San Diego County Greenhouse Gas Inventory

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

Waste Report

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Waste Report Acknowledgements

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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

Emissions from landfills and wastewater treatment constitute about 2% of greenhouse gas emissions (GHG) in the County. Biodegradable, carbon-bearing wastes decompose under largely anaerobic conditions to produce landfill gas composed of approximately 50% methane and 50% carbon dioxide. Methane is a more powerful greenhouse gas by a factor of 21[1] than carbon dioxide and degradable wastes in landfills continue to degrade for several decades. The treatment of domestic wastewater also results in the release of methane as well as nitrous oxides.

This report, a component of the San Diego County Greenhouse Gas Inventory project, provides an estimate of historical GHG emissions associated with both components of the waste category from 1990 to 2006 and projected future emissions to 2020 for the region. Emissions associated with waste disposal and wastewater treatment, such as transportation activities, are captured in other sectors of this inventory. 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 this sector. 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.) to achieve the AB32 statutory target of 1990 levels by 2020. Finally, the report identifies and quantifies potential emissions reduction strategies to evaluate the feasibility of reducing waste-related emissions 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 includes the following sections.

- Section 2 provides an overview of GHG emissions for the waste category total emissions divided into its two components, landfill emissions and wastewater treatment emissions from 1990 to 2020;
- Section 3 discusses the potential strategies to reduce landfill gas emissions beyond 2020 levels;
- Section 4 provides the method used to estimate emissions for this category.

1.1. Key Findings

The key findings are as follows:

- In 2006, GHG emissions from the waste category totaled 0.7 million metric tons of carbon dioxide equivalent (MMT CO_2E), about 2% of San Diego County's overall emissions.
- Both biogas and landfill gas have been captured for combustion and electricity production since at least 1997; therefore, the current (2006) total emissions of approximately 0.7 MMT are nearly 30% lower than the total emissions in 1990, which was modeled to have been 0.9 MMT.
- Landfill emissions constitute the larger of the two sources of waste sector emissions today. Carbon-bearing wastes still constitute more than 55% of the total waste disposed.
- Waste disposal per capita at landfills has increased from 1.2 metric tons in 1990 to 1.4 metric tons in 2005, despite the requirement for 50% diversion of waste disposed established in 1989 by the state of California. In 2005, San Diego County reported 48% diversion of total waste disposed.

- At the current rate of emissions growth and emissions controls, assuming no changes in percentage capture of landfill gas and biogas, and no changes in the per capita waste disposed, the business-as-usual (BAU) level is projected to be 0.9 MMT in 2020. Therefore, the 1990 baseline will not be exceeded until after 2020.

- The Discrete Early Action Measure currently approved by CARB under AB32 to increase landfill gas capture can provide an additional reduction of 0.3 MMT by 2020.

- The Executive Order S-3-05 target of 80% below 1990 levels means reaching total waste sector emissions of 0.2 MMT by 2050.

- The key limitation in the estimation of landfill emissions is the lack of accurate data for waste disposed at the 26 landfills in the County, and the need to interpolate and backcast the amount and composition of waste disposed. Based on the waste-disposed data available for one major landfill in the county (Miramar), it appears that landfill emissions may be underestimated. More data will be needed to more accurately assess emissions. On the other hand, the second limitation is the lack of landfill and biogas capture data for 1990. This may result in overestimation of the methane emissions for 1990.

2. GHG Emissions from Waste Sector

The following components are included in the waste sector of this inventory, consistent with the categories used in the CARB statewide Greenhouse Gas Inventory[2]:

- Landfill emissions

- Emissions from domestic wastewater treatment and discharge

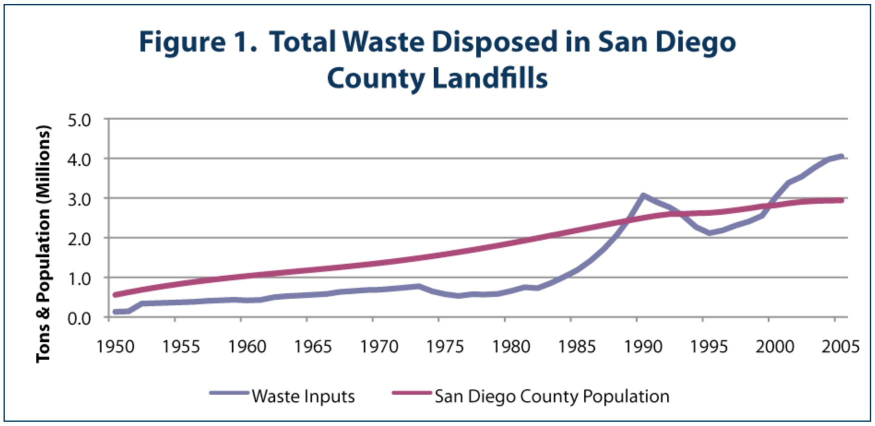
- Emissions from industrial wastewater treatment and discharge

Industrial wastewater consists of manufacturing and agricultural process wastewater. However, San Diego County has insignificant manufacturing and agricultural wastewater discharge and treatment. Any manufacturing or agricultural wastewater is reported to be pre-treated and discharged to the domestic wastewater system.[3] Therefore, this component is not included in the inventory as a separate item.

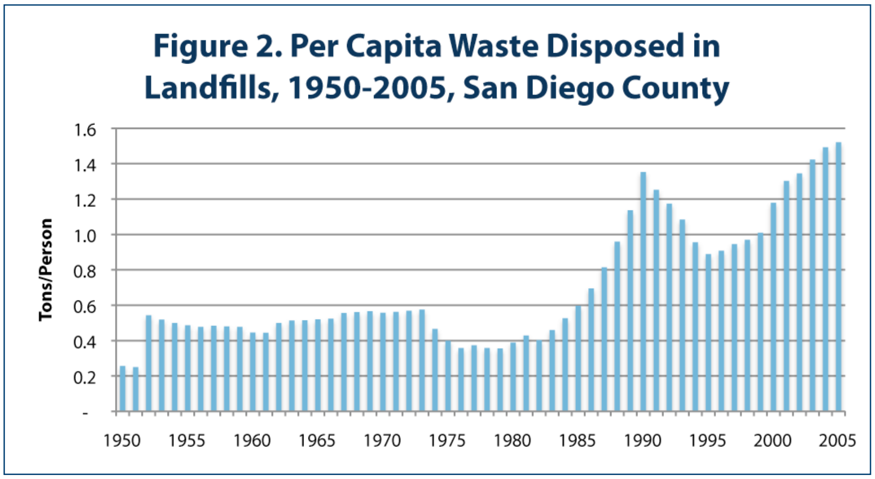
2.1. Landfills

Biodegradable, carbon-bearing wastes decompose under largely anaerobic conditions to produce landfill gas composed of approximately 50% methane and 50% carbon dioxide. Degradation is caused by bacteria which make use of the water content in the waste to cause degradation. Without water, no degradation will take place. Thus, a large fraction of carbon-bearing wastes will actually be sequestered as long as anaerobic conditions prevail and as long as the moisture content is low. The degree of compaction will also determine the availability of moisture for the degradation process. In addition, the moisture is often not uniformly distributed so that the degradation process is uneven through the landfill.[4]

Methane is a more powerful greenhouse gas by a factor of 21 than carbon dioxide and degradable wastes in landfills continue to degrade for several decades.[5] As long as carbon-bearing wastes are disposed in the landfill and sufficient moisture exists, degradation can occur from periods of 5 to 50 years. The highly biodegradable waste such as garden and newspaper decomposes more quickly to produce gas in the early years and gas production will begin within the first year of deposition. Other carbon-bearing wastes such as lumber are slower to degrade and may continue to do so over decades. Therefore carbon bearing wastes disposed today may still be degrading for decades after closure of the landfill although commercially viable amounts of methane may not be available for more than 20-30 years after closure.[6]



Most landfills are now equipped with landfill gas collection systems for the purposes of odor control by flaring and increasingly for the production of electricity. In either case, the methane emitted to the atmosphere – and net carbon dioxide equivalent emissions – will decrease. In addition, California's solid waste and recycling law AB 939 of 1989 mandated local jurisdictions, for the sake of limited disposal capacity, to meet numerical total waste diversion goals of 25% by 1995 and 50% by 2000.[7] San Diego County reports its diversion rate at 48% in 2005.[7] Despite this diversion, the waste disposed (Figure 1) has continued to increase after a large dip during the 1990s.[9]



The per capita waste disposed (Figure 2) has increased from 1,230 kilograms (1.2 metric tons) per year in 1990 to 1,380 kilograms (1.4 metric tons) in 2005.[10] A diversion rate of 48% means that the waste generated per capita is even greater, since the per capita data here only represents waste disposed at landfills.

Minor amounts of non-methane volatile organic compounds (NMVOCs) as well as smaller amounts of nitrous oxide (N_2O), nitrogen oxides (NOx) and carbon monoxide (CO) are also produced from the degradation process. However, these are not significant relative to the methane and carbon dioxide emissions. For the whole of the state of California, the N_2O emissions in carbon dioxide equivalents are of the order of 10e-7 MMT.[11] This component is therefore much less significant in San Diego County and is not included in the San Diego waste sector emissions.

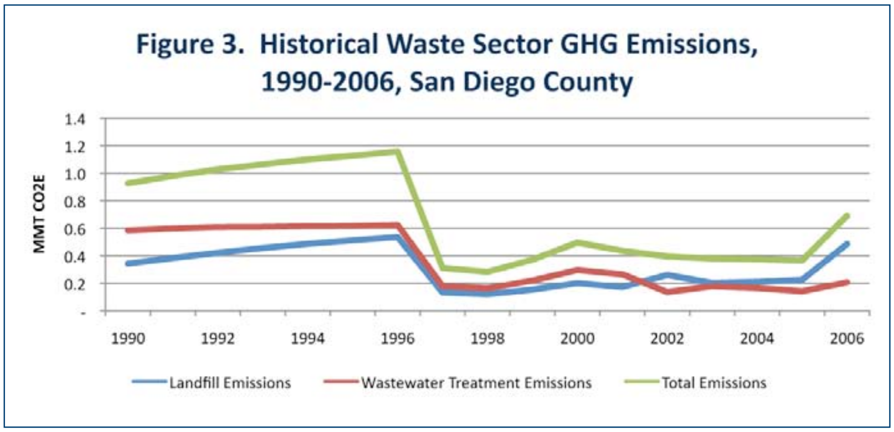
Currently, 372 landfills have been identified by the California Integrated Waste Management Board (CIWMB) in the state of California as having received or still receiving carbon-bearing wastes, of which 26 are located in San Diego County. Eight landfills are active in San Diego County. Three are operated by the City of San Diego, and the remaining are under the jurisdiction of the County Public Works Department, the local enforcement agency for the CIWMB.[12]

Landfill gas has been collected from 20 out of 26 landfills at least since 1997. CARB data indicates that a few landfills may have flared landfill gases from 1990.

2.2. Domestic Wastewater Treatment

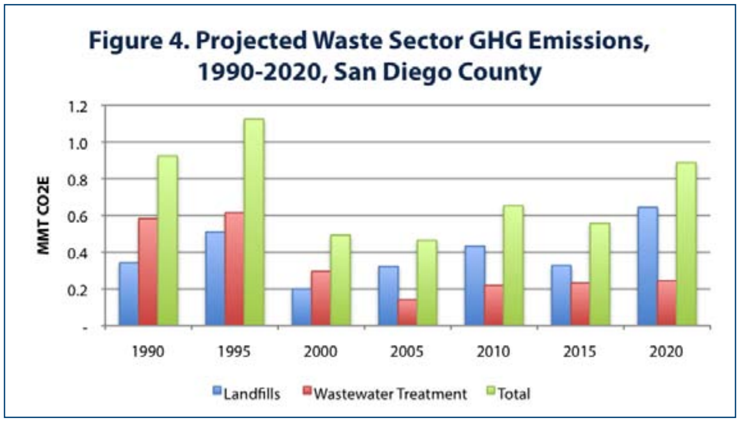
The city of San Diego operates three water treatment plants. The treatment of domestic wastewater produces sludge which is pumped into digesters where a bacterial digestion process is applied to produce methane gas. The Point Loma plant has 8 digesters to produce its own methane and electricity, and surplus electricity is fed into the grid. Excess sludge is piped to three digesters at the Metro Biosolids Center (MBC), located adjacent to the Miramar landfill. These digesters produce methane and heat used to run the digestion process while the methane, along with methane generated at the landfill, is burned to produce electricity. These cogeneration facilities produce about 10 MW of power, while the MBC digesters produce about 6.4 MW and the sludge from the North City plant is used to produce about 3.8 MW of which 75% is used for energy self sufficiency.

In 1990, the emissions from landfill gas and domestic wastewater treatment were 0.9 MMT CO_2E. In 2006, the level was 0.7 MMT CO_2E, a decrease of about 30%. The primary reason for this reduction is the diversion of landfill and wastewater treatment gases, recorded since 1997. Figure 3 shows waste sector emissions from 1990 to 2006.



2.3. Emissions Projections and Reduction Targets

The BAU emissions projection for this category was made based on current levels of per capita waste disposal (1.38 metric tons per person), projected population growth, the average percentage of landfill gas capture over the period 1996-2006 (67%), and the average capture rate of biogas (71%). Forecasts of wastewater discharge emissions were based on population growth, since the emissions are based on a grams-per-person value (see Methodology section, below). With these assumptions, the GHG forecast for this sector in 2020 is expected to be approximately 0.9 MMT. The greenhouse gas forecasts for the waste sector from 2007 to 2020 are provided in Figure 4.



In 2006 Governor Arnold Schwarzenegger signed into law the Global Warming Solutions Act (AB 32), establishing statutory limits on GHG emissions in California. AB 32 seeks to reduce statewide GHG 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. Due largely to the capture of landfill and biogas since at least 1997, the 1990 baseline is not projected to be exceeded until after 2020.

In 2005, Governor Schwarzenegger signed Executive Order S-3-05, which establishes long-term targets for GHG 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, the waste sector emissions would have to be approximately 0.18 MMT CO_2E. This would require an emissions reduction of approximately 0.5 MMT CO_2E (73%) from the 2006 level.

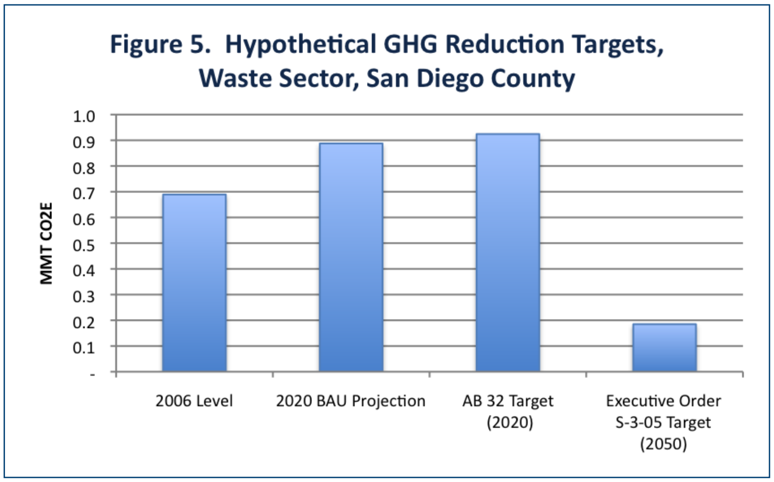


Figure 5 shows projected 2020 and actual 2006 emissions levels compared to the AB 32 and Executive Order S-3-05 targets.

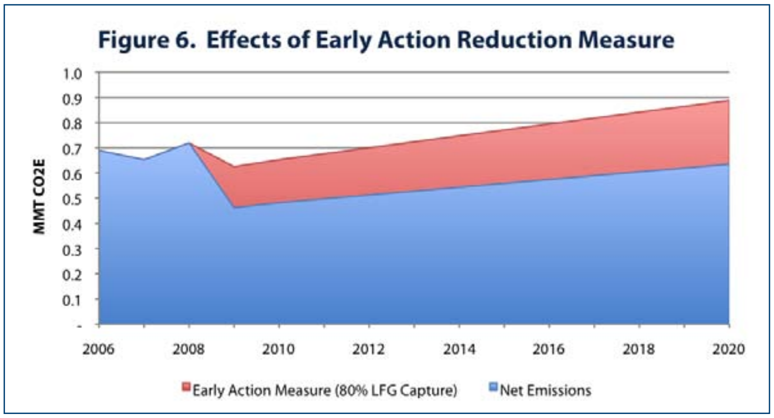
3. Reduction Strategies (Wedges)

Because both biogas and landfill gas have been captured for combustion and electricity production since at least 1997, the current (2006) total emissions of approximately 0.7 MMT are nearly 30% lower than the total emissions in 1990, which was modeled to have been 0.9 MMT. Provided the current rate of emissions growth does not change, there are no changes in percentage capture of landfill gas and biogas, and no changes in the per capita waste disposed, the business-as-usual (BAU) level is projected to be 0.9 MMT in 2020. Therefore, the 1990 baseline will not be exceeded until after 2020.

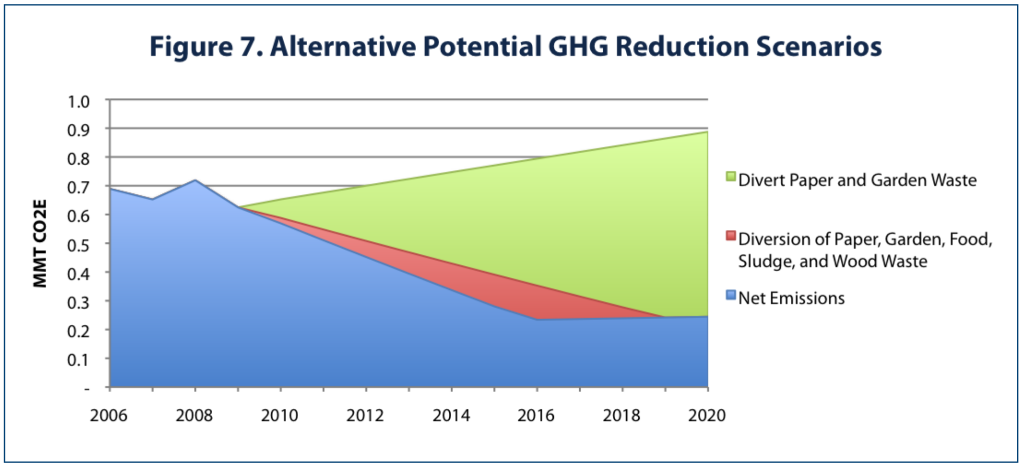
Nevertheless, further reductions in this sector may be able to contribute to a small extent to offset emissions in other sectors, and also contribute to achieving the target set by Executive Order S-03-05 for 2050. An Early Action Measure has been promulgated by CARB for increasing landfill gas capture in the state. An alternative more long-term strategy only for the purpose of reducing greenhouse gases may be provided by reducing the carbon-bearing material disposed in landfills to reduce and eventually halt the production of methane from landfills.

3.1. Increase Landfill Gas Capture Rates

The Discrete Early Action Reduction Measure approved by CARB under the wider mandate of AB 32 is to increase the capture of landfill gases in uncontrolled landfills, without specification of target capture levels. The average landfill gas capture rate in San Diego County between 1997 and 2007 has been 67%. Twenty out of twenty six landfills currently capture landfill gas. For the purposes of emissions reduction under the early action measure, it was assumed that it is feasible to increase the capture rate to 80% of the total production, or 13 percentage points more than the current average. (Figure 6)



3.2. Alternative Strategy: Diversion of Carbon Bearing Material



Although no other regulatory mechanisms are being considered for the reduction of landfill or wastewater treatment emissions, the effect of various potential strategies, which are practical and within reach, may be considered. Therefore, for example, if only the paper and garden waste components of carbon-bearing waste were reduced to 1% of the total disposed, the resulting decrease in rapidly-degrading carbon-bearing materials and the reduction in the per capita waste disposed in landfills to about 1 metric ton can provide an emissions reduction wedge as shown in Figure 7. If nearly all components of carbon bearing waste (paper, garden waste, wood, food, sludge), which currently constitute more than 55% of the waste disposed, were diverted from landfills, the achievement of the 2050 target may become feasible. Figure 7 shows both these reduction strategies as wedges. The reductions caused by the diversion of carbon-bearing organic waste are eventually overshadowed by the increasing population effect on wastewater treatment emissions. This is the reason for the increase in emissions after about 2016, when wastewater treatment emissions become the driving force for the total waste category emissions.

The diversion of carbon-bearing wastes from landfills would require a re-evaluation of any current waste policies with its reliance on landfilling of waste. Whether it is technically, socially and economically more feasible to divert organic wastes for alternative energy-producing processes, or whether there is any potential to increase composting practices, or if in fact incineration of wastes is feasible given environmental regulations and concerns, are policy issues which warrant further research but are beyond the scope of this project.

4. Waste Sector Emissions Inventory Methodology

4.1 Domestic Wastewater Treatment Emissions

The project team estimated emissions from the domestic wastewater treatment by multiplying the per capita emissions factors for nitrous oxide (N_2O) and methane (CH_4) provided by the California Air Resources Board (Table 1).[13] The emissions per person for N_2O have increased over the period of study while the methane emission factor per person has remained the same.[14]

Table 1. Waste Water Emissions Factors for Methane and Nitrous Oxide[15]

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CH4 emissions factor, wastewater treatment, grams/person	9855														
N2O emissions wastewater treatment grams/person	89.3	91	91	91	94	92	92	93	94	96	95	95	95	95	95

The CH_4 emissions factor is based on the Biochemical Oxygen Demand (BOD5)[16] production rate of 0.1 kg BOD5/capita/day and a methane production capacity for domestic wastewater of 0.6 kg CH_4/kg BOD5. It also assumes an average CH_4 correction factor for treatment, or the anaerobically degradable fraction, for all treatment systems of 0.5.

The biogas removed for combustion was provided by the Air Pollution Control District as millions of cubic feet of biogas produced per facility annually in the County. This was converted to mass of methane by assuming a density of biogas of 0.7 kg/m3, as provided by CARB. The data for biogas removed was available from 1997 to the present.

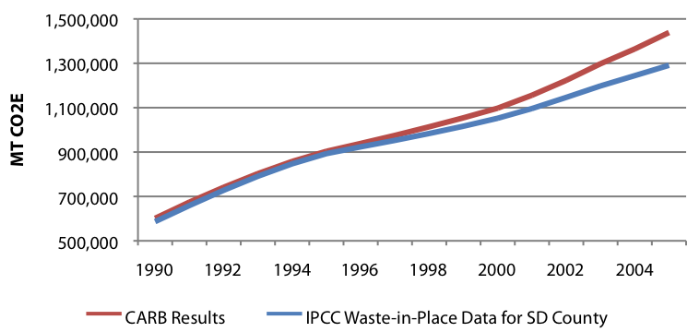
4.2. Landfill Gas Emissions

Since actual greenhouse gas emissions from landfills are not available, the project team relied on assumptions and models to calculate emissions based on waste disposed and the average composition of the waste disposed. The project team used the Mathematically Exact First Order Decay Model (FOD) from the IPCC Solid Waste Guidance Document.[17] This model requires input of the amount disposed from 1950. Not all 26 landfills in the County existed in 1950, and even if they did, the data available does not go back as far as 1950. Some landfills opened and closed within the 1950 to 2005 time frame and others were open for waste disposal for less than a decade. The City of San Diego provided waste disposed data for four city landfills (out of the total 26 County landfills), of which the Miramar landfill is the longest operating, with data available from 1960. However, the Miramar landfill has not been the largest in the County. For other County landfills, only random spot data were found within site assessment reports available at the County Public Works Department. Therefore, it was not possible to use the local data available for the countywide amounts disposed.

The California Air Resources Board provided the waste disposed data for each of the 26 landfills in the County that it had obtained to carry out its GHG inventory. The data available to CARB had been back extrapolated and interpolated where there were data gaps using several complementary methods, as well as additional data available from CWIMB and US Environmental Protection Agency (US EPA) studies. The project team therefore used this countywide total disposal data as inputs to the IPCC model from 1950 to 2004.

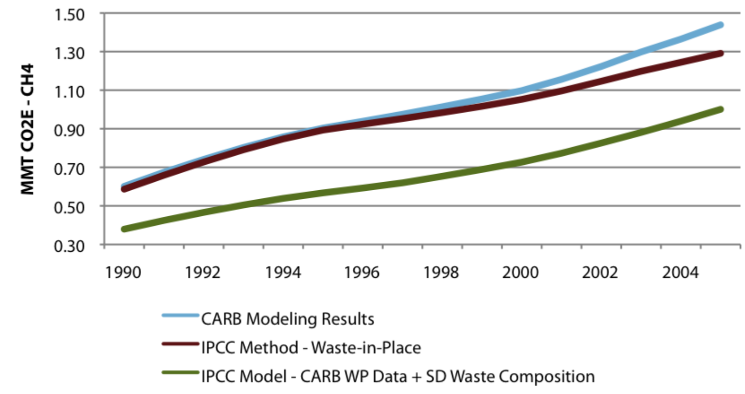
The project team tested the closeness of agreement of the emissions results produced by the IPCC Waste model and the CARB calculations. Thus, the IPCC model was used with the CARB data using the parameters used by CARB for the state of California. For instance, the California average waste composition data was used, which is based on several EPA and CWIMB studies. The results of the IPCC Waste Model were found to be in close agreement with the results of raw methane emissions data provided by CARB (Figure 8) especially in the beginning years, but diverge up to 5% in the recent years. For the purpose of establishing the 1990 county level, this divergence is not of consequence but it will overestimate emissions of the forecasted values compared with any forecasts made by CARB using its values back to the 1930s.

Figure 8. Comparision of Methods for Landfill Gas Emissions, San Diego County



The City of San Diego provided data on waste composition from studies carried out in 1996 and 2000. These show that the San Diego County waste profiles differ from the US EPA and CWIMB California-wide profiles, mainly in the lower content of organic matter. To account for this difference, the project team ran the IPCC Waste Model with the San Diego waste composition data and the CARB waste disposed data to obtain the results shown in Figure 9. These emissions values were used to determine the total carbon dioxide equivalents emissions from the landfill sector presented here.

Figure 9. Comparison of Methods for Landfill Gas Emissions, San Diego County



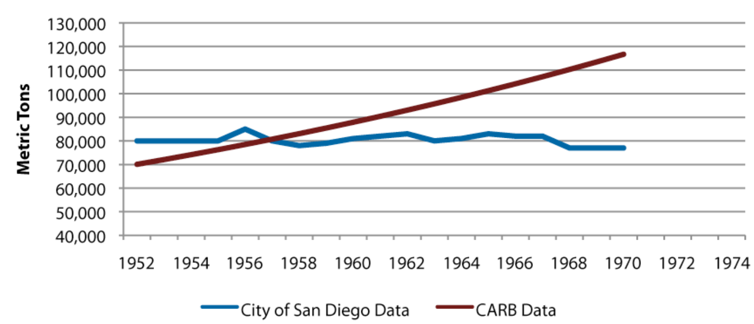
4.3 Method Limitations

Studies comparing modeling results with whole site methane emission measurements, though few, have shown that large differences in results occur depending on the model and when relying on backcast and interpolated data sets versus actual emissions.[18] Therefore it is important that at least the same model and default parameters are used for comparison purposes, as done here. Still, large errors in estimation occur because of the lack or variations of actual waste disposed data, and lack of testing of the model with real landfill gas monitoring data.

For example, Figures 10-12 show a comparison of the waste disposed provided by CARB for three city landfills versus the data provided by the City of San Diego. The total waste in place in 2005 for the Miramar Landfill is only 10% different from that provided by CARB; however, the same comparison for the Chollas Landfill shows a difference of at least 50%. Other such comprehensive data was not available for the other landfills but similar differences might be expected.

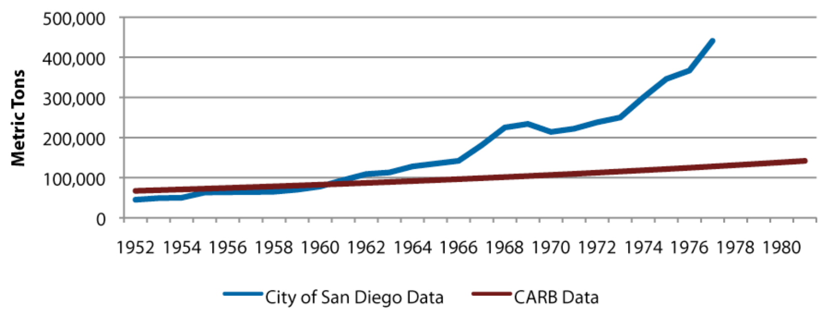
Caution is needed even for this landfill specific comparison as both sets of data consist of backcast and interpolated values where there are data gaps. In this sense, a better comparison of the data differences may be obtained using the total waste disposed over the whole lifetime of any particular landfill, and not the distribution over the years or difference in any one year. A comparison of the total waste in place by 2005 for each of the city landfills showed that the total waste in place estimated by CARB versus that provided by the city, though both containing backcast and interpolated data, differ by only 10%. However, when the IPCC Waste Model is run with the CARB data and the City data, the annual differences flatten out, due to the nature of landfill degradation and long lag times (Figure 13).

Figure 10. Method Limitations: Comparison of Waste Disposed Data, Arizona Street Landfill



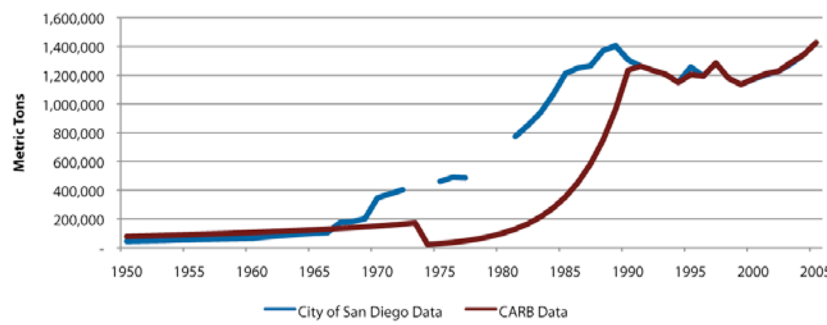
Therefore, further improvement of the total waste disposed data might be possible from the total capacity of the landfill as given in the permits with the assumption that when the landfill closes, all its capacity has been used. However, to be consistent with CARB methodology, and due to lack of time and resources in this phase of the project, this method was not pursued further.

Figure 11. Method Limitations: Comparison of Waste Disposed Data, Chollas Landfill



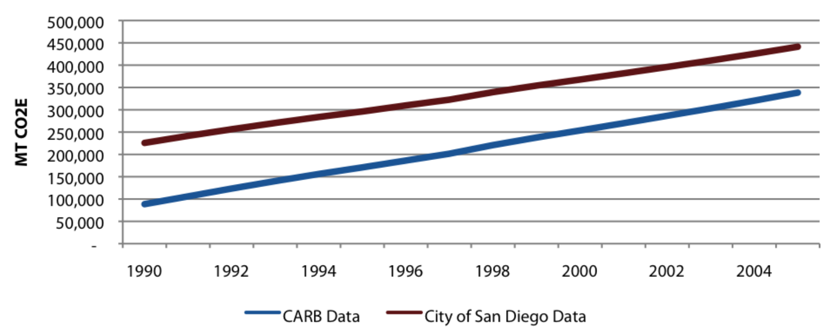
A second limitation is that waste composition varies not only between the state averages and San Diego County averages but also locally, among the county landfills. During the time of this study, it was not possible to find waste profile data for even all the existing active landfills. In addition, waste composition would have changed over the more than 50 years of disposal, while only two local studies are available, from 1996 and 2000, on waste composition.

Figure 12. Method Limitations: Comparison of Waste Disposed Data, Miramar Landfill



As water is the determining factor for anaerobic decomposition, more accurate results would also be obtained if annual rainfall averages were used in place of one average value for all the years. For such reasons, the waste sector emissions, especially those from landfills, may be under- or even over-estimated.

Figure 13. Comparison of IPCC Waste Model CO_2E-CH_4 Emissions Results for Miramar Landfill Based on City and CARB Waste Disposed Data



A final limitation of the method is the lack of data for the amount of landfill and bio-gas captured from 1990. It appears from the data provided by CARB that at least one county landfill was combusting landfill gas in 1990 and some were operating from 1993. If similarly biogas were removed prior to 1996, the 1990 waste sector emissions estimate would be lower.

End Notes

1. See End Note 5.
2. The inventory is available from 1990-2004 at http://www.arb.ca.gov/cc/inventory/data/data.htm.
3. According to the national agricultural statistics 2002 Census data tables 11, 12, 13, 16, 29, there is little or no processing of agricultural products in San Diego County. See http://www.nass.usda.gov/census/census02/volume1/ca/index2.htm. This was confirmed by telephone communication with personnel at NASS.
4. Tchobanoglous G., Theisen H., Vigil S., Integrated Solid Waste Management, Engineering Principles and Management Issues, 1993, p. 381.
5. Greenhouse gas warming potentials (GWP) of 21 and 310 for methane and nitrous oxide respectively, were used to be consistent with the CARB 2004 inventory for California. The IPCC 2001 revised GWPs were 23 and 296 and the 2007 revised values are 25 and 298 over a 100 year lifetime. http://ipcc-wg1.ucar.edu/wg1/wg1-report.html, Chapter 2.
6. See End Note 4.
7. For a description of California waste law and AB 939 see http://www.ciwmb.ca.gov/Statutes/Legislation/CalHist/1985to1989.htm
8. San Diego County Integrated Waste Management Plan, Countywide Siting Element, 2005 5-Yr Revision.
9. Waste-in-place data to 2004 was obtained from CARB and is also available at the California Integrated Waste Management Board web page, annual tonnage reports (from 1996), at http://www.ciwmb.ca.gov/Landfills/Tonnages/
10. The total waste disposed in County landfills was 4,050,647 metric tons from a county population estimate by the US Census Bureau for 2005 of 2,936,607. A comparison with the US national waste disposal rates and other countries indicates the much larger amounts of waste generated and disposed in Southern California than most other places. The US national average for landfill disposal in 2006 was 761 kg per capita (EPA Solid Waste Fact Sheets, 2006, at http://www.epa.gov/garbage/msw99.htm). The national average for landfill disposal in Germany is less than 300 kg, and that in the city of Freiburg is 109 kg. Policy changes since the 1990s have led to these developments in Germany, and thus also to a decrease in landfill methane emissions to basically zero today. Thus the German Technical Instructions for Handling Waste 1993 required that waste containing only a minimum of organic material be thermally treated (incinerated) so as to be inert, before landfill disposal. At the same time, the most stringent BACT standards have been adopted for incineration facilities.
11. This is an average of the values from 1991 to 2004 provided in the California GHG Inventory at http://www.arb.ca.gov/cc/inventory/doc/docs4/4A1_Landfills_Landfillemissions_LandfillGas_N2O_2004.htm.
12. Miramar is the only active city landfill. Arizona Street and Chollas landfill are closed. One demonstration facility, Montgomery landfill, accepted solid waste from 1975 to 1990 but is excluded from the present inventory.
13. Personal communication with Mr. Lin Ying, CARB, 5 May 2008.
14. The increase in N_2O emissions has been attributed to the increase in consumption of red meat. See Volume 5, Waste, available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/
15. The methane factor was the latest (May 2008) provided by CARB.
16. The Biological or Biochemical Oxygen Demand is the amount of oxygen consumed by microbial oxidation of wastewater in a 5-day period. It is used as an indicator of wastewater "strength". The BOD5 is proportional to the amount of organic matter in the water, and varies from country to country based on the quantity of water as well as diet.
17. The IPCC Waste Model available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html
18. Scharff, H., Jacobs, J., Applying Guidance for Methane Emission Estimation for Landfills, Waste Management, Volume 26, Issue 4, 2006, pp 417-429.