San Diego County Greenhouse Gas Inventory

An Analysis of Regional Emissions and Strategies to Achieve AB 32 Targets

Other Transportation Report

Civil Aviation • Water-Borne Navigation • Off-Road Equipment & Vehicles • Rail

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For an electronic copy of this report and the full documentation of the San Diego Greenhouse Gas Inventory project, go to www.sandiego.edu/epic/ghginventory.

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1. Introduction

On-road transportation (cars and trucks) is the largest category of greenhouse gas (GHG) emissions in the region; however, other transportation-related categories emit significant amounts of GHG emissions. This report presents GHG emissions totals for the other transportation categories included in the San Diego County Greenhouse Gas Emissions Inventory, consisting of off-road equipment and vehicles, civil aviation, water-borne vessels, and rail. Table 1 presents the subcategories that comprise each category included in this report. Together, these categories account for approximately 10% of San Diego County's GHG emissions in 2006.

Table 1. Other Transportation Categories and Subcategories

CIVIL AVIATION	**WATER-BORNE NAVIGATION**
Interstate Flights	Ocean Going Vessels (OGV)
Intrastate Flights	Harbor Craft
OFF-ROAD EQUIPMENT AND VEHICLES	**RAIL TRANSPORTATION**
Construction and Mining Equipment	
Pleasure Craft	
Industrial Equipment	
Agriculture Equipment	
Other	

This report provides historical emissions levels for each category from 1990 through 2006 and projected emissions through 2020. Using emissions reduction targets codified in California's Global Warming Solutions Act of 2006 (AB 32) as a guide, this report also establishes emissions reductions targets for each component of this category. Although AB 32 does not require individual sectors or jurisdictions (e.g., cities and counties) to reduce emissions by a specific amount, the project team calculated the theoretical emissions reductions necessary in each emissions category (e.g., transportation, electricity, etc.) for San Diego County to achieve the AB32 statutory target of 1990 levels by 2020. Finally, the report identifies and quantifies potential emissions reduction strategies in each component of this category to determine the feasibility of reducing emissions from other transportation sources to 1990 levels by 2020.

To the extent possible, the project team followed the same calculation methodology used by the California Air Resources Board (CARB) to develop the statewide GHG inventory. In some instances, when doing so could yield a more accurate or precise result, the project modified the CARB method.

This report is intended as an overview of the findings from research and analysis conducted for the categories noted above and includes the following sections.

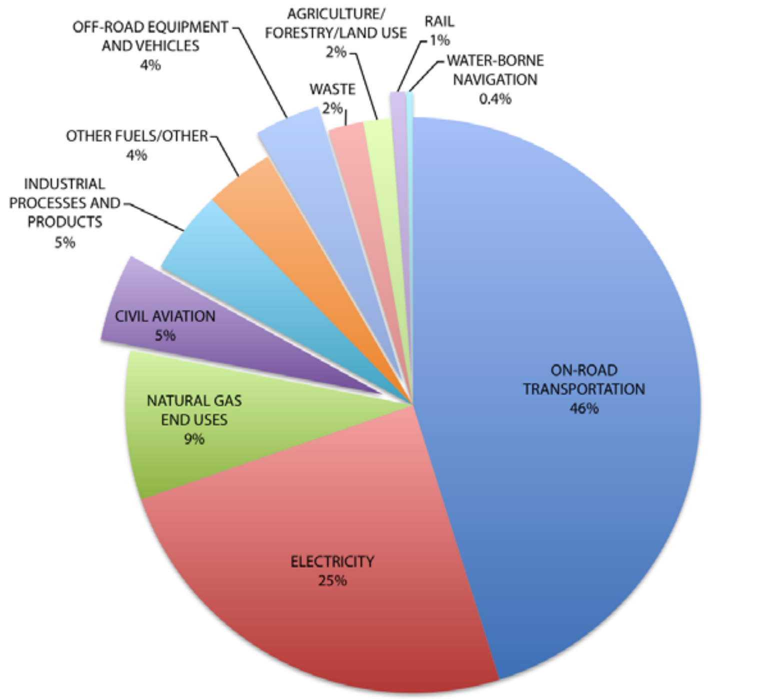
- Section 2 provides an overview of GHG emissions, forecast and methodology for the civil aviation category.
- Section 3 provides the GHG emissions, forecast and methodology for the water-borne navigation category.
- Section 4 provides the GHG emissions, forecast and methodology for the off-road equipment and vehicles category.
- Section 5 provides a brief summary of the GHG emissions, forecast and methodology for rail transportation category.

1.1. Key Findings

The largest contributor to regional GHG emissions in this category is civil aviation, which accounts for about 5% of total emissions in the San Diego region. This is followed by the off-road category, which contributes approximately 4% to the total regional GHG emissions. Figure 1 shows the relative contribution of each category to San Diego County's total GHG emissions.

The key findings of each category included in this report are as follows:

Figure 1. San Diego County GHG Emissions by Category (2006)



Civil Aviation

- In 2006, emissions from the civil aviation category totaled 1.7 million metric tons of carbon dioxide equivalent (MMT CO_2E), an increase of about 42% over 1990 levels.

- Emissions from civil aviation account for approximately 5% of the total greenhouse gas emissions in San Diego County.

- The 1990 baseline for the civil aviation category is estimated as 1.2 MMT CO_2E. This includes emissions from domestic commercial flights – both intrastate (within CA) and interstate (from CA to another state), but not international flights.

- The emissions calculations are not directly comparable to the emissions provided by the California Air Resources Board statewide emissions inventory, which does not include emissions from state-to-state flights. These emissions constitute the major part of aviation emissions from San Diego.

- The 2020 business-as-usual (BAU) forecast is estimated to be 2.6 MMT CO_2E, a 53% increase over 2006 levels. If AB32 targets were applied to the civil aviation category, more than 54% reduction in emissions would be required to meet the AB32 target (1990 baseline) in 2020.

Water-Borne Navigation

- In 2006, emissions from the water-borne navigation totaled 127,000 MT CO_2E (metric tons), an increase of over 150% of 1990 levels. The 1990 baseline for the water-borne navigation category is estimated at 42,700 MT CO_2E. This includes emissions only from ocean going vessels (OGVs), interstate and international, and harbor craft, within the 24-mile territorial and contiguous zone.

- In 2006, emissions from water-borne navigation accounted for approximately 0.4% of the total greenhouse gas emissions in San Diego County.

- The 2020 business-as-usual (BAU) forecast is estimated to be 180,595 MT CO2E, an increase of 42% above 2006 levels. The 2020 BAU forecast includes benefits to be obtained from the 2007 Shore Power Regulation and the 2005 Auxiliary Engine regulation affecting OGVs.[3]

- If AB32 targets were to be applied theoretically to each emissions category, unless international action is taken to reduce emissions from international shipping lines, additional reductions in greenhouse gas emissions in this category to the comparatively very low levels of 1990 will not be feasible.

Off-road Equipment and Vehicles

- In 2006, off-road equipment and vehicles generated approximately 1.3 MMT CO_2E.
- The BAU 2020 forecast estimate is 1.6 MMT CO_2E, approximately 23% greater than the 2006 estimate.

Rail

- In 2006, the rail category generated approximately 0.3 MMT CO_2E, about 1% of the total County GHG emissions.
- The BAU 2020 forecast estimate is 0.4 MMT CO_2E, approximately 35% greater than the 2006 estimate.

2. Greenhouse Gas Emissions from Civil Aviation

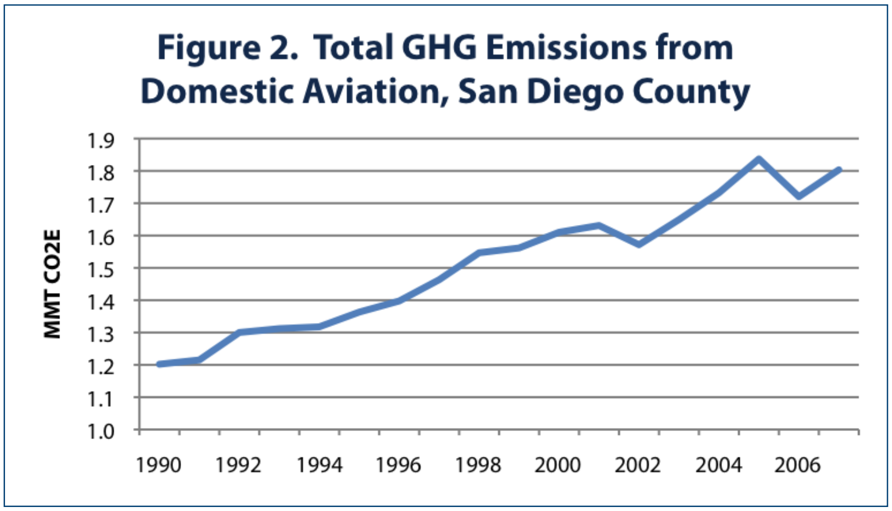
Eleven airports in San Diego County, including the region's main commercial and international airport at Lindbergh Field, constitute the sources of greenhouse gas emissions in the aviation category. The San Diego County Regional Airport Authority (SDCRAA) operates and controls the Lindbergh Field International Airport and a second smaller commercial airport, the McClellan-Palomar airport. Two small landing strips, Montgomery Field and Brown Field, are owned and operated by the City of San Diego. An additional nine general aviation (private and military) airstrips are operated by the County of San Diego: the Agua Caliente airport, the Borrego Valley airport, the Fallbrook airport, the Jacumba airport, the Ocotillo airport, the Ramona airport and Gillespie Field Airport. Only emissions from commercial aviation operations at the San Diego International Airport are included in this inventory, primarily due to the lack of data from the McClellan-Palomar Airport at the time of writing. However, the number of commercial flights from the San Diego Airport (more than 500 a day) dwarfs the daily 8 commercial flights departing the McClellan-Palomar Airport, so the estimate presented here would not change significantly if data from this airport were included.

Emissions sources considered by the California Air Resources Board Greenhouse Gas Inventory (CARB GHG inventory) to constitute the civil aviation category are:

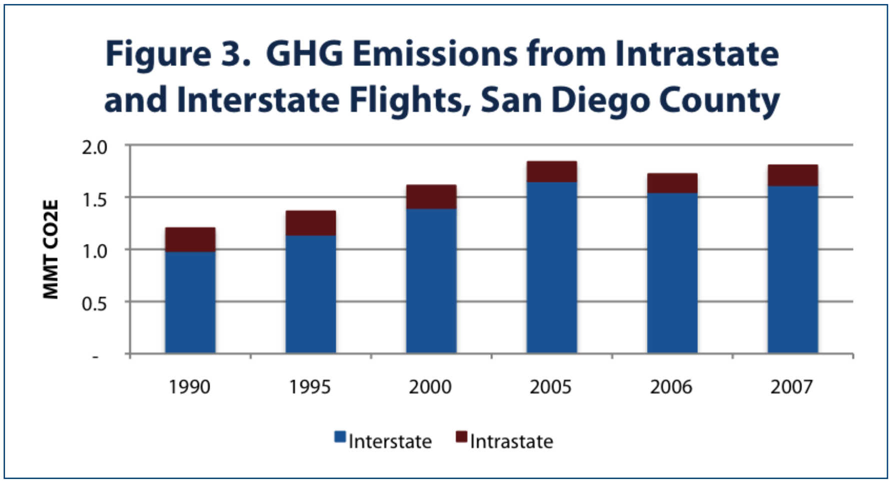
1. Emissions from the combustion of jet fuel and aviation gasoline[4] used in commercial operations
2. Emissions from the combustion of natural gas used in airport ground transport operations
3. Emissions from the combustion of jet fuel used in international aviation

However, international aviation emissions are itemized separately and excluded from the final aviation category emissions in the CARB GHG inventory. The CARB GHG inventory further distinguishes between intrastate (within California) and interstate (within the US) emissions and includes only the intrastate civil aviation emissions. While this report retains this distinction for San Diego County, the two emissions sub-sources (intrastate and interstate) are added together to estimate the total aviation emissions level. The project team included interstate emissions because these are the largest and fastest growing portion of the greenhouse gas emissions from aviation in this County. In 1990, the intrastate emissions from San Diego constituted less than 20% of the total civil aviation category emissions. In 2006, this percentage had decreased to less than 10% and in 2020, the percentage is projected to be about 6% of the total. Excluding interstate emissions would significantly underestimate GHG emissions from aviation in the County. All other sources of airport and aviation emissions, such as those caused by electricity consumption, off-road vehicles and stationary sources, with the exception of natural gas powered ground transportation, are included in other categories of the San Diego County Greenhouse Gas Inventory.

Figure 2 shows the total greenhouse gas emissions in San Diego County from the aviation category, which is the sum of jet fuel, aviation gasoline, and natural gas combustion emissions. Figure 3 shows the breakdown of the total into interstate and interstate components.

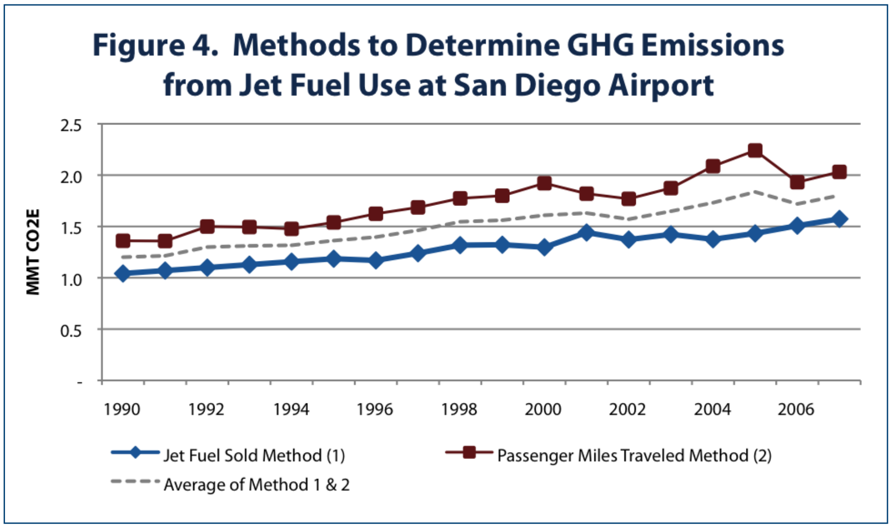


Emissions from civil aviation in San Diego County constitute a small but increasing percentage of statewide emissions from this category. Between 1990 and 2004, the contribution of San Diego County to the California total aviation category emissions increased from 4.9% to 7.7%.



2.1. Greenhouse Gas Emissions from Combustion of Jet Fuel

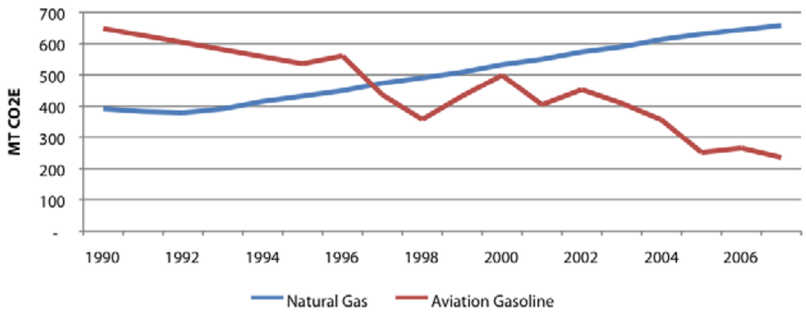
To determine the amount of greenhouse gas emissions from the combustion of jet fuel, the project team used two different methods and took the average, as shown in Figure 4. In the first method, we calculated emissions based on jet fuel-sold data provided by the two suppliers of jet fuel at the San Diego International Airport. The jet fuel data provided by one of the suppliers was separated into commercial and private use, whereas the other supplier reported that its jet fuel was sold only for commercial purposes. Because not all aircraft fuel in San Diego County, we used a second method using the miles departing San Diego International Airport to obtain an upper limit for civil aviation emissions from the county.[5] The true emissions levels will be somewhere between the results of these two methods. Thus the average of the two methods as presented here for the county provides a good representation of the jet fuel emissions from the region.



2.2. Greenhouse Gas Emissions from Aviation Gasoline and Natural Gas

Aviation gasoline is a high-octane gasoline used for aircraft and racing cars. The aviation gasoline sold at the San Diego International Airport is for private aviation and has decreased from 66,052 gallons in 1996 to 27,729 gallons in 2007. Concerns over the lead content of aviation gasoline[6] and its associated cost make it likely that aviation gasoline will not be used in San Diego County by 2015.[7] Natural gas is used for ground transportation at San Diego International Airport. The volume of natural gas use at the airport increased from 9.5 million cubic feet in 1990 to 52.5 million cubic feet in 2006.[8] Figure 5 presents the trends in emissions from aviation gasoline and natural gas in the civil aviation category.

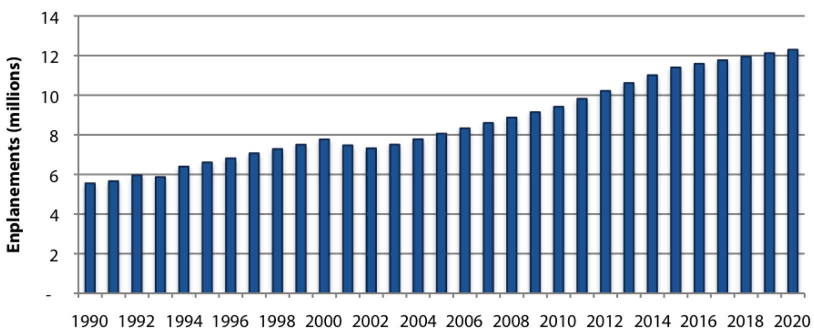
Figure 5. GHG Emissions from Aviation Gasoline and Natural Gas, San Diego Airport



2.3. Emissions Projections

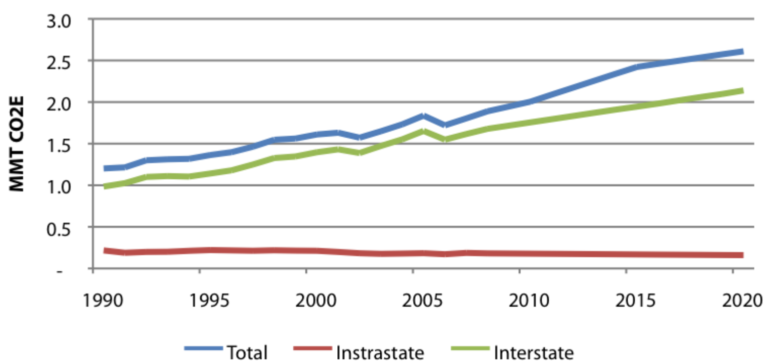
The SDCRAA published an Aviation Activity Forecast in June 2004 that projects growth scenarios through 2030 based on regional population and economic growth[9] including the number of enplanements[10] from the San Diego airport (Figure 6).[11]

Figure 6. Domestic Enplanements San Diego International Airport



The project team used the SDCRAA forecasts of domestic enplanements as the basis for projecting greenhouse gas emissions. The 2006 emissions are 1.7 MMT CO_2E, approximately 0.5 MMT CO_2E (43%) above 1990 levels. Based on the projected unconstrained airport forecast for 2020, the BAU emissions for the whole category will be approximately 2.6 MMT CO_2E, an increase of 53% (Figure 7).

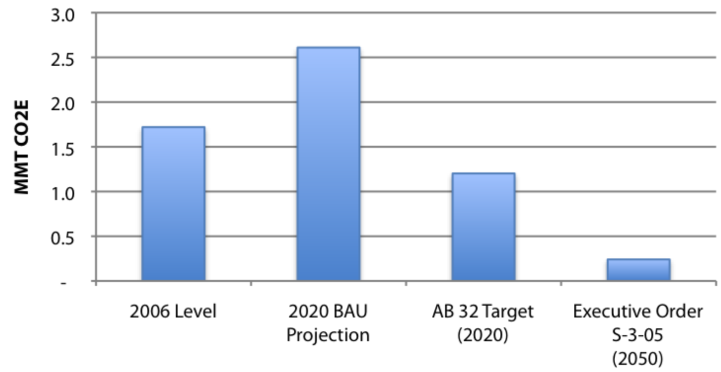
Figure 7. Total GHG Emissions from Domestic Aviation, San Diego County



2.4. Emissions Reduction Targets

In 2006 Governor Arnold Schwarzenegger signed into law the Global Warming Solutions Act (AB 32), establishing statutory limits on greenhouse gas emissions in California. AB 32 seeks to reduce statewide greenhouse gas emissions to 1990 levels by the year 2020. Even though AB 32 does not specify reduction targets for specific sectors or jurisdictions, this study calculated theoretical reductions targets as if the statewide statutory emissions reductions targets were applied to San Diego County and to each emitting category. To meet the targets established by AB 32, the San Diego region theoretically would have to reduce the projected emissions in the civil aviation category by 1.4 MMT CO_2E in 2020 to reach 1990 levels – a 54% reduction.

Figure 8. Hypothetical GHG Reduction Targets for the Civil Aviation Category, San Diego County

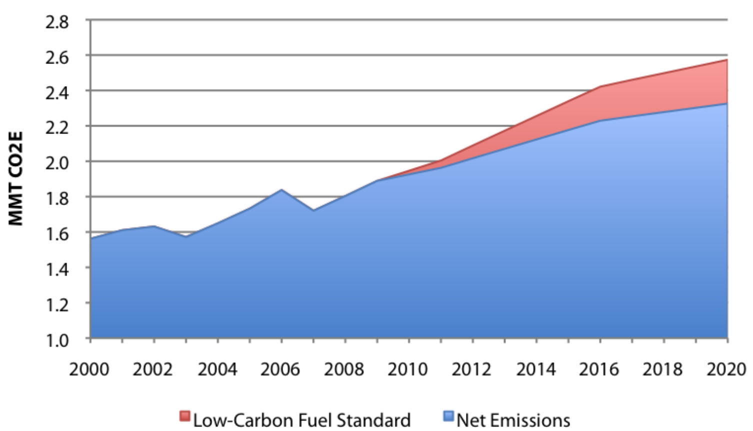


In 2005, Governor Schwarzenegger signed Executive Order S-3-05, which establishes long-term targets for greenhouse gas emissions reductions. It seeks to reduce emissions levels 80% below 1990 levels by 2050. While this reduction target is not law, it is generally accepted as the long-term target to which California regulations are aiming. Similar to AB 32, Executive Order S-3-05 is intended to be a statewide target, but if applied hypothetically to San Diego County, total emissions from the civil aviation category would have to be reduced to 0.2 MMT CO_2E – a reduction of 2.4 MMT CO_2E (91%) below the 2020 business-as-usual forecast and 0.9 MMT CO_2E (88%) below 2006 levels. Figure 8 compares 2006 emissions levels, 2020 business-as-usual projections, AB 32 and Executive Order S-3-05 targets.

2.5. Potential Emissions Reduction Strategies

The project team developed emissions reduction strategies for each emissions category to determine if it is possible to meet the theoretical targets under AB 32. Where possible these strategies are based on federal, state, county, city level policies. Similar to other transportation categories that rely on fossil fuel combustion, emissions from civil aviation are driven by air miles traveled, the amount of fuel used, and the type of fuel used. The strategy presented here focuses on the carbon intensity of fuel. A low-carbon fuel standard for jet fuel could potentially achieve a reduction on aircraft emissions. Because of the global projected large increase in commercial aviation by 2030, research is underway by the aircraft industry to develop fuel with a lower carbon intensity than jet fuel.[12] A potential reduction strategy may be achieved by

Figure 9. Emissions Reduction Strategy for Civil Aviation, San Diego County



applying the same type of low-carbon fuel standard as for on-road transport. A 10% decrease in emissions may be effected by such a reduction in carbon intensity of jet fuel by 2020 as well as further improvements in engine fuel efficiency. This could potentially result in a reduction of 0.26 MMT CO_2E by 2020, as shown in Figure 9. This falls short of the hypothetical AB 32 target reduction for this category.

2.6. Aviation Methodology

The project team calculated total greenhouse gas emissions from aviation activity using two different methods: a fuel-based method using actual and estimated jet fuel and aviation gas data, and another top-down approach using a combination of national and local data to estimate jet fuel use.

The two main suppliers of jet fuel and aviation gas in the region provided data on the amount of these fuels sold at San Diego International Airport. One supplier provided data from 1996-2007, the other from 1997-2007. The project team back cast values for 1990-1996 using linear regression based on this data (Method 1). Because the jet fuel sold does not reflect the emissions caused by departing flights that do not fuel up during a stopover in San Diego, an additional top-down method was used to estimate jet fuel use and therefore provide an upper limit for emissions. In this Method 2, we used passenger miles flown, separated into interstate and intrastate miles, in combination with average aircraft fuel efficiency data to obtain jet fuel use estimates.

Jet Fuel Emissions Using Fuel Sold (Method 1)

The annual jet fuel data obtained from the San Diego International Airport Lindbergh Field suppliers represents the jet fuel sold to commercial operations and some private flights departing from San Diego. As mentioned above, these data do not represent all departing flights, since some of which may not have refueled while stopping over in San Diego; therefore, calculations based solely on fuel sold to flights departing from San Diego will underestimate greenhouse emissions associated with flights departing from San Diego. In addition, these jet fuel data represent only fuel sold to the San Diego International Airport and not the jet fuel used by any of the other airports, which was not available at the time of writing. This represents an additional data gap that causes an underestimate of the emissions from aviation activities. On the other hand, Lindbergh Field represents over 95% of the commercial flights from the County.

The fuel sold method is the ideal method of GHG emissions estimation provided this information is available and each county or region uses this same method. The equation used to calculate the emissions is:

greenhouse gas emissions = fuel gallons * emissions factor,

where the emissions factors for commercial jet fuel and aviation gasoline were obtained from the CARB GHG inventory (Table 2).

Table 2. Emissions Factors Used in Civil Aviation Category [13]

Fuel type	Methane (grams/gallon)	Nitrous Oxide (grams/gallon)	Carbon Dioxide (grams/gallon)
Jet fuel	0.3	0.3	9,570
Aviation gasoline	7.1	0.11	8,310

Emissions depend on the number and type of aircraft operations, the types of fuel used, the length of flight and the times spent at each stage of the flight but the rough composition of any aircraft emissions are 70% CO_2, a little less than 30% water and the rest consists of the trace GHGs. Emissions factors differ slightly at each stage of engine use. The emissions factors for CO_2, CH_4 and N_2O from fuel combustion provided in Table 2 take into account these differences as well as the heat content of the fuel and may therefore be used in calculations carried out for San Diego County.

The CO_2 equivalent emissions are calculated by multiplying the above-calculated emissions by the respective global warming potential of 21 for methane and 310 for nitrous oxide.[14]

Passenger Miles Traveled Method (Method 2)

In this method, the passenger miles flown out of San Diego International Airport were used in combination with fleet energy intensity data to estimate fuel use. This method would capture the emissions due to passenger flights which do not fuel up in San Diego and would be appropriate for cases in which fuel data are sparse or if the purpose is to allocate passenger flight emissions to the source, or attribute emissions regionally. As emissions due to all departing passenger flights are accounted for, including flights that do not fuel here, emissions are necessarily greater than with Method 1. However, because this method is based on passenger activity, emissions due to cargo (mail and freight) flights are not captured, whereas Method 1 includes all types of domestic commercial flights.

Table 3. US Aircraft Fleet Fuel Intensity Data

Year	Passenger Miles (millions)	Fuel Consumed (million gallons)	Intensity (mpg)
1960	30,557	1,954	16
1965	51,887	3,889	13
1970	104,147	7,857	13
1975	131,728	7,558	17
1980	200,289	8,519	24
1985	270,584	10,115	27
1990	340,231	12,323	28
1991	332,566	11,506	29
1992	347,931	11,763	30
1993	354,177	11,959	30
1994	378,990	12,384	31
1995	394,708	12,672	31
1996	425,596	13,217	32
1997	450,612	13,563	33
1998	463,262	13,335	35
1999	488,357	14,402	34
2000	516,129	14,845	35
2001	486,506	14,017	35
2002	482,310	12,848	38
2003	505,158	12,959	39
2004	557,893	13,623	41
2005	584,996	13,789	42
2006	591,834	13,458	44

Passenger miles traveled from San Diego International Airport were extracted from the Bureau of Transportation Statistics Department (BTS RITA) database for each year from 1990 to 2007.[15] The energy intensity for a range of the total US commercial aircraft fleet over the past 20 years is also available in the same database and is shown in modified version in Table 3.

Note that the US fleet fuel efficiency has improved by more than 60% since 1960. Using the miles per gallon information from Table 3, the project team calculated an energy intensity or fuel efficiency range per passenger mile of 0.036 gallons in 1990 to 0.023 gallons in 2006. Assuming the same fleet mix in San Diego as in the United States,[16] multiplication of the fuel efficiency by the passenger miles gives jet fuel consumption for all domestic passenger departures from San Diego as follows:

Fuel efficiency (gallons/passenger mile) * passenger miles = gallons total.

As the miles traveled data can be separated into intrastate and interstate flights, this method allows calculation of the jet fuel used for intrastate versus interstate passenger flights and therefore a similar separation of emissions associated with each. The fuel use calculated using this method is presented in Table 4.

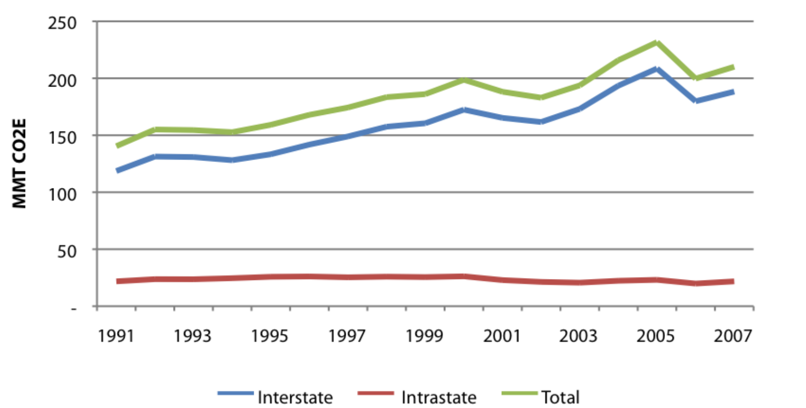
The results of Method 2 show a trend in the last 15 years towards decreasing intrastate miles and increasing interstate miles (Figure 10). Therefore in these years, the driving force for aviation emissions has been interstate miles flown.

Table 4. Fuel Use Based on Passenger Miles Departing San Diego (Method 2)

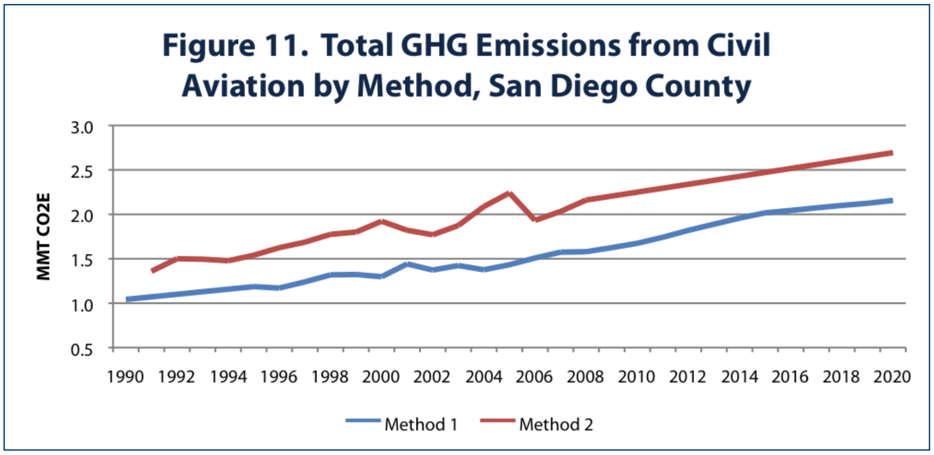
Year	Intrastate	Interstate	Total
1991	21,817,877	118,638,261	140,456,138
1992	23,737,743	131,318,319	155,056,062
1993	23,660,905	130,887,314	154,548,219
1994	24,603,035	128,113,028	152,716,063
1995	25,833,708	133,335,337	159,169,045
1996	26,102,819	141,834,122	167,936,941
1997	25,378,007	148,982,055	174,360,062
1998	25,930,321	157,532,786	183,463,107
1999	25,561,289	160,538,370	186,099,659
2000	26,230,055	172,465,508	198,695,563
2001	22,913,675	165,256,946	188,170,621
2002	21,323,554	161,645,578	182,969,133
2003	20,653,653	173,115,756	193,769,409
2004	22,338,965	193,519,222	215,858,187
2005	23,143,532	208,542,794	231,686,326
2006	19,863,520	179,848,234	199,711,754
2007	21,812,737	188,311,390	210,124,127

The emissions calculated by this method are necessarily greater than that calculated by the fuel sold (Method 1) since not all aircraft fuel in San Diego. With this method, it is possible to distinguish between intrastate and interstate emissions, which is not possible with the jet fuel sold method, as the data provided could not be separated. It is clear that intrastate emissions are significantly lower than interstate emissions, and that intrastate flights are the driving force for civil aviation emissions.

Figure 10. Fuel Use Based on Passenger Miles Departed from San Diego Airport



The difference in emissions between the fuel-sold method (Method 1) and the passenger miles departed method (Method 2) ranges from 300,000 to 800,000 metric tons, or from 30-50% of the emissions based on the fuel sold (Figure 11).



Although the emissions trend is positive and rising in both cases, the fuel sold method indicates a slower rate of increase than the passenger miles method, resulting in a gradually increasing gap between the two. One possible explanation for this difference, which has not been further examined, may be a tendency to reduce fueling at San Diego International Airport.

Because of the large difference in results of the two methods, an average of the results of the two methods reduces the error in the emissions estimates. The average values differ from the results of either method by about 20%. These averaged jet fuel emissions were used in the total aviation category emissions presented above.

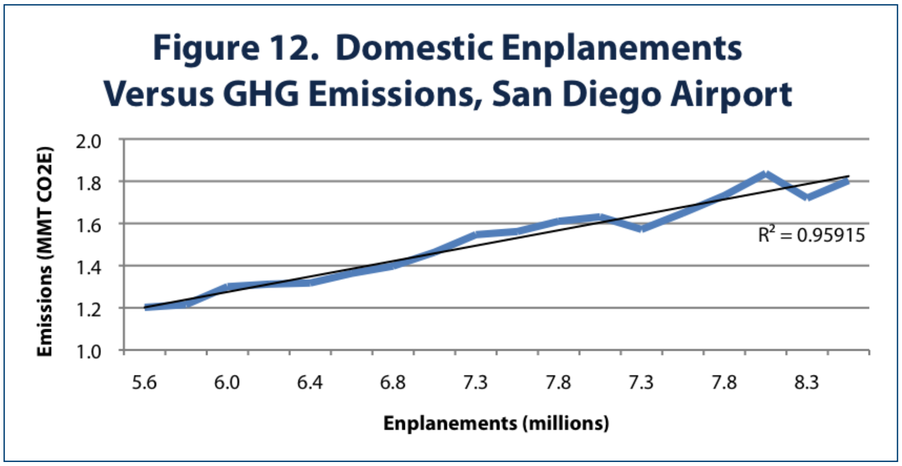
Aviation Gasoline and Natural Gas

In addition to jet fuel, the project team calculated the greenhouse gas emissions from aviation gasoline and natural gas. Only one of the fuel suppliers sells aviation gasoline at the San Diego International Airport. This data was available from 1996-2007. Only the fuel-sold method (Method 1) could be used to calculate emissions as the miles departed data for flights using aviation gasoline is not available.

Natural gas is also used in the aviation category for ground transportation purposes. The project team used data provided by the San Diego County Air Pollution Control District (APCD) for natural gas use at San Diego International Airport[17] together with Method 1 to calculate emissions from natural gas.

Calculation of Forecasts

The calculation of the emissions forecast was based on the trend relationship between total category emissions and domestic enplanements (Figure 12).



A potential strategy to reduce aviation emissions is to use a low carbon fuel standard in the same way as is expected for road vehicles. Such a low carbon jet fuel strategy, as well as further improvements in aircraft engine fuel efficiency, applied to the total category emissions, can be seen as a 10% reduction in the emissions to obtain the potential reduction wedge shown in Figure 8.

Limitations

The estimated 1990 baseline emissions level for San Diego County is not directly comparable to the CARB statewide greenhouse gas inventory results for the civil aviation category because CARB does not include interstate emissions. CARB calculations use the fuel-sold method; aircraft fuel sold in San Diego does not fuel all aircraft leaving the region, therefore this method is not as appropriate at the county level. In addition, it was not possible to obtain fuel use or commercial aircraft miles departing from other County airports, namely the McClellan Airport. This would give rise to a slight underestimation from civil aviation in the County.

A further methodological limitation is that an increasing percentage of the jet fuel data provided by one of the fuel suppliers is for private jets. On the other hand, between 1996 and 2007, this supplier has sold an average of 6% of the total jet fuel to the airport. Also, it was not possible to obtain fuel use data for private jets at other airports, which make up the majority of flights from the McClellan and all other county airports. Therefore, it is not possible to estimate the total emissions caused by private aircraft in the county, although we did include in the total estimate the relatively small volume of jet fuel sold for private aviation at the San Diego International Airport.

3. Greenhouse Gas Emissions from Water-Borne Navigation

All types of water-borne navigation in the County contribute to regional greenhouse gas emissions in this category, but only the largest sources of shipping emissions relating to the Port of San Diego (Port), including those ships that pass through the County water lines, were used for this inventory. The Port serves as a transshipment facility for San Diego, Orange, Riverside, San Bernardino and Imperial Counties, northern Baja California, Arizona, and other points east of California. The Port owns and has jurisdiction of the marine terminals at Tenth Avenue, the National City Marine Terminal and the B Street Cruise Ship Terminal. The Tenth Avenue terminal receives refrigerated commodities, fertilizer, cement, bulk commodities and forest products cargo ships. The National City Marine Terminal is mainly an auto terminal, but also has berths that handle forest products. The B Street Cruise Ship terminal is equipped to handle cruise lines.

The specific emissions sources included in this inventory, which are based on the categories used in the California Air Resources Board (CARB) statewide greenhouse gas inventory, are as follows:

- Ocean Going Vessels (OGVs) – these include auto carriers, bulk carriers, passenger cruise vessels, general cargo vessels, refrigerated vessels (reefers), roll-on roll-off Vessels (RoRo) and tankers for bulk liquids, which call at the Port of San Diego as well as those passing through.

- Harbor Craft – these include tugboats, ferries, and commercial fishing vessels.

With the exception of military vessels, all other categories that belong to emissions sources from the Port, as well as indirect emissions caused by electricity use, form part of other categories of this inventory as follows:

- Off-road cargo handling equipment (included in the Off-Road Equipment and Vehicles Section below)

- Railroad locomotives (included in the Rail Section below)
- On-road heavy duty diesel vehicles (Included in the On-Road Transportation Section)
- Stationary sources (combustion sources for electricity generation included in the Electricity Section)
- Recreational vessels (included to some extent in the Off-Road Equipment and Vehicles Section below)
- Non-port owned vessels and facilities (not included)
- Military vessels (not included)
- Other energy use such as electricity and natural gas use (included in the Electricity and Natural Gas categories)

The activities that cause OGV and harbor craft emissions are operations within the designated waters, transit and maneuvering inside the San Diego Bay, and hotelling.[18] The designated zone within which emissions are associated with the County is bordered to the south by the U.S.-Mexico international border extended over water, to the north by the San Diego County line extended over water and to the west within the internationally agreed 24-mile territorial and contiguous zone.

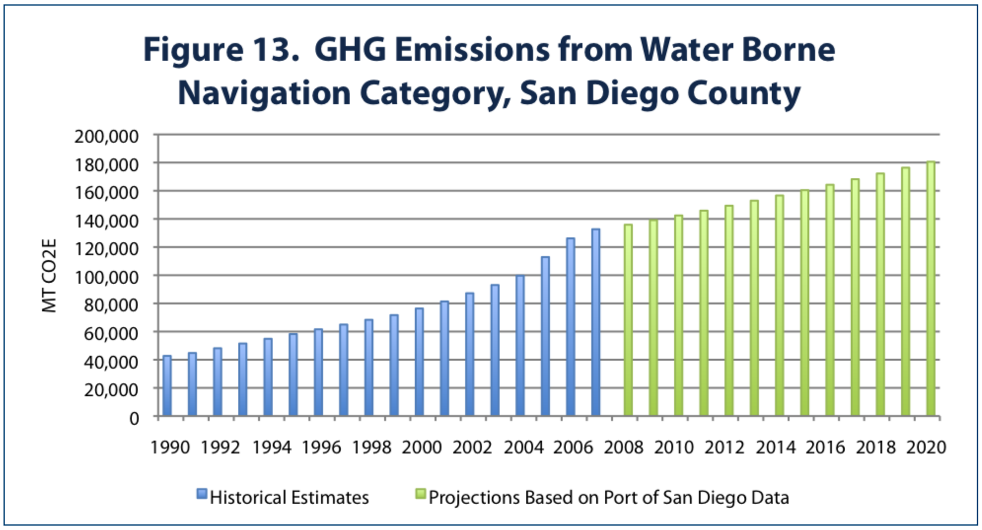
The methodology for greenhouse gas calculations by CARB and other entities requires the use of emissions factors based on the fuel type, the engine type and operating mode, the time spent in each mode –transit, anchorage, maneuvering and berthing (hotelling), engine rated power, engine load factors, fuel consumption of the engine types and the number of port calls of each type of OGV. While port call data is available from maritime organizations, the only other data available within the timeframe of this inventory was the total amount of fuel sold for the San Diego Port which includes fuel sold for international shipping outside of the 24 nautical mile boundary used for the inventory. Within the time frame of this project, it was not possible to produce ground-up calculations for shipping emissions from 1990. Instead, emissions data was provided by CARB from its 2007 updated statewide emissions data and scaled to the San Diego region.

The responsibility for traditional pollutant emissions control falls to the San Diego Air Pollution Control District (APCD), the Air Resources Board and the California Environmental Protection Agency (CA-EPA). The following proposed regulatory measures will have the effect of reducing greenhouse gas emissions from OGVs and have been taken into account in the forecasts for shipping emissions provided by CARB:

-CARB 2005 regulation for low sulfur fuel (0.5% S from 2007, <0.1% from 2010) for auxiliary engines within 24 nautical miles (nm)

-2007 Shore Power Regulation (Res 07-57), which aims to reduce emissions from diesel auxiliary engines on container ships, passenger ships, and refrigerated cargo ships while at-berth at a California Port.

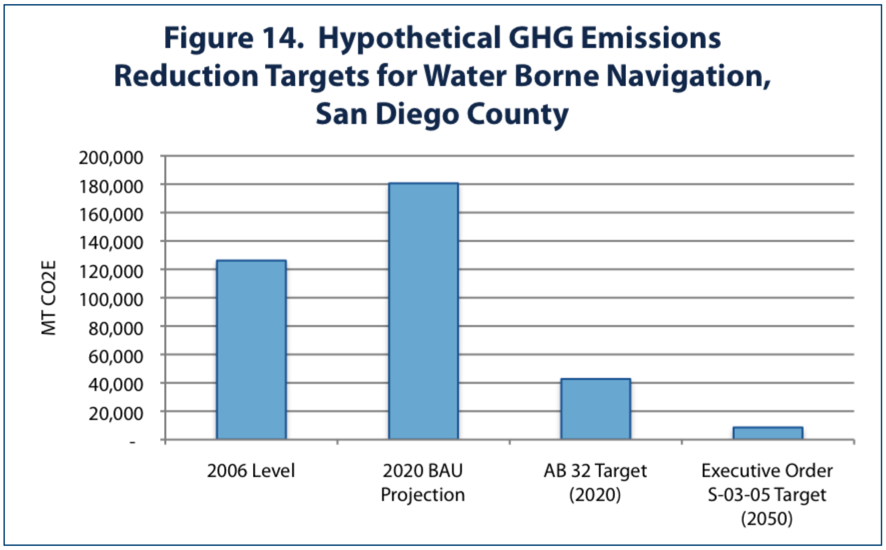
3.1. Historical and Projected Emissions



Shipping emissions have shown a gradual increase between 1990 and 2006 (Figure 13). The 1990 baseline estimate for San Diego County shipping emissions is 42,700 metric tons CO_2E. The 2006 emissions are estimated at 126,200 metric tons CO_2E, 0.4% of the total countywide emissions.[19] The projected 2020 level for OGVs and harbor craft is estimated to be 180,600 metric tons CO_2E, a 43% increase over 2006 levels. This projection includes the emissions reductions expected from the 2007 Shore Power Regulation and the 2005 Auxiliary Engine Regulation.

3.2. Emissions Reduction Targets

In 2006 Governor Arnold Schwarzenegger signed into law the Global Warming Solutions Act (AB 32), establishing statutory limits on greenhouse gas emissions in California. AB 32 seeks to reduce statewide greenhouse gas emissions to 1990 levels by the year 2020. Even though AB 32 does not specify reduction targets for specific sectors or jurisdictions, this study calculated theoretical reductions targets as if the statewide statutory emissions reductions targets were applied to San Diego County and to each emitting category. To meet the theoretical targets established by AB 32, the San Diego region would have to reduce projected water-borne navigation emissions by approximately 138,000 MT CO_2E to reach 1990 levels – a 76% reduction.



In 2005, Governor Schwarzenegger signed Executive Order S-3-05, which establishes long-term targets for greenhouse gas emissions reductions. It seeks to reduce emissions to reduce emissions levels 80% below 1990 levels by 2050. While this reduction target is not law, it is generally accepted as the long-term target to which California regulations are aiming. Similar to AB 32, Executive Order S-3-05 is intended to be a statewide target, but if applied hypothetically to this category of the San Diego County, total emissions from water-borne navigation would have to be reduced to approximately 9,000 MT CO_2E – a reduction of more than 95% below the 2020 business-as-usual forecast and about 93% below 2006 levels. Figure 14 compares 2006 emissions levels, 2020 business-as-usual projections, AB 32 and Executive Order S-3-05 targets.

3.3. Emissions Reduction Strategies

The 2007 Shore Power Regulation is already predicted to reduce carbon dioxide equivalent emissions by 50% by 2020.[20] This is taken into account in the CARB-based San Diego county forecast for OGVs, and therefore in the above numbers and forecasts. The 2005 auxiliary engine regulation is also taken into account but is not expected to contribute significantly to the reduction because its purpose is mainly traditional air pollution reduction. Given the already very low relative 2020 level, which constituted less than 1% of the region's total greenhouse gas emissions 2006, it seems unlikely that further significant reductions can be expected from this category.

Ninety-five percent of the OGVs calling at the port of San Diego are foreign flagged, and more than 60% of the vessels depart for international ports. Therefore the degree of local, state and national control over shipping emissions beyond what has already been adopted is limited.

3.4. Methodology

The basic equation used by CARB for estimating emissions from OGVs is:

E y, t, om, e = ∈ Pop t * EF e, om, f * Hrs om, t * VP om, t * %Load om, t

where

E = pollutant specific emissions (tons per year of NOx, HC, CO_2, SO_2, and diesel PM)

Pop = population of ocean-going vessels by vessel type

EF = emissions factor by engine type, operating mode, and fuel (units of g/kw-hr)

Hrs = average annual use in hours by operating mode and vessel type

VP = average power by operating mode and vessel type

% Load = average engine load by operating mode and vessel type

y = inventory year

om = operating mode (transit, maneuvering, hotelling)

t = vessel type (auto, container, bulk cargo, etc.)

f = fuel (HFO or MGO/MDO)

e = engine type

The emissions factor is expressed in terms of grams per kilowatt-hour (g/kW-hr). The emissions factors used by CARB are provided in the Tables 5-9 below.[21]

Table 5 Main Engine Emissions Factors, Transit Mode (g/kW-hr)

Engine Speed	Fuel	CH_4	CO	CO_2	NO_x	PM_{10}	$PM_{2.5}$	ROG	SO_x
Slow	Marine Distillate (0.1% S)	0.07	1.10	588	17.0	0.25	0.35	0.78	0.36
Slow	Marine Distillate (0.5% S)	0.07	1.10	588	17.0	0.38	0.35	0.78	1.90
Slow	Heavy Fuel Oil	0.08	1.38	620	18.1	1.50	1.46	0.69	10.50
Medium	Marine Distillate (0.1% S)	0.08	1.10	645	13.2	0.25	0.35	0.65	0.40
Medium	Marine Distillate (0.5% S)	0.08	1.10	645	13.2	0.38	0.35	0.65	2.08
Medium	Heavy Fuel Oil	0.09	1.10	677	14.0	1.50	1.46	0.57	11.50
High	Marine Distillate (0.1% S)	0.08	1.10	645	12.1	0.25	0.35	0.65	0.40
High	Marine Distillate (0.5% S)	0.08	1.10	645	12.1	0.38	0.35	0.65	2.08
High	Heavy Fuel Oil	0.09	1.10	645	12.7	1.50	1.46	0.23	11.50

Table 6 Main Engine Emissions Factors, Maneuvering Mode (g/kW-hr)

Engine Speed	Fuel	CH_4	CO	CO_2	NO_x	PM_{10}	$PM_{2.5}$	ROG	SO_x
Slow	Marine Distillate (0.1% S)	0.07	1.10	588	17.0	0.25	0.35	0.78	0.36
Slow	Marine Distillate (0.5% S)	0.07	1.10	588	17.0	0.38	0.35	0.78	1.90
Slow	Heavy Fuel Oil	0.08	1.38	620	18.1	1.50	1.46	0.69	10.50
Medium	Marine Distillate (0.1% S)	0.08	1.10	645	13.2	0.25	0.35	0.65	0.40
Medium	Marine Distillate (0.5% S)	0.08	1.10	645	13.2	0.38	0.35	0.65	2.08
Medium	Heavy Fuel Oil	0.09	1.10	677	14.0	1.50	1.46	0.57	11.50
High	Marine Distillate (0.1% S)	0.08	1.10	645	12.1	0.25	0.35	0.65	0.40
High	Marine Distillate (0.5% S)	0.08	1.10	645	12.1	0.38	0.35	0.65	2.08
High	Heavy Fuel Oil	0.09	1.10	645	12.7	1.50	1.46	0.23	11.50

Table 7 Auxiliary Engine Emissions Factors, Transit, Maneuvering, and Berthing (g/kW-hr)

Engine Speed	Fuel	CH_4	CO	CO_2	NO_x	PM_{10}	$PM_{2.5}$	ROG	SO_x
Medium	Marine Distillate (0.1% S)	0.09	1.10	690	13.9	0.25	0.35	0.52	0.40
Medium	Marine Distillate (0.5% S)	0.09	1.10	690	13.9	0.38	0.35	0.52	2.10
Medium	Heavy Fuel Oil	0.09	1.10	722	14.7	1.50	1.46	0.46	11.10

Table 8 Auxiliary Boiler Emissions Factors (g/kW-hr)

Fuel	CH_4	CO	CO_2	NO_x	PM_{10}	$PM_{2.5}$	ROG	SO_x
Marine Distillate (0.1% S)	0.03	0.20	970	2.0	0.13	0.78	0.11	0.57
Marine Distillate (0.5% S)	0.03	0.20	970	2.0	0.20	0.78	0.11	2.99
Heavy Fuel Oil	0.03	0.20	970	2.1	0.80	0.78	0.11	16.50

Table 9 Fuel Consumption by Engine Type (g/kW-hr)

Engine	Engine Speed	Mode	Fuel	Fuel Use Rate
Auxiliary	All	All	Marine Distillate	217
	All	All	Residual	227
Boiler	N. A.	All	Residual	305
Main	High	Transit	Residual	213
	Medium	Transit	Marine Distillate	203
	Slow	Transit	Marine Distillate	185
	Medium	Transit	Residual	213
	Slow	Transit	Residual	195
	High	Maneuvering	Residual	213
	Medium	Maneuvering	Marine Distillate	203
	Slow	Maneuvering	Marine Distillate	185
	Medium	Maneuvering	Residual	213
	Slow	Maneuvering	Residual	195

The above emissions factors are consistent with the emissions factors used by Starcrest in its Port emissions inventory of 2006.

The fuel consumption rates used by CARB for the different engines are given in Table 9. The equivalent values used by Starcrest were not available.

CARB assumed that the main engines and auxiliary boilers burned heavy fuel oil and that for auxiliary engines, 92% of cruise ships burned fuel oil and 8% distillate. For all other ships, the assumptions were 71% heavy fuel oil and 29% distillate. The equivalent information used by Starcrest was not available.

In their estimate, CARB used data from California Lands Commission for vessel population and number of port calls while berthing was obtained from the each California port. The vessel populations used by CARB are similar to that used by the San Diego Port Air Emissions Inventory 2007 (Figure 15).

Historical trend data for OGV port calls were not available from the Port of San Diego or CARB. According to OGV port call data available at the Maritime Administration from 2002-2006, none of the OGVs indicate an increasing trend, although auto ship calls increased from 2005 to 2006 (Figure 16). Cruise and auto ships make up the majority of the OGV calls in San Diego.

Figure 15. Distribution of OGV Port Calls at the San Diego Port, CARB, 2006

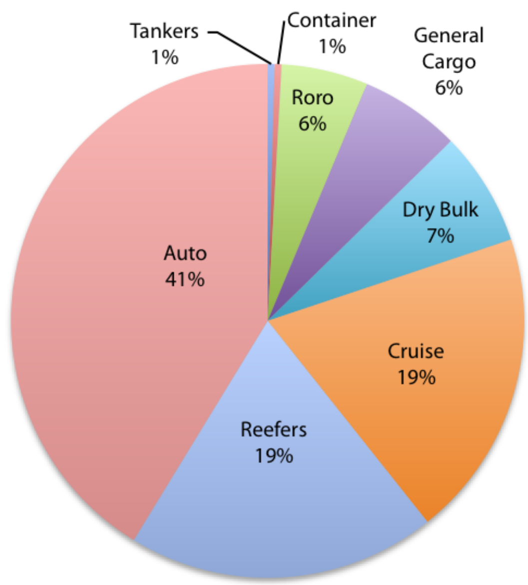
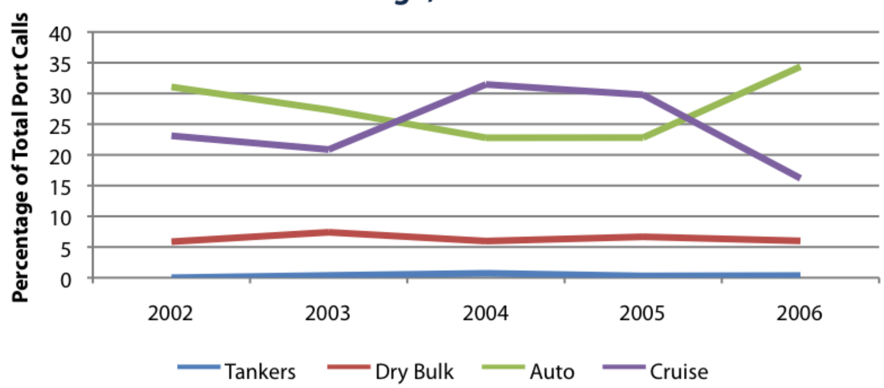


Figure 16. Trends in OGV Port Calls at the Port of San Diego, 2002-2006



3.4.1. Harbor Craft Emissions

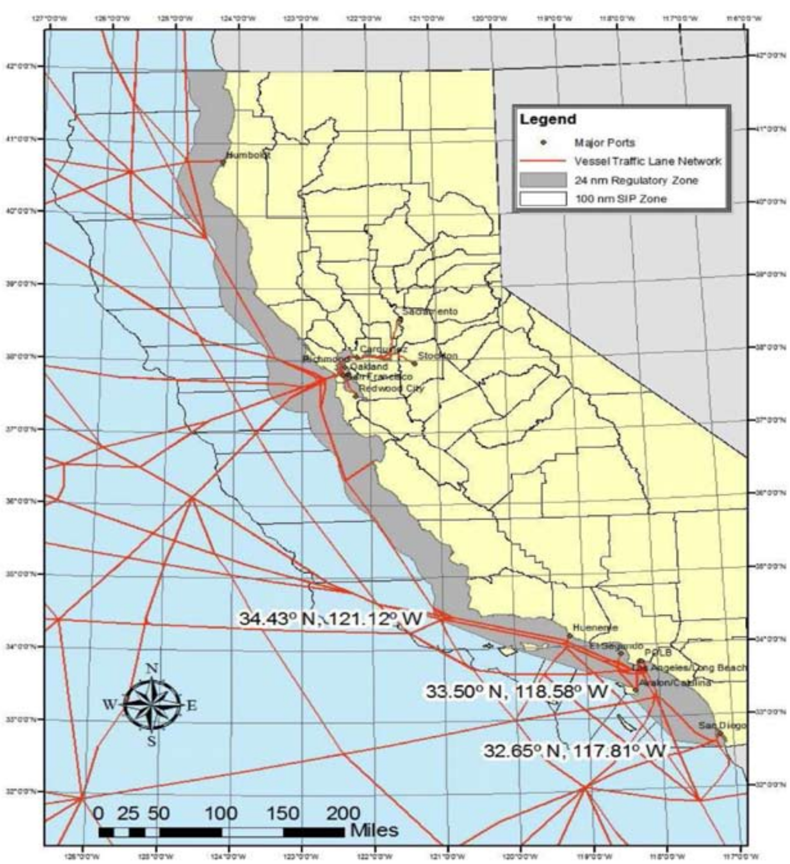
Harbor craft consist of tugboats, commercial and charter fishing boats, excursion boats, and government pilot boats. According to the 2007 CARB methodology on harbor craft emissions, as well as the Port Emissions Inventory (EI) of 2006, commercial and charter fishing boats make up the majority of the harbor craft. Although no data is available to compare the population of harbor craft in the same year, harbor craft vessel numbers data are available for 2004 and 2006 from the two sources, Starcrest and CARB. Large differences are observed between the number of harbor craft vessels provided in the Port EI for 2006 and the closest year for which CARB harbor craft numbers are available – 2004. The Port EI harbor craft population in 2006 was surveyed as 107 while the CARB 2004 allocation to the County was 307.[22] The largest difference lay in the number of commercial fishing and excursion vessels with the CARB number at 260 and the EI number at 72.

CARB also provided us with harbor craft emissions for the County and forecasts to 2020. However, the method of allocation of harbor craft and the emissions estimates from the state to county level may significantly overestimate harbor craft emissions, which would be of no significance in the calculation of the total state emissions for harbor craft. The allocation method does make a large difference when assigning emissions at the county level. We therefore based our harbor craft emissions (to a distance of 24 nm) on the one actual Starcrest EI survey obtained for 2006.[23] In that year harbor craft constituted 27% of the OGV number. With the assumption that the harbor craft use is proportional to the OGVs, the harbor craft emissions from 1990 to 2020 were estimated based on this percentage.

3.4.2. Scaling Statewide OGV Emissions to the County Level

OGV emissions for the County were provided by CARB scaled according to the operating hours in the various modes and calculated on the basis of the route taken between ports. OGVs passing through but not calling at the Port were also included. Vessel traffic lanes and routes (Figure 17) for California versus the San Diego County area as defined above were used for the route calculations.

Figure 17



3.4.3. Forecast Assumptions

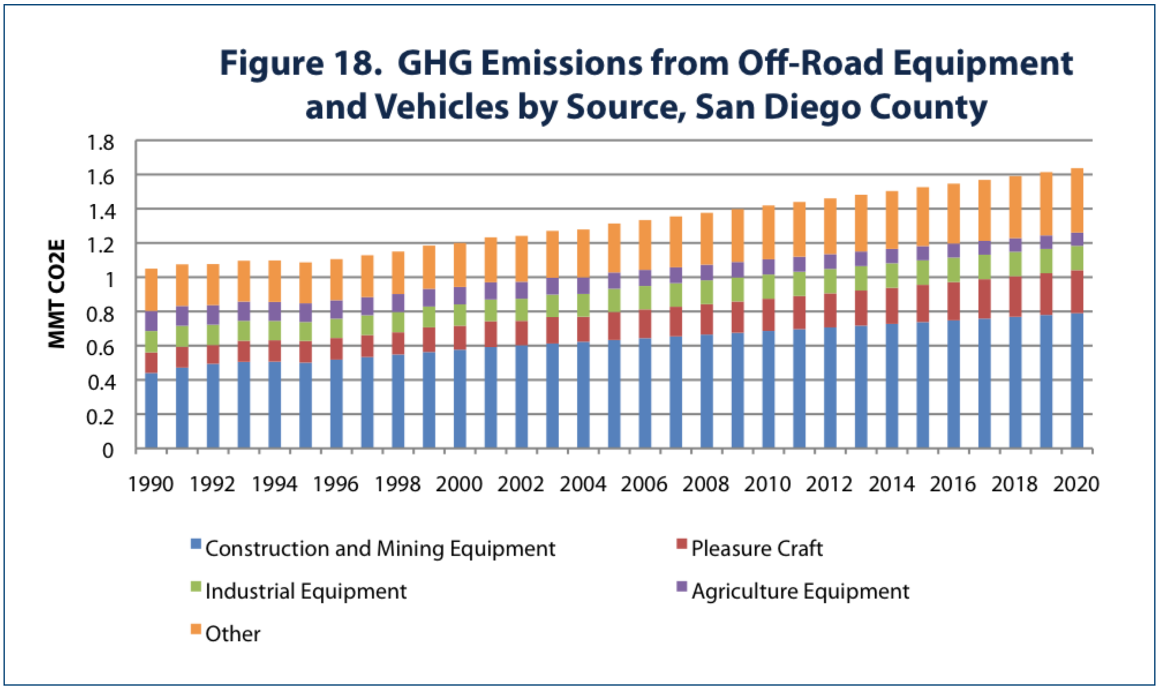
The Port of San Diego provided the OGV traffic growth rates to 2020.[24] An average annual growth rate of 2.4% was calculated based on that data. The net registered tonnage by vessel type is proportional to engine power and therefore to the OGV emissions, and emissions forecasts were made on the basis of a 2.4% annual increase. For harbor craft, since only one GHG emissions value was available for the Port from the Starcrest inventory of 2007, the percentage this represented of the total OGV emissions (27%) was considered constant and used as an estimate for all harbor craft emissions from 1990 to 2020.

3.4.4. Limitations

The main limitation is the lack of local survey data on harbor craft population except for the year 2006. Especially the number of commercial fishing boats may have varied significantly based on fluctuations in the fishery populations in the county waters since 1990 in place of the constant 27% of OGV assumption. However, as the total water-borne emissions in San Diego are small, these variations would be of little significance for the overall countywide greenhouse gas emissions.

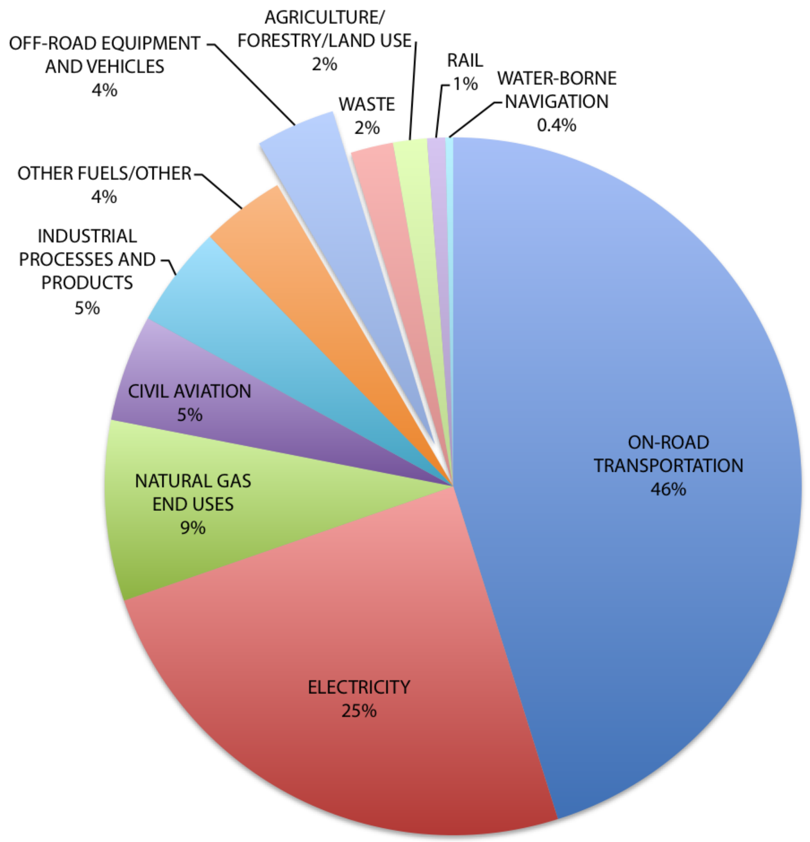
4. Greenhouse Gas Emissions from Off-Road Equipment and Vehicle Emissions

In addition to emissions from on-road vehicles such as cars and trucks, off-road equipment and vehicles also emit greenhouse gases. This category includes the following equipment subcategories: agricultural, airport ground and support, construction and mining, dredging, entertainment, industrial, lawn and garden, light commercial, military, other portable machinery, pleasure craft,[25] railroad operations, recreational vehicles, and transport refrigeration units. The four largest sources of greenhouse gas emissions in this category are: construction and mining, industrial, pleasure craft, and agricultural. They accounted for about 80% of emissions from this category in 2006 and are expected to continue to dominate this category until 2020, as shown in Figure 18.



In 2006, the off-road equipment and vehicle category accounted for emissions of 1.3 MMT CO_2E, an increase of 28% above 1990 levels. Off-road emissions were about 4% of the total in San Diego County in 2006 (Figure 19). If current trends continue, annual emissions from this category will be 1.6 MMT CO_2E in 2020, an increase of 23% above 2006 levels.

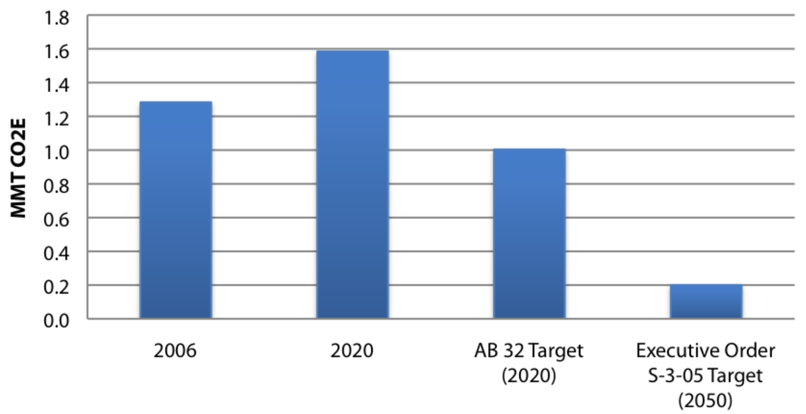
Figure 19. San Deigo County GHG Emissions by Category (2006)



4.1. Emissions Reductions Targets

In 2006, California Governor Arnold Schwarzenegger signed the Global Warming Solutions Act (AB 32), establishing statutory limits on greenhouse gas emissions in California. AB 32 seeks to reduce statewide emissions to 1990 levels by the year 2020. Even though it does not specify reduction targets for specific areas or jurisdictions, this study calculated theoretical reductions targets as if the statewide statutory emissions reductions targets were applied

Figure 20. Emissions Reduction Targets for Off-Road Equipment and Vehicles, San Diego County



proportionally to San Diego County. To meet the targets established by AB 32, San Diego would have to reduce its projected business-as-usual 2020 annual emissions in this category by 0.6 MMT CO_2E or 37%.

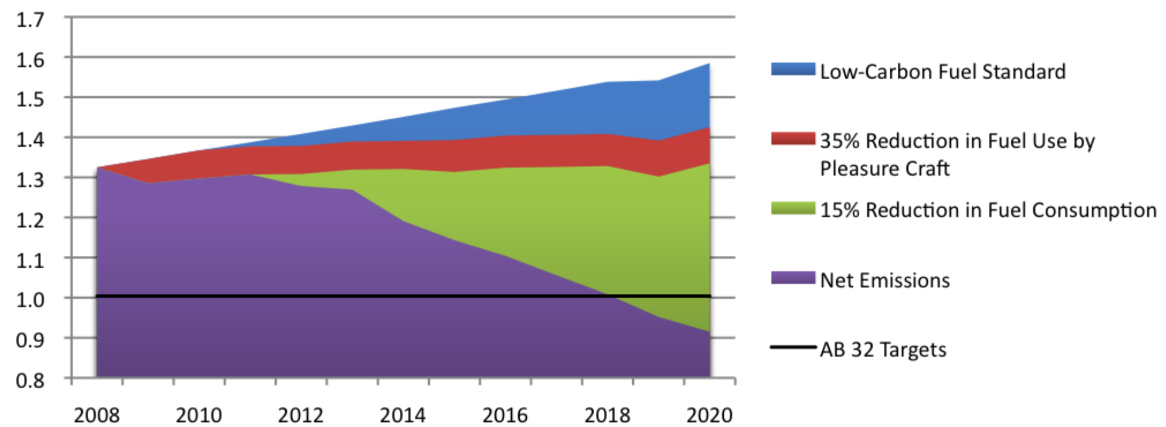
Earlier, in 2005, Governor Schwarzenegger signed Executive Order S-3-05, which established long-term emissions reduction targets of 80% below 1990 levels by 2050. While this target is not law, it is generally accepted as the ideal toward which California regulations are aiming. Like AB 32, Executive Order S-3-05 is intended to be a statewide target, but if applied hypothetically to San Diego County, off-road equipment and vehicle GHG emissions would have to be 0.2 MMT CO_2E by 2050 - a reduction of 1.4 MMT CO_2E below the 2020 business-as-usual forecast. Figure 20 illustrates a comparison of GHG emissions reduction targets for AB 32 and Executive Order S-3-05.

4.2. Emissions Reductions Strategies

To reduce off-road equipment and vehicle emissions to 1990 levels by 2020, emissions from this category will have to be reduced by 0.6 MMT CO_2E below the business-as-usual 2020 forecast.

To illustrate how the region could achieve this, the project team developed several strategies and calculated how much each strategy could reduce emissions. The results were used to develop the reduction "wedges" illustrated in Figure 21. This approach was adapted from the well-known study by Pacala and Socolow, who demonstrated that global emissions could be reduced to levels that would stabilize climate change with existing technologies.[26] They took the total amount of emissions reductions needed to stabilize emissions and split that amount into equal parts or wedges, with each wedge representing a certain amount of emissions reductions. The project team followed a similar approach.

Figure 21. Emissions Reduction Strategies for Off-Road Equipment and Vehicles, San Diego County



The project team developed three wedges to reduce emissions from the off-road equipment and vehicle category to 1990 levels. The wedges are: the Low Carbon Fuel Standard (LCFS), a 35% fuel use reduction by pleasure craft, and a 15% improvement in fuel economy. Table 10 lists each wedge and the reduction in emissions it would achieve by 2020. The combined reductions represented by these three wedges is 0.7 MMT CO_2E by 2020 -- enough to slightly exceed the AB 32 emissions reduction target.

Table 10. Emissions Reduction Strategies for Off-Road Equipment and Vehicles Category

Emissions Reduction Wedge	Emissions Reduction (MMT CO2E)	% of Total Reduction
Low-Carbon Fuel Standard	0.2	24%
35% Reduction of Pleasure Craft Fuel Consumption	0.1	13%
15% Improvement in Fuel Economy	0.4	63%
Total	**0.7**	**100%**

4.2.1. Low Carbon Fuel Standard (LCFS)

The Low Carbon Fuel Standard (LCFS) is expected to reduce greenhouse gas emissions by reducing the carbon content of fuel. It is primarily intended for on-road motor vehicles, but it is assumed that the same fuel will also be used by off-road equipment and vehicles, particularly gasoline and diesel fuel. As of this writing, CO_2E reductions due to the LCFS are not clearly defined or detailed; therefore, we assumed, as for the on-road transportation category in this study, that there will be a 10% CO_2E MMT reduction by 2020 due to the LCFS. For purposes of calculating the reduction potential of the LCFS in this category, we also assumed that it would be implemented and active by 2010.

4.2.2. 35% Fuel Use Reduction in Pleasure Craft (Boats)

Off-road pleasure craft in San Diego County are primarily boats. Since these boats are primarily dedicated to leisure and personal use and not an essential mode of transportation, it is speculated that an increase in fuel prices would deter people from using their boats as often or traveling as far. Taking into consideration the potential of increasing fuel prices, we assumed a 35% reduction in pleasure craft use and fuel consumption by 2020.

4.2.3. 15% Improvement in Fuel Economy

It is expected that on-road transportation fuel economy improvements driven by the Federal CAFE Standard will translate or be transferred via new technology to the pleasure craft industry. The on-road transportation category in some cases will realize a 50% improvement in fuel economy; therefore, it seemed reasonable to assume that this could translate into a 15% fuel economy improvement in the off-road equipment and vehicle category owing to technology transfer.

4.3. Methodology

The GHG emissions inventory for this category includes the analysis of CO_2, CH_4, and N_2O. The data for this category were generated with the California Air Resource Board (CARB) emissions modeling tool OFFROAD. The computations from this model are based on three main factors: equipment and vehicle population, activity, and emissions factors. These factors account for variables such as equipment and vehicle type, technology, age, and horsepower as well as the type of fuel consumed. Seasonal operating conditions and adjustments for ambient temperature are also included in the computation.[27]

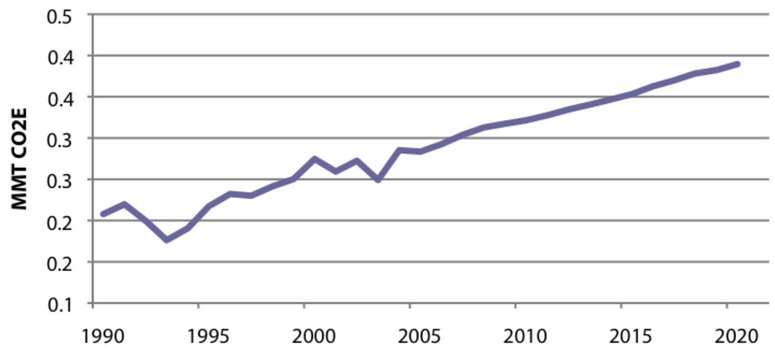
5. Greenhouse Gas Emissions from Rail Emissions

The CARB inventory for the state of California includes emissions from rail as part of the transportation category. To be consistent, we have included information about the Rail category in this report on the "other transportation" categories.

5.1. Historical and Projected Emissions

In 2006, emissions caused by the combustion of distillate fuels for use in rail transportation were 293,000 MT CO_2E, approximately 41% greater than the 1990 level of 208,000 MT CO_2E. The BAU projected level is estimated as 330,000 metric tons, 13% greater than the 2006 levels. Figure 21 shows the generally increasing trend in rail emissions over the 1990-2020 period. This trend is a linear projection from previous years. Transportation fuel costs is a significant factor in determining future emissions from the rail category. If high fuel prices cause a shift away from on-road transportation options, emissions from the rail category could increase, though overall emissions would be reduced due to the efficient nature (fuel use per person) of rail.

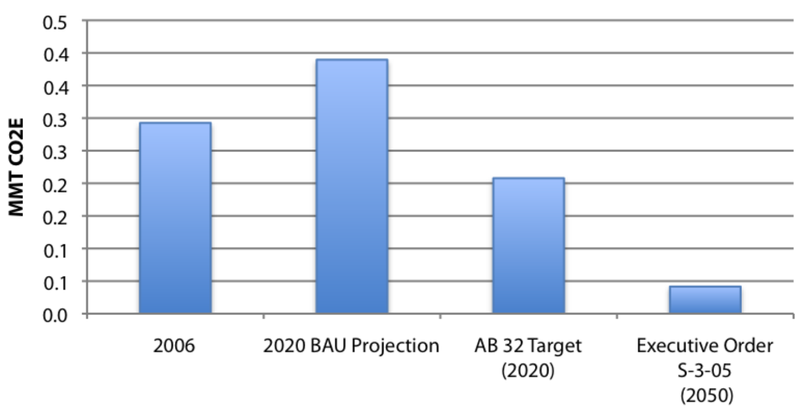
Figure 22. GHG Emissions from Rail Transportation, San Diego County



5.2. Emissions Reductions Targets

In 2006, California Governor Arnold Schwarzenegger signed the Global Warming Solutions Act (AB 32), establishing statutory limits on greenhouse gas emissions in California. AB 32 seeks to reduce statewide emissions to 1990 levels by the year 2020. Even though it does not specify reduction targets for specific areas or jurisdictions, this study calculated theoretical reductions targets as if the statewide statutory emissions reductions targets were applied proportionally to San Diego County. To meet the targets established by AB 32, San Diego would have to reduce its projected business-as-usual 2020 annual emissions in this category by 0.2 MMT CO_2E or 47%.

Figure 23. Hypothetical GHG Reduction Targets for Rail, San Diego County



Earlier, in 2005, Governor Schwarzenegger signed Executive Order S-3-05, which established long-term emissions reduction targets of 80% below 1990 levels by 2050. While this target is not law, it is generally accepted as the ideal toward which California regulations are aiming. Like AB 32, Executive Order S-3-05 is intended to be a statewide target, but if applied hypothetically to San Diego County, emissions from rail transportation would have to be 0.04 MMT CO_2E per year – a reduction of 0.35 MMT CO_2E (89%) below the 2020 business-as-usual forecast. Figure 23 illustrates a comparison of GHG emissions reduction targets for AB 32 and Executive Order S-3-05.

Rail transportation is not the target of GHG emissions reduction strategies at this time. Rail is already a fuel-efficient method of transportation on a per capita as well as on a per unit of freight weight basis. Further, if rail use increases, it is possible that emissions from this category could increase while overall emissions could decrease due to the efficiency of rail. The project team did not calculate emissions reduction strategies for this category.

5.3. Methodology

Activity data for rail transportation were not available within the time-frame of this project; therefore, GHG emissions for the County were scaled from the CARB GHG inventory using US Economic Census data. For this, the project team used data on the "total sales, shipments, receipts, revenue or business done by domestic establishments" for rail transportation.[28]

End Notes

1. Nilmini Silva-Send is the author of the Civil Aviation and Water-Borne Category reports.
2. Sean Tanaka is the author of the Off-Road Equipment and Vehicle Category report.
3. These regulations have been adopted by the Board and come into effect on different dates depending on the type of cold shoring method to be used, the earliest date of coming into effect for California is 2012, for the Port of San Diego the date is 2014. The Port is striving to provide cold ironing for its cruise ship terminal by January 2011, 3 years prior to the regulatory requirement. Approximately 50 ships per year are expected to use cold ironing before the required date. See http://www.arb.ca.gov/regact/2007/shorepwr07/shorepwr07.htm. The ARB rule on auxiliary diesel engines, adopted in 2005 and effective from January 2007 was struck down by the 9th Circuit upholding an August 2007 decision of a District Court, which found that the ARB regulation is preempted by the Clean Air Act (CAA), and that it wrongly complicates international commerce. Under the court ruling, the ARB must seek an EPA waiver for its marine engine regulation(s). While ARB pursues the waiver, it is also developing another rule, which would require ships to switch to low-sulfur fuels in their main engines when within 24 miles from California coasts, see http://www.arb.ca.gov/ports/marinevess/marinevess.htm.
4. Aviation gasoline is a high octane gasoline used for aircraft and racing cars. Jet fuel is unleaded kerosene with Jet-A being the US standard only used in the US.
5. A detailed explanation of the two methods is provided in Section 1.3.
6. Concern has led to a petition by Friends of the Earth to the EPA to regulate or evaluate the environmental and health effects of leaded aviation gasoline, see http://www.avweb.com/avwebflash/news/GroupAsksEPAToGetTheLeadOutOfAvgas_196596-1.html.
7. The future availability of aviation gasoline has led companies to develop alternatives. See "Teledyne Continental Plans Certified Diesel within two years", February 2008, at http://www.avweb.com/eletter/archives/avflash/1054-full.html.
8. California Energy Demand 2008-2018 Staff Revised Forecast. California Energy Commission (CEC) November 2007.
9. Airport Master Plan, San Diego International Airport, October 2007, available at http://www.san.org/airport_authority/airport_master_plan/index.asp
10. The number of enplanements is not the same as the number of passengers. Enplanements refer to the actual number of passengers boarding aircrafts, whereas the number of passengers is roughly double the number of enplanements and assumed to be in an airport at any one time. The number of passengers is the value used for airport expansion plans.
11. Forecasts for 2010, 2015, and 2020 are from the San Diego County Regional Airport's Master Plan, 2005 with interpolated values between.
12. Daggett, D.L, Hendricks, R.C., Walther, R. and Corporan, E., Alternate Fuels for use in Commercial Aircraft. This research is being carried out by a consortium consisting of Boeing, NASA Glenn Research Center, MTU Aero Engines (Germany) and the US Air Force Research Laboratory. Some of the algal based biofuels research is being carried out at UCSD, San Diego. Available on-line at: http://www.boeing.com/commercial/environment/pdf/alt_fuels.pdf
13. http://www.arb.ca.gov/cc/inventory/data/data.htm.

14. Global warming potentials of 21 and 310 for methane and nitrous oxide were used by CARB and are from the UNFCC IPCC report of 1995, http://unfccc.int/ghg_data/items/3825.php. The more recent revised IPCC GWP values were not used in order to be consistent with all the remaining county-wide inventory category reports as well as the CARB existing state-wide inventory.

15. http://www.transtats.bts.gov/. The departure miles for 1990 are not available and were backcast from the 1991-2007 linear plot.

16. A preliminary analysis for just one year, 1991, of the aircraft type mix in San Diego versus the aircraft type mix in California showed that San Diego had a more modern and therefore more fuel efficient fleet than the state. Time did not permit further evaluation to establish if this were true for all years to 2006. If it does hold true to the present day, then the emissions caused by the aircraft fleet in San Diego will be somewhat lower than the average of California.

17. The project team submitted a detailed data request to the APCD for all fuel used in San Diego County. This included emissions from aviation activities.

18. Hotelling is an alternative term used for ships at berth, usually at port.

19. This is the value provided by CARB in "Emissions Estimation Methodology for Ocean-Going Vessels", May 2008, Table ES-2 together with the harbor craft emissions value available in the San Diego Port Emissions Inventory of 2007.
A greenhouse gas emissions inventory for the Port was carried out as part of an air emissions inventory by Starcrest Consultants for 2006, see http://www.portofsandiego.org/environment/clean-air/65-clean-air/581-clean-air-program-overview.html. The total carbon dioxide equivalent emissions for OGVs and harbor craft from this study were 83,773 metric tons in 2006. Although the basic methodology used by CARB and Starcrest is the same (see Section 3, Methodology), differences are attributed to mainly to the inclusion of OGVs that pass through County waters, and less due to differences in vessel speed and engine load factors. In addition, the Starcrest fuel consumption data may differ from CARB fuel consumption data. The emissions factors for greenhouse gases used by CARB and Starcrest are the same.

20. See End Note 1.

21. Table 5 through Table 8 form part of the methodology used by CARB and were provided by CARB in "Emissions Estimation Methodology for Ocean-Going vessels", May 2008.

22. CARB describes its allocation of harbor craft to the ports. The vessels with home ports far away from navigable waters were assigned to the nearest port. Those that did not have a home port were assigned the port of the owner or operator. Those that had a home port outside California were assigned the port at which they landed their catch. See Appendix B, Emissions Estimation Methodology for Commercial Harbor Craft operating in California, 2007, provided by CARB and available at http://www.arb.ca.gov/regact/2007/chc07/appb.pdf.

23. See Port of San Diego 2006 Emissions Inventory, 2007 at http://www.portofsandiego.org/environment/clean-air.html.

24. The cruise ship growth data was taken from the Marketing Department forecast provided by the Port and all other growth forecasts provided by the Port are from the San Diego Unified Port District Maritime Business Plan (April 2007), pages 4-27 to 4-29 available at: http://www.portofsandiego.org/maritime/593-port-challenges-initiative-to-redevelop-the-tenth-avenue-marine-terminal-.html

25. Most of the pleasure craft in San Diego County are boats or other type of water vehicle. Recreational vehicles are in a different category.

26. S. Pacala and R. Socolow: Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies, Science, 13 August 2004, vol. 305, pp. 968-972.

27. California Air Resources Board, "Overview: OFFROAD Model" last viewed May 25, 2008, at http://www.arb.ca.gov/msei/offroad/pubs/offroad_overview.pdf

28. The economic data for the state of California is available at:
http://factfinder.census.gov/servlet/IBQTable?_bm=y&-geo_id=04000US06&-ds_name=EC0200A1&-_lang=en.
The equivalent data for the County of San Diego is available at:
http://factfinder.census.gov/servlet/IBQTable?_bm=y&-geo_id=31000US41740&-ds_name=EC0200A1&-_lang=en