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INTRODUCTION

2.1 This section summarizes operational opportunities at airports to minimize fuel consumption and resulting emissions from aircraft and airport-related sources including ground service equipment (GSE) and ground transportation. -Operational opportunities are broadly defined as including measures such as minimizing fuel use, optimizing airport design, modifying current operating practices, modernizing GSE and consolidating ground transport. It must be appreciated that site-specific limitations or conditions may preclude the application of a given technology or operational measure.

2.2 Reductions in fuel consumption from airport sources will reduce emissions of both CO_2, which affects global climate, and other emissions that affect local air quality (oxides of nitrogen (NOx), sulphur oxides (SOx), hydrocarbons (HC) which include volatile organic compounds (VOCs), carbon monoxide (CO), and particulate matter (PM)). While there is a direct correlation between the fuel burn reduction and associated CO_2 reduction achieved by any measure, some measures have differing effects on other emissions.

2.3 Identification and selection of any operational measures to reduce fuel and associated emissions at airports must be made in consultation with the airport operator, local/regional/national authorities, air navigation service providers, airlines, and affected suppliers. Given site-specific limitations, safety considerations, and potential impacts on the overall efficiency of air transport, it is not possible to define a single set of operational measures that is appropriate for all airports. However, fuel and therefore emissions reductions may be achieved from the implementation of a collaborative management of all operations of the airside stakeholders. These measures may also result in improvements in system efficiency and reductions in system operating costs. Airport operations need to be integrated with flight operations, ground service operations and air traffic management for maximum fuel savings. Chapter 6 addresses air traffic management aspects.

PREVIOUS WORK BY ICAO

2.4 ICAO has been concerned with emissions at airports for many years. Previous studies have indicated that aircraft emissions may dominate **on-airport** emissions inventories, but ICAO's CAEP noted in a 1995 report that "studies have, in general, confirmed earlier findings that air quality **in the vicinity of** airports is generally good and the contribution of aircraft and airside ground sources to pollution levels continues to be small." It also reported that studies of the future trends in air quality around airports indicate that pollutant levels will remain at present levels or be reduced at least until 2015. Although it will remain a small part of regional inventories, the relative contribution of aircraft to local air quality NOx may change in the future.

2.5 ICAO developed and periodically updates its *Airport Planning Manual*, Part 2, *Land Use and Environmental Control* (Doc 9184), which provides some information on means of reducing emissions, improving fuel efficiency, and encourages the use of environmental management systems at airports.

2.6 ICAO has also published Airport Air Quality Guidance Manual, Doc. 9889 which provides detailed information on air quality standards, conducting airport emissions inventories, aircraft and other emissions calculations, dispersion modeling, and monitoring and measuring air quality.

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AIRPORT DESIGN AND FACILITIES

2.7 An effective airport design can minimise aircraft and ground equipment fuel use. The design might be improved or modified during expansion processes. . This includes the layout of the buildings, service stations, runways, taxiway, rapid exit taxiways, pavement and other related facilities to provide additional capacity. Table 2-1 lists some examples of opportunities for minimizing fuel usage and resulting emissions.

Table 2-1. Examples of airport features that minimize fuel usage and emissions

Measure	Description	Comments
Airport Layout	Provide efficient runway, taxiway and apron layout.	Minimizes taxiing and congestion. Facilitates more efficient ground movements by improved infrastructure (taxiway design, Rapid Exit Taxiway location and design, aircraft passing / holding bays, etc)
	Site Selection (for new airports)	Allows for optimization of regional transit access, weather (low fog areas, etc)
Airport Facilities	Provide 400 Hz Fixed Electrical Ground Power (FEGP) and where necessary Pre-Conditioned Air (PCA) and at gates/maintenance areas and encourage their use.	Reduces or eliminates APU, GPU and air conditioning unit usage. Typically requires substantial capital investment, but often realizes fuel/maintenance savings.
	Improve low visibility take-off and landing capabilities, supported by surface movement guidance control systems, where necessary.	Reduces congestion and delay in bad weather and can reduce the need for diversions to other airfields
	The use of LED airfield lighting, where appropriate	Directly reduces primary energy use.

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AIRCRAFT OPERATIONS

2.8 There are a variety of operational measures that may be used to reduce emissions from aircraft engines while at, or in the vicinity of, an airport, table 2-2 lists some examples.

Table 2-2. Summary of operational opportunities to minimize aircraft fuel usage and emissions at airports

Measure	Description	Comments
1.1 Aircraft Procedures	Continuous Descent Operations (CDO)	Descending with engines at low power reduces fuel burn and noise under the flight path, but can be dependant on airspace management and capacity constraints
	Continuous Climb Operations (CCO)	Continuously climbing to avoid the need for level flight at low altitudes reduces fuel burn and noise under the flight path, but can be dependant on airspace management and capacity issues.
Discretionary pilot actions	Minimizing use of reverse thrust on landing.	Pilot must retain full authority over safe operation of the aircraft
	Engine(s) out taxi	Pilot must retain full authority over safe operation of the aircraft. Emissions reductions are site and aircraft specific.
Other procedures	Reduced engine idling time	HC and CO emissions are greatest during engine idling. Reducing idling can also result in decreased engine operation reducing maintenance and improving engine life.
	Aircraft towing	Aircraft towing can significantly reduce aircraft engine use and emissions. Logistic problems may occur at airports with limited manoeuvring areas..

2.9 Given the site-specific limitations and conditions, it is very difficult to estimate the emissions reduction that may be realized by these operational measures. Improvement in the efficiency of airport operations will probably have benefits beyond gaseous emissions reduction and reduced fuel costs, which may offset any capital costs incurred.

2.10 Noise reduction measures implemented at some airports, due to local community concerns or regulation, can result in increased fuel burn and emissions. Examples include: noise abatement procedures and noise sharing regimes that increase distances flown; preferential runways and flight tracks (e.g. Noise Preferential Routes - NPR) that require extra flying and taxi times; noise fines that can result in changes to procedures or take-off mass, reducing efficiency; curfews that can cause congestion leading to delays and holding, extra landings and take-offs and flying at non-optimum speeds. Efforts to reduce fuel burn and emissions should consider these interdependencies and the feasibility of reducing emissions penalties of noise-related measures. Also, initiatives by airports or other stakeholders that address aircraft noise and its impacts, including land use planning, and community relationship development, may in the long term, reduce the pressure for noise abatement procedures and their associated trade-offs affecting fuel burn and emissions, as will the ongoing process of fleet evolution.

GROUND SUPPORT EQUIPMENT

2.11 The term 'ground support equipment' (GSE) refers to the broad category of vehicles and equipment that service aircraft, including towing, maintenance, loading and unloading of passengers and cargo, and providing electric power, fuel, and other services to the aircraft.

2.12 Note that airports in different regions of the world have divergent responsibilities for the provision and operation of GSE services. For example, in North America and many parts of Europe responsibility for conversion or replacement for most GSE would rest with individual aircraft operators, rather than with the airport authority.

2.13 The most common types of GSE are:

a) *Aircraft Tractors*. Also known as aircraft tugs, are used in three separate duty cycles:

   1) push-back service, where the tug pushes the aircraft back from the gate;

   2) operational towing, where tractors are used to reposition the aircraft; and

   3) maintenance towing, where tugs are used to tow aircraft between the terminal and remote maintenance areas.

b) *Air Conditioning Units*. Air conditioning units are trailer- or truck-mounted units used to supply pre-conditioned air to stationary aircraft at the terminal and also during maintenance. As mentioned under Airport Facilities, gates are increasingly being modified to provide Pre-Conditioned Air (PCA) from dedicated electricity-powered compressors, thereby avoiding the use of internal combustion engines.

c) *Air Start Units*. Air start units are trailer-or-truck-mounted compressors that provide compressed air for starting an aircraft's main engines. Air starts are typically used only when an aircraft is not equipped with an auxiliary power unit (APU), or the APU is not operational. The APU is a small turbine generator that provides compressed air as well as electrical power, and cabin air conditioning for onboard equipment such as lights, avionics, galley and instrumentation.

d) *Baggage Tractors*. These are used to transport luggage or cargo between aircraft and terminal(s). Tractors dedicated to cargo services often have unique design features, such as side-hitches to allow for quick turnarounds. The duty cycle for baggage and cargo tractors typically varies as well: cargo tractors are typically rated for 45 000 kg loads, and are used continuously during freight loading/unloading over a 3 to 8-hour period, whereas baggage tractors typically require 13 500 to 27 000 kg ratings and operate sporadically over an 8-hour shift. Electric models are available for certain applications.

e) *Belt Loaders and Container Loaders*. A belt loader is a self-propelled conveyor belt used to move baggage and cargo between the ground and aircraft. Airline handling of cargo is typically associated with short travel distances between the terminal and the aircraft, whereas loaders used by cargo carriers may travel up to six to eight kilometres per day depending on the airport layout. Furthermore, cargo-loading operations typically require specialized platform loaders – self-propelled platform lifts designed for rapid transfer of containerized cargo between the ground and the aircraft. There are two types of cargo loaders: lower lobe platform loaders rated at 7 000 kg lift capacity, and wide body main deck loaders rated at 13 500 kg lift capacity that lift containerized cargo onto the main deck of wide body aircraft.

f) *Bobtail Tractors*. Bobtail tractors are used to provide high-speed transport of cargo and baggage over longer distances within the airport (i.e., from the terminal to remote cargo/mail/baggage sorting facilities). These units are modified on-road vehicles, with a shortened chassis to allow for the tighter turning radius required at airport terminals.

g) *De-icers*. De-icers typically consist of an on-road truck equipped with tank, pump, hose and spray gun to transport and spray de/anti-icing fluid on aircraft.

h) *Lavatory Service Trucks and Carts*. Lavatory trucks are self-propelled units equipped with stainless steel tanks, a pump, and a hose used to service aircraft lavatories. Lavatory carts, which are not self-propelled, have small engines used to power pumps that transfer lavatory fluids between the ground and the aircraft.

i) *Lifts*. This broad category includes forklifts, scissor lifts, and loaders that allow access to the aircraft for servicing at the terminal and at the maintenance base. Lifts typically include a substantial proportion of medium and heavy-duty on-road equipment, modified for the specific duty requirements.

j) *Ground Power Units (GPU)*. These provide 400 Hz electrical power to aircraft when the aircraft's APU and the main engines are not operating. Given a choice between GPU and APU usage, airlines typically use GPU as they cost less to operate. There are two basic types of GPU: the first type is a mobile trailer or truck-mounted generator powered by a diesel or gasoline engine that generates 400 Hz electricity for the aircraft. The second type is Fixed Electrical Ground Power (FEGP) which includes a frequency converter (mains frequency to 400 Hz) installed on the bottom of a passenger bridge, or on a fixed stand on the tarmac near the parked aircraft's nose (i.e. bridge-mounted power) drawing power from the airport's electrical grid.

k) *Passenger Ground Transport*. This includes passenger buses, passenger steps and mobile lounges (which replace buses and steps).

2.14 Mitigation options for GSE emissions can realize significant reductions. Table 2-3 lists some examples of the operational opportunities that may exist to reduce fuel usage and emissions from GSE.

Table 2-3. Examples of operational opportunities to minimize fuel usage and emissions from GSE

Measure	Description	Comments
Modify GSE Operations	Enhanced maintenance.	Difficult to predict emissions reduction. Existing maintenance may already be optimized, limiting reductions that may be realized.
	Reduced driving distances through route planning.	Emissions reduction and fuel savings are route-specific.
	Avoid unnecessary idling of equipment.	Emissions reduction and fuel savings are site-specific.
	Operate a performance monitoring, awareness, reporting and follow-up scheme	This is essential to effective operation of existing equipment and in prioritising and justifying replacement and upgrade strategies.
GSE Engine Retrofit	Gasoline engines retrofitted with oxidation catalyst.	
	Gasoline engines retrofitted with three-way catalysts.	
	Diesel engines retrofitted with oxidation catalysts.	
	Diesel engines retrofitted with particulate traps.	Retrofit filter may require ultra-low sulphur fuel (15-25 ppm sulphur).
	Installing turbo charging/ intercooling/timing retard.	Retrofits available only for some models.
	Reduced sulphur content in diesel fuel.	Availability of low sulphur fuel varies geographically but it is becoming more common.
	Diesel fuel additives/emulsifiers.	Many additives are still experimental.
	Engine heater for diesel engine coolant.	Assists start-up.

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Measure	Description	Comments
GSE Engine Replacement	Replacing uncontrolled diesel and gasoline engines with new fuel injected gasoline engines equipped with a 3-way catalyst.	Availability of new off-road engine technology may be limited. Retrofit of on-road equipment for non-road use typically requires additional modifications.
	Replacing uncontrolled gasoline or diesel engines with new diesel engines equipped with computer controlled fuel delivery system, turbo-charging, intercooling, and timing retard.	Improvements to fuel burn as well as significant NOx and HC reductions may be realised depending on the application of new engine technologies."
	Replacing two-stroke gasoline engines with four-stroke gasoline engines	
CNG/LPG GSE After Treatment Devices	Installation of oxidation catalyst	
	Installation of three-way catalyst.	
Alternative Fuels	Retrofit/replace diesel engines with compressed natural gas (CNG)/liquefied petroleum gas (LPG) fuelled engines	Relative to uncontrolled gasoline and diesel engines, purchase of new CNG/LPG engines may reduce NO_x and PM, but may increase CO and HC emissions. Note: CNG option typically requires substantial infrastructure improvements; such improvements must properly address safety and reliability issues. Retrofits of existing engines may increase emissions if not properly installed and maintained.
	Retrofit/replace gasoline engines with CNG/LPG fuelled engines.	CNG fuel option typically requires substantial infrastructure improvements; such improvements must properly address safety and reliability issues. Retrofits of existing engines may increase emissions if not properly installed and maintained.

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Measure	Description	Comments
	Replace with electric GSE.	May achieve up to 100% reduction in ramp emissions (excludes emissions arising from electric power generation). Electrification may require substantial investment in infrastructure; such improvements must properly address safety and reliability issues. NB Electric GSE may not be available or able to meet duty requirements for cargo tractors, aircraft tractors, cargo loaders, air starts, mobile GPU/air conditioning units; service trucks and lifts.
	Replacement by electro engines powered by fuel cell / hydrogen	Currently a significant proportion of hydrogen is produced from natural gas, however, it could potentially be generated from more sustainable sources in the future.

2.15 Costs for operational modifications vary widely; any analysis should include the costs of required enhancements to infrastructure. The infrastructure costs for alternate fuels (e.g. CNG and electric) are typically substantial:

a) CNG retrofits typically require the installation of fast-fill CNG dispensing systems capable of serving sixty to eighty vehicles. These dispensing units may require additional environmental approvals because of accidental release regulations and other safety considerations. Slow-fill dispensing systems cost less than one tenth of the price to install, but require ten times longer to dispense the same amount of fuel;

b) For electric GSE, even assuming adequate supply of electrical power to an airport, the cost of installing distribution and charging systems is significant.. Further, equipment costs for electricity-powered units typically do not include the cost of batteries, and batteries must be replaced every three to five years. If additional power must be supplied to the airport/terminal, costs will be greater;

c) Although infrastructure and purchase costs for alternative fuel GSE are typically greater than for gasoline and diesel-engine units, alternative fuel vehicles typically require reduced maintenance and lower operating and fuel costs compared with gasoline and diesel powered equipment. Another benefit associated with electrical GSE is that the equipment can deep-cycle charge during off-peak hours when there is a lower demand for electricity and the cost of charging is typically less than during peak demand times.

2.16 In comparison, gasoline engines that use existing fuel distribution systems can be retrofitted with three-way catalysts, or replaced with new technology without any infrastructure improvements. These retrofits or modifications may realize 90 per cent or more reduction in HC and NO_x. Compared with

CNG/electric conversions, the savings in infrastructure improvement costs could allow for additional engine conversions of uncontrolled GSE, i.e., more units could be retrofitted with 90 per cent control technology than could be electrified. Under such circumstances, additional conversions of existing, uncontrolled engines may lead to a greater reduction in total emissions than would electrification. Thus, the relative costs of possible conversion projects need to be carefully evaluated.

2.17 As with cost considerations, any operational change must continue to ensure that the minimum duty/performance requirements are met. Considerations that may limit electric conversion options include the availability of equipment and the ability of electrical units to:

a) have sufficient capacity to continue to provide power over a typical operating day;

b) provide sufficient power;

c) provide the reliability required of emergency back-up units; and

d) perform in cold climates.

2.18 However, these limitations should not preclude the use of electric GSE, where it could operate in a satisfactory manner. Due to the nature of electric GSE, energy is not consumed when work is not performed – there is no idle mode for electric GSE. Usually, due to the less complex nature of electric GSE, the unit is easier to operate and may require less maintenance than gasoline, diesel, CNG, and LPG powered equipment.

2.19 Thus, as with overall project costs, the selection of a given control strategy must involve careful consideration of site-specific performance limitations.

SURFACE ACCESS TRANSPORT

2.20 Depending on their size, airports serve as destination for up to hundreds of thousands of vehicles daily. These vehicles in turn can represent millions of kilometres travelled daily. Thus, reducing the total vehicle kilometres travelled (VKT) to and from an airport, and emissions from ground transport while at the airport, can achieve substantial emission reductions.

2.21 Ground transport emissions reduction measures typically focus on reducing VKT by:

a) employees of airlines, airport authorities and other companies located on airport properties,

b) passengers and freight, and

c) airport service providers such as hotel and parking lot shuttles.

Examples of measures for reducing VKT are provided for on-airport activities in Table 2-4. Additional measures, such as installation and/or improvement of rail transport, alternative fuel bus transport, and dedicated high-occupancy vehicle lanes may achieve reduced VKT, but are not considered. Given the high percentage of emissions associated with vehicle travel to and from some airports, it is critical to consider all possible means of reducing this segment's contribution.

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Table 2-4. Examples of operational opportunities to minimize ground transport fuel usage and emissions

Measure	Description	Comments
Employee Trip Reduction	Compressed work week/telecommuting: • 10 hr/day, 4 days/wk; etc.; and • working at home/remotely where appropriate; etc.	May realize up to 5% reduction in VKT. Requires substantially planning and implementation.**
	Employee rideshare/carpool incentives: • carpool matching; and • enhanced compensation or benefits for rideshare.	Reduction in VKT varies based on the programme.
	Parking pricing: • Increased fees for single occupancy of vehicles; and • Positive incentives for alternative fuel/zero emission vehicles (ZEV).	Reduction in VKT varies based on the programme.
	Bicycling infrastructure including bike paths, secure parking racks and showering facilities together with positive incentives for their use.	
	Public transit & alternate mode incentives, e.g.: • discount/free pass on public transport; • enhanced compensation for use of ZEV/alternative fuels; and • bus and rail infrastructure.	Depending on incentives and existing transit system, may increase public transport usage.
Passenger Transport Management Options	providing public transport infrastructure, securing public transport services and promoting their use	Often requires partnership planning development and funding
	providing public transport infrastructure, securing public transport services and promoting their use	Often requires partnership planning development and funding
	Safe, secure and efficient pedestrian infrastructure from ground transport nodes – including covered pedestrian routes	This also applies to public access

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	The use of remote car-parks with low emission transit systems to the airport.	Relocating emissions may not necessarily reduce overall inventory emissions, but may reduce the concentration of emissions at sensitive receptors around the airport.
	Alternative fuels for buses/taxis/shuttle/rental cars/ freight vehicles: • retrofit existing units with catalysts/traps/filters; • accelerate retirement; and • purchase of new alternate fuels/zero emission vehicles for replacement and growth. ▪ Provide alternative fuel infrastructure ▪ Sponsorship, other incentives, etc.	Voluntary measures have been introduced at many airports. Unlike GSE, most on-highway equipment already has controls on specific emissions. Reductions are substantially less than for GSE and are site-specific and require study.
	Idle restrictions on car/taxi/bus/delivery vehicles.	Possible emissions reduction.
	Circulation management for cars/taxis/vans/buses Consolidation of shuttles to hotels and car rental agencies	Potential decrease in VKT is site-specific, may enhance the use of alternative fuel powered equipment.

**Estimates represent potential reductions in VKT for each category. Reductions are site-specific and depend on average speed travelled during a trip, average emissions per kilometre, average number of passengers per trip, average length of trip, and degree of adoption of the operational measure.*

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