIES AND RECOVERABLE EFFICIENCY**

Some of the interdependencies can be directly influenced by ANSP, such as new operating procedures. However, many rely on other participants in the aviation system, such as airports, airlines, regulators and governments to reduce fragmentation of the airspace, for example.

Changing the interdependencies may deliver a step change in the recoverable efficiency as illustrated in Figure 13. One such example is Reduced Vertical Separation Minima (RVSM). Prior to 2002, aircraft flew in altitude bands separated by 2000-feet intervals in high altitude. Because aircraft have an optimal cruise altitude that minimizes fuel burn, the 2000 feet altitude bands meant that it was not always possible to fly the optimum route. RVSM reduces the altitude bands to 1000 feet without compromising safety (thanks to a more modern aircraft fleet and improved navigational aids) and allows aircraft to fly closer to their optimal altitudes. RVSM alone has been estimated to have improved global fuel efficiency by 1.8 percent. In addition, it has increased airspace capacity and thus reduces congestion, delivering a further efficiency benefit. RVSM is an example in which both the safety and capacity interdependency effects were addressed, thus increasing the pool of recoverable efficiency. While techniques such as RVSM reduce this interdependency, it cannot be reduced to zero.

Another example is noise restrictions. Aircraft operating around airports are generally subject to specified routings designed to limit noise exposure on the ground, which may require aircraft to fly longer than optimum routes, thus reducing efficiency. Quieter aircraft reduce the noise interdependency, which could free up efficiency that could be recovered by flying more direct routes. A consequence of this will be an increase in noise exposure. This is a clear tradeoff between reducing noise impact and reducing climate change impact. Continued analysis performed by ANSPs is needed to better quantify the recoverable inefficiencies related to the complex interactions between fuel efficiency and safety, weather, capacity and noise and others.

Flight control procedures—another important measure—help to minimize delays at airports, getting passengers to their gates faster and reducing airplane emissions by millions of pounds. Updating the world's aging air traffic control systems, which are based on 1950s-era technology, would reduce the carbon footprint of commercial travel by 12 percent, according to studies by the International Air Transport Association (IATA). Cutting the length of the average commercial flight by one minute would eliminate 4.8 million tons of CO₂ emissions annually.

One advanced procedure developed by Boeing, known as Tailored Arrivals, allows flight controllers, supported by ground automation, to tailor flight paths. This reduces fuel consumption and emissions. This procedure uses integrated data link technologies, as well as automation already installed on the airplane, to produce low-power, continuous descent approaches to runways. More efficient landings mean airplanes will spend less time circling airports in holding patterns during congested periods. Boeing researchers have demonstrated this new technique at major international airports in Amsterdam, Los Angeles, Melbourne, Miami, San Francisco and Sydney. At San Francisco International Airport, four airlines participated in these tests. Combined, the four carriers reduced fuel consumption by 1.1 million pounds (495,000 kilograms) and lowered CO₂ emissions by nearly 3.6 million pounds (nearly 1.6 million kilograms) over a one-year period. Similar results were generated at all airports involved in this research.

On the Ground

Over 95 percent of fuel is consumed by an aircraft when it is in the air, but the remainder is used as the aircraft is taxiing from the gate to the runway, from the runway to the gate, or while parked at an airport. While this is a comparatively small proportion of overall aviation emissions, there is a lot of work underway to reduce fuel use on the ground. Airlines have for some years been trialing single-engine taxiing. This is when the airplane is taxiing to or from the runway using only one of its engines to move the aircraft forward. By using this technique, a typical carrier can save at least 15 million liters of fuel per year. One carrier calculated in fact that one minute of single-engine taxiing per aircraft movement saves the company 430,000 liters of fuel annually.

There are other, more efficient methods of moving aircraft at an airport. Increasing numbers of aircraft tugs are being developed, which can be hooked to the nose wheel of the aircraft and used to tow the aircraft between runway and terminal. Trials are currently taking place with such semi-automated systems allowing the pilot to access and control robot tugs. However, developing this method into a global solution is complex, as airport operations differ widely in size and scope. Aircraft manufacturers are even looking at small electrical motors to drive the nose wheels forward, allowing aircraft to taxi using these devices and to switch on their engines

once they reach the runway at the busiest airports where a long wait for departure is common.

Another area at the airport where substantial fuel economies can be made is in cutting the use of aircraft auxiliary power units (APU), which power the aircraft's electrical systems on the ground when the aircraft's engines are turned off. A large number of airports are now installing fixed electrical ground power units; these plug the aircraft directly into the mains power so the aircraft does not use fuel while sitting at the airport gate. Every airport is different, and power can be provided by either ground-based generators or via a frequency converter plugged directly into the mains power supply of the airport. Studies suggest that up to 85 percent of APU use can be reduced if ground-based electrical power systems are available, cutting the fuel bill per gate by over US\$100,000 a year. Decreasing the amount of time the APU is in service also cuts APU maintenance costs. At one mid-sized airport alone, installing these units on 50 gates has resulted in 33,000 tons of CO₂ reduction annually.

3.1.3 INFRASTRUCTURE EFFICIENCY

Many airport operators are becoming carbon accredited in order to ensure that the wide ranges of on-site operations are running as efficiently as possible. Airports can be viewed as mini-cities, so collaboration is vital, whether it is through waste recycling programs within the terminal building or corporate emissions reduction initiatives undertaken between the airport and the airlines, caterers and ground handlers.

Airports around the world are leading the way in providing energy-efficient infrastructure projects. Terminal buildings are being constructed with sophisticated lighting, heating and cooling control systems to regulate the environment according to the number of passengers expected to use the facility at each hour of the day. Innovative cooling and heating systems are using geothermal, wind turbine, solar or biofuel energy sources. The extensive use of glass provides natural light. Ground service vehicles are increasingly being run on low-carbon fuels or electricity.

Aircraft at Airports

The operation of aircraft at airports represents the largest energy consumer at many airports. This section addresses the airport-related issues that must be considered to optimize the energy use of aircraft at airports during the landing and take-off (LTO) cycle including taxiing, queuing and the time spent at terminal gates and remote stands.

Planning and Design

1. Airport Siting

The initial siting (the choice of location) of an airport can have important effects on the efficiency of aircraft LTO. The proximity of physical features such as mountains, prevailing weather conditions, noise-sensitive residential areas and bodies of water can affect operations. Flight paths might need to be elongated or diverted to avoid noise-sensitive areas and extra distance travelled may mean increased fuel burn. However, the concerns of local communities regarding aircraft noise have to be taken into account. If the land use in areas adjacent to the extended runway centerlines does not include residential, school and other noise-sensitive activities, this will benefit the implementation of the most flexible and efficient aircraft LTO practices.

2. Airport Layout

The layout of an airport, including the location of the runways and taxiways relative to terminal buildings, clearly has an effect on taxiing distances and the consequent fuel burn. As will be seen in Section 3.3.2, the new Pier E at Zurich airport was located between the two main runways to minimize taxiing times in all wind conditions.

The design and construction of taxiways should also take into account the need to provide the most direct routes between runways and terminal gate locations. Reduction of delays and decreased taxiing time can provide significant GHG emissions reduction. For example, assuming sea level and ISA conditions,⁹ the

⁹ The International Standard Atmosphere (ISA) is an atmospheric model of how the pressure, temperature, density, and viscosity of the Earth's atmosphere change over a wide range of altitudes. At sea level the standard gives a pressure of 1013.25 hPa (1 atm) and a temperature of 15 °C, and an initial lapse rate of 6.5 °C/km (-2 °C/1,000 ft).

following fuel savings from taxiing and queuing (idling) are possible:

- A320 with CFM engines - about 12kg/min per aircraft at idle (taxi)
- A320 with V2500 engines - about 15kg/min per aircraft at idle
- A330 with RR Trent 772 engines - about 34kg/min per aircraft at idle

INFRASTRUCTURE

Another important use of aircraft fuel at airports is the on-board Auxiliary Power Unit (APU) which provides an aircraft with electricity for its equipment and ventilation system during taxiing or when the engines are switched off. An external source of electricity and ventilation will allow the pilot to switch off the APU when parked at a terminal gate or remote stand. This not only reduces this fuel burn but also improves the local air quality and noise in the apron area.

Fixed Electrical Ground Power (FEGP) equipment at the terminal gate converts mains power to 400 Hz required for aircraft systems. Pre-Conditioned Air (PCA) units provide heated or cooled ventilation air via flexible ducts that attach to the aircraft. Both FEGP and PCA can be installed during terminal construction or retrofitted to existing terminal gates and air bridges. The use of FEGP and PCA will invariably be more efficient than an aircraft APU in terms of total energy or fuel used and total gaseous emissions, especially in regions with low-emissions electricity generation. The Zurich case study includes images of such facilities. For remote stands, portable Ground Power Units (GPU) and PCA equipment, usually using diesel fuel, can be used to replace aircraft APU usage. The total fuel efficiency benefit will be less than for equipment using mainly electricity.

In some jurisdictions, airport operators find it necessary to encourage or even enforce the use of FEGP and PCA, and this can be achieved by operational restrictions on APU usage.

Airfield Design

The plan and design of infrastructure investments should allow for traffic growth and meet demand that is phased in staged developments to satisfy requirements. It is a cornerstone of SNC-Lavalin's philosophy that strategic and flexible master planning and design and construction techniques are critical to ensure that facilities have the capability to be responsive to traffic and regulatory demands, but must also

be developed in a way as to not be wasteful with resources for both the airport and terminal design.¹⁰ Maximum build-out potential of a site needs to be evaluated to ensure that it is planned in a way that reduced or eliminated the need to alter or remove infrastructure once established.

There are several strategies for airport civil works that can help obtain a more energy-efficient approach to design and construction. Tactics for soil conservation, soil management, ground water handling, pervious pavements and striving for minimal disturbance to indigenous landscape, thereby reducing disruption and the need for heavy equipment operations, are all factors that contribute to efficiency in design, construction, and operations. Advances in system and material selection and construction techniques can also be implemented to increase the energy efficiency during operations and construction.

AIRFIELD LIGHTING

There have been technological changes and product developments that provide significant energy savings in the airfield. Advanced technology and product/system selection, in conjunction with operational procedures and good practices, can amount to substantial increases in airfield electrical efficiency.

Advancements in light-emitting diode (LED) technology can substantially improve energy efficiency by reducing airfield lighting wattage by up to 90 percent. Specifications for high-pressure sodium where possible rather than metal halide also provide increased efficiency while reducing the amount of mercury in the lamp. Solar-powered airfield lighting and signage systems are being employed in several airports and the industry is developing new systems to allow for future alternative energy sources.

In addition to product selection, many best practices are simple to deploy and provide a reduction in energy consumption. Such simple strategies include airside lighting controls that reduce or shut off lighting when not required, controlled

¹⁰ Founded in 1911, SNC-Lavalin is Canada's largest engineering and Construction Company and an active participant in engineering projects for communities around the world. SNC-Lavalin's Airport Group provides planning, project management, engineering, construction, operation and investment expertise to international and local airports. The group has been active in airports for over 40 years and is committed to sustainable initiatives in all aspects key to the successful design, expansion and operation of airport infrastructure projects.

lighting solutions that include motion detectors, and the design of proper duct banks to allow for future flexibility of the system with minimal network disruption.

Pavement materials

Advancements in pavement materials and an understanding of the implications of large-scale civil works and new processes will help to reduce energy requirements and, consequently, associated emissions. The use of warm-mix asphalt techniques and recycled content in paving have demonstrated significant efficiency benefits by reducing fuel consumption required for asphalt. Field tests in Ohio showed (depending on the technique used) reduced fuel use of up to 17 percent and reductions in total particulate matter emissions of up to 77 percent. Additionally, reductions in nitrogen oxides were registered at up to 21 percent, in carbon monoxide at up to 63 percent, and in volatile organic compounds at up to 62 percent (Hurley et al 2009). This, of course, must be evaluated in terms of longevity and strength, as well as situational appropriateness, but it indicates a positive direction and may be relevant for many applications.

Additionally, for concrete applications, it is possible to reduce the total Portland cement content (the most common type of cement in general use around the world), where allowed, for all types of pavement on site. Cement production is one of the most energy-intensive industrial processes, and the industry currently relies heavily on coal. Fly ash, a recycled byproduct from coal combustion, can reduce the cement requirements. It is estimated that every ton of fly ash used is equivalent to a fuel reduction of one barrel of oil, or one ton of CO₂ (The Greenest Building). These measures should be incorporated wherever applicable to develop the most energy-efficient design and construction methodology, taking into account the embodied energy in materials, their source and the energy required to build with them.

Terminal Buildings

It is essential that the industry move towards adopting sustainable measures in all aspects of airport design and operation. Achieving sustainability should be at the forefront of the decision-making process when designing airport facilities. A full life-cycle cost analysis (LCA) will usually indicate that it is less expensive to invest in energy-savings equipment or features than to waste energy over the facility's lifetime. Rather than view sustainable development as a burden, in its design

approach SNC-Lavalin considers it as an opportunity for technological advancement, productivity gains, and energy security. The increase in projects that embrace this philosophy will have a direct correlation to the lowering costs associated with these technologies and design strategies.

There are a number of targets that are paramount in developing a sustainable airport approach that both meets energy efficiency standards and reduces greenhouse gas emissions while at the same time creating a socially, fiscally, and environmentally responsible airport. The following are some key objectives in achieving these goals as they relate specifically to energy efficiency:

- relationship to the environment
- integrated selection of products, systems and processes
- informed decision making
- energy management
- water management
- works waste management

There are many specific passive techniques that are simply good and wise design practices that not only reduce reliance on energy but also create higher quality spaces and better solutions for airports. Going green through energy efficiency and fewer carbon emissions will not hurt competitiveness. Each specific geographic location has different requirements and climatic conditions that have to be addressed. While the solutions will vary for individual airports, the following strategies can help to develop a site-specific solution that is situational, more responsive, and will ultimately require fewer resources and less energy consumption.

Climatic adaptation: wind, rainfall, sun and air quality

Passive techniques to capitalize on specific site considerations and reduce reliance on mechanical systems include:

- Protection from both the rain and sun: covered plazas, buildings oriented to capitalize on trees and vegetation acting as windbreaks, over-insulated roofs and large roof overhangs for solar shading on exposed facades;
- Natural ventilation promotion: openings on the façades, ventilation and light shafts to generate thermal drafts and protection from fuel fumes in the

interior of the terminal building, and reduced mechanical system requirements;

- Building orientation and façade design to reduce solar gain and cooling requirements such as double-glazing on sun-shielded façades, limited window openings on sun-facing façades, roof light shafts, solar radiation managed by operable shading panels; and
- Concrete floors for thermal mass inertia and intermediate concrete or wood floors.

Consistency with the region's sustainable development agenda while limiting constraints on the community by using the site's resources; measures include:

- Capitalize on solar radiation and optimize natural lighting, reducing needs in electrical power;
- Reclaim and store rainwater for irrigation, landscaping and cleaning and return this to the ground by seepage; and
- Treat wastewater in a self-contained drainage system (on-site wastewater treatment plant).

Conservation of the site's natural features where possible

Key measures are:

- Incorporate and maintain existing indigenous vegetation when possible;
- Ensure that wetlands with aquatic plants recollect water and release back into its natural catchment area;
- Balance excavation and back-filling earthworks over planning horizon, reducing the need to transport soil or earth to or from site; and
- Maintain biomass of the site.

INTEGRATED SELECTION OF PRODUCTS, SYSTEMS AND PROCESSES

Achieving a flexible building through design and technical networks increases the useful life span of the built space. "The greenest building is the one that is already built" (The Greenest Building), and by increasing capacity and designing adaptable space, there can be a reduced need to build new spaces. The following strategies allow for the ever-evolving needs of an airport, so that the building can be responsive and maintain efficiency:

- The building's service life depends on its flexibility to adapt to various needs and the inherent durability of its building materials. Interiors should feature light convertible partitioning and only distribution core kernels (stairs, elevators shafts) should be concrete (for building stability).
- Technical networks should be independent from dividing walls and ceilings for easy future expansions and modifications.
- Ideally, new technologies for increased capacity and throughput, such as CUSS (Common Use Self Service) facilities, should be accommodated.

MITIGATE ENVIRONMENTAL IMPACTS THROUGH INFORMED DECISION MAKING

A broad vision towards sustainability must be maintained in all the decision-making processes. Informed decisions and awareness of material properties allow sound environmental choices. Materials have embodied energy associated with their production and transportation; selection criteria should also include material quality, durability, cost, and ease to work with. The following evaluations and criteria help to quantify the impacts of choices and systems used in the design:

- Consider fabrication emissions when selecting products and materials. Table 4 illustrates CO₂ emissions associated with the production of various materials;
- Limit the amount of consumed resources, environmental pollutants, air and water pollution, and waste;
- Give preference to local materials in an effort to limit transportation and adopt policies that favor local industries while promoting a sense of place;
- Consider thermal and acoustic properties, durability, energy consumption, ease of implementation, ease of servicing, durability, and the use of fully or partially recycled materials; and
- Use products with low-pollutant emissions and containing fewer hazardous materials:
 - urea-formaldehyde compounds are avoided and formaldehyde emissions grading are taken into account;
 - chemical treatments are avoided (chrome and arsenic);
 - heavy metals or ethylene-glycol derivatives are avoided;
 - alternatives for noxious graded materials are identified; and

- low-VOC (Volatile Organic Compounds) materials are used for improved indoor air quality.

TABLE 4 - CO₂ EMISSIONS ASSOCIATED WITH PRODUCTION OF DIFFERENT MATERIALS (ADEME 2003)

Material	kg CO ₂ equivalent per ton of Material Produced (European values)
Steel	300 to 850 depending on percent scrap steel
Aluminum	600 to 3000 depending on percent scrap aluminum
Flat glass (window glass)	400
Bottle glass	120
Plastics (polyethylene, polystyrene, PET)	500 to 1600
Paper and card	300 to 500
Cement	250

Energy Conservation and Source

Efficiency and renewable energy sources are the twin pillars of energy management and emissions reduction (ACEEE 2007). The reduction of energy requirements and the source for the power are key in reducing GHG emissions associated with energy production. Reduction of energy needs can be realized in a terminal building and throughout the various building systems, including:

1. Heating, Ventilating, and Air Conditioning (HVAC)

Heated and air-conditioned spaces should be restricted to the areas where travelers spend the most time. For example, in cold climates, ambient temperature can be limited to 13°C in transit areas. Efficient systems should be developed, including: low-temperature radiant heating, radiant ceilings able to function both as heating or cooling systems, radiant heating for larger volumes (circulation and waiting areas), high-occupancy rate premises have pre-heated new air injected (double-flow ventilation with regenerator).

Emphasis on natural ventilation is another measure to conserve energy. Air conditioning is avoided, favoring air renewal via mechanical assistance according to

occupational loads data, with variable flow fans connected to Building Management System (BMS). Summer cooling is done by ground-coupled heat exchanger and additionally by cooling floors and ceilings or thanks to a passive ventilation system. Operable light shafts are used on the roof for summer thermal draft.

Heat recovery ventilation system with recovery rates of 80 percent. Low velocity displacement ventilation for buildings and ventilation exchange modulated according to needs through the use of area sensors and detectors, air quality probes and other devices. The result is reduced ventilation electrical consumption, while providing and controlling throughput flows at or in excess of regulatory flows and improved indoor air quality.

2. Lighting and Electrical

Technologies and designs to optimize lighting and minimize electricity use, such as: use of low-voltage high-efficiency lights (fluorescent, compact fluorescent and LED lighting—LEDs consume 90 percent less energy than comparable lamp types), envelope designed to maximize natural lighting, lighting and mechanical systems controlled by the BMS, occupation and motion sensors and daylight sensors to reduce energy wastage and promote efficiency.

Equipment chosen for its reduced consumption needs: elevators, escalators and pedestrian conveyors have intermittent functioning modes with detectors (40 percent of energy reduction and reduction in servicing and an extended service life). Avoid heat loss during the distribution process of domestic hot water supply by producing hot water in close proximity to points of use.

3. Building Management Systems (BMS)

Efficiency gains cannot be made without monitoring and measuring. A BMS allows for the operation of a building's ventilation, lighting, water consumption and heating and cooling systems to be monitored and controlled. The benefits of such a system include:

- Comfort levels by area and occupancy;
- Consumption measurements per type of use and area or system;
- Monitoring and control of all functions, especially sanitary fittings (filters status, network pressure and temperature status);

- Commissioning of devices enabling the detection of over-consumption in occupied areas, individual regulation of some spaces according to occupation rates (retail, offices) and intermittent use management;
- Air velocity and air quality measurement systems will be installed for continual evaluation of indoor air quality;
- Reduction in energy consumption by as much as 15 to 20 percent through reduction and demand management.

4. Alternative and Renewable Energy

The second cornerstone for energy management and strategies to reduce emissions is the selection of renewable or low-emissions energy sources for the airport. The use of cleaner sources of energy and alternatives that utilize renewable sources reduces GHG emissions and the net carbon footprint of the airport and its operations. Investment in renewable capacity at airports has a demonstrated track record of success. Renewable technologies are rapidly advancing and are increasingly becoming more efficient and less expensive, and are therefore sound economic, social and environmentally responsible choices.

Further to the notion of renewable energy is the consideration of the "life cycle analysis" (LCA) for the source. If the source is wind, solar, hydro or nuclear, then no carbon dioxide is being created during electricity generation, but a so-called life cycle analysis takes into account emissions during the manufacture, installation, operation, decommissioning and disposal of the equipment. Estimates of total life cycle CO₂ generation for various sources are listed in Table 5 below:

TABLE 5 - ESTIMATES OF TOTAL LIFE CYCLE CO₂ GENERATION (SOVACOOL 2008)

Technology	Description	Total CO₂ Generation (g CO₂/kWh_e)
Wind	2.5 MW offshore	9
Hydroelectric	3.1 MW reservoir	10
Wind	1.5 MW onshore	10
Biogas	Anaerobic digestion	11
Hydroelectric	300 kW run-of-river	13
Solar thermal	80 MW parabolic trough	13
Biomass	various	14-35
Solar PV	Polycrystalline silicon	32
Geothermal	80 MW hot dry rock	38
Nuclear	various reactor types	66
Natural gas	various combined cycle turbines	443
Diesel	various generator and turbine types	778
Heavy oil	various generator and turbine types	778
Coal	various generator types with scrubbing	960
Coal	various generator types without scrubbing	1050

Fleet Vehicles and Ground Support Equipment

Fleet Vehicles include most vehicles operating airside, ranging from airport service vehicles and passenger transfer buses to emergency vehicles and maintenance equipment for snow removal, grass cutting and landscaping. Ground Support Equipment (GSE) refers to the vehicles involved in servicing an aircraft, including baggage tractors, catering, refueling, water tankers, ground power units (GPU), air start units, and tractors.

PLANNING AND DESIGN

The layout of the airport, especially regarding the location of facilities and services relative to terminal gates, will greatly contribute to the efficiency of operations. Baggage tractors, for example, must have easy access to the aircraft and the terminal's baggage facility. In addition, operational strategies related to communication between crews, assignment of equipment to flights, and indeed, parking and gate assignments of flights served by various groups can have a significant impact on efficiency.

INFRASTRUCTURE

Investment in infrastructure and modern mobile equipment can greatly enhance the fuel efficiency and reduce the number of vehicles moving around the terminals and aprons of airports. Actions to address energy efficiency could include:

- Replacing old Fleet Vehicles with modern, more fuel-efficient models, such as hybrid cars;
- Replacing gasoline or diesel vehicles with alternatively fuelled vehicles using compressed natural gas (CNG), liquid petroleum gas (LPG), liquid hydrogen, electricity or compressed air;
- Providing infrastructure to refuel alternatively fuelled vehicles operated by both the airport and tenants;
- Replacing fuel trucks with built-in fuel hydrant distributions systems;
- Installing built-in fixed electrical ground power (FEGP) and pre-conditioned air (PCA) units at terminal gates and air bridges to eliminate the need for diesel-powered portable equipment and the vehicles needed to tow them into position;
- Replacing buses that move passengers between terminals with Automated People Movers (APM).

OPERATIONS

The following operational procedures can be implemented to improve vehicle energy efficiency:

- Enforcing a “no idling” policy requiring vehicle engines to be switched off when not in use;
- Providing driver with information on improving fuel efficiency by slowing down and accelerating and braking gently (“Tread Lightly” education);
- Working with facility schedulers to group flight assignments to reduce transit times and maximize equipment use.

Ground Access Vehicles

Landside traffic and ground transport include passenger and staff cars, taxis, buses, long-distance coaches, trains and heavy vehicles.

PLANNING AND DESIGN

An airport needs to be integrated into the local and regional ground transportation network. Airport planners cannot work in isolation and need to develop intermodal transport strategies in conjunction with road and rail authorities, as well as local and long-distance bus and rapid transit bodies.

INFRASTRUCTURE

Ground access infrastructure requirements will invariably start with an efficient road network linked to the local system, required not only for cars but also for buses and goods delivery trucks. Infrastructure for buses can extend beyond basic bus stops to a city bus interchange or a regional bus (or coach) station. Train services can range from links to a city’s metro, subway or local transit trains, to the integration of a major train hub with intercity train services. For large airports isolated from a city’s main train or other transport systems, a dedicated high-speed rail link between the airport and the city might be a solution.

Infrastructure that airports can develop without the involvement of external transport authorities can include the road system within the airport property and consolidated facilities for rental car agencies, retail, business parks, hotels and conference centers.

OPERATIONS

Policies and procedures that should be introduced and enforced can have important benefits with a relatively small investment. Examples include:

- Enforcing a “no idling” policy requiring vehicle engines to be switched off when not in use;
- High-efficiency (e.g. hybrid) or low-emissions (e.g. CNG or electric) vehicles can be incentivized. Such “green” taxis or “ecotaxis” can be assigned a priority queue to reduce waiting time or given a reduced airport user fee. The general public, including passengers using such vehicles, could be given priority parking spaces or reduced parking fees;
- Careful selection of trucking routes and vehicle movements;
- On-site speed limits;
- Taxi company contracts can allow taxis to pick up passengers after dropping others off. This reduces “deadheading” where a taxi might have to leave an airport without a passenger;
- Hotels and car rental agencies near airports often have their own shuttle vans that drive a regular circuit around the airport terminals and back. It may be possible to increase occupancy rates in the shuttle vans through the consolidation of different services;
- The practice of vehicles driving loops around an arrivals area can be discouraged. Airports can provide a parking and waiting area, sometimes called a “cell phone waiting” area, where people meeting arriving passengers can wait in cars until called by the passenger;
- Individual drop-off of passengers can be discouraged, as this requires double the vehicle trips to and from an airport;
- Airports can provide incentives for staff and tenants to carpool or use public transport rather than private vehicles.

Other Considerations

MAINTENANCE AND OPERATIONS

Asset maintenance provides a net energy efficiency gain by reducing replacement needs and increasing longevity and durability. These servicing and operating fundamentals should be taken into account during the design phase to effectively create a building and operation with fewer embodied energy requirements and increased serviceability:

- Select materials according to their durability and resistance to weathering, damage, and vandalism, rather than on the basis of cost alone;
- Design so that regular service operations can be handled by non-specialized personnel, without any specialized tools. Servicing can be performed without user service or operational disruptions;
- Streamline cleaning operations thanks to materials and finish quality, facilitated accessibility and design with O+M in the forefront:
 - windows accessible inside and outside by platform lifts/suspended scaffolding;
 - roof photovoltaic cells only require access to their inverters and roofs are accessible from staircases;
 - fabric panels dropped ceilings do not require any maintenance since there are no networks or lighting systems underneath and up the ceiling; and
 - cleaning of exterior and interior walls does not call for toxic chemicals.
- Technical installations that are reliable, easily accessed, easy to use and can be controlled easily;
- The hot and cold networks are split up to allow for servicing only in required areas without disruption to other zones;
- Lighting equipment will be simple, robust, easy to source, easily accessible without disrupting passenger comfort, and highly efficient;

- Energy consumption is optimized by use of motion sensors, light sensors, and timers to pilot the controlled areas;
- Computerized operation and maintenance management systems for conveyance devices such as escalators, moving walkways, elevators and automatic doors, to control electrical consumption and avoid wear/breakdowns;
- A preventive maintenance policy is recommended, via a computerized maintenance management system allowing for:
 - the best possible prevention/correction ratio in relation to the managed equipment and availability goals;
 - better planning of scheduled interventions and maintenance; and
 - decision support for equipment renewal.

MONITORING AND FOLLOW-UP

Establishing benchmarks and standards at airports can provide a measurable framework against which all improvements and progress can be measured. Once again, things that are measured can be improved. There are a number of programs that can be instituted to help guide and chart progress, as well as provide the necessary framework for success of any sustainability initiative. Some of the recommended steps and monitoring include:

- Maintenance of an annual inventory for GHG emissions for reporting and potential follow up and action plans for further reductions.
- Elaboration of a GHG emission plan and strategies that align with the airport's sustainability initiatives.
- Commissioning of a Green Plan to limit the worksite's environmental impacts:
 - Identification and rating of worksite wastes for recycling;
 - Commissioning of a waste management plan;
 - Definition of a management method to facilitate waste pick-up and identification (per type of waste: hazardous or not);
 - Minimum of 40 percent of waste is to be recycled;

- Operational procedures to reduce waste production at the source;
- Mitigation of acoustic and visual annoyances during the works; and
- Guaranteed clean worksite with limited dust emissions and soil erosion.

To sum up this section, the biggest efficiency gain on the ground remains the reduction in delays and wasted fuel burn as aircraft queue-up for a runway take-off slot, or wait until a terminal gate becomes free. Better coordination among airlines, airports and air traffic management as part of new collaborative decision-making techniques ensures that airline flight schedules are planned to more closely align with available runway and airspace capacity. The gains from collaborative decision-making will be substantial. In the United States alone, the cost of burning fuel on the ground as a result of delays to the airline schedule amounted to over US\$5 billion in 2008 alone. Airport collaborative decision making (A-CDM) directly links airports into the air traffic management network and gives users access to a range of operational data, allowing them to make their operations more efficient. Successful implementation leads to significant reduction in carbon emissions, which in turn helps airlines save fuel.

The sharing of accurate and timely data between air traffic management and airport operators, airlines, ground handlers and service providers involves investment in new systems and working methods. In one European airport, the introduction of A-CDM reduced taxi times by 10 percent, saving airlines US\$3.6 million a year in fuel bills. More advanced collaborative decision making will also provide for the sharing of information such as passenger flows and baggage information, contributing to an enhanced global picture and a better aviation system for all users and passengers. Passengers need to play their part too. By far the largest source of on-ground emissions around airports actually comes from passengers driving to the terminal for their flight. A large number of airports are now encouraging passengers to use public transport options to get to the airport and many airports are engaged in developing better intermodal connections with rail and city-based public transport (ATAG, 2010).

3.2 ROLE OF GOVERNMENT IN FOSTERING AND SUPPORTING ENERGY EFFICIENCY GAINS

3.2.1 FISCAL MEASURES

Increasing energy efficiency through technological improvements (engines, airframes), operational improvements (ATC, procedures) and infrastructure improvements (ATC, airports) will highly depend on government support to incentivize the right investments and partnerships. Supportive policy frameworks on a global basis will be critical in overcoming existing hurdles and implementation challenges.

Currently, inadequate policies, a lack of information and education on the part of policy makers with respect to challenges and required policy improvements, as well as insufficient political will to speed up decision making and implementation are considered by industry experts to be major hurdles to the implementation of energy-efficiency and emissions-reduction measures. A number of existing fiscal and regulatory policies are hindering the industry in its ability to implement energy-efficiency measures. Such obstructive regulations need to be replaced with policies that provide direction and stability to the market and protect against competitive distortion within aviation.

To increase innovation and support the implementation of energy efficiency levers, governments should view their role as that of creating a favorable climate. A government's role has different functions: providing incentives for and facilitating or supporting innovative projects; removing bureaucratic, regulatory, competitive and other obstacles to innovation; and improving the knowledge base and knowledge sharing, e.g. for developing technical education and research and development structures (Aubert 2010).

A global approach when devising fiscal measures and policies seems most appropriate, as international aviation operates between different countries and regions and any national or regional policy is likely to lead to competitive distortion. However, it must be acknowledged that the implementation of global fiscal policies is difficult and slow and its administration may require the creation of some type of

supra-national organization. Although national and regional fiscal policies could be agreed to and implemented more rapidly and more easily enforced under consideration of national sovereignty concerns, a patchwork of national or regional policies has to be avoided, as it leads to increasing complexity, lack of transparency, and competitive distortion among countries.

To develop global policies, different principles need to be considered to ensure fair treatment of players, countries, and regions. Moreover, to attain international agreement, different stages of national economic development must be taken into account. If a principle of equal treatment and nondiscrimination (which is the basis of ICAO policy structures) is applied, then all states have to be treated equally on a global basis with no regional differentiation other than special exceptions that might be provided in the case of demonstrated special need. On the other hand, if the principle of common but differentiated responsibilities (CBDR)—which is endorsed by the UNFCCC—is implemented, then it is the duty of states to equally share the burden of environmental protection and increasing energy efficiency but with differentiated responsibility based on the different material, social, and economic development stages of the states.

Some of the most promising policy options, which help to accelerate aviation's move to higher energy efficiency and thus sustainable growth, fall into the category of fiscal measures. This section gives an overview of the different fiscal policy options available, with their respective advantages and disadvantages. Subsequently, an evaluation of the types of fiscal policies most apt in supporting the implementation of each of the three energy-efficiency levers discussed in the previous section of this report in the context of a developed country. For a more specific discussion of fiscal policy options and other policy measures in developing countries, please refer to Chapter 4.

Fiscal policy measures

Fiscal policy measures that can help accelerate energy-efficiency improvement fall into the following categories: fiscal incentives, such as tax breaks and subsidies; green levies, such as an aircraft, fuel or CO₂ tax; and market-based measures in the form of emissions trading and offsetting schemes (World Economic Forum 2011). Fiscal incentives, such as *tax breaks, depreciation incentives, lump sums, grants, or subsidies*, can incentivize the supply (manufacturer) and demand (airlines) sides.

They are particularly effective in the early stages of technology development, as they reduce the risk of investment and lower total costs of R&D and technology. At the same time, financial incentives provide more flexibility to industry players than other regulatory measures, such as standards and regulation. However, global fiscal policies are hard to define and implement, as nations and regions operate under very different and, on many occasions, incompatible legislation.

Tax breaks can be introduced for investment in R&D (for new airframes, engines) or for purchase of more efficient aircraft. They are very attractive when fostering investment from players within the aviation industry and very effective in channeling investment into the desired areas (e.g., R&D). On the other hand, they do not provide large incentives to those players that are less profitable and thus do not pay taxes.

Depreciation incentives could help to accelerate fleet turnover. They feature roughly the same advantages and disadvantages as tax incentives. To ensure that faster depreciation has a real impact on energy-efficiency improvement, the ways in which faster depreciation of planes by more profitable carriers affects the market for used planes must be reviewed in depth.

Lump sums or grants that give a fixed amount of money to all players (e.g., a cash premium for aircraft R&D or early aircraft retirement) or other mechanisms that facilitate aircraft purchase financing and that are not bound to profitability, such as tax incentives, have the advantage of benefiting all players equally. A further advantage of this sort of mechanism is that a total limit can be set on available funds so that the incentive program ends when those funds are depleted. The effect of such policies highly depends on the criteria outlined (e.g., a cash premium for early aircraft retirement is only given if the aircraft is replaced by a model with certain higher energy efficiency). The timing for such programs should be aligned with the timelines for the introduction of new, more energy-efficient technology to ensure the greatest impact.

Subsidies can help to overcome the price differences between conventional technology and new technologies (e.g., conventional aircraft versus more expensive aircraft with higher energy efficiency). Such subsidies should be reduced step-wise as the supply of new technologies increases and production becomes more economical due to increasing scale and learning curve effects.

The aviation industry could draw from examples of fiscal incentive successfully deployed in other industries (see Figure 14).

Automotive - Cash for Clunker	Automotive - Leaded gas (U.S.)
<ul style="list-style-type: none"> Cash incentive scheme to promote replacement of old, high emission vehicles with new, efficient cars Set up by most Western governments to alleviate impact of financial crisis on automotive industry Commonly linked to age or emission requirements for applicable vehicles Environmental impact disputed 	<ul style="list-style-type: none"> Clean Air Act in 1970 imposed regulations on carmakers to use catalytic converters to meet new standards New catalytic converters required customers to buy unleaded gas Financial incentives for oil companies to produce efficient unleaded fuels Tax differences between leaded and unleaded gas accelerated switch
Energy - Wind/ Solar (Germany)	Property - HOME STAR (U.S.)
<ul style="list-style-type: none"> Introduction of feed-in tariffs in Germany to encourage deployment of renewable energy technologies Different rates for technologies Level of support declines over time by 1% p.a. CO₂ emission savings estimated at 52mT by 2010 at cost of €2.4bn 	<ul style="list-style-type: none"> Program proposed in U.S. in 2009 to encourage homeowner to retrofit existing homes and improve energy efficiency Financial incentives via tax credits up to \$12,000 per home Approximate cost of \$10bn p.a.

FIGURE 14 - EXAMPLES OF RECENT SUCCESSFUL FINANCIAL

For fiscal incentives to be effective, policymakers have to ensure that their good intentions do not lead to potentially undesired outcomes. Poorly designed fiscal incentives, despite the intention to increase eco-friendliness, could lead to high spending with little effect on energy-efficiency increase; that is, a cash premium to accelerate fleet renewal could have little impact if the effects on the secondary market for aircraft are not taken into account or if tax incentives and grants to foster R&D merely substitute existing or planned industry R&D programs with government-sponsored programs or channel research into few areas (“putting all eggs into one basket”).

Green levies

Green levies (on *tickets, aircraft, fuel, CO₂*) are intended by policymakers as a way to disincentivize the industry from burning fuel and thus indirectly incentivize the improvement of energy efficiency in the industry. However, green levies, if not directly correlated to energy usage, are not considered to be very effective in improving energy efficiency and can distort market competition. They are specifically not effective in situations where new, more energy-efficient

technologies are not yet available for purchase. They draw away money from the aviation industry that could be used to invest in green technology without first ensuring that governments use the money for investments in increased energy efficiency rather than to balance their budgets.

Ticket levies are charged on a per-ticket basis and are relatively easy to administer. The fees are covered by the airlines or, where possible, are passed on to the passengers or customers, as in the case of air cargo. Often, ticket levies are linked to the distance flown and less often to aircraft fuel burn. The effect is that ticket levies can reduce aviation energy use through increasing prices, which can limit or marginally reduce demand. They thereby can exclude those segments of society with less spendable income from aviation and, ultimately, impact destinations that are highly dependent on tourism receipts. The negative macroeconomic effects of reduced air traffic, especially to the economies of developing nations, need to be taken into account in order to evaluate the impact of reduction of aviation demand (ATAG 2008).

One example concerns the U.K. Air Passenger Duty (APD), as first introduced in 1994 and since replaced, which did not place differentiated pressure on airlines (it did not recognize the fuel efficiency of the plane or fleet). As such, more CO₂-efficient airlines were penalized, despite being more efficient. Furthermore, most airlines simply passed the additional cost on to customers. The increased price, albeit penalizing travelers with more expensive tickets, did not have the desired effect of decreasing overall demand. There is a very high price elasticity in ticket pricing, and a combination of the general desire to travel by many—especially among the growing middle class in developing countries—and the overall desire by nations to continue to attract the lucrative business and leisure tourism market, will likely render the increase in ticket pricing inefficient in reducing demand beyond very marginal effects. At the same time, one should consider that shifts to other modes of transport could lead to energy leakage, in the sense that energy usage increases in the alternate sectors.

An *aircraft levy* is, for example, an annual levy on an individual aircraft depending on type, age, or fuel burn. The advantage is that this type of levy can be easily applied to passenger and cargo planes alike. The challenge is that the number of flights per year, distances flown, and load factors are not considered, thus the levy

has no correlation to usage and actual fuel burn and energy efficiency. As such, this levy could put an unjust burden on the airlines that have older fleets. A *fuel levy* (i.e., a tax on jet fuel comparable to existing taxation of gasoline) considers the principle of causation, in the sense that is directly linked to fuel usage. Such a tax, however, is not supported in existing bilateral agreements and would thus require significant policy amendments on a global level. Without the availability of more efficient aircraft or alternative fuels, fuel levies would only put an additional burden on airlines for which fuel already constitutes more than 30 percent of total operating costs and therefore could only have a marginal effect in further increasing fuel efficiency. A *CO₂ levy* would indirectly have the same implications as those described previously for fuel levies, as CO₂ emissions are directly linked to fuel burn and thus energy efficiency. Moreover, it would have higher administrative costs as a result of the difficulties in measuring, monitoring, and reporting CO₂ emissions by all carriers.

All types of levies have to be evaluated, taking into account the negative macroeconomic effect of reduced aviation activity and the structural and financial difficulties they impose on the aviation industry (World Economic Forum 2011).

Market mechanisms: Emissions Trading Schemes (ETS) or offsetting

Market mechanisms such as emissions trading schemes (ETS) or offsetting represent another policy option that may have an indirect effect in regard to improving energy efficiency in the aviation industry. A tax on CO₂ would increase the cost of fuel burn and thus the cost of operating less energy-efficient aircraft. By putting a price on carbon and providing legal incentives in the form of longer-term policy security, an ETS may incentivize investment in low-carbon technologies and, as such, in technologies that increase fuel and energy efficiency. However, due to the likely money outflow from the aviation industry, the potential negative impact on industry investment in new technologies and the negative macroeconomic effects of reduced air traffic must also be considered. The effectiveness of an ETS highly depends on the concrete specification outlined (e.g. cap and trade with free allowances, cap and trade with auctioning of allowances where revenues to the administering government are reinvested in aviation efficiency, options to trade credits with other sectors and/or ETS schemes, or ETS with or without project offsetting options similar to Kyoto CDM, JI, or UN REDD [Reducing Emissions from

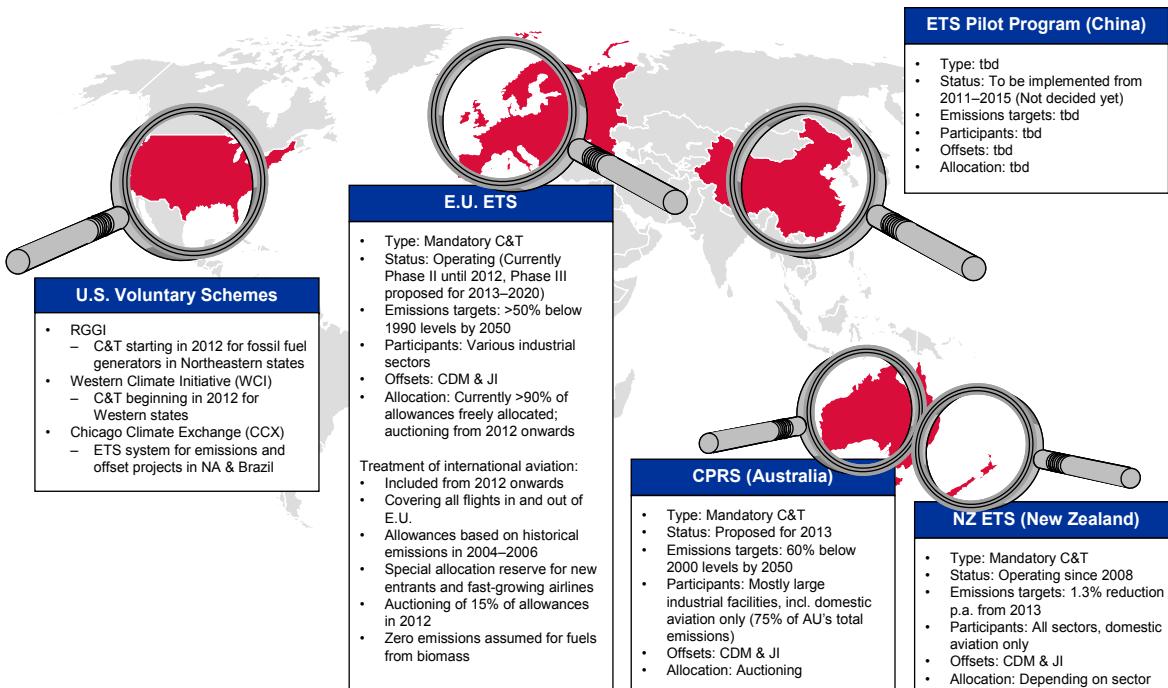
Deforestation and Forest Degradation] projects that provide a link to a developmental agenda).

While international aviation has been excluded from the Kyoto Protocol and any national emission targets so far and the aviation bunker fuels discussion was deferred to ICAO in the UNFCCC climate negotiations, international flights from and to the E.U. will be included in the E.U. ETS from 2012, though it has to be noted that a number of carriers have objected to this and initiated legal challenges. Since a number of countries (see Figure 39) have implemented or proposed to implement ETS, it is conceivable that in the future pressure to include aviation in ETS in one way or another will increase. It will be critical for the aviation industry to continue to work through ICAO¹¹ (as recognized by UNFCCC in the outcomes of COP16 in December 2010) to develop a global sectoral market-based measure (MBM) approach to prevent competitive distortion and increased complexity with proliferation of a patchwork of national schemes.

Developing a global sectoral ETS scheme will be challenging, as it will have to take into consideration existing agreements and treaties (e.g., Chicago Convention, Kyoto Protocol, bi-lateral agreements between states) (Havel 2010). To address the legal hurdles, individual nations can commit to individual voluntary action plans that acknowledge a global policy or, alternatively, plurilateral agreements need to be negotiated with the same scope. Further legal constraints may also exist in regard to using policy frameworks such as ETS or levies to raise funds to finance CO₂ abatement and energy-efficiency improvement mechanisms for the aviation industry, as national legislation of different countries does not allow for earmarking of such funds (Havel 2010).

With respect to offset programs, currently there are a limited number of projects (especially Kyoto-related projects, such as CDM and JI) that are not open to aviation. Additional opportunities might lie in enabling projects in African countries that are currently not eligible for Kyoto CDM projects. When setting up an MBM approach for aviation, it is essential to consider the different stages of development of various

¹¹ Emissions from international aviation were excluded from the national United Nations Framework Convention on Climate Change (UNFCCC) negotiations, and the mandate for developing a regulatory framework for emissions from international aviation was assigned to the International Civil Aviation Organization (ICAO), a specialized UN body.



Source: European Commission, Australian Government, U.S. Committee on Energy and Commerce, New Zealand Government, WEF/ Booz & Company analysis

FIGURE 15 - EXAMPLES OF CURRENT AND PLANNED ETS SCHEMES

countries and especially the resilience of small and remote island states that highly depend on tourism. A number of suggestions on how to structure MBMs have been proposed by different organizations. For example, the Aviation Global Deal (AGD) Group, which includes the Climate Group, made a proposal that maintains equal treatment among airlines by requiring all airlines to participate in a fuel-based emissions trading scheme but differentiates among countries by earmarking some of the revenues generated for projects in developing countries.

The Association of European Airlines (AEA) made a Global Approach Proposal (GAP) segmenting countries into three blocks, according to the maturity of their aviation markets, assigning them different emission-reduction targets. Under the AEA GAP approach, for all traffic between two blocks, the lowest target will be applied to all

airlines, regardless of nationality.¹² In conclusion, one of the main challenges for the development of a coherent and effective aviation climate change policy framework is a nonexistent overall global climate change policy framework. This void leads to insecurity on the national level.

An MBM policy that includes ETS and offsetting opportunities is, on the one hand, seen as a major option to reduce risk and uncertainty and thus attract more capital market investment into the discussed abatement areas (e.g., aircraft R&D and biofuels). On the other hand, an MBM scheme that extracts money from the industry could lead to lower investments in new aircraft technology and other CO₂ abatement initiatives by industry players due to financial constraints. An MBM scheme might also be taken as an excuse not to invest in CO₂ emission reduction within aviation, thereby neglecting the negative long-term effect on the carbon footprint of the aviation industry. To overcome this dilemma, if an ETS is put in place, a provision must be made to ensure that governments still invest in aviation infrastructure (especially ATM) improvements and that industry players are incentivized to invest in emission reduction within the industry. In addition, in the development of the ETS, it is critical that the scheme is designed to incentivize the best investment, including fuel/engine/airframe manufacturers. An ETS solely targeted at simply drawing airlines funds would miss the intention.

Current perceptions and opinions about MBMs for aviation differ among stakeholders from different regions. In Europe, with E.U. ETS having been in place for national emissions and the inclusion of international aviation in E.U. ETS from 2012, stakeholders have accommodated the idea that an ETS can help achieve ambitious emission-reduction targets. Concerns are mainly seen in countries introducing separate taxes on aviation, which leads to competitive distortion and potentially to double-counting, if they are not removed when an ETS is implemented. On the other hand, in regions in which no or few regulatory mandates exist for carbon emission reduction, such as in the United States, the introduction of MBM is seen as much more critical. In the United States, the fact that a large proportion of air traffic is domestic must be taken into consideration, and thus a

¹² The concept of setting targets and applying MBMs on a route rather than a unilateral country basis has been endorsed by the World Tourism Organization (UNWTO); this approach would not only resolve conflict between Chicago and UNFCCC provisions, but could provide, irrespective of the airline base, for reduced-emission targets or exemptions for routes to poorer countries, which are heavily dependent on tourism and often the most vulnerable to climate change.

larger portion of aviation CO₂ emissions may have to be dealt with in the UNFCCC negotiation on national emission targets rather than under ICAO.

In a recent World Economic Forum project, the greatest challenges in developing an MBM approach for aviation were perceived by industry experts as the need for a global scheme to avoid a patchwork of regional schemes that would lead to competitive distortion, the challenge of ensuring that emissions are only counted once and no double-counting occurs, and the risk that, with money flowing out of the aviation industry without any CO₂ and energy-efficiency gains within aviation, the long-term effect on aviation is not considered.

Other market mechanisms could be considered as potential alternatives to an ETS. For example, a carbon contract, as proposed by Dieter Helm and Cameron Hepburn, could be discussed for the aviation sector; under this scenario, the government would auction off carbon contracts for the supply of emission reductions over a long-term horizon that provides a forward revenue stream with long-term price certainty and that could be used to secure project finance (Hepburn 2005).

3.2.2 POLICY MEASURES

Standards and regulations, such as an aircraft technology CO₂ standard, fuel standard, or a labeling standard would encourage aviation players to develop and adopt new, more energy-efficient technologies or approaches. These policies won't, however, have much of an effect if the new technology is still in the early R&D phase and not available in the market for purchase. If introduced once technology is proven, standards and regulation can significantly accelerate manufacturing scale-up and technology rollout. For example, the aviation biofuel specification that is currently in development can stimulate additional R&D and accelerate its production.

An *aircraft technology CO₂ standard* that, for example, requires aircraft to meet certain energy-efficiency or emission levels (possible for new aircraft or all in-service aircraft), such as the new CO₂ standard for new aircraft proposed and under development by ICAO, creates an enabling environment for manufacturers to improve energy and thus the CO₂ efficiency of new aircraft generations. However, manufacturers already have a strong incentive to reduce fuel burn due to the weight and the constantly appreciating and increasingly fluctuating price of fuel, which

represents about 30 percent of all costs of their customers' operations. Such technology standards, if introduced for all in-service aircraft, would put carriers with older fleets at a disadvantage, which could especially impact developing countries.

Well-designed performance standards can be highly effective. Where the desired outcome is measurable (e.g. fuel efficiency, CO₂ emissions from aircraft), these policies can be economically efficient, since they directly mandate the outcome while allowing market forces to determine the best technologies to achieve this goal. Clearly, the standards must be set at the right level—too weak and not enough is achieved, too stringent and the burden on industry outweighs the benefit. Performance standards are also difficult to implement politically. Although these standards cost the government very little, they cost manufacturers—groups with very high lobbying power—immediately while the benefits to consumers are long-term and less visible. As a result, it is rare that these standards are sufficiently stringent. Governments should recognize the need for government support in R&D to make stringent standards acceptable to industry.

Other standards, such as technology or process mandates, are typically economically inefficient by forcing the path industry must take; however, they can stifle innovation in other areas and hence prevent a superior technology from being adopted. A case in point is the mandatory use of catalytic converters in cars, which slowed the development of lean burn technology.

Information policy, such as labeling standards that make the energy and CO₂ efficiency of aircraft (by aircraft, by airline etc.) visible to customers, would allow for market-based competition between airlines also on an energy-efficiency and CO₂-efficiency basis. Airlines could thereby position themselves as particularly energy- and CO₂-efficient and thereby obtain a competitive advantage as customer awareness of ecological and climate change matters increases. The difficulty with such standards is that energy usage and CO₂ efficiency of flights highly depends, not only on the fuel efficiency of the plane, but also on criteria such as load factors and lengths of flights. In general, the impact of information policy is moderate and reasonably quick if there are no implementation lead times. Making consumers aware of the presence of a consumption incentive is considered a type of information policy.

3.3 ROLE OF THE PRIVATE SECTOR

3.3.1 AIRLINES

Airlines fuel savings can be achieved in various ways. Some prominent examples are fleet modernization, engines renewal, more frequent engine washing, adopting Continuous Descent Operations (CDO), or using alternative fuel mix by ground-handling vehicles. Technology improvements in airframe and engine design are among manufacturers' research and development objectives, while airlines can achieve more energy efficiency through operational measures.

Continuous descent operations

In a CDO, an aircraft descends towards the airport from its cruising height in a gradual, continuous, approach with minimum thrust, rather than by making the conventional series of stepped descents. As there are no "leveling-off" procedures, which require the pilot to increase engine thrust to maintain level flight, less fuel is consumed.

In trials, fuel savings during the approach phase were recorded at up to 40 percent. This equates to between 50 and 150 kg of fuel, depending on the level at which CDO is commenced and the aircraft type. Up to 150,000 tons of fuel a year, or 500,000 tons of CO₂, could be saved in Europe alone if CDO approaches were more widely adopted. In addition, the noise footprints of CDOs are substantially smaller than the footprints of conventional approach procedures, and fuel consumption is approximately 25 to 40 percent lower during the last 45 km of the flight.

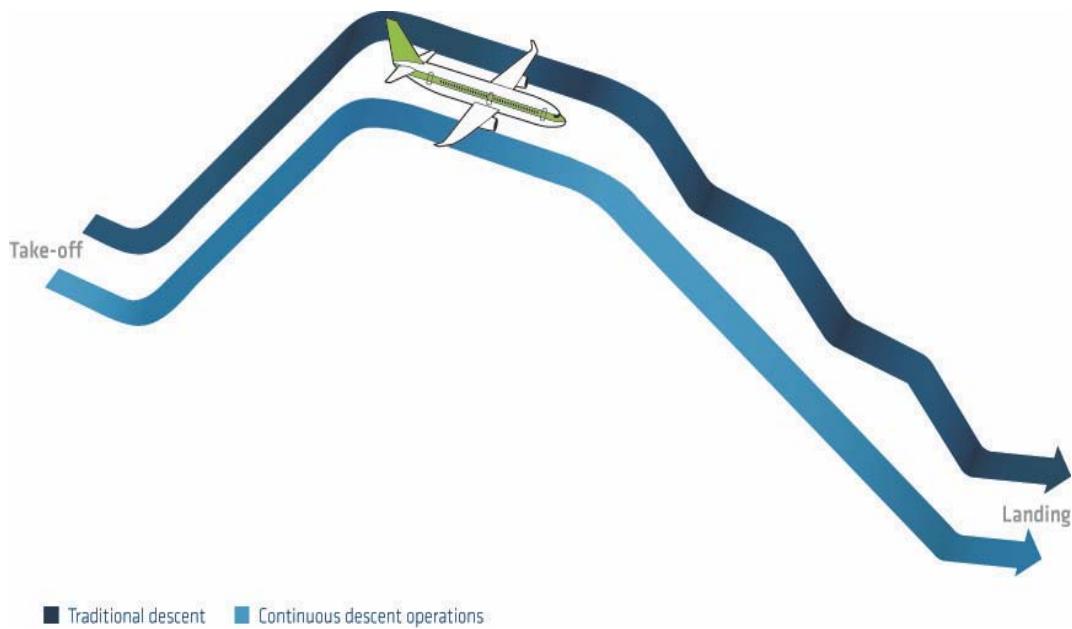


FIGURE 16 - ILLUSTRATION OF CDO

Airline network optimization

Another factor in improving fuel efficiency by airlines is to optimize their own network operations, including code-sharing partnerships with other airlines, which allow for greater use of larger aircraft with more passengers. New yield management techniques can also increase the number of passengers per flight and therefore the fuel efficiency of each seat on board. More flexible use of different aircraft in the fleet also allows for greater efficiency; for example, an airline's ability to use smaller twin-engine aircraft in longer operations means that passengers are now able to fly directly between mid-sized cities, rather than having to take extra flights between hubs.

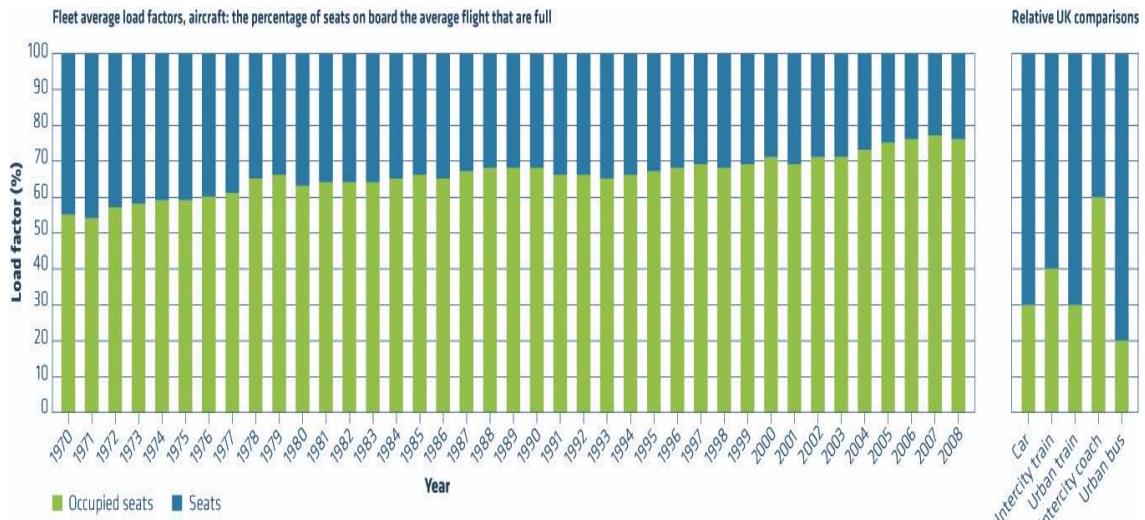


FIGURE 17 - FLEET AVERAGE LOAD FACTORS AND RELATIVE COMPARISON TO OTHER TRANSPORT MODES IN U.K.

In addition, there have been major improvements in fuel efficiency with the development of highly sophisticated flight-planning and flight-management tools. These allow pilots to exploit prevailing wind conditions, calculate precise fuel loads, set different flight levels and speeds for the aircraft to achieve the most economic performance and determine the exact center of gravity of the aircraft as it becomes lighter in flight, since placing slightly more weight at the back of the aircraft rather than at the front can improve the aircraft's fuel consumption rates. In fact, even an adjustment of 28 cm in where the heaviest bags and cargo containers are stowed can save 0.5 percent of fuel on a flight.

CASE STUDY I: FINNAIR

Finnair, the flag carrier and largest airline of Finland, has numerous company-wide programs aiming to reduce emissions, fuel burn and energy consumption. Finnair's ambitious but realistic targets are based on maintaining a modern fleet, making operational and technical improvements, and deploying economic instruments. The targets will be achieved through a four-pillar strategy: emissions reductions through improvements in technology, infrastructure, operations, and economic instruments. Finnair is committed to reducing emissions and fuel burn by 24 percent per seat in

the period 2009-2017, with total emissions and fuel burn reductions of as much as 41 percent per seat.

Finnair's most important environmental act is modernizing its fleet of aircraft. Every new generation of jet aircraft consumes up to a quarter less fuel and consequently produces a quarter less carbon dioxide emissions than the previous generation of aircraft. Moreover, other emissions and noise can be reduced with advanced engine technology. Finnair now operates with one of the youngest fleets in the business. The company flies its European and domestic routes with Airbus A320 and Embraer aircraft.

The modernization of the long-haul fleet was initiated in 2007, when Finnair took delivery of its first new Airbus A340 wide-bodied aircraft. The first Airbus A330 aircraft arrived in 2009. The Airbus A340 consumes around 10 percent less fuel and thus 10 percent lower carbon dioxide emissions than earlier wide-bodied aircraft. In terms of the Airbus A330 aircraft, the savings is 20 percent. The biggest leap will come in 2014 when the long-haul fleet is supplemented with new technology Airbus A350 XWB wide-bodied aircraft, whose average consumption is less than three liters per hundred kilometers per passenger. The company will also discontinue flying the Boeing 757 aircraft used in leisure traffic.

In addition to fleet modernization and direct routes, Finnair also strives to reduce emissions through operational measures. Every flight is individually planned so that travel speed and altitude, for example, are optimal and aircraft fuel consumption is as low as possible. Finnair also uses the CDA (Continuous Descent Approach) method as much as possible. Landings performed in this way use less engine power. Approaches made with a continuous descent save the company around five million kilos per year in fuel consumption. In addition, the method reduces approach noise. Fuel consumption is also controlled by paying close attention to the weight of aircraft. Through means connected with the weight of aircraft and refueling, Finnair's Fuel Saving Taskforce has reduced fuel consumption by 2.5 percent from summer 2008 to summer 2009.

In addition to flying, Finnair tries in all of its operations to reduce the amount of waste and to lower its energy consumption. At Finnair's operating locations, whether on land or in the air, every effort is made to recycle glass, paper and metal, and collect energy waste, which is suitable as an industrial energy source. On flights,

aluminum, glass, energy waste and plastic have been sorted wherever possible for many years now. Finnair Technical Services and Finnair Catering are the units that use most heat, electricity and water in the company. Finnair Catering has an environmental system certified according to the ISO14001 standard. In February 2008, Finnair Catering moved to new premises, where the goal is to use water and energy more efficiently.

Finnair Technical Services' operations are covered by a permit granted by the Uusimaa Regional Environmental Centre. The Technical Services unit is particularly focused on VOC (Volatile Organic Compound) emissions and on reducing problem waste. A key element of Finnair's environmental work is cooperation with different actors, such as airports, aircraft and engine manufacturers, air-traffic control and aviation authorities. Environmental loading both in the air and on land can be reduced through technical improvements, infrastructure development, operational means and financial management, all of which require open cooperation with different actors.

CASE STUDY II: LUFTHANSA

Sustainability: Guiding principles are more important than ever

Lufthansa, Germany's flag carrier and the largest airline in Europe, is aligning economic activity with ecological and social objectives. This policy offers the right responses, especially in the current economic crisis: conserving jet fuel helps to reduce carbon emissions and fuel costs. Innovative models of work schedules enable employees to achieve work-life balance and offers the company greater flexibility in responding to falling demand.

Lufthansa is systematically pursuing its environmental goals by setting ambitious goals for climate and environmental protection. Lufthansa intends to reduce its specific carbon emissions by another 25 percent by 2020 relative to 2006 levels. Since the 1970s, the airline has been able to increase its CO₂ efficiency by 70 percent. Another major focus is the further development of alternative fuels. Lufthansa aims to add up to 10 percent of biofuel to traditional kerosene by 2020 and, to this end, is already conducting intensive inquiries with fuel producers, as well as with engine and aircraft manufacturers.

Cutting-edge technology pays off

In recent years, Lufthansa has implemented over 120 environmental measures based on cutting-edge technologies and know-how from Germany. Some examples from Lufthansa's business segments include:

- *Passenger Airline Group*: Investments in fuel-efficient aircraft are climate protection at its best. Through 2016, Lufthansa has ordered 154 new, fuel-efficient aircraft that will also replace older models. The average fuel consumption for the Lufthansa fleet is exactly 4.3 liters per 100 passenger kilometers. This is a historically low mark.
- *Logistics*: Lufthansa Cargo has been testing light containers since last autumn. If they pass the field test, the airline will be able to save close to 30,000 tons of jet fuel in the next 10 years.
- *Maintenance, repair, and overhaul (MRO)*: Lufthansa Technik offers a new process to make engine cleaning more efficient. Instead of the previous five hours, the process is accelerated to about one hour and additionally conserves resources such as water and power. As a result, the airline can clean its engines in shorter intervals and reduce carbon emissions by up to 75,000 tons because the engines function more efficiently.
- *IT Services*: Flight routes are optimized through the Lido OC software developed by Lufthansa Systems, saving up to 5 percent of jet fuel per flight route.
- *Catering*: Cooling food and beverages is energy-intensive. To address this issue, in May 2008, LSG Sky Chefs moved into a new operations building in Frankfurt, where it now relies on a computer-based control system for its cooling machines, thereby saving 30 percent energy.

Policymakers have a responsibility

Lufthansa also continues to heavily invest in energy-efficient technologies, advancing employees, and assuming social responsibility. As the largest customer of the Frankfurt Airport, Lufthansa is helping to ensure that over EUR 10 billion in private capital will be invested in the site over the coming years and tens of thousands of additional workers will have jobs. But it is also clear that policymakers

must bolster business efforts by providing the proper regulatory framework for improving energy efficiency.

Mode of transport analysis: Aviation convincing

Only intelligent integration of road, rail, and air transport will ensure efficient and sustainable mobility. This is the conclusion of a study, commissioned by the German Air Transport Initiative, a group to which Lufthansa belongs. The focus of the study was on analyzing the German infrastructure, but lessons drawn might be transferable to other regions as well.

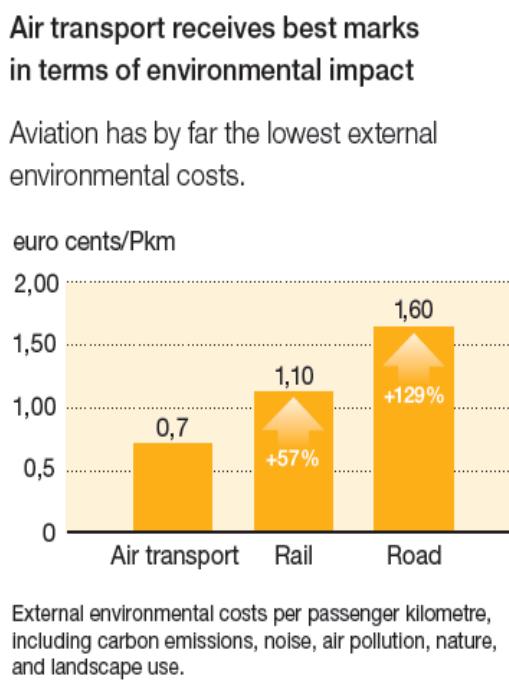


FIGURE 18 – EXTERNAL ENVIRONMENTAL COST

Already today the German economy profits from an intelligent system in which road, rail, maritime, and air transport complement each other in a practical fashion. And yet there are differences among the individual modes of transport, which also lie in the nature of the various systems. For example, air transport in Germany is the only mode of transportation that, at 95 percent, almost entirely covers its costs. This is consistent with the fact that air transport receives only 4 percent of total subsidies received by all the various transport modes. Rail receives 52 percent of subsidies, while road transport takes in 24 percent. If we look at the costs of the various modes of transport, air far

outpaces the others in terms of cost efficiency, starting from a distance of 400 to 500 km and up. Aspects such as infrastructure, accidents, environmental costs, operational costs, and the cost of utilization were taken into account in the overall analysis.

These are some of the core findings of a study on modes of transport. The study, which was prepared by an experienced and independent group of authors—the research and consulting firm INFRAS Zurich and the Fraunhofer Institute for Systems and Innovation Research, which has also produced studies for, among other industries, the railway sector—for the first time examines the economic and ecological aspects of German rail, road, and air transport in a comprehensive and concise fashion. It is intended to contribute to a strategic debate on the future-oriented development of the transport sector as a whole. Figure 19 depicts the air transport advantage: starting from 500 km and up, clear overall cost advantages (operations, infrastructure, cost of utilization, external environmental and accident costs). Already starting from routes of 500 km and beyond, travel by air, including environmental costs, is more cost-efficient than road or rail.

The analysis underscores the specific strengths of air transport. There is de facto no alternative when it comes to longer continental routes. Lufthansa competes with rail for only 15 percent of its passenger traffic. "Air transport made in Germany" creates tens of thousands of new jobs and pays for its own infrastructure costs. Yet it also depends on a fair international regulatory environment.

CASE STUDY III: QATAR AIRWAYS

Qatar Airways, the flag carrier of Qatar, has realized that it is important to go beyond the current industry best practices for fuel and environmental management in order to ensure a sustainable future for the airline, its staff and its neighborhoods. The airline takes on the responsibility to deal with its impact on global climate

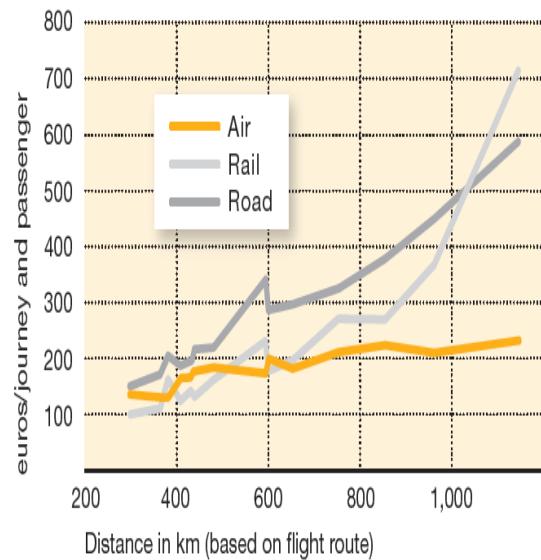


FIGURE 19 -ENVIRONMENTAL COST ADVANTAGE OF AIR TRANSPORT AGAINST RAIL AND ROAD TRAVEL

change, noise, local air quality, non-renewable resources and waste. Qatar Airways created the innovative “Five Pillar Corporate Social Responsibility Strategy,” which embraces Change Management, Environment, Integrated Fuel Management, and Communication and leads to Sustainable Development.

One of the Most Efficient Aircraft Fleets in the Industry

At just 3.2 years old in 2010, Qatar Airway’s state-of-the-art fleet will be among the youngest flying today, naturally helping to reduce its carbon- and noise-emissions footprint. The airline’s newest aircraft, the Boeing 777-200LR, is at the pinnacle of its effort to reduce emissions.

The airline has placed orders for new-generation Boeing 777s, Boeing 787s, Airbus A320/321s, Airbus A350s, Airbus A380s, and is in the process of almost doubling its fleet size to 120 aircraft. The highly efficient Airbus A380 will offer more fuel efficiency per passenger than a small family car. This multi-billion dollar investment will further help to improve local air quality in the neighborhood of the airline’s destinations and reduce the overall emission of greenhouse gases and the noise level. Already today the fleet meets the most stringent ICAO noise levels.

In 2007, Qatar Airways was the first airline in the region to host a visit from a “Green Team,” which conducted a Fuel Efficiency Analysis and presented its findings. Qatar Airways subsequently implemented a “state-of-the-art” fuel-management system and, coupled with its modern fleet, achieved one of the lowest carbon footprints of a legacy carrier with just 94.5 grams per RPK, compared to 109 and 111 grams per RPK among other legacy carriers.

Alternative Fuels – Gas-to-Liquid Jet Fuel

Qatar Airways is a travel industry innovator when it comes to the study of the potential commercial use of jet fuel derived from natural gas as a means of reducing the impact of aviation on local and global air quality. The airline has partnered with companies such as Qatar Petroleum, Shell, Airbus, Rolls Royce, Qatar Science & Technology Park and Woqod with a view to testing the use of cleaner burning alternative fuels on commercial flights. Qatar Airways and its partners are striving to make a jet fuel blend including Gas-to-Liquids (GTL) kerosene a cleaner-burning

fuel of choice for the air transport industry in the future. A Letter of Intent has been signed at the Dubai Airshow on November 17, 2007.

The world's largest Gas-to-Liquids production plant is currently under construction in Qatar under a development and production sharing agreement between Qatar Petroleum and Shell. Qatar Airways aims to be the first airline in the world to operate a commercial flight using jet fuel containing Gas-to-Liquids kerosene. In February 2008, an Airbus A380 conducted the first test flight of a commercial aircraft using GTL Jet Fuel, flying from Filton, UK, to Toulouse, France. The study partners are driving industry initiatives such as Commercial Aviation Alternative Fuels Initiative (CAAFI) to include GTL Jet Fuel in jet fuel specification (50 percent blend). The ASTM specifications, D7566, were published just two weeks before the first commercial flight took to the skies. Qatar Airways was the first airline in the world to fly commercially on GTL. On October 12, 2009, it flew an Airbus A340-600 from London to Doha on a 50-percent blend of GTL and Jet A1 in all four engines.

GTL Jet Fuel will likely be used in a semi-synthetic 50/50 blend with conventional jet fuel and can be used without any modifications to existing aircraft and engines. GTL Jet Fuel is virtually free of Sulphur and aromatics. As a result, the aircraft engine will emit less Sulphur Oxide and fewer particulates during operation. The environmental benefits of this change are being quantified and are likely to include improved air quality around airports. GTL Jet Fuel has higher energy content by weight compared to conventional jet fuel; for example, it has a lower density. It also offers improved thermal stability, meaning engines would be able to run hotter. Both of these characteristics may lead to potential fuel economy and improved payload/range performance, which could result in a limited CO₂ benefit for specific aircraft/route combinations.

These cleaner-burning fuels could become a major factor in future air quality improvement initiatives for the entire airline industry, further proving that Qatar Airways' product leadership extends far beyond passenger comfort.

From GTL to BTL – Qatar Airways Pursues its Roadmap

On January 10, 2010, Qatar Airways, Qatar Science & Technology Park (QSTP) and Qatar Petroleum (QP) announced that they would jointly carry out engineering and economic analysis before moving on to the development of sustainable bio jet fuel,

also examining production and supply methods, with the support of Airbus. The Qatar Advanced Biofuel Platform (QABP) was launched; meanwhile, Rolls Royce and Qatar University joined the QABP. The ground-breaking initiative—a world first—comes just months after the State of Qatar's national airline completed an historical milestone in the aviation industry.

In 2009, Qatar Airways, Qatar Science & Technology Park, together with US-based Verno Systems Inc., embarked on a very comprehensive and detailed feasibility study on sustainable Biomass-to-Liquid (BTL) jet fuel and possible by-products, such as bio diesel. This study looked at all available bio feed stocks that would not affect the food or fresh water supply chain. It also considered existing and future production technologies through a viability analysis. Based on the result of this in-depth study, the partners have agreed to establish the "*Qatar Advanced Biofuel Platform*" (QABP), which will lead activities in the following four areas:

- A detailed engineering and implementation plan for economically viable and sustainable bio fuel production
- A bio fuel investment strategy
- An advanced technology development program
- Ongoing market and strategic analysis

These activities will be built on, and primarily motivated by, the objective of executing advanced bio fuel projects, with Qatar Airways initially as a dedicated end-user. QABP will be structured so that it can be expanded to include additional projects, technologies, investments and partnerships on a global scale. QABP takes a portfolio approach to the development of advanced bio fuels across feed stocks, technologies and geographies in order to meet short-, medium- and long-term goals. Specific feed stocks have been identified that could be developed and processed with the aim of providing access to BTL jet fuel for use by Qatar Airways.

In conclusion, Qatar Airways has identified energy security and the reduction of the environmental impact as key elements of its strategic approach in order to ensure sustainable growth and development. Currently, airlines fully depend on crude oil-derived jet fuel, but this is changing. The era of cheap oil is considered over and, according to reports from the IEA, the world may face the effects of "Peak Oil" within the next few years. This would result in prices climbing to unprecedented levels, higher than in 2008. At the same time, the industry faces environmental charges,

such as from the EU Emissions Trading Scheme. Taking all this into account, Qatar Airways is determined to continue investing in the development of cleaner alternative fuels.

CASE STUDY IV: THE SPANISH INITIATIVE FOR THE PRODUCTION AND CONSUMPTION OF BIO-JET FUEL FOR AVIATION

Airbus has joined the Spanish bio-jet fuel initiative with Iberia, Honeywell's UOP, CCE and other partners to develop a complete national value chain for the implementation of a new sustainable and renewable aviation biofuel industry in Spain.

At the 2011 Aerodays in Madrid, the Spanish Government, Iberia Airlines and Airbus signed an agreement that would strengthen the initiative. Signatories to the agreement signed include the State Secretary of Transport Isaías Táboas Suárez, Iberia Airlines Chairman Antonio Vazquez, and Airbus President and CEO Tom Enders.

The agreement promotes and backs initiatives to develop a complete biofuel production chain for Spanish aviation, using sustainable resources from production to consumption in commercial aviation, with special consideration for economic and technical analysis.

Airbus's focus is on providing expertise and management of the feasibility, life cycle and sustainability analysis. All industry players, including governments, have a role to play in helping to reduce global CO₂ emission levels. Airbus is supporting value chains to accelerate the commercialization of aviation biofuels.

The value chain brings together farmers, oil refiners and airlines to spearhead the commercialization of sustainable biofuel production. Phase one of the project will be the feasibility study. Phase two will narrow down the most promising solutions to a demonstration level. Phase three, from 2014 onwards, will be devoted to the implementation and scaling up of the production process.

The initiative is being led by the Air Safety State Agency (AES) and the Services and Studies for Air Navigation and Aeronautical Safety/Observatory of Sustainability in

Aviation (SENASA/OBSA), under the auspices of the Ministries of the Environment, of Transportation and of Industry.

3.3.2 AIRPORT OPERATORS

The airport is a uniquely complicated space, typically bringing together hundreds of companies, thousands of vehicles and millions of passengers. Airlines, air traffic control, ground handlers, baggage handlers, catering companies, refueling trucks, passenger shuttles, airport maintenance services, emergency services, police, border control, retailers—all of these have a place at the airport.

Since the 1970s airports have been carrying out environmental management programs dealing with monitoring air quality, water management, noise mitigation and biodiversity management. Now, in the context of climate change, different initiatives are under way to help lower carbon dioxide emissions at the airport. One recent initiative is *Airport Carbon Accreditation*, launched by ACI EUROPE in 2009 (see: www.airportcarbonaccreditation.org). This program assesses and recognizes participating airports' efforts to manage and reduce their CO₂ emissions, with an ultimate objective of becoming carbon neutral. Airports can participate at any of the four following levels: 1. Mapping, 2. Reduction, 3. Optimization and 3+. Carbon Neutrality. Airport Carbon Accreditation is an independent program administered by WSP Environment & Energy, an international consultancy firm appointed by ACI EUROPE to enforce the accreditation criteria for airports on an annual basis. The administration of the scheme is overseen by an Advisory Board. As of September 2011, 43 European airports were participating in the program, representing 43 percent of European passenger traffic. It is expected that by the end of 2011, the first airport outside Europe will also join the program.

Airports must have their carbon footprints independently verified in accordance with ISO14064.¹³ Evidence of this verification must be provided to the administrator, together with all claims regarding carbon management processes, which must also be independently verified. The definitions of emissions footprints used by Airport Carbon Accreditation follow the principles of the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute

¹³ International standard for greenhouse gas emissions inventories and verification.

(WRI) "Greenhouse Gas Protocol" Corporate Accounting and Reporting Standard. When considering the emissions from aircraft within the airport perimeter and on final approach and initial departure, Airport Carbon Accreditation uses ICAO's definition of the landing/take-off cycle and requires airports to comply with these definitions.

Operational measures at the airport to improve the efficiency of aircraft fuel use can include:

- a facility layer to minimize taxiing time
- providing fixed electrical ground power and pre-conditioned air to reduce aircraft APU usage.

Other low-carbon and energy-efficient airport operational measures for terminal and ground-based activity include:

- alternative power sources
- modernized and alternatively-powered ground vehicles and ground service equipment
- efficient airport access, including public transport
- energy-efficient architecture and building design.

CASE STUDY V: ZURICH AIRPORT, NEW PIER E

General information

The construction of Pier E was part of the fifth expansion of Zurich Airport (IATA Airport Code: ZRH). From the beginning, the building was optimized for energy efficiency and conservation of natural resources. Today, Pier E includes several features that profit from its particular conditions and contribute essentially to the fact that Zurich Airport could stabilize its total energy consumption in spite of the expansion. Already during the construction phase, from 2000 to 2003, measures were taken to minimize adverse environmental effects. That means, for example, that construction companies were bound to employ vehicles with particle filters and that concrete was manufactured on site.

ZRH Key Figures 2010

268,765 movements

174 destinations

22.9 million passengers

440,000 t cargo/mail

24,000 staff

The new pier is located between runways, which results in shorter taxiways for aircraft. Therefore, the time during which aircraft engines are running is reduced, which saves fuel and reduces emissions on the order of 11,000 tons of CO₂ annually. Additionally, because of the central location of the pier, aircraft have to cross other runways less frequently, resulting in more efficient ground traffic with less waiting time and overall safer operations.

Today, with its 27 gates all featuring passenger loading bridges, Pier E represents the core of intercontinental air traffic at Zurich Airport. One aircraft stand was designed and was later equipped with a third passenger loading bridge to accommodate new large aircraft, such as the Airbus A380. Pier E is linked to the terminals by the Skymetro for passengers and by a road tunnel for handling vehicles. The Skymetro is a cableway, hovering on a 0.6 mm air cushion. In 2009, 25 percent of the airport's 22 million passengers were handled at Pier E.

Zurich Airport has reduced its own CO₂ emissions from scopes 1 and 2 (emission sources owned and operated by Zurich Airport and external electricity purchased) by more than 15,000 tons (a decrease of 31 percent) since 1991, despite a 40-percent increase in infrastructure and a 60-percent increase in traffic units. In addition, total energy consumption for the entire airport has been stabilized at the level of the year 1994. This has only been possible through concerted efforts to attain energy efficiency and conserve natural resources when renovating the infrastructure and realizing new buildings like Pier E. The achievements of the airport have been credited through the Airports Council International (ACI EUROPE) *Airport Carbon Accreditation* program.



FIGURE 20 - ZURICH AIRPORT PIER E, CENTRALLY LOCATED BETWEEN RUNWAYS, REDUCING AIRCRAFT TAXIING TIMES



FIGURE 21 - CONSTRUCTION OF THE ENERGY PILES

Due to the unstable soil, the pier was constructed on 441 piles. Of these piles, approximately 310 were equipped as energy piles,¹⁴ reaching 30 meters down to the ground moraine. A water-glycol mixture is pumped through tubes integrated into the concrete piles in order to exchange heat with the surrounding soil. This heat-

¹⁴ Energy piles are foundation piles made of concrete that contain two inlaid hoses connected on the bottom with a water-glycol mix. This liquid is used to transport heat from the building to the stable ground water table and back.

exchanger is being used in conjunction with the ground water-saturated soil as a seasonal storage unit. During the summer, internal excess heat is collected through a heat exchange and ventilation system and is stored in the soil via the energy piles.

The necessary cooling that is required for the heat exchange can be provided almost entirely by the energy piles. In winter, the heating can be covered by internal excess heat and heat from the soil storage. A heat pump is used as part of this process. In total, about 80 percent of the cooling and 50 percent heating demand can be covered by this system. This concept was recognized with the Swiss Geothermal Award 2010, received from the Swiss Geothermal Society.

Photovoltaic plant

The roof of pier E as the “fifth façade” has a triple function: the roof as a solar power plant, the shading of the façade, and a design function. Approximately 5,000 solar

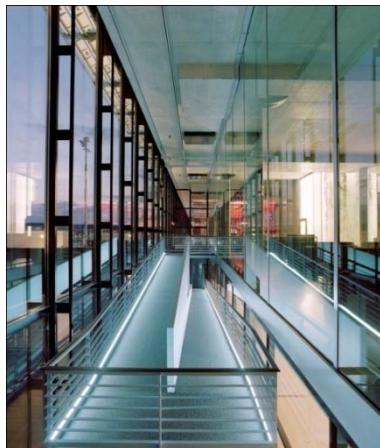


FIGURE 22 - CLIMATE BUFFER FAÇADE



FIGURE 23 - PHOTOVOLTAIC PLANT ON THE ROOF OF PIER E

modules cover an area of 5,800 square meters. The solar plant is designed as part of the electricity network. The power production of 270,000 MWh per annum contributes to the electricity supply of Pier E. The additional costs for the plant were approximately US\$3 million. In 2002, the airport received the Swiss solar prize award for its solar initiatives. The plant saves about 80 tons of CO₂ and is an important contributor to the protection of non-renewable resources.

Glass façade as climate buffer

The double-glass façades have a substantial share in contributing to energy efficiency by functioning as climate buffers. The air inside the 3-meter-wide space between the two glass walls is hardly mixed with air inside the building and therefore is effectively insulating the interior from extreme temperatures outdoors. The heated air during the summer months and the cooled air during winter inside the buffer are led away by natural ventilation directly over the roof. Thanks to this excellent insulation and use of the excess heat emitted by technical equipment and people, the overall energy used for heating can be reduced. Furthermore, the use of glass for most parts of the façade allows utilizing daylight to a great extent, which lowers the power consumption for lighting significantly.

Fixed ground power for aircraft

All aircraft stands are equipped with fixed ground systems for supplying aircraft with electricity (400 Hz) and pre-conditioned air (PCA). Electricity is provided directly to the plane by cable, the conditioned air through a flexible tube. In return, the fuel-consuming auxiliary power units (APU) of the aircraft can remain switched off. The use of the stationary systems, which are located inside and underneath the buildings, is mandatory. This measure contributes substantially to reducing fuel consumption and improving air quality at the apron and in the area surrounding the airport. Considering all equipped gates at the airport (piers A and E), the savings total up to 30,000 tons of CO₂ annually.



FIGURE 24 - FIXED GROUND POWER SYSTEM AT PIER E

Worldwide initiatives

Zurich airport's Pier E demonstrates the various opportunities that can be implemented with a systematic approach to energy efficiency that starts already at

the master planning stage and seamlessly continues throughout the design, construction and operation phase. Given the long lifetime of airport infrastructures, it is even more important to consider a range of options aimed at reducing environmental impacts. Today, many airports worldwide undertake various and successful initiatives to respond to the concerns associated with the use of energy resources and climate change.

3.3.3 AIR NAVIGATION SERVICE PROVIDERS

Every day, over 100,000 flights take off from airports worldwide. Some are short hops to nearby destinations, while some flights cross the oceans; all, however, have to share the same sky. It is estimated that up to 8 percent of all aviation fuel is wasted as a result of inefficient routing. Fortunately, the global air navigation industry is evolving and has embraced measures aimed at handling aircraft in increasing numbers, more safely, efficiently, and in more environmentally responsible ways than in the past.

Airspace is divided into different control sectors. Before a flight, the pilot files a flight plan that outlines the aircraft's intended route. Details of the flight will be determined in conjunction with air traffic control, including the altitude at which the aircraft will fly and the time at which it will pass through various sectors. Controllers will therefore know in advance how much traffic is coming their way before an aircraft actually enters their airspace. In many areas, one controller manages an aircraft's flight plan data while another monitors the traffic flow on the radar screen, talking to the pilot directly on the radio if route changes or weather issues need to be negotiated. With radar, aircraft are normally separated by five nautical miles (9.2 km) from each other horizontally; without radar, depending on the area of the world, between 30 and 50 nautical miles (55 to 92 km) is the normal minimum separation distance.

The number of aircraft in service is expected to double over the next 20 years. This growth can only be accommodated safely if the "control" function evolves into an air traffic "management" (ATM) system. This will require redesigning the ATM system around the performance of the flight itself, with controllers managing the optimized use of the airspace rather than taking "hands-on" tactical control of each flight. Once implemented worldwide, the 21st century aircraft that airlines are flying today will

fly in a 21st century air navigation system, instead of one that has its origins in the 1940s. This will allow controllers to handle more aircraft at a given time while improving the level of safety and reducing delays.

Two elements will be required to make this possible:

- i. The development of new technologies based on automated data links for communications, navigation and surveillance, which will allow the aircraft to fly within a global framework of information systems, rather than rely on voice communications between pilots and air traffic control. In this framework, aircraft will dynamically change their direction and altitude to exploit prevailing weather and traffic conditions.
- ii. The recognition that an ATM system is not a national but a global operation, with common automated technologies and procedures, many of them based on satellite data links. A fragmented airspace is an inefficient airspace. Each time an aircraft currently crosses a national boundary, the workload in the cockpit and in the control room rapidly increases. The new ATM system will automate many of the tasks currently handled by the pilot and the controller.

The benefits of moving from a national to an international approach to air traffic control services have been proven for some time. On January 24, 2002, reduced vertical separation minimum (RVSM) was introduced in the airspace of 41 European countries. This meant that, between the altitudes of 29,000 feet and 41,000 feet, the vertical separation distance between aircraft was reduced from 2,000 feet to 1,000 feet and, as a result, six new flight levels were created. The introduction of RVSM increased the en-route airspace capacity above Europe by 14 percent overnight (Eurocontrol RVSM). More capacity has resulted in reduced flight delays, better fuel economies for aircraft operators, more operational flexibility for air traffic controllers and, last but not least, considerable environmental benefits from reduced fuel burn.

On certain oceanic routes, flight control computers are automatically plotting their own most efficient routings with some impressive results. One airline, for example, has been working with Australian air traffic management to save almost 10 million liters of jet fuel and 772 hours of flight time in five years.¹⁵ It does this by exploiting the jet streams and tailwinds in the Indian Ocean.

¹⁵The airline is Emirates of the United Arab Emirates.

Next generation air traffic management

The next generation of ATM network-enabled technologies—based on the Single European Sky ATM Research program (SESAR) in Europe and the Next Generation Air Transportation System (NextGen) program in the US—promise to deliver considerably more efficiencies by maturing and implementing ATM technologies and procedures.

The SESAR goals are to triple airspace capacity by 2020 in Europe, halve the costs of providing air navigation services, reduce the environmental impact per flight by 10 percent over 2005 levels and improve safety by a factor of ten. NextGen is expected to yield significant benefits in terms of delay reduction, fuel savings, additional capacity, improved access, enhanced safety, and reduced environmental impact. The US Federal Aviation Administration estimates that NextGen will reduce delays by 35 to 40 percent in 2018, compared with today's systems (FAA); every minute of delay avoided also means a reduction in fuel use. SESAR and NextGen will enable air traffic control to evolve further—from air traffic management to air traffic enabling—freeing the aircraft to fly at its most efficient profile possible while achieving new levels of safety in the air and on the ground.

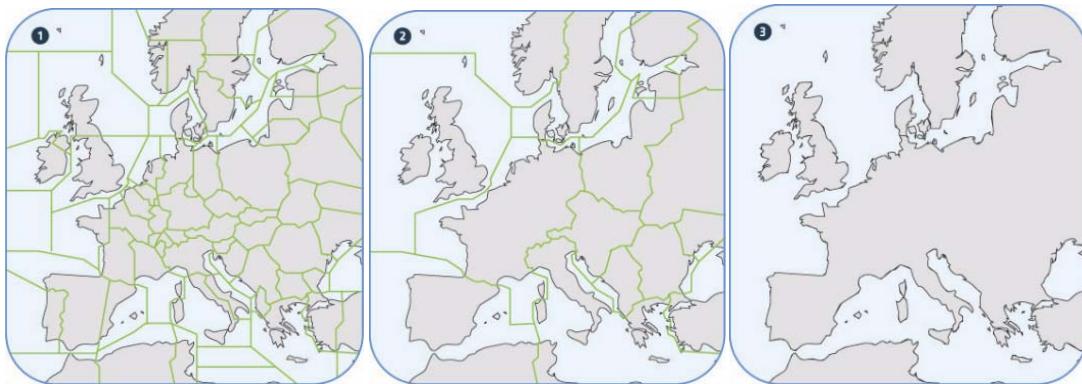


FIGURE 25 - MOVING TOWARDS A SINGLE EUROPEAN SKY

Today, (1) the airspace over Europe is split into approximately 40 different flight control zones. To reduce this maze of flight paths to something more manageable and a good deal more efficient, the plan is to move in stages. In the coming years, (2) the current 36 zones will be amalgamated into 15 larger zones called "functional airspace blocks," or FABs. These will eventually also merge (3) to become a single European sky.¹⁶

Preparing for take-off

By tapping into the extraordinarily accurate navigation systems of modern aircraft, air navigation service providers (ANSP) can design new take-off, cruise and landing procedures and routings that offer some important efficiency improvements.

A number of airports and airlines are experimenting with the use of so-called "green departures," allowing pilots to take off and climb to the optimal cruising altitude in one smooth, continuous ascent. This is in contrast to the traditional method of climbing to the cruising altitude in several steps. By using this new departure method at one airport alone, some 10,000 tons of fuel and 32,000 tons of carbon dioxide were saved in a single year.¹⁷

Using satellite-based and on-board precision navigation systems, such as "Area Navigation" and "Required Navigation Performance" capabilities, allows ANSP to redesign airspace and procedures so aircraft can fly automatic fuel-saving routes into and out of the busiest airports in the world. These new departure routes have reduced departure delays by more than 2.5 minutes per flight at one airport since

¹⁶ Maps are indicative of how the consolidation of airspace in Europe will occur and are based on information from Lufthansa Policy Brief, October 2007 (http://presse.lufthansa.com/fileadmin/downloads/en/policy-brief/10_2007/Lufthansa_PolicyBrief_Oct2007_Air_Traffic_Control.pdf) and from the European Commission (http://ec.europa.eu/transport/air/single_european_sky/functional_airspace_blocks_en.htm)

¹⁷ Copenhagen Airport.

their introduction.¹⁸ Annual fuel savings are estimated at US\$34 million, with cumulative savings of US\$105 million from 2006 through 2008 (FAA 2009).

Summary of efficiency improvement measures

This section briefly describes fuel efficiency improvement initiatives. In each region, we have identified a rough timeframe for implementation and used this information to phase the global goals for efficiency improvement. Independently from these programs, individual ANSP are implementing many efficiency improvements at a national level.

Europe – Flight Efficiency Plan

The Flight Efficiency Plan is a joint initiative launched by Eurocontrol, IATA and Civil Air Navigation Services Organization (CANSO) in September 2008 to drive immediate efficiency improvements. The five action points of the Flight Efficiency Plan are:

1. Enhancing European en-route airspace design through annual improvements to the European ATS route network, high priority being given to:
 - Implementing a coherent package of annual improvements and of shorter routes;
 - Improving efficiency for the most penalized city pairs;
 - Implementing additional Conditional Routes for main traffic flows;
 - Supporting initial implementation of free route airspace.
2. Improving airspace utilization and route network availability through:
 - Actively supporting and involving aircraft operators and the computer flight plan service providers in flight plan quality improvements;
 - Gradually applying route availability restrictions only where and when required;
 - Improving the utilization of civil/military airspace structures.
3. Achieving efficient TMA design and utilization, through:

¹⁸ Atlanta International Airport.

- Implementing advanced navigation capabilities;
 - Implementing Continuous Descent Approaches (CDA), improved arrival/departure routes, optimized departure profiles, and others.
4. Optimizing airport operations, through:
- Implementing Airport Collaborative Decision Making.
5. Improving awareness on performance.

The implementation of the improvements is expected to bring benefits of approximately 1.5 metric tons of CO₂ per year, which equates to just over 1 percent improvement over the 2005 baseline for Europe. The Flight Efficiency Plan indicates that the greatest benefit is in improved airspace utilization, in the terminal area/airport operations, and goes on to say that ATM on its own can achieve little.

Europe - SESAR

The Single European Sky Air Traffic Management Research program (SESAR) is the European Union's 30 billion Euro air traffic management modernization program.

The proposed SESAR vision is to achieve a performance-based European ATM system, built in partnership, to best support European States'—including military—expectations for air transport with respect to the growing mobility of both citizens and goods and all other aviation activities, in a safe, secure, environmentally sustainable and cost-effective manner.

It combines technological, economic and regulatory aspects and will use the Single European Sky (SES) legislation to synchronize the plans and actions of the different stakeholders and bring together resources for the development and implementation of the required improvements throughout Europe, in both airborne and ground systems.

Objectives for environmental impact reduction

The objectives are to achieve a future European ATM system for 2020 and beyond, which can, relative to today's performance:

- Enable a 3-fold increase in capacity that will also reduce delays, both on the ground and in the air;

- Improve the safety performance by a factor of 10;
- Enable a 10-percent reduction in the effects flights have on the environment; and
- Provide ATM services at a cost to the airspace user that is at least 50 percent less than at present.

Implementation

ATM performance covers a very broad spectrum of aspects, which are represented through eleven Key Performance Areas (KPAs). One KPA is *Environment Efficiency*, which will deliver its maximum contribution to the environment. As a first step towards the political objective of enabling a 10-percent reduction in the effects of flights on the environment:

- Achieve the implicit emission improvements through the reduction of gate-to-gate excess fuel consumption addressed in the KPA Efficiency. However, no specific separate target could be defined at this stage for the ATM contribution to atmospheric emission reductions.
- Minimize noise emissions and their impact for each flight to the greatest extent possible.
- Minimize other adverse atmospheric effects to the greatest extent possible. Suitable indicators are yet to be developed.
- The aim is that all proposed environmentally-related ATM constraints would be subject to a transparent assessment with an environment and socio-economic scope, and, following this assessment, the best alternative solutions from a European sustainability perspective are seen to be adopted.
- Local environmental rules affecting ATM are to be 100 percent respected (e.g. aircraft type restrictions, night movement bans, noise routes and noise quotas, etc.). Exceptions are only allowed for safety or security reasons.

NextGen is a wide-ranging transformation of the entire US air traffic management system. It will replace ground-based technologies with new and more dynamic satellite-based technology.¹⁹ It is a collaborative effort between

¹⁹ More information about SESAR can be found at <http://www.sesar-consortium.aero/USA - NextGen>

the FAA and partners from the airports, airlines, manufacturers, government agencies, state, local and foreign governments, universities and associations.

Objectives for environmental impact reduction

Establish the most cost-effective approach to reducing the significant impact of aviation noise and emissions in absolute terms while enabling the future air traffic system to handle growth in demand.

Performance targets, as documented in the FAA Flight Plan, include:

- Reduce the number of people exposed to significant noise by 4 percent each year through FY2011, as measured by a three-year moving average, from the three-year average from calendar years 2000-2002.
- Improve aviation fuel efficiency per revenue plane-mile by 1 percent each year through FY2011, as measured by a three-year moving average, from the three-year average from calendar years 2000-2002.

For NextGen by 2015:²⁰

- Reduce significant aviation noise and local air quality emissions in absolute terms in a cost-effective way through a combination of new vehicle technologies, cleaner and quieter operations, better land use and alternative fuels.
- Limit or reduce the impact of aviation greenhouse gas emissions on climate change.
- Document the effects of particulate matter and global climate impacts understood to levels that allow appropriate metrics and action.
- Determine and mitigate significant water quality impacts.

²⁰ Further details on these initiatives are available at
http://www.faa.gov/about/office_org/headquarters_offices/ato/publications/nextgenplan/

**TABLE 6 - SELECTED IMPLEMENTATION ACTIVITIES RELATING TO
ATM FUEL EFFICIENCY**

FAA-Nextgen Initiative	Flight phase affected	Selected ATM Implementations		
		Near Term Committed	Mid Term 2012-2018	Far Term 2020*
<u>Collaborative Air Traffic Management</u>				
Airspace Flow Program	Horizontal, Delay, Taxi			
Reroute Impact Assessment and Resolution	Taxi and Horizontal			
TMI w flight specific trajectories	Taxi and Horizontal			
Improve Special Airspace Management	Horizontal			
Trajectory flight data management	Horizontal			
Manage Airspace to Flow/Trajectories	All airspace delay/Taxi			
Full Collaborative Decision Making	Horizontal/Vertical/Taxi			
<u>Initiate Trajectory based Operations</u>				
RNAV/RNP Increased Departure Routes	Taxi and terminal			
NY and ORD Area Airspace Redesign	Taxi and terminal			
Time Based Metering (moves delay to more fuel efficient altitudes)	Delay and vertical			
ADS-B in Gulf of Mexico	Delay/Horizontal			
Delegated responsibility for Separation	Horizontal/Vertical			
Initial Conflict Resolution Advisories	Horizontal			
Point in Space Metering	All			
Increase Capacity and Efficiency Using RNAV and RNP	All			
Expand Conflict Resolution via Data Communication	Horizontal			
<u>Increase Arrivals and Departures at High Density Airports</u>				
Improved operations at closely spaced parallel runways	All in Low Vis			
Initial Surface Traffic management	Taxi			
Time Based Metering Using RNAV and RNP Route Assignments	Horizontal/Vertical			
Integrated Arrival and Departure Airspace management	Horizontal/Vertical/Taxi			
Optimize Runway Assignments	Taxi			
Use Data Management to Provide Flow and Taxi Assignments	Taxi and Horizontal			
Reduce Horizontal Separation Standard to 3 miles	Horizontal			
Full Surface Traffic Management with Conformance Monitoring	Taxi			
Use Aircraft Provided Intent Data to Improve Flow and Conflict resolution	Horizontal/Vertical			

*Far Term designates initial operating capability prior to 2025

Asia-Pacific - Aspire

Asia and South Pacific Initiative to Reduce Emissions (ASPIRE) is a partnership between the FAA, Airservices Australia and Airways New Zealand. The ASPIRE Agreement was signed on February 18, 2008 with ongoing collaboration leading to the first ASPIRE flight, which took place in September 2008.

Objectives for environmental impact reduction

The aim is to work closely with governments, airlines and other air navigation service providers in the region to:

- Accelerate the development and implementation of operational procedures to reduce the environmental footprint for all phases of flight on an operation-by-operation basis, from gate to gate;
- Facilitate worldwide interoperability of environmentally friendly procedures and standards;
- Capitalize on existing technology and best practices;
- Develop shared performance metrics to measure improvements in the environmental performance of the air transport system; and
- Provide a systematic approach to ensure appropriate mitigation actions with short-, medium- and long-term results.

ASPIRE partners have committed to moving forward to foster the implementation of the program along key Asian and South Pacific routes. ASPIRE believes that aggressive action to realize new concepts of operation and take advantage of innovations in aircraft and air traffic management technology are crucial if aviation is to exercise its proper stewardship of the environment.

A series of flights have taken place from New Zealand and Australia to Los Angeles and San Francisco using fuel-efficient procedures that have demonstrated savings of many tons of CO₂ emissions.

These flights have made use of fuel-efficient ATM procedures, such as:

- priority clearance from air traffic control for taxiing and departure;
- priority departure route out of Los Angeles and unimpeded climb to cruise altitude;
- permission to reach optimum cruise altitude as quickly and efficiently as possible;
- adoption of a user-preferred route for the most efficient path, taking into account winds and aircraft weight;
- real time updates of current weather and wind conditions that allow the flight crew to modify their flight path; and
- a tailored arrival procedure.

With approximately 156 flights per week between Australia, New Zealand and the United States and Canada, the potential annual savings from initiatives such as the

ASPIRE Programme are in excess of 100,000 tons of CO₂ emissions. More research is needed to determine if the ASPIRE demonstrations can be realized in more congested regions of airspace.

**TABLE 7 - AIRSERVICES AUSTRALIA SELECTED ACTIVITIES
RELATING TO ATM FUEL EFFICIENCY**

AirservicesAustralia Initiative	Flight phase affected	Implementation			
		2005	2010	2015	2020
Flextracks	Horizontal enroute				
User-Preferred Routes (UPR)	Horizontal enroute				
ADS-B	All				
Gate-to-Gate, System Wide Information Management (SWIM), Collaborative Decision Making (CDM)	TMA/Ground				
Continuous Descent Approach (CDA)	Vertical				
Tailored Arrivals (TA)	Vertical				
Green Approaches - Required Navigation Performance (RNP) Approach and Departure	TMA				
Pre-departure ground holding	Ground				
Speed control - ATM Long Range Optimal Flow (ALOFT) and Maestro	Horizontal enroute				
Airspace Management (SIDS/STARS design)	TMA				
GNSS Approaches	TMA				

4 POLICY OPTIONS FOR DEVELOPING COUNTRIES ON ENERGY EFFICIENCY

Developing countries face specific challenges in regard to increasing energy efficiency in aviation. Evaluating the opportunities and roles that the government and private sector can play in these countries to support the improvement of energy efficiency in aviation requires a more detailed evaluation of the challenges.

4.1 AIR TRANSPORT SECTOR IN DEVELOPING COUNTRIES

For the purpose of this report, within the group of developing countries we will differentiate between countries with high-density air traffic and countries with low-density air traffic. Developing countries with a relatively high density of air traffic fall into the World Bank category of International Bank for Reconstruction and Development (IBRD) countries, thus middle-income and credit-worthy lower income countries with a per capita income of between around US\$1,000 and US\$10,000, which qualify to borrow from the World Bank's IBRD group.

Countries with low-density air traffic mainly fall into the World Bank category of IDA countries, or countries with lower per capita income (in 2009, of less than US\$1,165) that lack the financial ability to borrow from the IBRD but are eligible to receive low- or no-interest loans and grants from the World Bank International Development Association (IDA). An overview of IBRD and IDA countries can be found in Annex 2.

In IBRD countries, the satisfactory or strong air traffic growth in recent decades has led these countries to primarily focus on maintaining safety and meeting capacity with increased traffic. Reducing fuel consumption and increasing energy efficiency within the sector has obtained little or hardly any attention so far and is not demanded by most operators at this time. However, with increasing oil prices or a globally binding environmental framework, such as the European ETS, IBRD countries are expected to have incentives to implement energy-efficiency measures

similar to those of developed countries. IBRD countries might also be among the largest benefiters from carbon credits under ETS schemes in developed countries (e.g., China, Mexico, and Thailand). For IBRD countries, it is expected that the private sector and the government adopt the most appropriate policies to support the move toward higher energy efficiency in aviation and that these policies resemble those described for developed countries in the previous sections of this report. They are not discussed further in this section.

In IDA countries, the challenges are greater. Due to the low density of air traffic, operators can only generate low income from flight operations (e.g., Malawi, Haiti, and Burkina Faso). In addition, those countries generally have weak institutional capacity (e.g., they have difficulty retaining good professional staff), few incentives to improve operations (e.g. they lack adequate policy), serious governance problems, such as corruption and poor supervision (equipment stolen or sold, e.g. airport installations) and no or very little international awareness about or interest in improving the efficiency of operations. In the IDA country context, many of the aspects discussed in previous sections of this report do not hold (some of the policies capable of driving change in developed or IBRD countries might not lead to the desired results).

At the same time, different opportunities might also exist to help overcome the specific challenges facing IDA countries. For example, multi-lateral development banks (MDB) can intervene to help support infrastructure improvements and development. In regard to the need for innovative financing models for fleet renewal, manufacturers can collaborate with export/import banks or government guarantees. Knowledge transfer with respect to the lack of skilled labor technology for developing countries is also an opportunity worth exploring.

The following sections of this report will discuss the specific challenges and the opportunities in IBRD and IDA countries in greater detail.

4.2 TAXATION AND FISCAL MEASURES

Carbon market

Below is a list of options that countries and international organizations may consider when leveraging carbon markets to support energy-efficient and low-carbon growth:

- Develop a green fund for the purpose of purchasing certified offsets from aviation-related industries;
- Generate certified offsets, through schemes such as the CDM (would apply to domestic aviation only);
- Work with the UNFCCC (in collaboration with the International Maritime Organization, which faces challenges similar to those of the ICAO) on developing a CDM-like offset scheme for the aviation sector as a whole, which would enable participation from developed and developing country members; or
- Develop an internal compliance or voluntary allowance trading scheme within the global aviation sector (with linkages to external offset markets).

Specific recommendations for IBRD and IDA countries

- Taxes or tax incentives do not work if no taxes are paid, because carriers are not profitable → support the restructuring, privatization or liquidation of non-viable state-owned airlines;
- Financing of energy-efficient aircraft of commercially sound carriers by IFC or similar organizations should also be considered from an environmental standpoint;
- Government subsidies, grants, and lump-sum fiscal incentives are appropriate if funds are available; if not, they could use money flowing into the country from abroad, for example development aid; however, these funds are often limited and compete with more urgent sectors;
- FDI policy can provide new options for private foreign investment (e.g. for airport infrastructure development “green solutions” should be mandated);
- The most promising option involves government with technical assistance and investment finance supporting sustainable infrastructure development projects, which lead to the highest adaptation rates to energy efficiency and the reduction of greenhouse gas emissions.

5 SUPPORT AND FINANCING OF MEASURES ADDRESSING AIR TRANSPORT AND ENERGY EFFICIENCY

5.1 NATURE AND DESIGN OF POTENTIAL WORLD BANK GROUP PROJECTS FOR ENERGY EFFICIENCY IN AIR TRANSPORT (POLICY ADVICE, TECHNICAL ASSISTANCE, INVESTMENT LENDING)

Infrastructure improvements are especially important in developing countries to ensure that these countries are able to experience the positive economic returns provided by growth in trade, tourism, and service that efficient ground air-transport infrastructure and air-navigation services can bring.

MDB can play a major role in developing countries, for example through the establishment of specific green funds. MDB already finance airport infrastructure to some extent today, but specific green funds such as those established by the World Bank in the past have not yet been used to finance aviation projects. A successful example is the Egyptian Government's NAVISAT²¹ initiative that aims to provide satellite-based ATM services for Africa and the Middle East and that was initially financed with help from the African Development Bank (AfDB).

5.2 IBRD OR IDA FINANCING FOR INFRASTRUCTURE INVESTMENT TO ADDRESS ENERGY AND ENVIRONMENTAL MEASURES (GREEN AIRPORTS, ATC DESIGN)

With a portfolio of US\$12 billion in projects with clear environmental objectives in developing countries, the World Bank is the single largest financier of environmental projects worldwide. The World Bank plans to include in its aviation

²¹ NAVISAT is an international organization that fills the regional gap in worldwide satellite-based ATM services for the Africa and Middle East region with a safe, dependable and economically viable satellite system, and which provides value-maximizing services to adjacent markets.

portfolio infrastructure and technology components that improve energy efficiency and address environmental challenges. Examples of recent airport investments with sustainable components include the financing of GNSS and instrument approaches in countries in Africa, which improve energy efficiency in fuel consumption and mitigate greenhouse gas emissions.

Although there are many options for mitigating emissions and improving energy efficiency in the aviation sector, particularly in terms of improvements in on-ground infrastructure and facilities, aircraft technology, and aircraft operations, to date, the Bank has primarily focused on improvements in on-ground facilities.

The World Bank provides sovereign loans and grants (e.g., for on-ground aviation infrastructure) and the International Finance Corporation (IFC), which is part of the World Bank Group, supports private sector investment (e.g., investment in airlines). Within the World Bank, there are several financing mechanisms designed to support energy-efficiency programs that reduce greenhouse gas emissions; these could be mobilized to assist ICAO's developing country members meet greenhouse gas emissions mitigation and efficiency goals. These financing mechanisms fall into three categories: 1) program design and piloting support; 2) implementation support; and 3) on-going operations and maintenance support.

Program design and piloting support include grant programs that help developing countries overcome initial technical and other barriers to introducing new technologies. The most significant grant program is the Global Environment Facility, which provides grant assistance for new green initiatives, but the Bank also manages dozens of other trust funds targeted at supporting green investments. After initial barriers to introducing new technologies are overcome, the Bank can provide technical and financing support to implement the technology on a larger scale through concessional financing and green bonds. Finally, after a project is developed, to mitigate on-going operations and maintenance costs, the Bank offers support through carbon finance, a performance-based mechanism that rewards programs for reducing greenhouse gas emissions. The following section describes these financing mechanisms in greater detail.

GLOBAL ENVIRONMENT FACILITY PROGRAM

The Global Environment Facility (GEF) was established in 1991 before the United Nations Convention on Environment and Development to provide incremental cost financing for projects with global environmental benefits. It was originally a partnership between the United Nations Development Programme, the United Nations Environment Programme, and the World Bank, but it now provides its support through 10 agencies. In recent years, the GEF has committed about US\$250 million per year—largely in the form of grants to eligible countries—as the financial mechanism of the UNFCCC. These projects are designed to support energy efficiency, renewable energy, new clean energy technology, and sustainable transport projects. Its approach focuses on removing barriers to “win-win” mitigation projects by providing support for technical assistance, policy reform, capacity building, piloting, and partial risk guarantees.

GEF grants through the World Bank average between US\$8 million and US\$10 million each and are meant to be implemented as part of a larger investment engagement. It is undertaken in an eligible country and consistent with national priorities and programs.

In general, a GEF-eligible project will meet the following criteria:

- It addresses one or more of the GEF Focal Areas, improving the global environment or advancing the prospect of reducing risks to it;
- It is consistent with the GEF operational strategy;
- It seeks GEF financing only for the agreed-on incremental costs on measures to achieve global environmental benefits;
- It involves the public in project design and implementation; and
- It is endorsed by the government(s) of the country/ies in which it will be implemented.

Given these criteria, most investments in improving the sustainability and efficiency of on-ground facilities would be eligible for participation.

The GEF has recently completed negotiations for its fifth replenishment; new donor funding has increased by 52 percent to US\$3.49 billion, the largest increase in GEF

history. With projected carry-over from the previous replenishment period, total funding available for disbursement beginning this fiscal year will be US\$4.25 billion.

GREEN BONDS

The World Bank Green Bond Program raises funds from fixed-income investors to support lending for eligible projects that seek to mitigate climate change or to support adaptation. The product was designed in partnership with Skandinaviska Enskilda Banken (SEB) to respond to specific investor demand for a triple-A rated fixed-income product that supports projects that address the climate challenge. Since 2008, the World Bank has issued approximately US\$1.5 billion in green bonds.

Eligible projects are selected by World Bank environment specialists and meet specific criteria for low-carbon development. Examples of the types of eligible mitigation projects are the following:

- On-site renewable power generation for on-ground facilities;
- New technologies that result in significant reductions in greenhouse gas emissions ;
- Greater efficiency in transportation, including fuel switching and mass transport (e.g., ground service vehicles);
- Construction of energy-efficient buildings (such as terminals or hangers);
- Use of low-emissions materials in construction of infrastructure facilities.

The green bond criteria have undergone an independent review with the Center for International Climate and Environmental Research at the University of Oslo (CICERO). CICERO concurred that, combined with the governance structure of the World Bank and safeguards for its projects, these activities provided a sound basis for selecting climate-friendly projects.

CLEAN TECHNOLOGY FUND

The Clean Technology Fund was established in 2008 as one of the Climate Investment Funds (CIF), a family of funds devoted to climate change initiatives hosted by the World Bank and implemented cooperatively by the multi-lateral development banks. It is meant to be transformative, taking clean technology investments and markets to scale in the participating recipient countries. Between 15 and 20 countries will participate as recipients during this initial phase, which

will run until 2012. The CTF provides limited grants, concessional loans, and partial risk guarantees of between US\$50 million and US\$200 million per project to help countries scale up clean technology initiatives intended to transform a country's development path.

To date, US\$4.3 billion in CTF financing has been pledged to programs in: Colombia, Egypt, Indonesia, Kazakhstan, Mexico, Morocco, the Philippines, South Africa, Thailand, Turkey, Ukraine, and Vietnam.

CARBON FINANCE

Under current regulations, international aviation emissions are excluded from the Clean Development Mechanism (CDM), the United Nations Convention on Climate Change (UNFCCC) program that enables developing countries to receive financial support for programs and activities that mitigate greenhouse gas emissions through the sale of offsets, called Certified Emissions Reductions (CER). However, investments in low carbon domestic aviation activities, including supporting aviation infrastructure, such as airports and related ground facilities, are eligible for participation.

As trustee of 12 Carbon Funds and Facilities, the World Bank manages a portfolio of more than 200 projects, estimated to generate more than US\$2 billion in emissions reductions (CER) through 2013. The World Bank's carbon finance products help grow the market by extending and expanding carbon finance in both developing countries and economies in transition, linking private sector buyers of carbon-emission reductions with climate-friendly projects seeking financing.

The following table lists approved CDM methodologies that may be applied to the aviation sector, with only small requests for revision:

**TABLE 8 - APPROVED CDM METHODOLOGIES THAT MAY BE APPLIED TO
THE AVIATION SECTOR**

CDM ID#	Methodology	Aviation Applications
Operations		
AMS III.T	BioDiesel	Alternative fuels*
AMS III.C	Low-emissions vehicles	Aircraft technology*; airside vehicles
AMS III.S	Low-emissions vehicles (fixed route)	Aircraft technology*
AMS III.AA	Vehicle retrofits	Aircraft technology*, airside vehicles
Infrastructure		
AMS II.C	Energy-efficient equipment	Airport facilities and terminals
AMS II.E	Building efficiency and fuel switching	Airport facilities and terminals
AMS I.D	Renewable energy generation	Power generation
AMS II.B	Renewable energy generation (grid)	Power generation

* Domestic use only

Upon approval of a project proposal from an eligible participating project sponsor, Carbon Finance Unit staff work closely with the sponsor on completing the processes for applying for CDM registration and, after program implementation, provide annual payments based on the annual emissions reductions achieved. In 2010, emission reductions were priced in the range of EUR 7 – 10 per ton of CER for pre-2013 deliveries, in the primary market.

5.3 MOVING FORWARD

It is the objective that the above-mentioned general overview of select financing mechanisms to support low-carbon, energy-efficiency growth in the aviation sector in developing countries will inspire ideas for further discussion about ways the World Bank can work with client countries to support their energy-efficient and environmental goals. In addition to these climate-specific sources of finance, the core funds of the World Bank can be used for mitigation action, either in combination with these climate-based financing courses or as stand-alone projects.

On the other hand, the governments of emerging countries as well as developed countries may take the following policy measures and set their investment priorities to achieve energy-efficiency gains in technology, operation, and infrastructure development.

FISCAL POLICY MEASURES TO SUPPORT TECHNOLOGICAL EFFICIENCY GAINS

To support energy-efficiency gains through technological innovation (aircraft, engines) beyond past annual energy-efficiency gains, additional emphasis must be placed on R&D of radical new aircraft technologies, such as a blended wing body aircraft or open-rotor engine. Once they are more mature, these new technologies could help to improve the energy efficiency of future generations of new aircraft and thus significantly influence the industry's fuel use in the future.

The most appropriate policy options to support the development, introduction and roll-out of new technology depend on the technology's respective stage of development. The following figure gives an overview of the different stages of aircraft technology development with the main policy challenges and proposed best-suited policies to overcome those challenges.

**FIGURE 26 - AIRCRAFT TECHNOLOGY POLICIES BY STATE OF DEVELOPMENT
(WORLD ECONOMIC FORUM/BOOZ & COMPANY)**

Process	Technology Research	Technology Development	Manufacturing Scale-Up	Roll-Out (Asset Finance)
Policy Challenges	<ul style="list-style-type: none"> • Increase the volume of early-stage research • Improve the flow of funding to promising research • Transfer academic research into commercial environment • Don't write off promising technologies too early 	<ul style="list-style-type: none"> • Identify scalable, lab-proven technologies • Increase availability of equity • Provide soft debt where it is required for equity to achieve target returns • Establish clear performance milestones • Avoid chasing fads • Don't try to pick winners, but cull losers aggressively 	<ul style="list-style-type: none"> • Develop a replicable blueprint for large volume roll-out • Provide support to close cost gap with mature technologies • Ensure availability of debt despite technology, market and policy risk • Support/ create lead customers 	<ul style="list-style-type: none"> • Protect public budgets • Avoid locking in uncompetitive market structures • Shift emphasis to "polluter pays" rather than maintaining subsidies forever
Policies To Address Challenges				
Fiscal Incentives	<ul style="list-style-type: none"> • R&D Tax Credits • Capital Gains Tax Waivers 	<ul style="list-style-type: none"> • Development zones (e.g. demonstration prototypes) 	<ul style="list-style-type: none"> • Accelerated Depreciation • Investment Tax Credits • Production Tax Credits 	<ul style="list-style-type: none"> • Carbon Tax
Standard/ Regulation			<ul style="list-style-type: none"> • Green Certificates • Technology standards for a/c 	<ul style="list-style-type: none"> • Best available technology requirement for new a/c
Aviation ETS		<ul style="list-style-type: none"> • Price on carbon as basis to attract (external) investment • Free EST allowances in return for R&D investment 	<ul style="list-style-type: none"> • Price on carbon as basis to attract (external) investment 	<ul style="list-style-type: none"> • Use of proceeds from ETS to support asset purchases
Capital Market Incentives	<ul style="list-style-type: none"> • Incubators • National Laboratories • Prizes • National/State-Funded VC • R&D Grants 	<ul style="list-style-type: none"> • Project Grants • Mezzanine/ Subordinated Debt Funds • Venture Loan Guarantees 	<ul style="list-style-type: none"> • Green Bonds • Loan Softening/ Loan Guarantees • Senior Debt Funds 	<ul style="list-style-type: none"> • Technology Transfer Funds

For early-stage new technologies, such as radical new aircraft technology currently still in the research stage, positive fiscal incentives such as tax credits are considered most valuable; in later stages of technology development, fiscal incentives that support the set up of larger-scale demonstration projects are critical. A price on carbon, for example through an ETS, can then constitute an additional incentive to investing in more energy-efficient technology and give a higher extent of security to investors that those investments are worthwhile and that demand for those new technologies will develop. In the phase of manufacturing scale up of the new technologies, tax incentives but also depreciation incentives can enhance the take up of the emerging, more energy-efficient technologies. In later stages of the wider technology rollout, negative fiscal measures such as a tax on carbon or energy usage could also be used to accelerate the new, more energy-efficient technologies' penetration of the market.

FISCAL POLICY MEASURES TO SUPPORT OPERATIONAL EFFICIENCY GAINS

In an effort to increase energy efficiency through operational improvements such as ATC, procedures including continuous descent approach, improved fuel management, reduction of cabin weight (e.g., through use of lightweight seats), and center of gravity optimization need to be implemented by airlines. Prior industry analysis shows that most operational improvements can be implemented by carriers at a net benefit under consideration of the expected fuel savings derived from energy efficiency increases of aircraft. Considering that fuel costs currently make up over 30 percent of total operations costs, carriers already have large incentives to implement operational efficiency improvements. The aviation industry is also already accelerating implementation of operations improvements through best practice sharing (e.g., through IATA “Green Teams” and ICAO Circulars).

However, it must be noted that operations improvements are partly dependent on infrastructure improvements (e.g., technical infrastructure required to implement continuous descent approach), and such improvements typically require up-front capital investment by the airlines. Fiscal incentives could help to overcome such up-front capital investment. Tax credits for investment in new aircraft equipment required to use more advanced ATC approaches could be one way to further incentivize and support airlines in making those critical investments to improve the energy efficiency of their operations.

FISCAL POLICY MEASURES TO SUPPORT INFRASTRUCTURE EFFICIENCY GAINS

Aviation infrastructure investments, including the introduction of new ATC systems and the modernization and improvement of existing airport infrastructure, as well as the development of new greenfield airports, are very critical to maintaining the current high operational efficiency levels and eventually further increase them, thus ensuring the energy efficiency of the aviation industry as air traffic grows over the coming decades.

Significant challenges to the implementation of infrastructure improvements currently lie in the insufficient political will and perceived sense of urgency to speed up decision making and implementation, which is also due to the insufficient

information and education of policymakers and the public on ATM challenges and necessary improvement measures. In addition, regional and national issues exist with ATM ground infrastructure and constraining policies, the lack of global ATM metrics and standards, and the existing airspace organization (e.g., airspace reserved for military versus commercial use).

Large-scale investments are required for new ATC systems and airports. Funding will mainly need to come from governments, at least initially. Fiscal policy measures to increase private sector investment are seen as less of an issue by industry experts for aviation infrastructure improvements in developed countries. However, as it is unlikely that governments will be able to provide all the required funds and because priority must be given to involving capital markets and private equity players as soon as possible, positive fiscal incentives that encourage investment in these areas could help to speed up implementation (World Economic Forum 2011).

A checklist for green airport design was recently developed by the World Bank in the context of a new feeder airport to be built in Shangrao, China (see Annex 3 for details). It also serves as a general reference to other countries interested in pursuing green airport development.

ANNEX 1 - EXAMPLES OF AIRCRAFT DESIGN IMPROVEMENT AMONG SELECTED MANUFACTURERS

This section briefly describes some of the aircraft and aircraft component improvements emerging in the marketplace over the next few years.

Airbus

The A320 Family

The A320 Family comprises the A318, A319, A320 and A321 aircraft, covering capacities from 100 to 220 seats. These aircraft have the same flight deck, systems and structural components but with different parallel fuselage/cabin lengths to offer different seating capacity; it is effectively one aircraft type in four sizes.



FIGURE 27 - AIRBUS A320

A320s are in widespread use, but there are still over 2,000 older aircraft of a previous generation and of similar size in operation. Fuel consumption per seat on today's A320 is between 11 and 25 percent lower than on legacy aircraft. The recently launched new A320 family development programs reduce fuel consumption even further. Aerodynamic refinements to the wing-body shape, which

includes the wing-pylon shape and outer wing detail, were incorporated in 2009. The development of a completely new shape of the wingtip devices (the small vertical wing-like shapes at the outer tip of the wing), now called “sharklets,” will be available in 2012. The recently launched *“New Engine Option,”* which offers two alternative power plants to those already offered on the A320, was under evaluation in 2009 and 2010 and will be available by the end of 2015. Together, these modifications will result in further fuel consumption reduction of 15 percent or greater compared to the current deliveries of the A320 versions. In addition, the new engine options within the A320 family will also generate lower airport area external noise levels, resulting in up to 14 EPNdB (Effective Perceived Noise decibels)—cumulative improvements making the A320neo compliant with future regulations and positioning it as a champion of environmental responsibility.

The A380

The A380 is Airbus’s largest model, which is a 525-seat (three-class cabin configuration) aircraft with two passenger decks and a non-stop range of over 8,000 nautical miles (15,000 kilometers).

The A380 has an entirely new wing design. The primary structure is made of roughly 25 percent composite material, the highest proportion of any commercial aircraft at the time of its service entry. The 2H/2E (H for hydraulic, E for electrical) power system is a new architecture that is significantly lighter than earlier systems. Automated fuel transfer assures better balances of the aircraft, which reduces the drag from trimming the aircraft. The aircraft’s fuel consumption per seat is about 18 percent lower when compared to previous generations of very large aircraft. Another improvement will be achieved in the longer term, when next generation air traffic management systems are introduced: the A380’s operational performance allows climbing to higher than typical cruise altitudes at the onset of a long flight, which will enable more efficient flight tracks in less crowded airspace and at cruise altitudes where aircraft operates more efficiently. In addition, the A380’s airport area external noise level is 14 EPNdB lower than that of the previous generation of very large aircraft, despite being 40 percent larger in seat capacity.

The A350 XWB Family

The A350 XWB Family is Airbus's newest design and comprises three versions with the same flight deck, systems, and engines but different parallel fuselage/cabin lengths, to cover the 250 to 400 seat capacity range.

To reduce weight, the primary structure of the aircraft will be made up of 53 percent composite material, including most of the fuselage and wing (up from about 25 percent in the A380) and 14 percent titanium. The fuselage is made from long carbon fiber panels that are easier to manufacture and to assemble than barrel sections. However, for the rear part of the fuselage, which is tapered, Airbus has selected a barrel as being the optimum structure. The aircraft's take-off weight for a given mission can be up to 50 tons lighter than that of an equivalent aircraft belonging to a previous generation. The wing benefits from the A380 design experience, complemented by extensive CFD (Computational Fluid Dynamics) analyses and inputs from various R&D programs. The result is a highly tapered platform with exceptional aerodynamics. Low speed efficiency is achieved using "droop nose" leading edge devices (certified on the A380) and simple but effective adaptive dropped hinge flaps.



FIGURE 28 - A350XB EFFICIENCY BY DESIGN

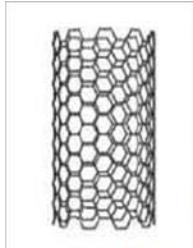
The A350 XWB will also incorporate the latest flight management software and systems allowing shorter, high precision routes and optimized ground maneuvering, further reducing fuel burn. The targeted fuel consumption of this family of aircraft is 25 percent lower than that of previous generation aircraft, which it is intended to replace.

Boeing

Similar to Airbus, Boeing has also made significant commitments in terms of the environmental performance of its commercial aircraft: (1) to deliver progressive new products and services that reduce CO₂ emissions and improve fuel efficiency by at least 1 percent; and (2) to pioneer new technologies and devote more than 75 percent of its R&D towards improving environmental performance. These commitments are a further progression of the environmental benefits that Boeing airplanes have delivered since the beginning of the jet age. Compared to the Boeing 707, Douglas DC-8 and other early jetliners, today's Boeing commercial airplanes generate 70 percent fewer emissions and have a 90 percent smaller noise footprint.

Boeing continuously seeks to make improvements to its aircraft in four areas of efficiency: structural, aerodynamic, propulsion and systems. The use of carbon fiber for the major primary structure on commercial airplanes was pioneered on the 787 in order to reduce weight. Research continues on ways to apply the next-generation composite materials to future products in order to provide even more weight reduction, which translates into less fuel used and lower CO₂ emissions. One area of research is nanotechnology—studying carbon fiber tubes whose walls are one carbon cell thick. Aerodynamic design and engine research leads to lower drag, less fuel consumption and noise reduction. The 787 was designed using state-of-the-art optimization methods and features an advanced wing design that minimizes the drag and weight of the airplane to provide unmatched fuel efficiency and low CO₂ emissions. Research continues to develop an even more efficient next generation of wings for future Boeing products. Elements of these new designs include improved airfoil technology and advanced tip treatments, with many more evolutionary and revolutionary technologies being researched. Concepts such as the raked wing tip continue to enable new, more structurally-efficient, and hence, more fuel-efficient designs. The 787 pioneered the use of “more electric architecture” to improve fuel

efficiency by reducing the need to bleed pressurized air from the engines to power pneumatic systems. System efficiency leads to power efficiency and less demand on the engine, which has environmental benefits.



Researching next generation materials

Example: Next generation composites

Result: Reduces weight, which reduces fuel use and emissions

Designing aerodynamic improvements

Example: Advanced wing design, raked wing tip

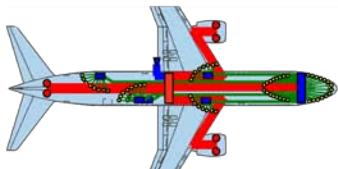
Result: Reduces drag which reduces fuel use and emissions



Researching improved propulsion systems

Example: Integrating new, more efficient engines

Result: Reduces fuel consumption and emissions and lowers noise



Researching less energy-intensive electric systems

Example: Reducing pneumatic systems

Result: Improving electrical efficiency improves fuel efficiency

FIGURE 29 - BOEING'S ACTIVE PURSUIT OF TECHNOLOGY RESEARCH FOR FUEL, CO₂ AND NOISE EFFICIENCY

Boeing 787

The chief breakthrough material technology on the 787 is the increased use of composites. The 787 is 50 percent composite by weight. A majority of the primary structure is made of composite materials, most notably the fuselage. Coupled with advances in engine and wing design, this results in higher fuel efficiency, lower greenhouse gases and less noise. The 787's path-breaking use of composites has many environmental advantages. The composite materials allow for a lighter, simpler structure, which increases airplane efficiency and reduces fuel consumption. It also allows for lower thrust engines, thereby reducing noise. The

787's advanced smooth wing technology brings simple pivot trailing edge flaps, allowing for much smaller flap track fairings than on conventional airplanes. This gives the airplane highly efficient lift-to-drag characteristics, which reduce fuel consumption and CO₂ emissions. In addition, the wing incorporates trailing edge variable camber control to automatically optimize the wing configuration in cruise for even more fuel and CO₂ efficiency.



FIGURE 30 - THE BOEING 787 DREAMLINER USES ADVANCED TECHNOLOGIES TO IMPROVE ENVIRONMENTAL IMPACT (20% REDUCTION IN FUEL AND CO₂, 60% LESS NOISE FOOTPRINT)

The enhanced flight deck is configured to take advantage of current and future advances in air traffic management and safety systems for more efficient flight paths. In addition, the 787's advanced engines contribute to the aircraft's environmental performance. The engines incorporate a high bypass ratio that allows the engine to be quieter for the community and significantly reduce fuel consumption. These next generation engines also burn fuel more efficiently, yielding fewer emissions such as NO_x. Innovative systems technology like the use of more electric systems to replace the less efficient pneumatic system create, distribute, and use energy more efficiently, reducing fuel burn and emissions.

The net result is an airplane with 20 percent lower fuel consumption and CO₂ emissions, and a 60 percent smaller noise footprint than those of the airplanes it is designed to replace. In addition, the targeted NO_x emissions have also been significantly reduced.

Boeing 747

The 747-8 is the new addition to Boeing's iconic 747 airplane family, and is an environmental benchmark for large airplanes, once again demonstrating Boeing's commitment to delivering progressive new products that bring at least 15 percent improvement in fuel and CO₂ efficiency. The 747-8 was born of the highly successful and world-recognized 747 family, married with new technologies developed for the 787. The new wing design brings advanced technology airfoils with raked tips to reduce cruise drag for improved overall performance and greater fuel efficiency. Redesigned simplified flaps with optimized flap-track fairings, improved rigging, and aileron droop improve low-speed performance and noise. The 787 Dreamliner technology high-bypass engines were optimized for the 747-8 for a quieter, more fuel-efficient and lower NO_x emission operation. As with the 787, the 747-8's enhanced flight deck is configured to take advantage of current and future advances in air traffic management and safety systems for more efficient flight paths. Overall, these technology advances bring a greater than 16 percent reduction in fuel consumption and CO₂ emissions, plus a 30 percent smaller noise footprint relative to the 747-400.



FIGURE 31 - THE BOEING 747-8 USES ADVANCED TECHNOLOGIES TO IMPROVE ENVIRONMENTAL IMPACT (16% REDUCTION IN FUEL AND CO₂, 30% LESS NOISE FOOTPRINT)

Boeing 737

The Next-Generation 737 has consistently brought new technologies to the fleet beyond its initial entry into service. Quiet Climb technology automatically reduces thrust just after takeoff to safely and significantly reduce the takeoff noise footprint. Required Navigation Performance (RNP) capability allows the Next-Generation 737 to fly more precise routes as well as ensure safe operations in reduced weather minimums, which in turn reduces fuel burn by permitting safe landings at airports that otherwise would require airplanes to hold until weather improves. CFM

International (CFMI), a joint venture between GE Aviation and Snecma, contributed to these efforts by developing a tech insertion package that increases the time-on-wing of the engine, but also reduces NO_x emissions. The blended winglets that are available for the -700, -800 and -900ER provide a 2 to 4 percent reduction in fuel and therefore CO₂ emissions. These are examples of technologies available for retrofit on the Next-Generation 737 family.

In August 2011, Boeing launched a new engine variant of the 737: the 737 MAX. The new 737 family member will be powered by CFMI LEAP-1B engines, and will enable further fuel efficiency gains. When compared to a fleet of 100 of today's most fuel-efficient airplanes, this new model will emit 277,000 fewer tons of CO₂ and save nearly 175 million pounds of fuel per year, which translates to US\$85 million in cost savings.

Boeing 777

The 777 has also continued to improve since entry into service. The 777 is delivering greater fuel efficiency along with reduced emissions as a result of a Performance Improvement Package that reduces emissions of the 777-200, -200ER and -300 models through improved aerodynamics and wing vortex generators. These improvements will also be installed on new 777 models during factory production.

Actively pursuing renewable energy sources



ENERGY HARVESTING TECHNOLOGIES

Electrodynamic: Powering light switches with your finger.

Thermoelectric: Using temperature gradients to power dimmable windows.

Piezoelectric: A vibration-powered wireless sensor

The Spectrolab solar cell: Concentrating solar power to make it cost-effective



FUEL CELLS

The Boeing Fuel Cell Demonstrator, achieved the first manned mission where straight-level flight was powered solely by a hydrogen fuel cell.

Energy Harvesting Technologies

Boeing also undertakes research in innovative and renewable energy technologies for the operation of aircraft. An example of this is the use of electrodynamic push-button switches that convert finger pressure into electrical power to send a wireless signal used to control a system. This technology can be applied, for instance, to controls for building lighting and motorized window shades. Boeing is investigating the use of these switches to control lighting, such as overhead Passenger Service Unit (PSU) reading lights. When combined with powering the PSUs via their mounting structure, this concept allows the elimination of all custom wiring to the PSUs, reducing airplane weight and fuel use.

Thermoelectric: Using temperature gradients to power dimmable windows

Thermoelectric devices convert a temperature gradient into electrical power. When one side of the device has a greater temperature than the other, electrical power is generated through a phenomenon known as the Seebeck effect. Thermal gradients exist on commercial airplanes in abundance. In the electrochromic dimmable

windows application, a thermoelectric generator will be placed on the fuselage structure behind the return air grill below each passenger window. This structure is -30°C during flight while the warm cabin air flowing through the return air grill is +20°C. This gradient generates approximately 30 milliwatts of power.

Piezoelectric: A vibration-powered wireless sensor

Piezoelectric energy harvesters convert vibration energy into electrical energy by way of the *piezoelectric effect*, which can be used to power devices such as wireless sensors.

In this application, a cantilevered bi-morph piezoelectric beam converts fuselage vibration into electrical energy, which is conditioned to power a wireless transmitter. The transmitter could be used to monitor structural health, leading to simplified aircraft maintenance procedures and extended vehicle life.

The Spectrolab solar cell

Solar cell technologies capture the sun's energy and convert it directly into electricity. These cells are called "photovoltaic"—photons in, volts out.

Boeing's solar cell technologies are honed through development for space applications, from satellites to roving explorers on Mars. The technologies are unique, utilizing a high reflector-to-solar-cell area ratio to allow large amounts of light to be concentrated on a small cell in order to provide a cost-effective yet highly efficient system. We are now leveraging this technology to generate clean, terrestrial energy generation. Spectrolab—a subsidiary of Boeing—holds the world record for solar cell efficiency (the percentage of power converted from incident sunlight to electrical energy) at just over 40 percent.

Fuel Cells

In 2007, the Boeing Fuel Cell Demonstrator achieved the first manned mission in which straight-level flight was powered solely by a hydrogen fuel cell.

A two-seat Super Dimona motor glider was modified to include a proton exchange membrane (PEM) fuel cell/lithium-ion battery hybrid system. During take-off and climb, the aircraft drew from the combined power of the lithium-ion batteries and

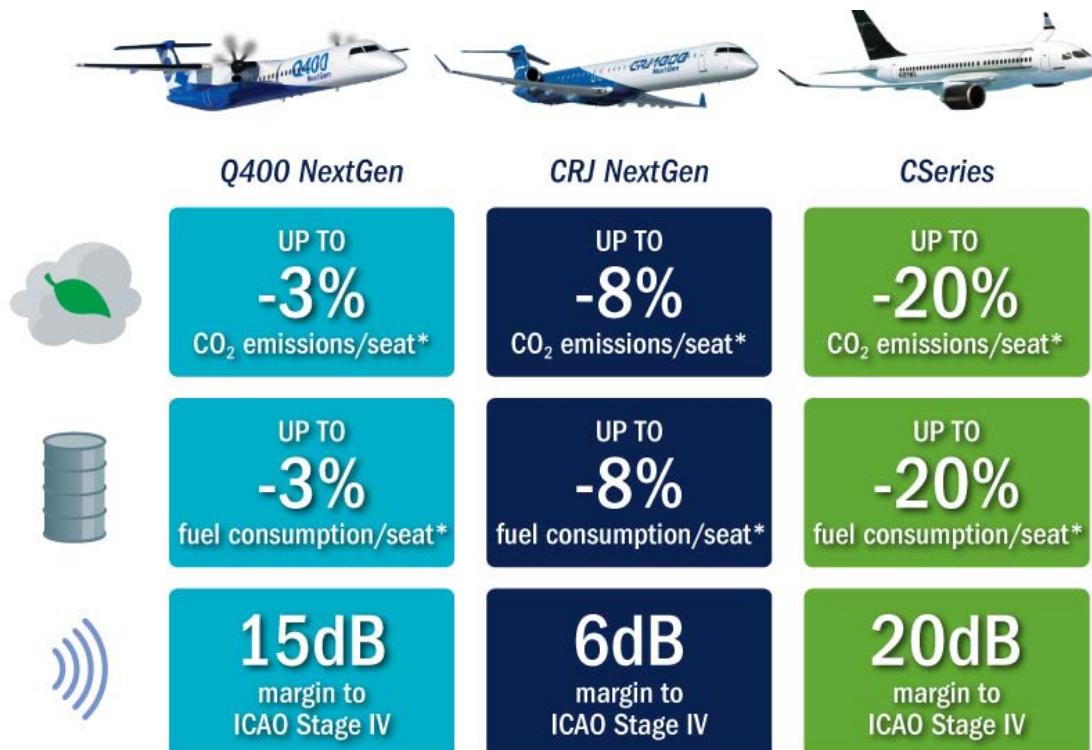
the fuel cell. The fuel cell then provided all power for the cruise phase of flight. While Boeing envisions fuel cells providing power to ground-based support vehicles (rather than primary power for commercial airplanes), demonstrations like this help pave the way for using this technology in the future. The Fuel Cell Demonstrator research project has been underway since 2003 at Boeing Research and Technology-Europe (BR&TE), located in Madrid, Spain. BR&TE has worked closely with its Spanish partners and with companies in Austria, France, Germany, the United Kingdom and the United States to design and assemble the experimental airplane.

Starting in 2012, Boeing will begin flying an ecoDemonstrator 737 to test low-emissions and low-noise technologies. The following year, an ecoDemonstrator twin-aisle airplane will join the program. These first ecoDemonstrator tests will be conducted in partnership with the U.S. Federal Aviation Administration's CLEEN (Continuous Lower Energy, Emissions, Noise) program.

The ecoDemonstrator program will accelerate the development of technologies in the areas of fuel efficiency, emissions, and noise reduction. The program will explore concepts such as ceramic matrix composite acoustic engine nozzles, advanced inlets, and adaptive wing trailing-edge flaps that can help reduce fuel consumption and noise during the takeoff, climb and landing phases of flight.

Bombardier

The world's third largest civil aircraft manufacturer, Bombardier, designs and manufactures innovative aviation products and services for the business, regional and amphibious aircraft markets. Bombardier has been dedicated to developing fuel-efficient aircraft with competitively lower noise and emissions in their category. Their commercial airline products comprising the Q400 NextGen, CRJ (Canada Regional Jet) NextGen, and upcoming CSeries excel in their environmental performance.



*Compared to in-production competitors over 500 nautical miles.

FIGURE 32 - BOMBARDIER ENVIRONMENTALLY-FOCUSED PRODUCTS

Q400 Turboprop

The lower-emission, fuel-efficient, "Comfortably Greener" Q400 and Q400 NextGen aircraft balance passenger comfort and operating economics with a reduced environmental footprint. On average, these turboprops burn 30 percent less fuel and emit 30 percent fewer carbon emissions than the jets they typically replace.

The first Q400 was delivered in January 2000. The Q400 and Q400 NextGen aircraft are currently used by some 30 airlines and other operators in Europe, the Americas, the Asia-Pacific region, Africa and the Middle East.

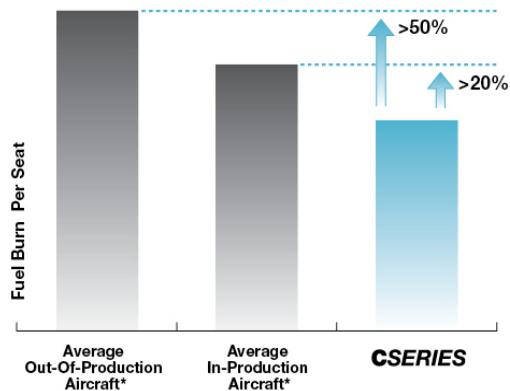
CRJ1000 NextGen

The CRJ1000 NextGen is Bombardier's latest addition to its CRJ regional jets family and entered service in December 2010. Over a typical 500 nautical mile mission, the 100-seat CRJ1000 NextGen aircraft can consume as little as 3.33 liters of fuel per 100 kilometers per seat. It can produce 85 grams per kilometer per seat of CO₂, setting a new standard for 100-seat class regional jets.

CSeries Commercial Aircraft

Since its launch in July 2008, the Bombardier's CSeries has attracted growing attention across the aviation industry thanks to both its economic and environmental advantages. The CSeries, scheduled to enter service in 2013, is expected to offer 20 percent less fuel burn and a 20 percent CO₂ emissions reduction compared to current in-production aircraft in the same category. At less than 3 liters of jet fuel per 100 kilometers-passengers, Bombardier's new CSeries aircraft will match the most modern fuel efficient compact cars.

CSeries Fuel Burn Advantage



CO₂ Emissions

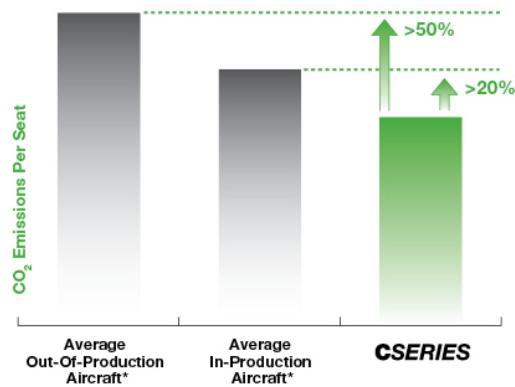


FIGURE 33 - BOMBARDIER CSERIES FUEL BURN AND CO₂ EMISSIONS

This environmental advantage of the CSeries has been achieved through several technological advances: a state-of-the-art engine technology, an advanced aerodynamic design, and the use of advanced structural materials (see Figure 34).



FIGURE 34 - BOMBARDIER CSERIES TECHNOLOGICAL ADVANTAGES

About half of the environmental benefits stem from the new Pratt & Whitney PurePower PW1524G geared turbofan engines, which alone boast double-digit reductions in fuel consumption, CO₂ and NO_x emissions and engine noise. The other half comes from design innovations in aerodynamics, advanced materials and next-generation aircraft and cockpit systems. Bombardier engineers have designed CSeries models to be as light as possible using advanced structural materials making up 70 percent of the airframe and a numerically optimized fourth-generation transonic wing. This wing is being made almost entirely of lightweight composites but the push for a lighter-weight aircraft does not end with composites. The aircraft's fuselage will be made from third-generation aluminum-lithium alloy, which, while lighter, has even better corrosion and fatigue resistance than conventional alloys (see **Figure 35**).

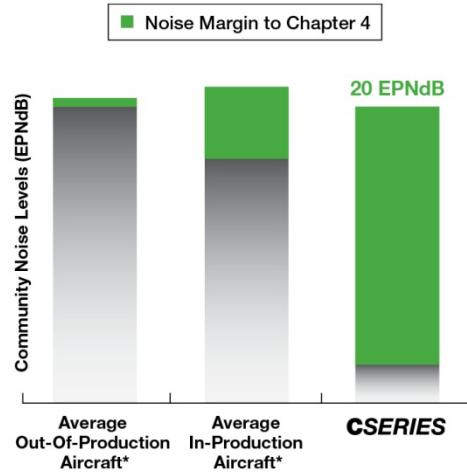


FIGURE 35 - BOMBARDIER CSERIES ADVANCED STRUCTURAL MATERIALS

While a lighter airframe translates to lower emissions, designers of this “clean sheet” aircraft have also anticipated the environmental regulations and reporting requirements on the horizon and built compliance right into the CSeries design. The CSeries aircraft will also be four times quieter than current aircraft in the same category, with a 20-decibel margin to the most stringent noise regulations (ICAO Chapter 4)²² and could be as much as 10 decibels quieter than ICAO’s Chapter 5 standard, currently under development and expected mid-decade. The same holds true for NO_x emissions, where the aircraft promises to exceed the ICAO CAEP 6 standard by more than 50 percent (see Figure 36).

²² The ICAO noise certification limits, for which the adopted standards (referred to in Chapters 2, 3 and 4) are contained in Annex 16, Volume I to the Chicago Convention, reflect the best noise-reduction technology that can be integrated into the aircraft fleet. The Chapter 4 standard, adopted by the ICAO Council in 2001, is applicable to jet airplanes for which a type certificate is requested as from January 1, 2006.

Noise Margin Comparison



*110-seat & 130-seat categories @ Maximum Takeoff Thrust

NO_x Emissions

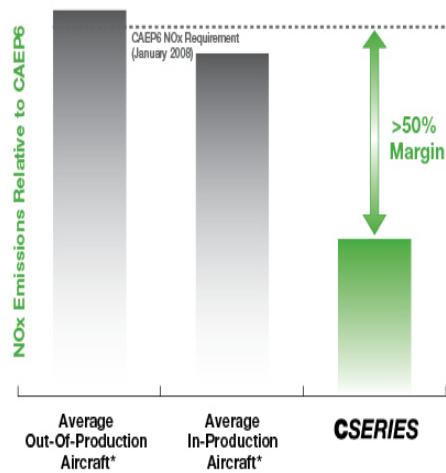


FIGURE 36 - BOMBARDIER CSERIES REDUCED NOISE AND NO_x ADVANTAGE

In addition, the CSeries aircraft is being designed to set new standards of sustainability throughout its lifecycle by quantifying the overall environmental impact of each aircraft, from design to disposal. Through an Environmental Product Declaration, when this aircraft enters into service in 2013, the CSeries customer will know the overall lifecycle impact their aircraft is having on the environment—something that cannot be determined today with current models to any significant degree of accuracy. By anticipating the environmental benefits that new technology can bring and single-mindedly incorporating these into the overall design at every turn, Bombardier claims to produce an aircraft family that will emerge in 2013 as an aircraft ahead of the environmental curve.

Embraer

E-Jets

Embraer's E-Jets is a family of four commercial aircraft specifically designed for the segment of 70- to 120-seat capacity segment. E-Jets are not stretched from smaller airplanes or shrunk from larger platforms. This clean design approach sets new standards in terms of efficiency. Today, thousands of aircraft in this segment are operating for commercial carriers. E-Jets could replace many of the oldest models. With their lower fuel burn and reduced CO₂ output, substituting E-Jets could cut the emissions of the ageing fleet by as much as 20 percent. E-Jets are available today in the market, allowing for immediate emissions reduction.

With the E-Jets replacing older generation aircraft, it is possible to cut emissions on individual flights by up to 50 percent and save thousands of tons of carbon dioxide released annually into the atmosphere.



FIGURE 37 - COMPARISON OF E-JETS WITH OTHER AIRCRAFT IN CARBON FOOTPRINT OF ONE SINGLE FLIGHT

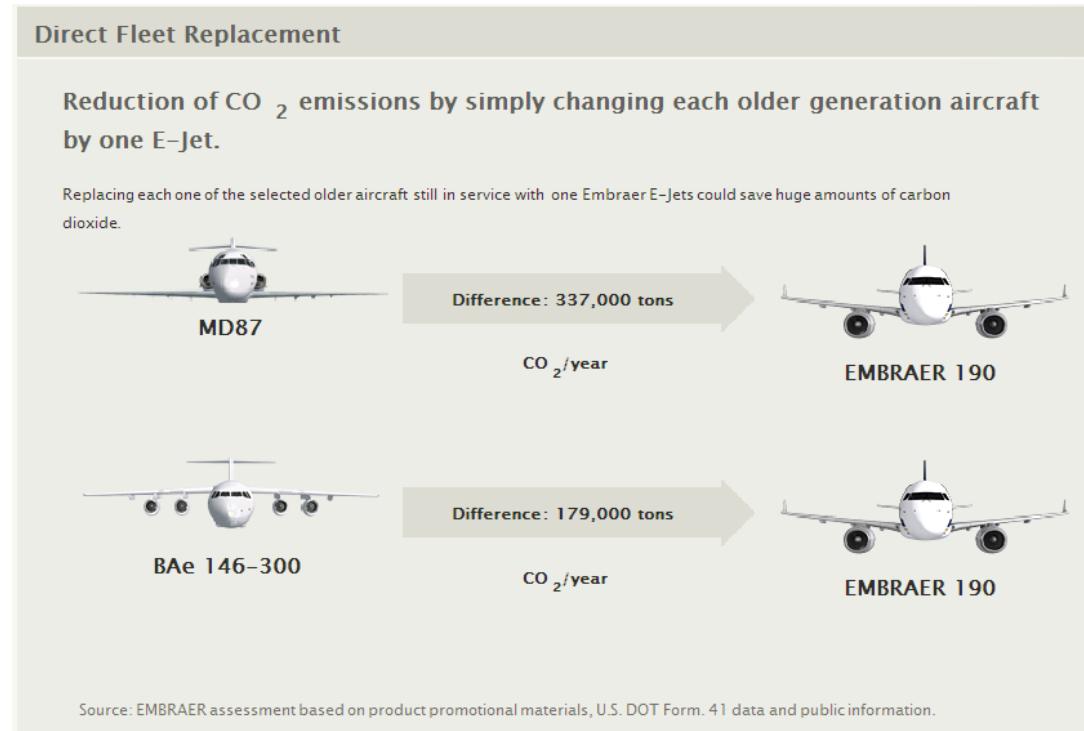


FIGURE 38 - REDUCTION OF CO₂ EMISSIONS THROUGH FLEET REPLACEMENT BY E-JET

It is possible to calculate the annual number of average-sized trees from the Brazilian rainforest needed to offset the difference in carbon dioxide emissions of one older-model aircraft and one Embraer E-Jet. For those who are already committed to neutralizing their carbon footprint by planting trees, Embraer claims that the replacement of one single aircraft may represent up to 34,000 additional trees.

While CO₂ emissions are identified as the primary contributor to global warming, other pollutants are also harmful to the environment and have dedicated limitations regulated by ICAO. E-Jets certified emissions exceed by large margins even the more stringent ICAO CAEP/6 regulations.

	EMBRAER 190	EMBRAER 195	MD87	BAe 146-300
Carbon monoxide (CO)	+29.8%	+29.8%	+52.4%	+17.1%
Oxides of nitrogen (NOx)	+31.0%	+31.0%	-6.5%	+30.9%
Unburned hydrocarbons (UHC)	+8.6%	+8.6%	+100.0%	+30.6%
Smoke	+77.1%	+77.1%	+67.3%	+48.2%

Source: United Kingdom Civil Aviation Authority (CAA)

FIGURE 39 - E-JETS EMISSIONS COMPARED TO ICAO CAEP/4 REGULATIONS

Future improvements

Embraer consistently invests in technological development to ensure that its products can satisfy the growing environmental demands and restrictions of the 21st century. Its Technological Development Plan emphasizes initiatives that strive to improve the performance of its products and mitigate their environmental impacts. Foremost among these innovation initiatives are the following projects that seek to increase aircraft efficiency:

- Striving to enhance aircraft aerodynamics;

- Making intensive use of lighter materials, reducing the structural weight of airplanes;
- Developing airplanes that make greater use of electric systems, which are less dependent on energy generated by the engines;
- Actively engaging in helping to develop new generations of aircraft engines in cooperation with the propulsion systems manufacturers; and
- Further investigating new technologies to reduce both internal and external aircraft noise levels in order to increase passenger comfort and reduce the impact in the vicinity of airports.

ANNEX 2 - IBRD AND IDA BORROWING COUNTRIES

IBRD countries

<i>Economy</i>	<i>Code</i>
Albania	ALB
Algeria	DZA
Antigua and Barbuda	ATG
Argentina	ARG
Belarus	BLR
Belize	BLZ
Botswana	BWA
Brazil	BRA
Bulgaria	BGR
Chile	CHL
China	CHN
Colombia	COL
Costa Rica	CRI
Croatia	HRV
Dominican Republic	DOM
Ecuador	ECU
Egypt, Arab Rep.	EGY
El Salvador	SLV
Equatorial Guinea	GNQ
Fiji	FJI
Gabon	GAB
Guatemala	GTM
Indonesia	IDN
Iran, Islamic Rep.	IRN
Iraq	IRQ
Jamaica	JAM
Jordan	JOR
Kazakhstan	KAZ
Korea, Rep.	KOR
Lebanon	LBN
Libya	LBY
Macedonia, FYR	MKD
Malaysia	MYS
Marshall Islands	MHL
Mauritius	MUS
Mexico	MEX
Micronesia, Fed. Sts.	FSM
Montenegro	MNE
Morocco	MAR
Namibia	NAM
Palau	PLW
Panama	PAN
Paraguay	PRY
Peru	PER
Philippines	PHL
Poland	POL
Romania	ROM
Russian Federation	RUS
Serbia	SRB
Seychelles	SYC
South Africa	ZAF
St. Kitts and Nevis	KNA
Suriname	SUR
Swaziland	SWZ
Syrian Arab Republic	SYR
Thailand	THA
Trinidad and Tobago	TTO
Tunisia	TUN
Turkey	TUR
Turkmenistan	TKM
Ukraine	UKR
Uruguay	URY
Venezuela, RB	VEN

IDA countries

<i>Economy</i>	<i>Code</i>
Afghanistan	AFG
Angola	AGO
Bangladesh	BGD
Benin	BEN
Bhutan	BTN
Burkina Faso	BFA
Burundi	BDI
Cambodia	KHM
Cameroon	CMR
Central African Republic	CAF
Chad	TCD
Comoros	COM
Congo, Dem. Rep.	ZAR
Congo, Rep.	COG
Côte d'Ivoire	CIV
Djibouti	DJI
Eritrea	ERI
Ethiopia	ETH
Gambia, The	GMB
Ghana	GHA
Guinea	GIN
Guinea-Bissau	GNB
Guyana	GUY
Haiti	HTI
Honduras	HND
Kenya	KEN
Kiribati	KIR
Kosovo	KSV
Kyrgyz Republic	KGZ
Lao PDR	LAO
Lesotho	LSO
Liberia	LBR
Madagascar	MDG
Malawi	MWI
Maldives	MDV
Mali	MLI
Mauritania	MRT
Moldova	MDA
Mongolia	MNG
Mozambique	MOZ
Myanmar	MMR
Nepal	NPL
Nicaragua	NIC
Niger	NER
Nigeria	NGA
Rwanda	RWA
Samoa	WSM
São Tomé and Príncipe	STP
Senegal	SEN
Sierra Leone	SLE
Solomon Islands	SLB
Somalia	SOM
Sri Lanka	LKA
Sudan	SDN
Tajikistan	TJK
Tanzania	TZA
Timor-Leste	TMP
Togo	TGO
Tonga	TON
Uganda	UGA
Vanuatu	VUT
Yemen, Rep.	YEM
Zambia	ZMB

ANNEX 3: GUIDELINES FOR GREEN AIRPORT DESIGN

There has been an increasing global trend to make airport design, construction and operation more human-friendly while achieving benefits in environmental quality and energy savings.²³ The following guidelines, developed by the World Bank for a recent feeder airport to be built in Shangrao, China, establish the principles of green airport design and foster the consideration of innovative technologies and operational practices that are tailored to the needs of the World Bank Shangrao Sanqingshan Airport Project.

Benefits of Green Airport Design

Green airport design, construction and operation can bring about various benefits to the environment, developers, and society in general.

Initial Cost Savings

- Reduced infrastructure costs
- Reduced material use
- Savings in construction waste disposal
- Savings from downsizing mechanical equipment

Reduced Operating Costs

- Lower energy costs
- Lower water costs
- Greater durability and fewer repairs

²³ For instance, the Clean Airport Partnership recently launched “The Green Airport Initiative” to help airports achieve quick and measurable benefits in environmental quality and energy savings and reduce conflicts with local communities. See: <http://www.cleanairports.com>

Environmental Benefits

- Reduced global warming impacts
- Reduced contributions to local and regional air pollution
- Reduced local and regional water pollution
- Protection of biodiversity/natural vegetation
- Increased environmental awareness

External Incentives

- Positive public and intergovernmental image
- Marketability of the airport to customers that value environmental protection
- Possible certification in programs such as LEED

Technological Principles and Options

There are many technological options to achieve the green airport concept. These options need to be evaluated based on their own economic and environmental merit, the setting of the airport, cost effectiveness, and safety/operational limitations. Commensurate to the small size of this airport, basic principles and options are suggested below.

Energy Efficiency

Principle: Design and construct energy-efficient buildings to reduce air, water, and land pollution, environmental impacts and operating costs.

Fuel Efficiency

Principle: Design and construct runways and taxiways to reduce aircraft fuel consumption.

Water Efficiency

Principle: Minimize water use in buildings and landscape irrigation in order to reduce the impact on natural water resources, reduce the burden on municipal water supply and wastewater systems, and reduce operating costs.

Natural Light

Principle: Contribute to energy efficiency by minimizing the use of artificial lighting by creating the optimum conditions for the use of passive and active solar strategies.

Storm Water Management

Principle: Reduce adverse impacts on water resources by mimicking the natural hydrology of the region on the project site, including groundwater recharge. Reduce pollutant loadings from storm water discharges, reduce peak flow rates to minimize stream channel erosion, and maintain or restore chemical, physical, and biological integrity of downstream waterways, especially those used by communities for water supply and irrigation.

- Manage storm water using low-impact airport development.
- Preserve and utilize natural water and drainage features.
- Develop and implement storm water management plans that minimize concentrated flows and seek to mimic natural hydrology.
- Minimize impervious surfaces and use permeable materials for driveways, parking areas, walkways, and patios.
- Percolation through soil is one of the most effective means for filtering pollutants carried by storm water. By using natural water and drainage features, minimizing impervious surfaces, and distributing storm water flows, harmful pollutants carried off site can be minimized while safely and effectively managing much of their storm water load onsite.

Landscape

Principle: Design landscaping to limit water and energy demand while preserving or enhancing the natural environment. Formulate a plan to restore or enhance natural

vegetation that is cleared during development, phasing landscaping to ensure denuded areas are quickly vegetated.

Wastewater Management

Principle: Reduce pollution from wastewater and encourage water reuse.

On-site Renewable Energy Sources

Principle: Reduce air, water, and land pollution from energy consumption and production by increasing the efficiency of the power delivery system. In addition, increase the reliability of power. Encourage on-site renewable energy self-supply in order to reduce environmental impacts. Case study: Denver International Airport, Solar Energy.²⁴

Universal Accessibility

Principle: Enable a wide spectrum of people to more easily participate in their community by increasing the proportion of areas that are usable by people of diverse abilities and age.

OPTIONS

The above principles can be implemented through a series or a combination of technological options, as follows:

Energy/Fuel/Light Efficiency

- Provide high-efficiency motors and systems.
- Provide energy-efficient lighting systems.
- Organize circuiting of lighting and building systems so that individual areas may be separately controlled relative to daylight and heating/cooling zones.
- Orient building to optimize passive solar and/or daylight penetration.
- Optimize architectural features for day lighting and glare control. Consider light shelves, ceiling design, window placement, and window treatments.

²⁴ "Technical Guidance for Evaluating Selected Solar Technologies on Airports," FAA, November 2010.

- Provide motion sensors in stairs, restrooms, storage rooms and equipment rooms, unless life safety is compromised.
- Provide “Energy Star”-compliant equipment and appliances.
- Energy efficient buildings: efficient bulbs, heat-efficient windows, minimizing use of electric equipment (escalators), heat-reflecting roofs, roof insulation.
- On-site renewable energy (photovoltaic, wind turbines).
- Increased daylight and views through a combination of skylights and high windows.
- Using LED technology for airfield lighting.
- Natural ventilation promotion: openings on the façades, ventilation and light shafts to generate thermal drafts and protection from fuel fumes in interior of terminal building and to reduce mechanical system requirements;
- Building orientation and façade design to reduce solar gain and cooling requirements, such as double-glazing on sun-shielded façades, limited window openings on sun-facing façades, roof light shafts; solar radiation managed by operable shading panels.
- Runway layout can improve fuel efficiency in several ways: runway direction in expected prevailing wind direction and suitable for straight-in continuous descent approaches, and runway ends providing short taxi times and high-speed taxiways for exit.

Water Efficiency

- Water-conserving fixtures that maximize water efficiency within the buildings.
- Utilize fixtures such as dual-flush toilets and waterless urinals to reduce wastewater volumes.

Storm water Management

- Permeable surfaces in parking lots and other non-operation areas.
- Evaluate reusing storm water for non-potable uses.

- Establish a water supply system that supports vehicle maintenance without the use of potable water by using recycled water or diverted storm water for vehicle washing.
- Use captured rain or recycled site water to reduce potable water consumption for irrigation. Install drought-tolerant and native vegetation.

Wastewater/Solid Waste

- Innovative wastewater technologies.
- Waste recycling: reuse of wastewater, rainwater storage for landscaping purposes, solid waste recycling programs and facilities.
- Provide an easily accessible area serving the entire building, including ancillary buildings, dedicated to the separation, collection and storage of materials for recycling, including (at a minimum) paper, corrugated cardboard, glass, plastics and metals.

Landscaping

- A high ratio of open space in the development footprint to promote biodiversity.
- Landscaping with attention to local flora and/or biodiversity conservation.
- Water-efficient landscaping.
- Protection from both the rain and sun: covered plazas, buildings orientated to capitalize on trees and vegetation to act as windbreaks, over-insulated roofs and large roof overhangs for solar shading on exposed facades;
- Wetlands with aquatic plants recollect water and release back into its natural catchment area.
- Maintain biomass of the site.

Construction Management/Design Features

- Building products that incorporate recycled content materials.
- Concrete floors for thermal mass inertia and intermediate concrete or wood floors.

- Balance excavation and back-filling earthworks over planning horizon, reducing the need to transport soil or earth to or from site.
- Facilities for public transport, bicycles for workers.
- Materials selection according to their durability and resistance to weathering, damage and vandalism, rather than cost alone.
- Pavement materials: reduced energy consumption for asphalt and concrete.
- Building Management System (BMS): a BMS allows for the operation of ventilation, lighting, water consumption and heating and cooling systems of a building to be monitored and controlled.
- Design of ground access vehicle: infrastructure for buses at an airport can extend beyond basic bus stops to a city bus interchange or a regional bus/coach station.
- Develop a balanced earthwork plan.
- Establish goals for landfill diversion and adopt a construction waste management plan to achieve these goals.

International Examples

There are many airports around the world that have incorporated responsible sustainable or green measures in the building or remodeling of their airports. Some are listed here:

- Boston has 20 wind turbines that crank out 100,000 kilowatt hours per year, meeting 2 percent of electricity needs. The airport terminal features a heat-reflecting roof, waterless urinals and storm water filtration.
- Denver has two airport solar energy development projects. The first is a 2 MW ground-mounted project consisting of 9,250 216-watt solar panels on a single axis tracking system. A second project is a 1.6 MW ground-mounted project consisting of 7,400 fixed solar panels.
- Toronto is home to 29 raptors that scare away intruding flocks of birds the natural way. They have hybrid handling vehicles and an on-site composting program.
- Vancouver uses two border collies (dogs) with handlers to scour the 3,200 acre grounds for unwanted critters and uses a solar-powered heating system.

- Madrid's new airport's passenger and baggage terminals are oriented in a north-south direction and use passive design features to reduce the need for energy-intensive heating and cooling as much as possible. Eco friendly bamboo is used in the ceiling design.
- Regional airport in Santa Clara, California will use "total" green airport design.
- Zurich airport enhancements featured geothermal energy, solar cells, utilizing rainwater for toilet flushing (Pier E) and an on-site compressed natural gas station. Passengers will be able to observe the airports adjoining "safe habitat for over 50 species of flora and fauna." 74 hectares of fen land are nestled in between the two main runways.
- Among others, New Jersey's Atlantic City International, Hammonton Municipal airports, North Dakota's Grand, and Forks International Airport have used LEDs for various airport lighting applications.
- Since the summer of 2011, Athens International Airport has operated an 8 MW photovoltaic park (one of the largest photovoltaic projects at an airport), covering approximately 9 percent of airport electricity needs.

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