Bay Area Airports Emission Inventory for Base Year (2007) and Target Analysis Scenarios in 2035

Draft Final Technical Report

Prepared for San Francisco Bay Area Metropolitan Transportation Commission

August 2010

Baseline and Target Analysis Scenarios

To evaluate the impacts of the Bay Area Airports on the region's air quality, emission inventories were developed for each of the major airports (San Francisco International (SFO), Oakland International (OAK), and Norman Y. Mineta San Jose International (SJC)) for each target analysis scenario and for the current and future baseline scenarios.[1] The base year emission inventory for 2007 was developed based on reported aircraft operations and modeled taxi delay. Future year emission inventories for 2035 were modeled using projected estimates of aircraft operations and taxi delay. These included the 2035 baseline and six target analysis scenarios (Table E-1). These scenarios are further described in the *Target Analysis Approach for Analyzing Regional Airport System Strategies* memo from RAPC staff, dated September 25, 2009.

Airport emission estimates were made for PM_{10}, $PM_{2.5}$, NO_x, SO_2, volatile organic compounds (VOC), CO, CO_2, N_2O, CH_4, and total greenhouse gases (GHG)[2] as CO_2-equivalent[3], for aircraft as well as for ground support equipment (GSE), and auxiliary power units (APU). The primary pollutants emitted at the Bay Area airports are NO_x, CO, VOC and CO_2. These airport emissions are a small fraction of the total Bay Area emissions. Airport related NO_x emissions compose 4.0% of the total Bay Area NO_x emissions, followed by VOC at 2.7%, CO_2 at 2.6% and CO at 2.1%.

The Bay Area is in federal non-attainment for both $PM_{2.5}$ and ozone[4]. GSE emissions were included in the 2007 emission inventory using default aircraft assignments as used in the Emission Dispersion Modeling System (EDMS). The GSE CO emissions contribute the largest percentage to the total airport emissions ranging from 35.6% at OAK to 52.8% at SFO; GSE NO_x percentage ranges from 11% at SFO to 16.8% at SJC; and VOC percentages range from 11% at SFO to 16.8% at SJC, with GSE CO_2 emissions much smaller at just about 2% at each airport. All three of the Bay Area Airports have long-term objectives to electrify GSE. These efforts represent a significant reduction in future GSE emissions of CO, VOC and $NO_{x.}$ Thus the analysis has assumed that by 2035 all ground support equipment (GSE) at the three Bay Area Airports will be electrified[5] resulting in no on-airport emissions from GSE.

An overview of the emission inventory is presented in the next section which details the consistent methodological approach used in developing the emission inventory for each scenario. Model results are then presented with discussion about the findings for each scenario.

---

[1] Emissions from passenger ground vehicles accessing the airport were also calculated by the study team and are reported separately in the "Ground Access Analysis Methodology and Results" technical paper.

[2] Emission factors for CH_4 and N_2O used the Airport Cooperative Research Program (ACRP) Report 11, Guidebook on Preparing Airport GHG Emission Inventories (2009) and reported as CO_2 equivalent. However, the contribution of these emissions relative to CO_2 emissions is a small (<1%) fraction of the total GHG emissions.

[3] CO_2-equilvaent is the quantity of greenhouse gases which have equivalent global warming potential as CO_2 only when measured over 100 years.

[4] NO_x and VOC are the primary contributors to ozone formation.

[5] Under AB 32 (Global Warming Solutions Act, 2006) a 40% decrease over 1990 levels is targeted in aircraft generated CO_2 emissions. All three Bay Area airports have aggressive emission reduction programs underway for GSE emission reductions including baggage handling and electrification of terminals gates along with inducements to encourage each airline and cargo handler for conversion to electric GSE (Airports Council International, Environmental Initiatives Around the World, Case Study 14 – Air quality high on the agenda at Oakland International Airport, July, 2007).

Overview of Emission Inventory Development

The general approach in developing the Bay Area Aircraft Emission Inventory was to develop an airport specific emission inventory for each of the three major airports in the region (SFO, OAK, SJC) using the latest version of FAA's EDMS 5.1.1 tool. No explicit calculations were made for other smaller airports in the region. However for the Internal Regional Airports scenario (Case 3) which involves new air services at secondary Bay Area airports (Charles M. Schulz – Sonoma County Airport (STS), Buchanan Field Airport in Concord (CCR) , and Travis Air Force Base in Fairfield (SUU)) the incremental aircraft emissions associated with the assumed air services at the secondary airports were calculated. Further details on the emission inventory are described in the following section.

TABLE E-1. TARGET ANALYSIS SCENAROS

Case	Name	Years
Case0a	Base Year	2007
Case0b	Baseline	2035
Case1	Redistribution	2035
Case2	External Regional Airports	2035
Case3	Internal Regional Airports	2035
Case4	High Speed Rail	2035
Case5	ATC Technology	2035
Case6	Demand Management	2035
Case7	Continuous Descent Approach	2035

Emission Inventory Development for Three Bay Area Major Airports

EDMS has two approaches for determining times in mode for the aircraft during flight: a dynamic Aircraft Performance based module and ICAO/EPA default values based on aircraft category. The dynamic aircraft performance module requires additional data as input on specific aircraft and engine characteristics as well as weather data to dynamically model each aircraft flight. Because our focus for this analysis is on a comparison between the scenarios, which will not change as a result of using the aircraft performance module, we used the more simplified approach of using the default time in mode values.

Taxi Delay Calculations

While EDMS has its own queuing model, WWLMINET, which predicts hourly airport ground and approach delay, considerable effort has already been undertaken using FTA's FLAPS and DELAYSIM models to determine capacity and aircraft delay. For consistency with the runway capacity and delays analysis, we relied on the runway taxi delay estimates from DELAYSIM to estimate taxi-in, taxi-out and approach times including delay. Future improvements that may reduce delay, such as advancements in air traffic control (ATC) technology and demand management (e.g., Cases 5 and 6), were accounted for in the emissions calculations to the extent they are included in the FLAPS and DELAYSIM modeling.

Baseline, unimpeded taxi-in and taxi-out times were determined for each of the three principal airports using information in the ASPM/APM FAA databases.[6] Raw taxi times, including

[6] http://aspm.faa.gov/information.asp

impeded and unimpeded, characterized by air carrier and season, were taken from the ASPM interface. The number of departures and arrivals by airline by month were taken from the APM database. Months were then assigned to seasons and the two databases combined to calculate annual average taxi in/out times weighted by the number of departures or arrivals for taxi-out or taxi-in, respectively. The unimpeded taxi-in and taxi-out times for SFO were 4.58 and 13.29 minutes, respectively. OAK and SJC had unimpeded taxi-in times of 5.08 and 3.29 minutes, respectively, and unimpeded taxi-out times of 8.92 and 9.46 minutes, respectively. These measured unimpeded taxi delay times for 2007 were assumed unchanged for 2035.Impeded taxi-out times were derived by combining the unimpeded taxi-out times with the taxi delay values derived from the FLAPS and DELAYSIM model for a given scenario. Finally, impeded taxi-in times were estimated to be equal to the unimpeded taxi-in times, since taxi delays to arriving flights occur at the origin airport and not the destination airport. This assumes all other delay occurs outside of the airspace in question (40 nm horizontal radius for greenhouse gas emission calculations and 2,300 vertical feet for criteria pollutants, as discussed below). Table E-2 shows the total (impeded plus unimpeded) taxi-in, taxi-out, and total taxi times for each airport for each scenario. Taxi delays at secondary airports (Case 3) were assumed to be equal to those at SJC), as these are the lowest of the DELAYSIM-modeled values.

TABLE E-2. AVERAGE TOTAL TAXI TIME FOR EACH TARGET ANALYSIS SCENARIO.

			SFO			SJC			OAK		
Case	Scenario	Year	Total (min)	Taxi-In (min)	Taxi-Out (min)	Total (min)	Taxi-In (min)	Taxi-Out (min)	Total (min)	Taxi-In (min)	Taxi-Out (min)
Case0a	Base Year	2007	23.95	4.58	19.37	13.14	3.29	9.86	14.90	5.08	9.82
Case0b	Baseline	2035	35.31	4.58	30.74	13.09	3.29	9.80	16.25	5.08	11.17
Case1	Airport Redistribution	2035	26.06	4.58	21.48	13.14	3.29	9.85	16.74	5.08	11.66
Case2	External Regional Airports	2035	30.82	4.58	26.25	13.08	3.29	9.79	16.29	5.08	11.21
Case3	Internal Regional Airports	2035	29.12	4.58	24.54	13.08	3.29	9.80	15.75	5.08	10.67
Case4	High Speed Rail	2035	27.48	4.58	22.90	13.01	3.29	9.73	15.66	5.08	10.58
Case5	ATC Improve	2035	34.06	4.58	29.48	13.09	3.29	9.80	15.55	5.08	10.46
Case6	Demand Management	2035	28.71	4.58	24.14	13.09	3.29	9.80	16.25	5.08	11.17

Emissions were calculated for GSE (in the baseline year only), APUs, and the five aircraft operating modes in the EDMS model: taxi-out, takeoff, climb-out, approach, and taxi-In. The sum across all modes gives the total emissions for a particular aircraft type and the sum of all emissions across all aircraft types (sizes, designation, engine type and uses) determines the total annual emissions for the airport. Generally, the emissions for criteria pollutants and greenhouse gases (GHG) were calculated similarly. However, separate simulations and post-processing were required due to altitude limitations in the EDMS model.

Criteria Pollutant Emission Calculations

EDMS assigns aircraft engine combinations as typically found at each airport which usually only vary across international regions. These default engine types are based on the actual engine type which is the most common or the most widely used engine type for that particular aircraft type in the United States based on data as extracted from the BACK aviation database (http://www.backaviation.com/information_services/products/schedules.htm). In cases where defaults are not available, a reasonable substitute alternative was used. All aircraft Time-in-mode (TIM) values are set to ICAO/EPA defaults, except taxi times, which were estimated as described above. All aircraft were assigned an engine(s). No APUs were used for plane types labeled as multi-engine land (MEL), single engine land (SEL), turboprop (TP), military (MIL), and local (LOC), unless a default exists in EDMS. For other types (business jet (BJ), air cargo (AC), and passenger) the default APU is used if available. No changes were made to default assignments of GSE. All modeled activity was understood to be operations, where one operation is taken as either a departure or landing. To determine activity in EDMS, the modeled values were divided by 2 and this value distributed among all the relevant plane sub-types. Furthermore, all aircraft activity was modeled in EDMS as landing-take offs (LTOs) for all plane types except local operations (LOC), which were modeled as touch-and-go's (TGOs) combined with the default taxi-times, as available in EDMS, for these general aviation aircraft. For example, the 2035 OAK baseline scenario has 18,305 local operations for Cesena-152s. This was included in the model as 18,305 arrivals and 18,305 departures. The same scenario also shows 152,645 operations for passenger aircraft type "737-700/800/900". This was modeled as 25,441 LTOs for each of Boeing 737-700, 737-800, and 737-900 aircraft. For future years, in cases where aircraft not currently available are used (principally the Boeing 787 and Airbus A350), the most similar extant aircraft and engine in the database was assumed. (These were the Boeing 767-200 Series with a CF6-80A engine and Airbus A340-600 Series with a Trent 556-61 Phase 5 tiled engine, respectively). Other aircraft substitutions were sometimes necessary to resolve discrepancies in the modeled activity and those types available in the database. Although infrequently occurring in the model, this was done using the best-available match. Table E-3 shows these substitutions.

Table E-3. Aircraft substitutions used for missing aircraft types in EDMS

Plane Type (EDMS Name)	Engine Type (EDMS Name)	Used as a Surrogate for (FLAPS/Activity Modeling Name)
BEECH36	TIO540	BE35
BEECH60	TIO540	BE76
BEECH99	PT6A36	BE95
CNA150	O200	C152
CNA525	1PW035	C25A
CNA525	1PW035	C25B
DHC8-3	PW123	DH8D
DHC8-3	PW123	DHC8-400
GLOBALEXPRESS	4BR009	GL5T
GULF2-B	1RR016	GLF3
MD81	4PW070	MD80
MIL-T2	J852	T33
PA23	TIO540	PA18
PA46T	PT6A42	UNK
SA226	TPE3U	SW4

Criteria pollutant emissions were calculated up to an altitude of 2,300 feet, the default annual average mixing depth in the Bay Area[7] (BAAQMD, 2004). This is also the value used by the BAAQMD in developing their inventory for Bay Area aircraft emissions. All criteria pollutant emissions were determined directly in the EDMS model.

GHG Emission Calculations

CO_2, CH_4 and N_2O emissions were determined based on simulations similar to those for criteria pollutants, although some modifications to the model output were necessary. Principally, this involved calculating emissions out to a horizontal distance of 40 nm (radius) from each airport rather than up to a vertical height of 2,300 ft. This was done to be consistent with the approach the BAAQMD adopted in developing their GHG emission inventory. This distance is approximately equivalent to the average travel distance within the nine-county airspace of 80 nautical miles per operation (diameter) as a composite distance across the three airports. The approach vertical height at 40 nautical miles was estimated at 12,700 and a departure height of 25,500 ft. However, the EDMS model is limited to vertical calculations of less than or equal to 10,000 ft. Thus, the following approach was used for determining the GHG emissions. The model was run once for the criteria emissions with a vertical extent of 2,300 ft and again for GHG emissions with a vertical extent of 10,000 ft. Total fuel consumption for all aircraft were then computed for each mode from both simulations. The difference in these values was used to determine total fuel consumption per vertical foot by mode in the 2,300 to 10,000 ft range. This value was assumed to also apply above 10,000 feet. Thus, a linear extrapolation up to the 12,700 feet (approach) or 25,500 feet (departure) threshold was performed by mode to determine the total fuel consumption within a 40 nm horizontal distance of any airport.

GHG emissions were then determined from the extrapolated fuel consumption values. CO_2 emissions are based on ICAO emission factors as used in EDMS for typical jet fuel (3.15 g/g of fuel) and aviation gasoline for piston engined aircraft. This is equivalent to the BAAQMD's fuel based CO_2 emission factor of 21.1 lb/gallon of jet fuel assuming a jet fuel density of 6.7 lbs per gallon. An N_2O emission factor of 2.96E-02 (g CO_2e per g fuel) was used, which incorporates a CO_2e value for N_2O of 296.[8] CH_4 emissions up to 10,000 ft were calculated using the EDMS calculated values of VOC, with the CH_4 fraction of total VOC taken as 10%.[9] Total CH_4 emissions within 40 nm were then calculated by applying the ratio of total fuel consumption within 40 nm horizontally to fuel consumption within 10,000 vertical feet.

Continuous Descent Approach (CDA)

CDA emission changes relative to non-CDA emissions were derived from research funded by the FAA Office of Environment and Energy (Dinges, 2008)[10]. CDA does not affect the criteria pollutant emission calculations for this study because below 2,300 ft the CDA and non-CDA

---

[7] Steinberger, Joseph, 2004 “General Aviations Contribution to Emissions”, Senior Planner BAAQMD, March 2004 presented at the Jet Set Go, Environmental Aviation Takes Off Program, March 2004.

[8] *Procedure for the Calculation of Aircraft Emissions*, SAE Document Number: AIR5715, July 2009, , p46

[9] *Procedure for the Calculation of Aircraft Emissions*, SAE Document Number: AIR5715, July 2009, , p44

[10] Dinges, EP. 2008. "Determining the Environmental Benefits of Implementing Continuous Descent Arrival Procedures", Paper #594 presented at the Annual Conference of the 101st Air & Waste Management Association, June 2008, Portland OR.

approaches are essentially identical. The difference in CDA's approach typically takes place between 10,000 ft and 3,000 ft with a net reduction in GHG emissions due to reduced fuel consumption during approach which averages about 24.2% (Dinges, 2008). The reduced fuel consumption was based on twenty-four days of data from FAA/NASA Performance Data Analysis and Reporting System using LAX radar data to define the average daily flight operations and the baseline flight profiles. This information was then combined with FAA's Aviation Environmental Design Tool which contains aircraft performance data necessary to derive thrust, which in combination with aircraft engine emission indices (g of pollutant/kg of fuel burned) was used to determine emission changes. The emission reduction changes developed by Dinges were applied assuming all aircraft would land using CDA.

Emission Inventory Development for Other Airports within the Nine-County Region

Emissions from aircraft operations at other airports were only included for the Internal Secondary Airports Scenario (Case 3), which involves changes that shift aircraft activity from one or more of the three primary airports to alternative secondary airports in the region. As identified in the Target Analysis Approach for Analyzing Regional Airport System Strategies, emissions at airports outside the region, which applies to the External Airports Scenario (Case 2), were not quantified. In this scenario the number of operations at the primary airports is reduced as the external airports gain new services and fewer passengers from the external airport market areas travel to the primary Bay Area airports for air service. While emissions within the Bay Area region decline, there is an increase in emissions at the external airports.

High Speed Rail (HSR) Scenario

For the HSR Scenario (Case 4) the estimated change in aircraft emissions was based on the reduction in aircraft operations and corresponding reduction in taxi delay. In addition, an analysis comparing GHG emissions form high speed rail and aircraft operations was developed. The comparison was done on a per passenger mile basis for each airport based on projected passenger load and aircraft operations bound for the Southern California market for the least fuel efficient aircraft (A-321) and the most fuel-efficient aircraft (A-319) used in that market. Air passenger load factors in Southern California markets ranged from 70.4% at SFO to 76.3% at SJC. Emissions from high speed rail were determined on a per passenger basis[11] for two top speed rail configurations (175 mph and 220 mph) for the current baseline energy mix, a 33% renewable energy mix (currently targeted by the state for 2020), and a 50% renewable energy mix. The current mix of non-renewable fuels is 45.7% natural gas, 18.2% coal, and 14.5% nuclear; the 33% renewable mix had non-renewables of 39.1% natural gas, 15.6% coal, and 12.3% nuclear; the 50% renewable mix had non-renewables of 29.2% natural gas, 8.5% coal, and 12.3% nuclear. Since California has no coal power plants adjustments for electrical transmission, losses from the burning of coal were made assuming an 8.5% transmission loss per 100 miles over 765kV lines over a distance of 500 miles.

Resulting Emissions and Discussion

Predicted Emissions and Emissions Changes by Scenario

Tables E-4 through E-36 show the predicted emissions from each of the three airports for the 2007 and 2035 baseline and for the 2035 target analysis scenarios. In each case, the

---

[11] Per passenger mile energy requirement based on the energy requirement reported in *the Bay Area to Central Valley High Speed Train Final Program EIR/EIS*, Volume 1, May 2008, Chapter 3.5 Energy, for a 16-car train set with a 1,200 passenger carrying capacity with an average of 994 passengers (82.8% occupancy rate).

emissions represent the total at each airport except for the Internal Regional Airports scenario (Case 3). In that case, the emissions at the three primary airports (SFO, OAK, SJC) represent the total emissions at those airports, but emissions at the three secondary airports (CCR, STS, SUU) only represent the change in activity above their respective baseline values. Emissions are reported for aircraft, auxiliary power units (APU), and ground support equipment (GSE) (only for 2007). By 2035 all GSE are assumed to be electrified and thus produce zero on-site emissions.

The first set of tables shows the results for the 2007 base year and the 2035 baseline scenarios, while subsequent tables show the modeled emissions for each target analysis scenario and their reduction relative to the future baseline scenario. In all cases, the relative reductions are defined as:

> Percent Relative Reduction = (value for scenario case - value for baseline case) / (value for baseline case) x 100

In examining the emission totals it should be noted that the emission rates vary substantially by operating mode particularly for NO_x and VOC. In general, jet aircraft produce substantially more NO_x than VOC (2-7 times depending upon aircraft performance characteristics) over an LTO cycle. However, most (> 70%) of the NO_x emissions occur during the takeoff and climb-out modes.

Additionally, most of the CO emissions from aircraft occur during taxi-in or taxi-out, ranging from 33% to 96% with the highest percentages occurring where taxi delay times are highest. Most of the VOC emissions occur during taxi operations ranging from a low of 60% up to 93% again with the highest percentages occurring where delays are largest. NO_x however exhibits the reverse pattern where most NO_x emissions occur during aircraft flight (77-87%). Finally, 94-96% of CO_2 emissions occur during flight.

Baseline (2007) and Future Baseline (2035) Scenario

Table E-4 shows the modeled criteria pollutant emissions for each airport. Table E-5 shows a comparison between the results found in this study with the criteria emission inventory developed by Bay Area Air Quality Management District (BAAQMD) for 2005[12]. Table E-6 summarizes the total greenhouse gas emissions and Table E-7 compares the 2007 baseline to the inventory developed independently by the Bay Area Air Quality Management District (BAAQMD) which was available for 2007[13].

In Table E-4 an emission comparison between the 2035 baseline and 2007 shows that CO and VOC emissions increase substantially at SFO while both OAK and SJC show small decreases. The primary cause for this is the significant increase is the increase in average taxi time of just over 11.4 minutes at SFO compared to an increase of just 1.3 minutes at OAK and almost no change at SJC (Table E-2). In addition, the elimination of the GSE emissions was sufficient at OAK and SJC to overcome the increase in aircraft activity. In all cases NO_x emissions showed increases with a near doubling of emissions for SFO.

---

[12] Base Year 2005 Emission Inventory Summary Report, BAAQMD, December 2008. Prepared by the Emission Inventory Section.
[13] Source Inventory of Bay Area Greenhouse Gas Emissions, BAAQMD, December, 2008

Table E-5 compares the results of this study for the baseline year (2007) to BAAQMD 2005 inventory. Exact agreement is not expected due to the different modeling methodologies[14], different numbers of aircraft operations and aircraft types, different taxi delay values and different analysis years. Comparisons are only made for CO, VOC and NO_x as the reported values for PM and SO_x were only reported at less than 0.1 ton per day. In general, results are similar although the largest difference is seen for SJC where the BAAQMD estimates are 30-50% higher. This could be due to differences in the default taxi-in/taxi-out delay times used in the BAAQMD analysis or, possibly, to declining activity between the two years.

Table E-6 shows that the CO_2e will increase by about 50% at SJC and OAK, but nearly double for SFO under the future baseline scenario. As a basis of quality assurance, the CO_2 emissions for 2007 baseline scenario (Case 0a) are compared with those derived by the Bay Area Air Quality Management District's 2007 Greenhouse Gas Emission Inventory. Table E-7 compares the modeled results for 2007 to the average daily results for 2005 calculated by the BAAQMD. Again, exact agreement is not expected due to the different modeling methodologies, activity level assumptions, and taxi-time values. However, the results demonstrate a reasonably strong agreement. SJC showed the greatest discrepancy, with the findings about 24% higher than the BAAQMD results. OAK is in very close agreement, while the results for SFO are about 11% lower than the BAAQMD.

[14] BAAQMD used a projected fleet of aircraft, this analysis used reported; BAAQMD used default time-in-mode, while this analysis used specific aircraft/engine performance data as available within EDMS.

Table E-4. Criteria Pollutant Emissions for 2007 Baseline (Case 0a) and 2035 Future Baseline (Case0b).

			Criteria Air Pollutants				
		CO (kg)	VOC (kg)	NOx (kg)	SOx (kg)	PM-10 (kg)	PM-2.5 (kg)
2007	OAK EDMS Aircraft Total	2,319,978	204,114	837,280	83,146	11,794	11,794
	EDMS GSE Total	1,306,191	45,072	144,727	7,750	4,514	4,342
	EDMS APU Total	45,449	3,313	32,823	5,086	4,956	4,956
	Total, All	3,671,618	252,499	1,014,831	95,982	21,264	21,092
	SFO EDMS Aircraft Total	2,536,739	729,518	1,978,801	190,683	33,774	33,774
	EDMS GSE Total	2,201,447	77,031	253,978	13,808	8,503	8,186
	EDMS APU Total	71,764	5,562	68,708	9,550	9,166	9,166
	Total, All	4,809,950	812,111	2,301,487	214,040	51,442	51,126
	SJC EDMS Aircraft Total	768,371	117,084	458,606	47,583	7,267	7,267
	EDMS GSE Total	895,632	30,687	97,115	5,092	2,879	2,767
	EDMS APU Total	32,966	2,392	22,175	3,544	3,547	3,547
	Total, All	1,696,969	150,163	577,896	56,219	13,693	13,581
2035	OAK EDMS Aircraft Total	1,876,012	199,833	1,349,178	114,759	16,218	16,218
	EDMS APU Total	37,230	2,985	50,728	6,930	5,471	5,471
	EDMS GSE Total	-	-	-	-	-	-
	Total, All	1,913,242	202,817	1,399,906	121,689	21,689	21,689
	SFO EDMS Aircraft Total	5,733,852	1,756,167	4,166,850	423,643	77,681	77,681
	EDMS APU Total	89,181	6,873	115,800	15,039	13,039	13,039
	EDMS GSE Total	-	-	-	-	-	-
	Total, All	5,823,033	1,763,039	4,282,650	438,682	90,721	90,721
	SJC EDMS Aircraft Total	739,329	99,798	716,741	63,204	9,300	9,300
	EDMS APU Total	27,852	2,024	35,467	4,754	3,843	3,843
	EDMS GSE Total	-	-	-	-	-	-
	Total, All	767,182	101,821	752,207	67,958	13,143	13,143

Table E-5. Criteria Pollutant Emissions Comparison for the Base Year

	BAAQMD 2005			Present Analysis (2007)			Relative Difference		
	CO (kg)	VOC (kg)	NOx (kg)	CO (kg)	VOC (kg)	NOx (kg)	CO (kg)	VOC (kg)	NOx (kg)
OAK	2,616,606	231,851	1,059,891	3,671,618	252,499	1,014,831	40%	9%	-4%
SFO	4,868,875	629,310	3,477,768	4,809,950	812,111	2,301,487	-1%	29%	-34%
SJC	2,715,971	298,094	828,040	1,696,969	150,163	577,896	-38%	-50%	-30%

Table E-6 Greenhouse Gas Emissions for 2007 Baseline (Case 0a) and 2035 Future Baseline (Case0b).

Greenhouse Gases (kg/yr)

			OAK	SFO	SJC
2007	CO_2 (kg)	Aircraft	534,708,386	1,196,217,782	315,199,275
		GSE	11,241,428	20,027,774	7,385,666
		APU	7,377,194	13,851,865	5,140,352
		Total	553,327,008	1,230,097,420	327,725,293
2035	CO_2 (kg)	Aircraft	733,224,842	2,316,591,765	408,226,080
		GSE	-	-	-
		APU	10,052,259	21,814,080	6,895,172
		Total	743,277,101	2,338,405,844	415,121,253

			OAK	SFO	SJC
2007	CO_2e (kg)	Aircraft	540,666,914	1,210,534,065	318,712,440
		GSE	11,326,963	20,180,163	7,441,863
		APU	7,433,326	13,957,262	5,179,464
		Total	559,427,204	1,244,671,490	331,333,767
2035	CO_2e (kg)	Aircraft	741,007,721	2,345,115,907	412,492,162
		GSE	-	-	-
		APU	10,128,746	21,980,061	6,947,637
		Total	751,136,467	2,367,095,968	419,439,799

Table E-7. Greenhouse Gas Emissions Comparison for Baseline (Case 0a).

BAAQMD Baseline Inventory of CO_2e (metric ton/yr) Emissions (2007)			
	SFO	OAK	SJC
BAAQMD Aircraft+GSE (mton/yr)	1,120,523	557,710	434,257
Present Analysis (2007)	1,244,671	559,427	331,334
Relative Difference	-11%	-0.3%	24%

Airport Redistribution Scenario (Case 1)

For the redistribution scenario (Table E-8), SFO criteria pollutant emissions decreased by about 10-27% depending on pollutant for aircraft and from 5 to 6 percent for auxiliary power units (APUs) with an overall decrease of about 10-27 percent. As would be expected, OAK and SJC criteria pollutant emissions increased from 5-10% for OAK and from 6-11% for SJC (Table E-9). GHG emissions (Tables E-10 and E-11) increase by about 10% at both OAK and SJC, and decrease by about 11% at SFO. However the net effect for implementing a redistribution plan would be to reduce overall GHG emissions by about 4%.

TABLE E-8. CRITERIA POLLUTANT EMISSIONS FOR AIRPORT REDISTRIBUTION (CASE 1).

			Criteria Air Pollutants					
			CO (kg)	VOC (kg)	NOx (kg)	SOx (kg)	PM-10 (kg)	PM-2.5 (kg)
2035	OAK	EDMS Aircraft Total	1,964,176	214,882	1,463,271	125,699	17,833	17,833
		EDMS APU Total	40,138	3,227	54,595	7,484	5,924	5,924
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	2,004,314	218,109	1,517,866	133,183	23,757	23,757
	SFO	EDMS Aircraft Total	4,173,324	1,324,607	3,750,528	341,711	61,567	61,567
		EDMS APU Total	85,049	6,532	108,561	14,163	12,369	12,369
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	4,258,372	1,331,139	3,859,089	355,874	73,936	73,936
	SJC	EDMS Aircraft Total	779,727	107,516	793,906	69,861	10,331	10,331
		EDMS APU Total	30,186	2,208	38,684	5,181	4,192	4,192
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	809,913	109,723	832,589	75,042	14,524	14,524

Table E-9. Change in Criteria Pollutant Emissions, Airport Redistribution (Case 1) versus 2035 Baseline.

	Criteria Pollutants, 2035	CO	VOC	NOx	SOx	PM-10	PM-2.5
OAK	EDMS Aircraft Total	4.70%	7.53%	8.46%	9.53%	9.96%	9.96%
	EDMS APU Total	7.81%	8.13%	7.62%	7.99%	8.27%	8.27%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	4.76%	7.54%	8.43%	9.45%	9.53%	9.53%
SFO	EDMS Aircraft Total	-27.22%	-24.57%	-9.99%	-19.34%	-20.74%	-20.74%
	EDMS APU Total	-4.63%	-4.95%	-6.25%	-5.82%	-5.14%	-5.14%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-26.87%	-24.50%	-9.89%	-18.88%	-18.50%	-18.50%
SJC	EDMS Aircraft Total	5.46%	7.73%	10.77%	10.53%	11.09%	11.09%
	EDMS APU Total	8.38%	9.09%	9.07%	8.98%	9.09%	9.09%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	5.57%	7.76%	10.69%	10.42%	10.51%	10.51%

Table E-10. Greenhouse Gas Emissions for Airport Redistribution (Case 1).

Greenhouse Gases											
			OAK	SFO	SJC				OAK	SFO	SJC
2035	CO2 (kg)	Aircraft	796,470,414	2,060,320,307	450,841,899	2035	CO2e (kg)	Aircraft	804,906,512	2,085,111,762	455,540,793
		GSE	-	-	-			GSE	-	-	-
		APU	10,855,293	20,543,760	7,514,691			APU	10,937,890	20,700,076	7,571,870
		Total	807,325,707	2,080,864,067	458,356,590			Total	815,844,402	2,105,811,837	463,112,663

Table E-11. Change in CO2e Emissions, Airport Redistribution (Case 1) versus 2035 Baseline.

CO2e, 2035	OAK	SFO	SJC
Aircraft	8.6%	-11.1%	10.4%
GSE	n/a	n/a	n/a
APU	8.0%	-5.8%	9.0%
Total	8.6%	-11.0%	10.4%

External Regional Airport Scenario (Case 2)

In the External Regional Airports Scenario (Tables E-12 and E-13), all three principal Bay Area airports show reductions relative to the 2035 baseline, but reductions range from 0 to 12% depending upon the airport and the pollutant. Table E-14 shows the greenhouse gas emissions and relative reduction in GHG emissions for the External Regional Airports scenario. GHG emissions (Tables E-14 and E-15) decreased by approximately 1.5% to 4%, however the net effect for implementing an external regional redistribution plan would be to reduce overall GHG emissions by only about 3% and if external airport emissions were included this reduction would be even less.

Table E-12. Criteria Pollutant Emissions for External Regional Airports (Case 2).

			Criteria Air Pollutants					
			CO (kg)	VOC (kg)	NOx (kg)	SOx (kg)	PM-10 (kg)	PM-2.5 (kg)
2035	OAK	EDMS Aircraft Total	1,866,566	198,082	1,328,566	113,026	15,961	15,961
		EDMS APU Total	36,672	2,938	49,987	6,824	5,385	5,385
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	1,903,237	201,020	1,378,553	119,850	21,346	21,346
	SFO	EDMS Aircraft Total	5,057,904	1,567,627	4,042,170	391,774	70,942	70,942
		EDMS APU Total	88,811	6,840	115,055	14,950	12,973	12,973
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	5,146,715	1,574,467	4,157,225	406,723	83,915	83,915
	SJC	EDMS Aircraft Total	723,035	96,666	684,959	60,478	8,877	8,877
		EDMS APU Total	26,889	1,948	34,138	4,577	3,699	3,699
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	749,924	98,614	719,097	65,055	12,575	12,575

TABLE E-13. CHANGE IN CRITERIA POLLUTANT EMISSIONS, EXTERNAL REGIONAL AIRPORTS (CASE 2) VERSUS 2035 BASELINE.

	Criteria Pollutants, 2035	CO	VOC	NOx	SOx	PM-1	PM-2
OAK	EDMS Aircraft Total	-0.50%	-0.88%	-1.53%	-1.51%	-1.58%	-1.58%
	EDMS APU Total	-1.50%	-1.56%	-1.46%	-1.53%	-1.59%	-1.59%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-0.52%	-0.89%	-1.53%	-1.51%	-1.58%	-1.58%
SFO	EDMS Aircraft Total	-11.79%	-10.74%	-2.99%	-7.52%	-8.68%	-8.68%
	EDMS APU Total	-0.41%	-0.47%	-0.64%	-0.60%	-0.51%	-0.51%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-11.61%	-10.70%	-2.93%	-7.29%	-7.50%	-7.50%
SJC	EDMS Aircraft Total	-2.20%	-3.14%	-4.43%	-4.31%	-4.55%	-4.55%
	EDMS APU Total	-3.46%	-3.75%	-3.75%	-3.71%	-3.75%	-3.75%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-2.25%	-3.15%	-4.40%	-4.27%	-4.32%	-4.32%

TABLE E-14. GREENHOUSE GAS EMISSIONS FOR EXTERNAL REGIONAL AIRPORTS (CASE 2).

Greenhouse Gases											
			OAK	SFO	SJC				OAK	SFO	SJC
2035	CO2 (kg)	Aircraft	721,989,317	2,236,506,308	390,686,947	2035	CO2e (kg)	Aircraft	729,658,960	2,263,721,440	394,775,034
		GSE	-	-	-			GSE	-	-	-
		APU	9,898,255	21,684,073	6,639,406			APU	9,973,570	21,849,065	6,689,924
		Total	731,887,572	2,258,190,380	397,326,353			Total	739,632,530	2,285,570,505	401,464,959

TABLE E-15. CHANGE IN CO2E EMISSIONS, EXTERNAL REGIONAL AIRPORTS (CASE 2) VERSUS 2035 BASELINE.

CO2e, 2035	OAK	SFO	SJC
Aircraft	-1.53%	-3.47%	-4.30%
GSE	n/a	n/a	n/a
APU	-1.53%	-0.60%	-3.71%
Total	-1.53%	-3.44%	-4.29%

Internal Regional Airport Scenario (Case 3)

In the Internal Regional Airports Scenario, criteria emissions decrease at all three principal airports, with SFO showing the largest percentage decrease (5-17%). At SJC emissions decrease by 5-10% and at OAK the decline in emissions is 3-6%. (Table E-17) However, additional emission increases will occur at the secondary airports, as shown in Tables E-18 and E-21. Tables E-19 and E-20 show a decrease in GHG emissions at the 3 major airports. Inclusion of the 3 secondary airports results in a net decrease in GHG emissions of about 1.5% over the 2035 baseline scenario.

TABLE E-16. CRITERIA POLLUTANT EMISSIONS AT PRIMARY AIRPORTS FOR INTERNAL REGIONAL AIRPORTS (CASE 3).

			Criteria Air Pollutants					
			CO (kg)	VOC (kg)	NOx (kg)	SOx (kg)	PM-10 (kg)	PM-2.5 (kg)
2035	OAK	EDMS Aircraft Total	1,815,803	189,664	1,282,451	108,060	15,230	15,230
		EDMS APU Total	35,568	2,846	48,519	6,614	5,213	5,213
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	1,851,371	192,510	1,330,971	114,674	20,442	20,442
	SFO	EDMS Aircraft Total	4,760,847	1,483,896	3,965,913	376,492	67,974	67,974
		EDMS APU Total	88,086	6,781	113,785	14,796	12,855	12,855
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	4,848,933	1,490,676	4,079,697	391,288	80,830	80,830
	SJC	EDMS Aircraft Total	738,195	99,579	714,494	63,012	9,270	9,270
		EDMS APU Total	27,784	2,018	35,372	4,741	3,833	3,833
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	765,979	101,597	749,867	67,754	13,103	13,103

TABLE E-17. CHANGE IN CRITERIA POLLUTANT EMISSIONS, INTERNAL REGIONAL AIRPORTS (CASE 3) VERSUS 2035 BASELINE.

	Criteria Pollutants, 2035	CO	VOC	NOx	SOx	PM-1	PM-2
OAK	EDMS Aircraft Total	-3.21%	-5.09%	-4.95%	-5.84%	-6.09%	-6.09%
	EDMS APU Total	-4.46%	-4.64%	-4.35%	-4.56%	-4.72%	-4.72%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-3.23%	-5.08%	-4.92%	-5.76%	-5.75%	-5.75%
SFO	EDMS Aircraft Total	-16.97%	-15.50%	-4.82%	-11.13%	-12.50%	-12.50%
	EDMS APU Total	-1.23%	-1.34%	-1.74%	-1.62%	-1.41%	-1.41%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-16.73%	-15.45%	-4.74%	-10.80%	-10.90%	-10.90%
SJC	EDMS Aircraft Total	-5.33%	-7.38%	-10.00%	-9.80%	-10.27%	-10.27%
	EDMS APU Total	-7.96%	-8.58%	-8.56%	-8.49%	-8.58%	-8.58%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-5.42%	-7.41%	-9.94%	-9.71%	-9.78%	-9.78%

TABLE E-18. ADDITIONAL CRITERIA POLLUTANT EMISSIONS FOR SECONDARY AIRPORTS (CASE 3).

			Criteria Air Pollutants					
			CO (kg)	VOC (kg)	NOx (kg)	SOx (kg)	PM-10 (kg)	PM-2.5 (kg)
2035	CCR	EDMS Aircraft Total	25,680	2,993	46,885	5,597	555	555
		EDMS APU Total	2,028	221	1,442	314	288	288
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	27,708	3,213	48,326	5,911	843	843
	STS	EDMS Aircraft Total	12,478	1,455	22,714	2,716	269	269
		EDMS APU Total	986	107	701	153	140	140
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	13,464	1,562	23,415	2,869	410	410
	SUU	EDMS Aircraft Total	25,183	2,935	45,929	5,486	544	544
		EDMS APU Total	1,989	216	1,414	308	283	283
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	27,172	3,152	47,343	5,794	827	827

TABLE E-19. GREENHOUSE GAS EMISSIONS FOR PRIMARY AIRPORTS IN THE INTERNAL REGIONAL AIRPORTS SCENARIO (CASE 3).

			Greenhouse Gases								
			OAK	SFO	SJC				OAK	SFO	SJC
2035	CO2 (kg)	Aircraft	696,000,265	2,188,621,743	406,986,870	2035	CO2e (kg)	Aircraft	703,394,619	2,215,126,465	411,240,384
		GSE	-	-	-			GSE	-	-	-
		APU	9,593,447	21,461,283	6,877,046			APU	9,666,443	21,624,580	6,929,373
		Total	705,593,712	2,210,083,026	413,863,916			Total	713,061,061	2,236,751,045	418,169,757

Table E-20. Change in CO2e Emissions, Internal Regional Airports (Case 3) versus 2035 Baseline.

CO2e, 2035	OAK	SFO	SJC
Aircraft	-5.08%	-5.54%	-0.30%
GSE	n/a	n/a	n/a
APU	-4.56%	-1.62%	-0.26%
Total	-5.07%	-5.51%	-0.30%

Table E-21. Additional Greenhouse Gas Emissions for Secondary Airports in the Internal Regional Airports Scenario (Case 3).

Additional Greenhouse Gas Emissions at Secondary Airports											
			CCR	STS	SUU				CCR	STS	SUU
2035	CO2 (kg)	Aircraft	43,431,712	21,101,974	42,589,642	2035	CO2e (kg)	Aircraft	43,852,542	21,306,447	43,002,317
		GSE	6,877,046	-	455,946			GSE	6,929,373	-	459,416
		APU	-	455,946	-			APU	-	459,416	-
		Total	50,308,758	21,557,920	43,045,588			Total	50,781,914	21,765,863	43,461,733

High Speed Rail Scenario (Case 4)

In the High Speed Rail Scenario, emissions are reduced as a result of both the reduced number of aircraft operations as well as decreases in aircraft taxi delay. The greatest percentage emission reductions are seen at SFO (7-22%), as shown in Tables E-22 and E-23. Higher emission reductions are seen for CO and VOC from the reduced taxi delay. Some of these emission reductions will be offset by increased emissions associated with the operation of the high speed rail. However, a net reduction should occur, due to the generally greater efficiency of rail over aircraft on a per passenger mile basis, but this depends upon the source of the electrical power for the operation of the high speed rail. Table E-25 shows that with the operation of the high speed rail, GHG emissions from the three Bay Area Airports would be reduced by 7-14%. Tables E-26 and E-27 show that GHG emissions from high speed rail produces less GHG emissions per passenger mile travelled. The HSR is the more efficient mode of travel ranging from a low efficiency of 2.2 (=152/68) which is the most fuel efficient aircraft and the highest speed train operating with today's energy mix to a high end efficiency of 8.7 (=253/29) operating with the lower train speeds and 50% renewable energy mix with the least efficient aircraft.

TABLE E-22. CRITERIA POLLUTANT EMISSIONS FOR HIGH SPEED RAIL (CASE 4).

			Criteria Air Pollutants					
			CO (kg)	VOC (kg)	NOx (kg)	SOx (kg)	PM-10 (kg)	PM-2.5 (kg)
2035	OAK	EDMS Aircraft Total	1,796,552	186,073	1,250,620	105,260	14,805	14,805
		EDMS APU Total	35,113	2,800	47,551	6,473	5,111	5,111
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	1,831,665	188,873	1,298,171	111,733	19,916	19,916
	SFO	EDMS Aircraft Total	4,449,717	1,400,760	3,874,185	359,062	64,723	64,723
		EDMS APU Total	86,170	6,629	111,596	14,484	12,586	12,586
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	4,535,887	1,407,389	3,985,781	373,546	77,309	77,309
	SJC	EDMS Aircraft Total	688,294	89,410	610,597	54,295	7,894	7,894
		EDMS APU Total	25,801	1,846	31,274	4,222	3,451	3,451
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	714,095	91,256	641,872	58,518	11,345	11,345

Table E-23. Change in Criteria Pollutant Emissions, High Speed Rail (Case 4) versus 2035 baseline.

	Criteria Pollutants, 2035	CO	VOC	NOx	SOx	PM-10	PM-2.5
OAK	EDMS Aircraft Total	-4.24%	-6.89%	-7.31%	-8.28%	-8.71%	-8.71%
	EDMS APU Total	-5.69%	-6.18%	-6.26%	-6.60%	-6.58%	-6.58%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-4.26%	-6.88%	-7.27%	-8.18%	-8.17%	-8.17%
SFO	EDMS Aircraft Total	-22.40%	-20.24%	-7.02%	-15.24%	-16.68%	-16.68%
	EDMS APU Total	-3.38%	-3.54%	-3.63%	-3.69%	-3.48%	-3.48%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-22.10%	-20.17%	-6.93%	-14.85%	-14.78%	-14.78%
SJC	EDMS Aircraft Total	-6.90%	-10.41%	-14.81%	-14.10%	-15.12%	-15.12%
	EDMS APU Total	-7.36%	-8.78%	-11.82%	-11.18%	-10.19%	-10.19%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-6.92%	-10.38%	-14.67%	-13.89%	-13.68%	-13.68%

Table E-24. Greenhouse Gas Emissions for High Speed Rail (Case 4).

Greenhouse Gases											
			OAK	SFO	SJC				OAK	SFO	SJC
2035	CO2 (kg)	Aircraft	678,913,220	2,126,682,912	350,901,410	2035	CO2e (kg)	Aircraft	686,132,400	2,152,343,889	354,584,977
		GSE	-	-	-			GSE	-	-	-
		APU	9,388,955	21,008,733	6,124,308			APU	9,460,395	21,168,586	6,170,907
		Total	688,302,175	2,147,691,645	357,025,718			Total	695,592,795	2,173,512,476	360,755,884

TABLE-25. CHANGE IN CO2E EMISSIONS, HIGH SPEED RAIL (CASE 4) VERSUS 2035 BASELINE.

CO2e, 2035	OAK	SFO	SJC
Aircraft	-7.41%	-8.22%	-14.04%
GSE	n/a	n/a	n/a
APU	-6.60%	-3.69%	-11.18%
Total	-7.39%	-8.18%	-13.99%

TABLE E-26. GHG EMISSIONS PER PASSENGER MILE IN 2035 FROM THE BAY AREA TO THE SOUTHERN CALIFORNIA MARKET.

	CO_2e Intensity (g/mi-passenger)		
Aircraft	OAK	SFO	SJC
Most Efficient Aircraft	156	152	180
Least Efficient Aircraft	218	212	253

TABLE E-27 GHG EMISSIONS PER PASSENGER MILE IN 2035 FOR HIGH SPEED RAIL (HSR) TRAVEL FROM THE BAY AREA TO SOUTHERN CALIFORNIA

Mode	Baseline Energy Mix*	33% renewable**	50% renewable***
HSR 175 mph top speed	52	45	29
HSR 220 mph top speed	68	58	37

*Current Baseline for CA based on CA Energy Commission 2008 Total System Power

** the remaining 67% to come from 39.1% natural gas, 15.6% coal, 12.3% nuclear

*** the remaining 50% to come from 29.2% natural gas, 8.5% coal, and 12.3% nuclear

Air Traffic Control Technology Scenario (Case 5)

ATC technology improvements primarily reduce emissions by reducing aircraft taxi delays. As shown below the use of ATC technology decreased emissions more so for CO and VOC and less so for NOx emissions (which are less associated with taxi delay). Because ATC did not affect taxi delay at SJC no changes were seen in emissions. Both OAK and SFO showed similar reductions in GHG emissions of 0.6 to 0.7%.

TABLE E-28. CRITERIA POLLUTANT EMISSIONS FOR ATC TECHNOLOGY (CASE 5).

			Criteria Air Pollutants					
			CO (kg)	VOC (kg)	NOx (kg)	SOx (kg)	PM-10 (kg)	PM-2.5 (kg)
2035	OAK	EDMS Aircraft Total	1,838,054	194,011	1,342,835	112,922	15,951	15,951
		EDMS APU Total	37,230	2,985	50,728	6,930	5,471	5,471
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	1,875,284	196,995	1,393,563	119,853	21,423	21,423
	SFO	EDMS Aircraft Total	5,538,315	1,698,732	4,136,836	415,054	75,883	75,883
		EDMS APU Total	89,181	6,873	115,800	15,039	13,039	13,039
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	5,627,496	1,705,605	4,252,636	430,094	88,922	88,922
	SJC	EDMS Aircraft Total	739,329	99,798	716,741	63,204	9,300	9,300
		EDMS APU Total	27,852	2,024	35,467	4,754	3,843	3,843
		EDMS GSE Total	-	-	-	-	-	-
		Total, All	767,182	101,821	752,207	67,958	13,143	13,143

Table E-29. Change in Criteria Pollutant Emissions, ATC Technology (Case 5) versus 2035 Baseline.

	Criteria Pollutants, 2035	CO	VOC	NOx	SOx	PM-1	PM-2
OAK	EDMS Aircraft Total	-2.02%	-2.91%	-0.47%	-1.60%	-1.64%	-1.64%
	EDMS APU Total	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-1.98%	-2.87%	-0.45%	-1.51%	-1.23%	-1.23%
SFO	EDMS Aircraft Total	-3.41%	-3.27%	-0.72%	-2.03%	-2.32%	-2.32%
	EDMS APU Total	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-3.36%	-3.26%	-0.70%	-1.96%	-1.98%	-1.98%
SJC	EDMS Aircraft Total	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	EDMS APU Total	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table E-30. Greenhouse Gas Emissions for ATC Technology (Case 5).

Greenhouse Gases											
			OAK	SFO	SJC				OAK	SFO	SJC
2035	CO2 (kg)	Aircraft	728,747,290	2,299,625,252	408,226,080	2035	CO2e (kg)	Aircraft	736,469,366	2,327,835,106	412,492,162
		GSE	-	-	-			GSE	-	-	-
		APU	10,052,259	21,814,080	6,895,172			APU	10,128,746	21,980,061	6,947,637
		Total	738,799,549	2,321,439,331	415,121,253			Total	746,598,112	2,349,815,167	419,439,799

TABLE E-31. CHANGE IN CO2E EMISSIONS, ATC TECHNOLOGY (CASE 5) VERSUS 2035 BASELINE.

CO2e, 2035	OAK	SFO	SJC
Aircraft	-0.61%	-0.74%	0.00%
GSE	n/a	n/a	n/a
APU	0.00%	0.00%	0.00%
Total	-0.60%	-0.73%	0.00%

Demand Management Scenario (Case 6)

The Demand Management Scenario (Case 6) results in a decrease in emissions due to the decrease in taxi delay at SFO. The Demand management Scenario only assumes that demand management is implemented at SFO, therefore there are no changes in emissions relative to the future base case for OAK or SJC. Criteria pollutant emission reductions at SFO are largest for VOC and CO and smallest for NO_x. GHG emission reductions are relatively modest at just 2.4%.

TABLE E-32. CRITERIA POLLUTANT EMISSIONS FOR DEMAND MANAGEMENT (CASE 6).

		Criteria Air Pollutants					
		CO (kg)	VOC (kg)	NOx (kg)	SOx (kg)	PM-10 (kg)	PM-2.5 (kg)
SFO	EDMS Aircraft Total	4,673,761	1,447,885	4,022,065	378,488	67,431	67,431
	EDMS APU Total	83,745	6,571	114,059	14,742	12,634	12,634
	EDMS GSE Total	-	-	-	-	-	-
	Total, All	4,757,506	1,454,456	4,136,124	393,230	80,065	80,065

TABLE E-33. CHANGE IN CRITERIA POLLUTANT EMISSIONS, DEMAND MANAGEMENT (CASE 6) VERSUS 2035 BASELINE.

	Criteria Pollutants, 2035	CO	VOC	NOx	SOx	PM-10	PM-2.5
SFO	EDMS Aircraft Total	-18.49%	-17.55%	-3.47%	-10.66%	-13.20%	-13.20%
	EDMS APU Total	-6.10%	-4.39%	-1.50%	-1.97%	-3.11%	-3.11%
	EDMS GSE Total	n/a	n/a	n/a	n/a	n/a	n/a
	Total, All	-18.30%	-17.50%	-3.42%	-10.36%	-11.75%	-11.75%

TABLE E-34. GREENHOUSE GAS EMISSIONS FOR DEMAND MANAGEMENT (CASE 6).

			SFO				SFO
2035	CO_2	Aircraft	2,262,215,506	2035	CO_{2e}	Aircraft	2,289,508,899
		GSE	-			GSE	-
		APU	21,383,476			APU	21,546,181
		Total	2,283,598,982			Total	2,311,055,080

TABLE E-35. CHANGE IN CO2E EMISSIONS, DEMAND MANAGEMENT (CASE 6) VERSUS 2035 BASELINE.

CO2e, 2035	SFO
Aircraft	-2.4%
APU	-2.0%
Total	-2.4%

Continuous Descent Approach (Case 7)

Greenhouse gas emissions under the Continuous Descent Approach (CDA) scenario (Case7) are reduced from those under the 2035 Baseline scenario (Case0b) due to a reduction in fuel use during aircraft approach. The approach patterns for CDA and conventional approach are identical between 2,300 ft and landing, but GHG emissions are reduced over the longer flight paths considered in this analysis. However, the CDA approach only contributes a relatively small fraction of the total GHG emissions with taxi-in, taxi-out, climb-out and takeoff making up the majority (88-92%) of the GHG emissions. Thus the overall greenhouse gas emissions are only reduced (measured in kg CO2e) between 1-3%. The greatest percentage reductions for GHG emissions are seen at OAK (2.5%), but the largest emission reductions (44.8 million kg CO_2e) occur at SFO. Nearly all (~99%) of these emission changes are due to reductions in CO_2 emissions. Table E-36 shows the actual and relative GHG emissions for CDA.

TABLE E-36. GREENHOUSE GAS EMISSIONS FOR CONTINUOUS DESCENT APPROACH (CASE 7).

				Greenhouse Gases (kg CO2e)				
			CDA Change from Future Baseline	Future Baseline Approach	All Other Future Baseline	Total Future Baseline	CDA	Change from Baseline
OAK								
	Aircraft	CO_2	(24.2%)	75,635,084	657,589,758	733,224,842	714,921,151	
		CH_4	8.5%	140,852	752,042	892,894	904,866	
		N_2O	(24.2%)	710,730	6,179,256	6,889,986	6,717,989	
		CO_2e	-	76,486,665	664,521,056	741,007,721	722,544,007	-2.5%
	APU	CO_2	(24.2%)	-	10,052,259	10,052,259	10,052,259	
		CH_4	8.5%	-	11,675	11,675	11,675	
		N_2O	(24.2%)	-	64,812	64,812	64,812	
		CO_2e	-	-	10,128,746	10,128,746	10,128,746	0.0%
	Total	CO_2e		76,486,665	674,649,802	751,136,467	732,672,752	-2.5%
SFO								
	Aircraft	CO_2	(24.2%)	183,592,078	2,132,999,687	2,316,591,765	2,272,162,482	
		CH_4	8.5%	511,574	6,243,960	6,755,534	6,799,018	
		N_2O	(24.2%)	1,725,183	20,043,426	21,768,608	21,351,114	
		CO_2e	-	185,828,834	2,159,287,073	2,345,115,907	2,300,312,614	-1.9%
	APU	CO_2	(24.2%)	-	21,814,080	21,814,080	21,814,080	
		CH_4	8.5%	-	25,335	25,335	25,335	
		N_2O	(24.2%)	-	140,647	140,647	140,647	
		CO_2e	-	-	21,980,061	21,980,061	21,980,061	0.0%
	Total	CO_2e		185,828,834	2,181,267,134	2,367,095,968	2,322,292,675	-1.8%
SJC								
	Aircraft	CO_2	(24.2%)	39,778,762	368,447,318	408,226,080	398,599,620	
		CH_4	8.5%	56,699	373,354	430,053	434,872	
		N_2O	(24.2%)	373,794	3,462,235	3,836,029	3,745,571	
		CO_2e	-	40,209,255	372,282,908	412,492,162	402,780,063	-2.4%
	APU	CO_2	(24.2%)	-	6,895,172	6,895,172	6,895,172	
		CH_4	8.5%	-	8,008	8,008	8,008	
		N_2O	(24.2%)	-	44,457	44,457	44,457	
		CO_2e	-	-	6,947,637	6,947,637	6,947,637	0.0%
	Total	CO_2e		40,209,255	379,230,545	419,439,799	409,727,700	-2.3%