FINAL DRAFT

San Diego International Airport Air Quality Management Plan

Analysis of Ground-Based Aircraft Movement Greenhouse Gases

Prepared by:
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Prepared for the:
San Diego County Regional Airport Authority

October 20, 2009

I. BACKGROUND INFORMATION AND PURPOSE OF THE REPORT

The San Diego County Regional Airport Authority (SDCRAA or the "Airport Authority") is preparing an Air Quality Management Plan (AQMP) for San Diego International Airport (SAN). The AQMP is a multi-faceted program to aid the Airport Authority in the quantification, reduction and management of air emissions associated with SAN. In summary, the AQMP is designed to accomplish the following:

- Identity the sources and quantify the amounts of air emissions (e.g., criteria pollutants and greenhouse gases - GHG) associated with the operation of, and planned improvements to, the airport;
- Address the energy and GHG emission reduction measures called for in the Attorney General Memorandum of Understanding (MOU)[1].
- Identify future emission reduction measures;
- Support the Airport Authority's on-going Environmental Sustainability Program; and

The MOU arose due to questions that the Attorney General's office had concerning the Environmental Impact Report (EIR) for the proposed SAN Master Plan Improvements. It contains seven sections; the first of which requires the Airport Authority to reduce specific source-related emissions, whereas the other sections address the administration of the MOU.

Exhibit A of the MOU also contains several *Specific Measures* addressing energy use at SAN. These are separated into five sections: 1) Aircraft On-the-Ground Energy Usage; 2) Reduction in Landside Energy Use, 3) Use of Green Materials and Sustainable Design; 4) Use of Green Construction Methods and Equipment; and 5) Coordination and Encouragement of Tenants to Address GHG

Specific Measure 1 (*Reduction in Aircraft On-the-Ground Energy Use*) further comprises six sub-components (a. through f.) centered on the provision of electric power and preconditioned air (PCA) at all new and existing terminal gates, cargo areas, and general aviation (GA) facilities - as well as an assessment of energy use (and the associated GHG emissions) associated with aircraft movements. In particular, *Specific Measure 1.f.* (*Aircraft Movements*) calls out a goal and timeframe for a 20 percent reduction of 2010 (i.e., Baseline) GHG emissions attributable to aircraft engine on-the-ground movements by 2015 – which is the subject of this report.

Purpose of the Report

The MOU Specific Measure 1.f calls for a 20 percent reduction of 2010 aircraft engine-related "on-the-ground" GHG emissions at SAN by 2015. This report quantifies these emissions and evaluates alternative measures and the overall feasibility for reducing these emissions.

[1] *Memorandum of Understanding Between the Attorney General of the State of California and the San Diego County Regional Airport Authority Regarding the San Diego International Airport Master Plan*, May 5, 2008. www.san.org/documents/airport_authority/MOU_SDCRAA_AG_Master_Plan_2008.pdf

II. SPECIFIC MEASURE 1.F (AIRCRAFT MOVEMENTS)

For reference, the full text of *Specific Measure 1.f* (Aircraft Movements) is restated below:

MOU Specific Measure 1.f – Aircraft Movements

The Airport Authority will prepare an inventory of those greenhouse gas emissions attributable to the movement of aircraft at the Airport that it expects in 2010. The Authority will then establish a goal to reduce, by 2015 and with due regard to regulations to be issued pursuant to AB 32, annual GHG emissions levels by an amount equivalent to 20 percent of the emissions in 2010 from the movement of aircraft.

Toward that end, by January 1, 2010, the Authority will prepare and make available to the public a study, with or without the participation of the airlines and the FAA, to identify and evaluate techniques to reduce fuel consumption and GHG emissions during all stages of aircraft movement at the Airport. The study shall recommend specific measures to achieve such reductions, based on an assessment of technical, economic, environmental and safety issues associated with the measures.

The Airport Authority will then investigate and attempt to implement meaningful incentives or other programs to encourage the use of those measures that were studied and recommended for implementation.

Because this measure is stipulated in the MOU under the broader provision entitled *Reduction in Aircraft On-the-Ground Energy Use*, <u>it is assumed that the goal pertains principally to aircraft GHG emissions that occur "on-the-ground"</u>. By comparison, aircraft emissions are typically characterized by four key operating modes: (1.) taxi-delay, (2.) approach, (3.) climb-out, and (4.) takeoff. Thus, this specific MOU measure focuses on aircraft operating on-the-ground in the taxi-delay mode.

GHG emissions associated with ground support equipment (GSE) and auxiliary power units (APUs) at the gate are addressed separately under *Specific Measure 1*, or elsewhere in the MOU, it is also assumed that these sources are not included in this analysis even though they are related to aircraft movements that occur on the ground.

III. ANALYSIS OF SPECIFIC MEASURE 1.F (AIRCRAFT MOVEMENTS)

As shown above in Section II, Specific Measure 1.f contains a number of individual conditions and steps that, taken altogether, provide the basis of how the goal of reducing 20 percent of the 2010 on-the-ground aircraft-related GHG emissions at SAN is to be achieved by 2015. For ease of understanding, they specified A. through E. and are individually restated below (**in bold font**) followed by an explanation of the AQMP Team's current approach.

A. ***The Authority will prepare an inventory of those greenhouse gas emissions attributable to the movement of aircraft at the Airport that it expects in 2010.***

As part of the AQMP, the Airport Authority has undertaken a comprehensive update of the Criteria Pollutant and GHG emissions inventory for SAN (see **Figure 1**). This inventory includes GHG emissions associated with aircraft (both airborne and on-the-ground), APUs, GSE, ground access vehicles (GAV), electrical usage, and an array of stationary sources associated with the airport.

With the principal focus on 2010 Baseline conditions, the overall approach to the preparation of this inventory is based on three important fundamentals: a.) representative of emission sources and conditions that are characteristic of SAN; b.) uses the most up-to-date information and data currently available for the airport; and c.) and is consistent with the most appropriate guidelines for quantifying airport-related GHG emissions.


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San Diego International Airport
Air Quality Management Plan

Criteria Pollutant & Greenhouse Gases Baseline Emissions Inventory

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Prepared for the:
San Diego County Regional Airport Authority

October 20, 2009

Figure 1: SAN Emissions Inventory

For example, the number of aircraft operations, fleet mix characteristics, and ground-based operating times (i.e., taxi-in, taxi-out, and delay) are based upon SAN-specific data obtained from Federal Aviation Administration (FAA) records, Authority staff and the recently-completed *SAN Master Plan Environmental Impact Report*.[2] Similarly, aircraft engine fuel throughput and GHG emission rates were obtained from the latest version of the FAA's Emissions & Dispersion Modeling System (EDMS) (Version 5.1).

The preparation of the emissions inventory also followed recommendations recently-issued in the Transportation Research Board (TRB) Airport Cooperative Research Program (ACRP) Report 11: *Guidebook for Preparing Airport-Related Greenhouse Gas (GHG) Emissions Inventories.* [3]

The results of the baseline (2010) GHG emissions inventory for SAN are summarized in **Table 1**. The emissions associated with the subject of this report (i.e., "Aircraft Ground Emissions") are highlighted. The other emission sources associated with aircraft, ground access vehicles, stationary sources, etc. will be discussed in the AQMP, published separately.

[2] *San Diego International Airport Master Plan Environmental Impact Report*; Lead Agency – San Diego County Regional Airport Authority, 2007.

[3] *Guidebook for Preparing Airport-Related Greenhouse Gas Emissions Inventories, prepared for the Airport Cooperative Research Program, Transportation Research Board, April 2009.*

Table 1: 2010 Baseline Greenhouse Gas Emissions Inventory for SAN

Emission Source	Scope	CO_{2e}	Percent of Category	Percent of Total
Category 1: Airport Owned/Controlled				
Purchased Electricity	2	14,055	59.8	0.87
Stationary Sources - Central Plant - Emergency Generators	 1 1	 1,443 139	 6.14 0.59	 0.09 0.01
Ground Service Vehicles	1	423	1.80	0.03
Ground Access Vehicles – On-airport Roadways - Employee Auto/Trucks - Public Auto/Trucks - Taxis/Limos - Vans/Shuttles/Buses	 3 3 3 3	 23 1,771 700 3,521	 0.10 7.54 2.98 15.0	 0.00 0.11 0.04 0.22
Ground Access Vehicles – Parking Facilities	3	525	2.24	0.03
Ground Access Vehicles – Off-airport Roadways - Employee Auto/Trucks - Vans/Shuttles/Buses	 3 3	 819 79	 3.49 0.34	 0.05 0.00
Subtotal-Airport Owned/Controlled		**23,498**	**100**	**1.45**
Category 2: Airline, Aircraft Operator, or Tenant Owned/Controlled				
Aircraft - Ground - Ground to 3,000 feet - Above 3,000 feet **Aircraft Total**	 3 3 3 	 79,133 121,439 1,269,066 **1,469,638**	 5.29 8.12 84.8 **98.2**	 4.88 7.49 78.3 **90.6**
Aircraft Engine Startup	3	1,267	0.08	0.08
Auxiliary Power Units	3	8,965	0.60	0.55
Ground Support Equipment	3	3,725	0.25	0.23
Ground Access Vehicles – On-airport Roadways - Employee Auto/Trucks - Vans/Shuttles/Buses	 3 3	 310 212	 0.02 0.01	 0.02 0.01
Ground Access Vehicles – Off-airport Roadways - Employee Auto/Trucks - Vans/Shuttles/Buses	 3 3	 11,266 1,083	 0.75 0.07	 0.69 0.07
Subtotal-Tenant Owned/Controlled		**1,496,465**	**100**	**92.3**
Category 3: Public Owned/Controlled				
Ground Access Vehicles – Off-airport Roadways - Public Auto/Trucks - Taxis/Limos - Vans/Shuttles/Buses	 3 3 3	 65,949 10,087 22,658	 66.8 10.2 23.0	 4.07 0.62 1.40
Subtotal-Public Owned/Controlled		**98,695**	**100**	**6.09**
Construction Activities		3,558		0.22
Waste Management		(837)		-0.05
Grand Total		**1,621,378**	**100**	**100**

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See Glossary for definition of the terms “Category” and “Scope”.
Shaded area (79,133) contains aircraft ground-based emissions information and data.

> The MOU GHG reduction goal of 20 percent attributable to "on-the-ground" aircraft movements at SAN is 15,827 MT.

As shown, aircraft are expected to represent the largest overall source of GHG emissions associated with SAN in 2010 comprising over 90 percent (1,469,638 MT) of the estimated total (1,621,378MT).[4] Importantly, this includes aircraft-related emissions that occur beyond an altitude of 3,000 feet while in the "cruise" mode (1,269,066 MT or about 85 percent); during take-off and landing operations that occur from ground level and 3,000 feet (121,493 MT or about 7.5 percent); and those that are associated with on-the-ground movements (79,133 MT or about 4.9 percent). This contribution to total airport-related GHGs is generally consistent with the experiences at other airports using this same accounting methodology.

B. *The Authority will then establish a goal to reduce, by 2015 and with due regard to regulations to be issued pursuant to AB 32, annual GHG emissions levels by an amount equivalent to 20 percent of the emissions in 2010 from the movement of aircraft.*

Again, the initial outcome of the 2010 Baseline Emissions Inventory for SAN reveals that on-the-ground aircraft movements represent 79,133 MT of GHGs. From this, the MOU goal to reduce these emissions by 20 percent corresponds to reducing these emissions by 15,827 MT (as follows:

79,133 MT (Aircraft On-the-Ground Emissions) x 0.20 = 15,827 MT (Reduction Goal)

For ease of comprehension, **Figure 2** illustrates these important findings.

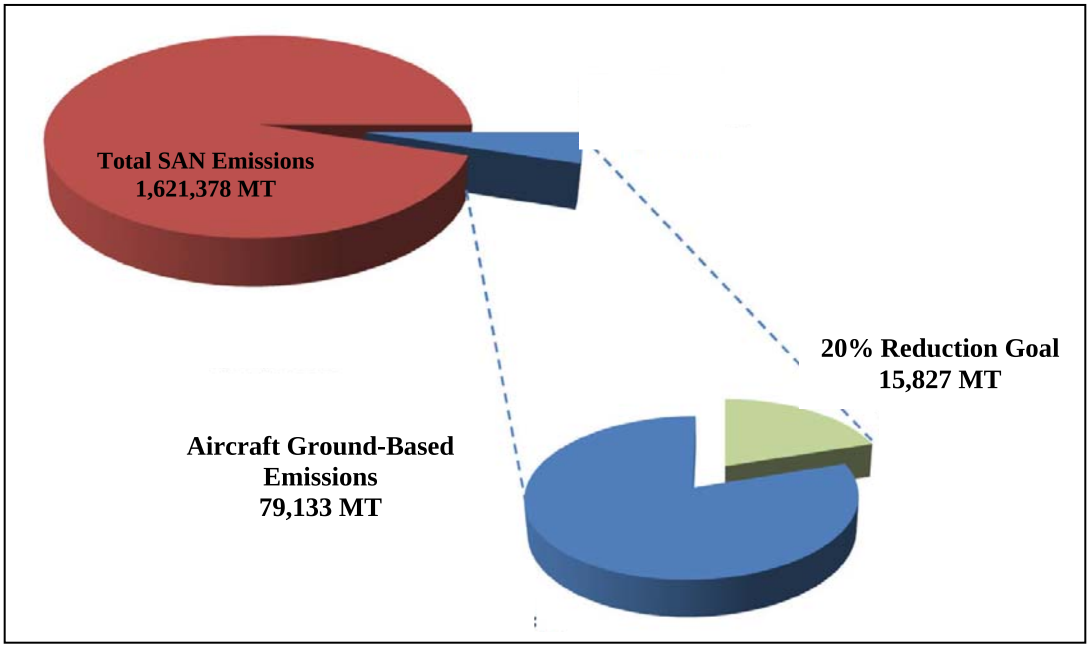

Figure 2: Total and Aircraft Ground Movement GHG Emissions

[4] For this assessment greenhouse gases comprise the following: carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (N_2O) expressed as "CO_2 equivalents" (CO_{2e}) as metric tons (MT). One MT = 0.9 Short Tons

With respect to AB 32 (the California Global Solutions Act), it is understood that the MOU-based goal to reduce GHGs attributable to on-the-ground aircraft movements at SAN by 20 percent is separate, or apart, from this state regulation. In other words, AB 32 aims to reduce GHG emissions state-wide to 1990 levels by 2020, it potentially applies to other airport-related sources (e.g., stationary sources, electrical use, etc.), As the Authority does not own aircraft sources or control these sources, the Authority would not be responsible for these emissions under AB 32.

C. ***Toward that end, by January 1, 2010, the Authority will prepare and make available to the public a study, with or without the participation of the airlines and the FAA, to identify and evaluate techniques to reduce fuel consumption and GHG emissions during all stages of aircraft movement at the Airport.***

As discussed above in Section I, this report quantifies the GHG emissions associated with aircraft "on-the-ground" movements at SAN and evaluates alternative measures reducing these emissions. During the course of this assessment, the Authority implemented a "stakeholder" participation program involving the airlines and other airport tenants.[5] The input from this process is summarized and discussed below in Section III.D.

Moreover, the Authority is also preparing an assessment of potential fuel consumption and GHG emission reduction measures airport-wide including landside power and pre-conditioned air (PCA) at all new and existing terminal area gates, cargo facilities and GA hangars; the replacement of aircraft tow vehicles and pushback tugs with alternative-fueled GSE; and incentive programs applicable to airport shuttle van operators (e.g., hotel, rental car, parking), taxis/limos, and employee transportation (see **Figure 3**).


San Diego County Regional Airport Authority
Air Quality Management Program
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San Diego International Airport
Air Quality Management Plan

Analysis of Potential Air Emission Reduction Opportunities

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San Diego County Regional Airport Authority

September 15, 2009

Figure 3: Emission Reduction Measures

[5] The stakeholder participation program comprised a comprehensive and multi-faceted attempt to obtain feedback from those that have the greatest level of involvement with aircraft ground-based movements: namely the airlines, cargo carriers, fixed-base operators, and the air traffic controllers. To this end, the following coordination was accomplished:

- Workshop No. 1 with SAN-based airlines and air cargo operators on July 24, 2009.
- Workshop No. 2 with SAN-based airlines and air cargo operators on August 25, 2009.
- Written comments from airlines obtained August and September, 2009.
- Meeting with SAN-based airline station managers September, 2009.
- SAN FAA Air Traffic Control Tower visit, September 2009.

D. *The study shall recommend specific measures to achieve such reductions, based on an assessment of technical, economic, environmental and safety issues associated with the measures.*

There are a number of measures, or initiatives, that have been undertaken or are presently being considered by airports, airlines and regulators to identify, evaluate and implement measures that will help to reduce aircraft engine fuel burn and the associated GHG emissions while on-the-ground. The most relevant of these that are described in publications are listed in the References Section to this report. Broadly categorized as design-, operational-, or policy-based, the most commonly cited measures are listed alphabetically in **Table 2** along with the MOU-recommended evaluation criteria.

With respect to these MOU evaluation criteria, the following general definitions apply for the purposes of this analysis:

- Safety – The safeguarding of health and safety to the traveling public; airport and airline employees; and nearby businesses and residents as well as the protection of property.
- Technological – The overall effectiveness based on current and future availability of the technology.
- Economic – The estimated monetary costs and relative cost-effectiveness.
- Environmental – The benefits and tradeoffs to the environment.

Applying these criteria, combined with what is known by the AQMP Team about airport GHG emissions and input from the stakeholder participation program, **Table 2** also contains summary statements pertaining to the potential applicability of each measure at SAN.

Of the 18 emission reduction measures evaluated**,** four are considered to have “good” potential at SAN. These include the following:

- Airfield and Terminal Area Improvements.
- Gate-hold Procedures.
- Reduce APU Usage.
- Single Engine Taxing.

These measures are discussed in the next Section.

E. The Authority will then investigate and attempt to implement meaningful incentives or other programs to encourage the use of those measures that were studied and recommended for implementation.

Of the 18 potential emission reduction measures identified and evaluated in support of this assessment**,** four are considered to have "good" potential at SAN. These include the following:

- Airfield and Terminal Area Improvements - Resolves "bottle-necks" and other airfield conflicts or delays with added runways, taxiways, turn-outs, etc. The *SAN Airport Master Plan* contains recommended improvements to airfield and terminal areas. By way of example, airfield and terminal area improvements that reduce aircraft taxi-in, taxi-out and/or delay times will result in the following reductions in ground-based GHG emissions:

  - 15-seconds = 1,125 MT CO2e.
  - 30-seconds = 2,259 MT CO2e.
  - 1-minute = 4,500 MT CO2e.

  As shown, these reductions in ground-based aircraft emissions represent approximately 7 to 28 percent of the 15,827 MT goal set by the MOU.

- Gate-hold Procedures - Involves controlling the time and frequency of aircraft departures thus avoiding or minimizing delays during taxi-out. Subject to FAA air and ground traffic control at SAN. Reductions in aircraft engine GHG emissions associated with this measure are expected to be similar to those associated with Airfield and Terminal Area Improvements, described above. In other words, a 1 minute delay in engine start-up at the gate results in 4,500 MT savings of CO2e.

- Reduce APU Usage - Install gate-furnished power and pre-conditioned air (PCA) as a means of reducing the use of APUs. Ground-start units can be employed to start aircraft engines rather than relying on APU. Potential for outside funding. Again, by way of example, the theoretical reductions in APU usage associated with this measure are estimated to result in the following reductions in ground-based GHG emissions:

  - PCA and power at 10 new gates = 1,030 MT CO2e.
  - PCA and power at all remaining gates = 4,240 MT CO2e.
  - Eliminate APU usage during taxi-in and taxi-out operations = 3,700 MT CO2e.

  As shown, these reductions represent approximately 7 to 28 percent of the 15,827 MT goal set by the MOU.

- Single Engine Taxing - Because the principle aim of MOU Specific Measure 1.f is to reduce ground-based aircraft engine GHG emissions, single engine taxiing (SET) was expansively evaluated as it is among the most commonly suggested measures. In general terms, the concept involves aircraft using less than all its engines to taxi-in and taxi-out between the runway ends and the terminal areas. With only one engine running (in the case of a two-engine aircraft) the fuel savings and thus the emission reductions are projected to be 20 to 40 percent (the benefits are less than ½ (or 50 percent) as more power is required from the operating engine).

As the practice of SET directly involves the aircraft operators, input was expressly solicited from the airlines and air cargo operators at SAN on the feasibility of this measure (see footnote 5). This feedback is summarized in **Table 3** and reveals some important aspects of this practice, particularly as it applies to SAN. In summary, the principle issues and concerns are listed as follows:

- As a policy, most airlines already encourage SET as a means of saving fuel and to reduce emissions.
- In general, SET is most often used during taxi-in and sometimes during taxi-out when long queues and delays are expected.
- Importantly, SET is implemented solely at the discretion of the aircraft pilot for safety and operational considerations.
- Aircraft engines have approximately a five-minute warm-up and a three-minute cool-down period, respectively. Time for operational checks during taxi-out is also necessary.
- The taxi-in and taxi-out periods at SAN are relatively short (i.e., 3 to 14 minutes, respectively, on average).

Based on the above, it is apparent that passenger safety and aircraft engine operational considerations make a mandatory policy for SET at SAN impracticable. Moreover, the relatively short taxi times at SAN significantly reduce the overall benefits of this measure in reducing ground-based aircraft engine GHG emissions. However, it does appear that on a voluntary basis and during certain periods (e.g., taxi-in operations and taxi-out operations when the taxi times exceed five minutes) SET has the potential to reduce ground-based aircraft engines at SAN.

The following theoretical SET conditions at SAN reveal the potential GHG emission reduction benefits at SAN:

- SET for 50 percent of the taxi out (~7 minutes) and 25 percent of the taxi in (~1 minute) during 25 percent of SAN operations = 3,080 MT CO2e.
- SET for 50 percent of the taxi out (~7 minutes) and 25 percent of the taxi in (~1 minute) during 50 percent of SAN operations = 6,150 MT CO2e.

As shown, these reductions in ground-based aircraft emissions represent approximately 20 to 40 percent of the 15,827 MT goal set by the MOU.

Other, longer-term measures that may also improve airport operations, reduce delays both on the airfield and at the terminal, and thereby further lessen ground-based GHG emissions comprise the FAA's "NexGen" navigation system, a variety of other on-board aircraft GPS systems, and an array of other tools and techniques designed to provide pilots, ground handlers, and air traffic controllers with expanded efficiencies to manage aircraft at airports, including SAN.

Finally, as a means of ensuring ongoing compliance with the MOU Specific Measure 1.f, the following recommendations are provided:

- Require that airlines, air cargo carriers, and GA operators (i.e., Measure 1.f Stakeholders) acknowledge and accept all of the conditions of the MOU as part of updated lease agreements.
- Require Measure 1.f Stakeholders include provisions for SET and reduced APU usage in their Flight Operations Manuals for SAN.
- Assess annually aircraft taxi-in and taxi-out times, single-engine taxiing procedures, and other ground-based GHG emission reduction measures.
- Continue regular coordination with stakeholders to reinforce and advance the goals of the ground-based aircraft emission reduction initiatives.

[**End of Report.]**

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Operational Opportunities to Minimize Fuel Use and Reduce Emissions, International Civil Aviation Organization Circular 303-AN/176, February 2004.

Table 2 – Evaluation of Specific Aircraft Ground Movement Emission Reduction Measures

Measure	Description	Evaluation Criteria				Potential for Reducing Aircraft Ground Movement GHG at SAN
		Safety	Technological	Economic	Environmental	
Airfield and Terminal Area Improvements	Resolve "bottle-necks" and other airfield conflicts or delays with added runways, taxiways, turn-outs, etc.	Must comply with FAA guidelines and design standards for airfield clearances and separation distances.	Technologically feasible.	New runways, taxiways and other airfield infrastructure are costly and not easily cost-effective for reducing fuel burn and emissions.	Beneficial to fuel burn and GHG reductions.	Good: *SAN Master Plan* contains recommended improvements to airfield and terminal areas.
Derated take-off	Rather than using maximum thrust during take-off, thrust is reduced to the minimum required for safe take-off.	Must be cognizant of velocity and distance requirements to ensure safe take-off.	Limitations based on aircraft type, size, and payload; weather conditions; and noise abatement procedures.	None.	Some pollutants are emitted at higher concentrations at lower power settings, so a pollutant trade-off may be involved.	Fair: Subject to pilot discretion and safety factors.
Engine and Airframe Maintenance	Routine maintenance reduces aerodynamic drag, engine wear, and combustion efficiency.	Ensures passenger and operator safety.	Technologically feasible.	Increased maintenance costs are mitigated by extension of airframe/engine useful life.	Reducing drag and engine wear, and increasing combustion efficiency, reduces fuel burn and emissions.	Fair: Implementable and cost-controllable, under airline control.

Measure	Description	Evaluation Criteria				Potential for Reducing Aircraft Ground Movement GHG at SAN
		Safety	**Technological**	**Economic**	**Environmental**	
Engine Modifications	Turbofan engines with increased combustion efficiency and adjusted bypass ratios reduce NOx, CO, HC and GHG emissions over all stages of operation., including lower engine power settings, significantly reducing ground-based emissions	Responsibility of engine manufacturer.	Older airframes in an aircraft fleet might not be compatible with new engine technology, or could require retrofitting.	Increased combustion efficiency reduces fuel consumption, which can offset the cost of fleet replacement and retrofitting.	Trade-off between noise mitigation and emissions mitigation; some engine improvements that reduce emissions might increase the amount of operational noise.	Fair: Implementable and cost-controllable, under airline control.
Further Limit Non-Revenue Flights	Decrease run-up testing, utilize flight simulators during training, limit positioning and test flights.	Limitation of engine testing and test flights must not occur counter to safety considerations.	Technologically feasible.	No significant economic benefits or costs.	Saves fuel and reduces emissions, however non-revenue flights represent a small component of airport activity.	Poor: Emissions savings are comparatively small at SAN.
Gate-hold Procedures	Involves controlling the time and frequency of departures thus avoiding or minimizing delays during taxi-out.	None.	Efficacy can depend on air/ground traffic control and dispatch limitations.	May impact flight scheduling and increase gate electricity usage.	May increase APU usage and emissions if gate power is unavailable.	Good: Subject to air traffic control.

Measure	Description	Evaluation Criteria				Potential for Reducing Aircraft Ground Movement GHG at SAN
		Safety	Technological	Economic	Environmental	
Increase Aircraft Load Factors	Accomplished by increasing the number of passengers per flight or using larger aircraft, thus decreasing the number of necessary flights.	Must be balanced with FAA take-off weight requirements, fuel requirements and other safety considerations.	See Safety criteria.	Fewer flights reduce overall fuel consumption.	Beneficial to fuel burn and GHG reductions.	Poor: Most airlines at SAN are operating at maximum load capacity.
Institute Landing Fees	The Anti-Head Tax Act (AHTA) allows levying of reasonable landing fees on high-emitting aircraft, so long as the revenue is used entirely for airport of aeronautical purposes. Used to encourage use of more fuel-efficient, less-polluting aircraft.	None.	None.	Can generate revenue that the airport can use to further other emissions reduction strategies.	To help align emissions reduction measures with noise reductions, Part 161 (14 CFR 161) allows FAA to impose restrictions on fee programs pertaining to Stage 2 and 3 aircraft, including imposition of public comment periods and agreements with aircraft operators subject to the fees.	Fair: Can generate revenue for GHG reductions at the airport, but unlikely to change aircraft fleet characteristics.
Limit Aircraft Types	Imposes limitations on types of aircraft allowed to use airport and encourages more fuel efficient, less-polluting aircraft.	Pre-emptable under the Federal Aviation Act, on grounds that it impedes FAA's control of traffic flow.	None.	Could reduce level of commercial service and enplanements.	Per-operation emissions are greatly reduced when restricting use of high-emitting aircraft.	Poor: Preemptive by law.

Measure	Description	Evaluation Criteria				Potential for Reducing Aircraft Ground Movement GHG at SAN
		Safety	Technological	Economic	Environmental	
Limit Flights	Limits the number of available flight slots in an airport's schedule and thus the number of operations and fuel use.	Limitation of flight procedures falls under the jurisdiction of FAA as it relates to regulation of flight safety, and thus is pre-emptable under the Federal Aviation Act.	None.	Reduced landing fees to airport and lower revenues to airlines and other airport tenants.	None.	Poor: Preemptive by law.
Limit Power-Back / Reverse Thrust	Discouraging the use of reverse thrust during landing and push-back from gates.	Pilots must exercise caution when limiting reverse thrust to ensure that the aircraft has adequate time and distance to stop safely.	Can result in additional wear on engines	Comparatively low costs to implement but additional costs associated with push-back tractors and aircraft engine wear.	Minor reductions to fuel burn and GHG reductions.	Good: Few barriers to implementation, subject to pilot discretion, safety concerns.
Reduce APU usage	Install gate-furnished power and pre-conditioned air to substitute that which the on-board engines would normally generate. Ground-start units can be employed to start aircraft engines rather than relying on APU.	None.	Technologically feasible.	Would likely increase the amount of electricity the airport would need to purchase	APU are very fuel-inefficient. Restriction of use can reduce fuel burn and GHG emissions.	Good: Fuel and emissions savings per operation.

Measure	Description	Evaluation Criteria				Potential for Reducing Aircraft Ground Movement GHG at SAN
		Safety	Technological	Economic	Environmental	
Reduce Empty Aircraft Mass	Utilize lighter cargo containers and safety equipment, limit fuel bunkering or carrying excess fuel, remove excess comfort items such as water coolers.	Refrain from removal of safety implements.	Technologically feasible.	Eliminating extraneous on-board mass can result in direct savings.	Minimizing empty mass reduces aircraft weight, increasing fuel efficiency and reducing emissions.	Poor: Most airlines at SAN are operating at maximum load capacity.
Single Engine Taxi	Reduces fuel consumption during taxing to and from terminals, apron areas and runways.	Pilots exercise discretion over when to cut engine power. Weather conditions can impact the ease with which pilots can steer the aircraft using a reduced number of engines.	Efficacy is tempered by the number of engines on an aircraft as well as the engine placement. Some aircraft require a minimum number of engines to operate.	Lower fuel costs could reduce operational costs.	Beneficial to fuel burn and GHG reductions.	Fair to Good: Subject to pilot discretion and dependent on safety considerations.
Terminal and Aircraft Staging Area Spacing	Construct terminals, aircraft aprons, and hangars or scheduling flights at gates proximal to the designated departure/arrival runways to minimize taxi times.	Must comply with FAA guidelines and design standards for clearances and separation distances.	Efficacy can be dependent on air/ground traffic control and dispatch limitations.	New or relocated terminals and other airport infrastructure are costly and not easily cost-effective for reducing fuel burn and emissions. Scheduling is more cost-effective and easier to implement.	Increased construction could temporarily increase airport-related emissions, counteracting operational reductions.	Fair: Gate locations at SAN already enable short taxi distances.

Measure	Description	Evaluation Criteria				Potential for Reducing Aircraft Ground Movement GHG at SAN
		Safety	Technological	Economic	Environmental	
Tow Aircraft to Runway	Employs aircraft tugs and tractors to move aircraft from the terminal gates and aprons to the runways.	Causes excess wear on aircraft nose-gear. Increased potential for aircraft incursions and accidents.	Fuselage nose-gear must be adequately protected from wear due to increased towing frequency. Also requires a staging area near runways for aircraft to detach from the towing device.	Reduced fuel costs translate directly into operational cost savings. Involves expenditures to expand/convert existing GSE fleet. Airports and airlines can apply for federal funding through the VALE program to help mitigate conversion costs.	Towing aircraft to the runway using low-emissions vehicles should be employed wherever possible, rather than using fossil fueled GSE and aircraft engines to move the aircraft to the runway.	Poor: Aircraft engine warm-up and cool-down periods equal or exceed the taxi-in/taxi-out times at SAN.
Use of Biofuels	Plant-based alternatives to fossil fuels are being developed that significantly reduce GHG and other air emissions	Certain aircraft technology (i.e. piston engines) cannot safely use these fuels.	Still in development stages. See also Safety criteria.	Involves expenditures on necessary technological modifications to aircraft and storage/dispensing facilities.	Areas used for fuel-stock production can displace natural flora and fauna, however there are no direct implications for airports.	Fair: Exhibits significant potential as research is advanced.

Table 3 – Airline & Air Cargo Feedback Regarding Aircraft Single Engine Taxiing at SAN

I.D.[1]	Summarized Feedback[2]	
	Single Engine Taxi (SET)	**Other Related Comments**
A	- Pilots are policy-directed to use SET when opportunity arises; especially during taxi-out. - Practice of SET at SAN undocumented. - Not recommended as a mandated measure.	- Will use gate power and PCA when available.
B	- Pilot must have ultimate control to ensure safety and operational feasibility. - SET incorporated into *Flight Operations Manual* and used when feasible. - Airline policy to use SET when long queue occurs at take-off runway. - Where taxi times are relatively short, end-of-runway hold times for aircraft engine warm-up and/or cool down may increase airfield congestion, taxi times, engine use and emissions.	- Non-use of APUs during taxi modes could cause unintended delays due to discontinuous power to flight systems. - APU use during taxi mode should be the discretion of pilot based on manufactures recommendations. - Will use gate power and PCA when available. - Supports airfield improvements for more efficiency.
C	- Airline has limited taxi times at SAN due to gate locations. - Preflight check-list requires all engines to be operating. - Aircraft engines require warm-up and cool-down periods. - Where taxi times are relatively short, aircraft engine warm-up and/or cool down may increase airfield delays and emissions and unsafe aircraft. - Single engine taxi does not always cool cabin interior adequately.	- Will use gate power and PCA when available.

I.D.[1]	Summarized Feedback[2]	
	Single Engine Taxi (SET)	Other Related Comments
D	- Use of SET decision left to pilot. - Airline policy to use SET inbound after 3-minute engine cool-down period. - Relatively short taxi-out at times at SAN and required engine warm-up period makes SET impractical.	
E	- Current fleet of turbo-prop aircraft precludes use of SET due to steering problems with one engine. - Airline has limited taxi times at SAN due to gate locations. - Policy and Flight Manual call for SET, when possible.	- APU use during taxi periods is rare, but mechanical issues sometime require it. - Will use gate power and PCA when available.
F	- Policy to use SET when possible.	- APUs are not used during taxi periods. - APUs not used at gate when power and PCA are available.
G	- Use of SET should be voluntary so not to interfere with safety. - Use of SET should be the pilot's discretion. - Taxi-in is most likely operation to use SET.	- Will use gate power and PCA when available. - Supports airfield improvements for more efficiency.
H	- Limited taxi times at SAN due to airport locations. - Smaller aircraft use SET occasionally at pilot's discretion.	

Footnotes:

[1] Names of airlines and air cargo companies withheld for proprietary reasons.

[2] Summary information excerpted from verbal and written feedback.