Activity Trends for Key Emission Sources in California's San Joaquin Valley, 1970-2030

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ABSTRACT

Growth surrogates and growth activity data are key components of emission forecasting tools such as the Environmental Protection Agency's (EPA) Economic Growth Analysis System (EGAS) and the California Air Resources Board's (CARB) Emission Forecasting System (CEFS). While these tools, which are heavily dependent on the output of regional economic models, may provide reasonable projections of emissions-related activities at a national or state level, it is desirable to gather local growth activity data for regional emission inventory development purposes.

In a study sponsored by the San Joaquin Valley Unified Air Pollution Control District (District), Sonoma Technology, Inc. (STI) developed growth surrogates and growth activity data for several key emission sources in the San JoaquinValley (SJV), including civilian aircraft, locomotives, petroleum refineries, foam manufacturing plants, cogeneration operations, and wineries. Historical and projected activity data were collected for the years 1970 through 2030 and compared with activity data incorporated into CEFS, which backcasts and forecasts emission levels from a base year to some historical or future year.

The results of this project showed that, in general, the updated activity data collected by STI produced lower future-year emission forecasts than the data currently incorporated into CEFS. For example, CEFS predicted a 21% growth in natural gas production activities in the Valley from 2002 to 2020, while the activity data collected by STI showed a 45% decrease in natural gas production over that same period. This paper will highlight methods and data sources utilized in this project and demonstrate how activity data collection efforts can improve estimates of future trends in emissions.

INTRODUCTION

The work described in this paper was sponsored by the San Joaquin Valley Unified Air Pollution Control District (District), which has jurisdiction in the Central California counties of San Joaquin, Stanislaus, Merced, Madera, Fresno, Tulare, Kings, and the western portion of Kern. The purpose of this project was to assist the District in future efforts to reduce emissions in the San Joaquin Valley (SJV) by developing emission growth surrogates and growth activity data for a number of facilities and emission source categories, including

- Civilian aircraft
- Locomotives
- Petroleum refineries
- Oil production
- Natural gas production
- Cogeneration

Once an appropriate growth surrogate was selected for each source category, historical activity data were collected for every five-year period from 1970 to 1995 and for every year from 1995 to 2004.

In addition, growth activity forecasts were developed for every year from 2005 to 2020 and every five-year period from 2020 to 2030.

Growth surrogates and growth activity data are key components of the California Air Resources Board (CARB) emission forecasting system (CEFS), which assigns a default growth surrogate to each emission source category used to characterize emissions growth. For area and mobile sources, CARB assigns growth surrogates identified by a 14-digit emission inventory code (EIC) or a 5-digit category of emissions source code (CES) used to identify individual source types. For point sources, CARB typically assigns growth surrogates identified by an 8-digit source classification code (SCC), a 4-digit Standard Industrial Classification (SIC) code, or both. For each growth surrogate, economic output, employment, socio-economic data, and other growth activity data are assembled by year and used within CEFS to backcast or forecast emission levels from a base year to some historical or future year.

For the source categories listed above, an appropriate growth surrogate was selected based on available information sources. Then, historical growth activity data and future-year growth activity forecasts for the EIC, SCC, and SIC codes associated with each source category were collected for the years 1970 to 2030 and formatted for incorporation into the CEFS model.

METHODS AND RESULTS

Future-year emission projections can be markedly different based on the choices of surrogates or economic indicators used to forecast growth for a given source category. Therefore, Sonoma Technology, Inc. (STI) evaluated individual source category indicators and surrogates to assess their quality based on data availability, representativeness of the industry in question, and relationship to the production of emissions (e.g., for combustion categories, fuel consumption is directly connected to the generation of emissions). The following sections describe the methods used to derive activity data estimates for each source category or facility addressed and compares resulting forecasts with corresponding forecasts from CEFS.

Civilian Aircraft

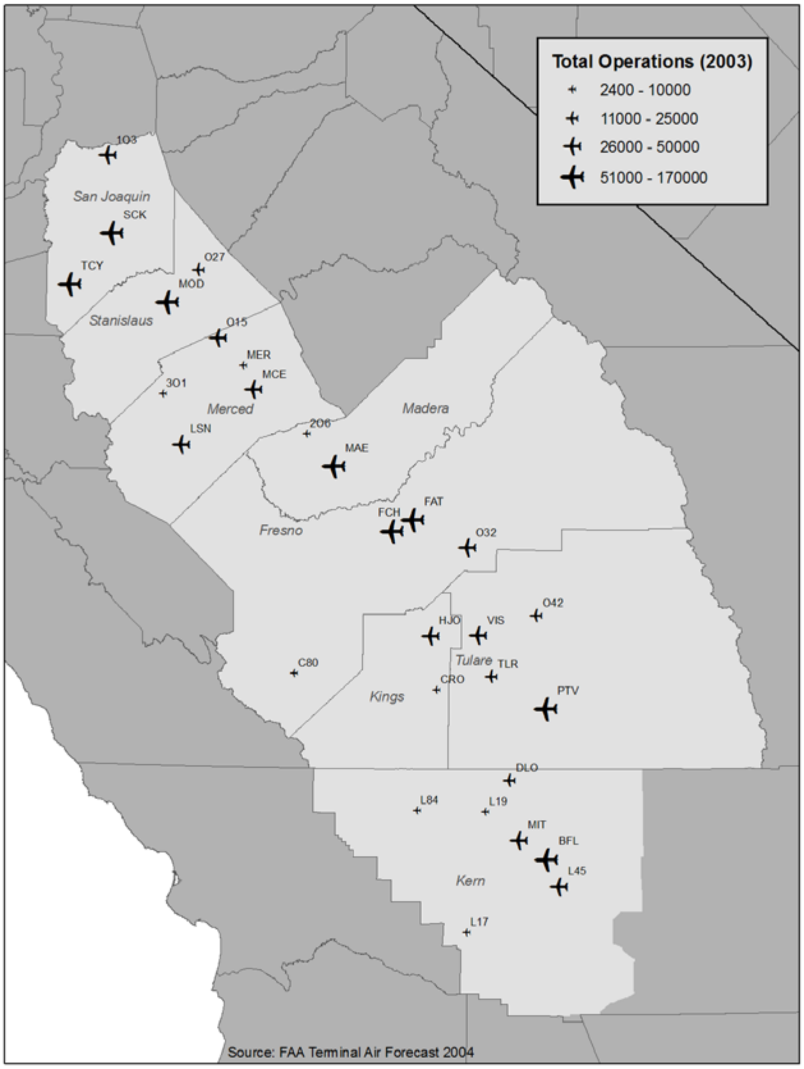
Background

The Federal Aviation Administration’s (FAA) National Flight Data Center (NFDC) identifies 126 non-military airports in the District (California Department of Transportation, 2000). A variety of civilian aircraft operate at these facilities, and all jet planes and piston-engine planes used for non-military purposes were included in this analysis. Helicopters were excluded from this analysis because they represent only 0.01% of commercial aircraft operations (Bureau of Transportation Statistics, 2005).

Activity Trends

Annual operations were used as a surrogate for aircraft activity. An operation is defined as a takeoff, landing, or “touch-and-go” (a maneuver by which an aircraft lands and departs without stopping or exiting the runway). Annual operations for civilian aircraft were acquired from the FAA’s 2004 Terminal Area Forecasts (TAF) (Federal Aviation Administration, 2005). The 2004 TAF includes historical operations data for 1976 through 2003 and presents forecasts of operations for 2004 through 2020. The 2004 TAF covers 29 of 126 airports in the District, including all those with FAA towers. Figure 1 shows the TAF airports in the District. Eighty-four percent of airport-based civilian aircraft in the District are based at one of the 29 airports covered by the TAF. Therefore, most aircraft operations were assumed to have occurred at airports covered by the TAF, and the 2004 TAF was assumed to represent historical and projected trends of aircraft activity patterns for the entire District.

Figure 1. Coverage of TAF airports for counties within the District.



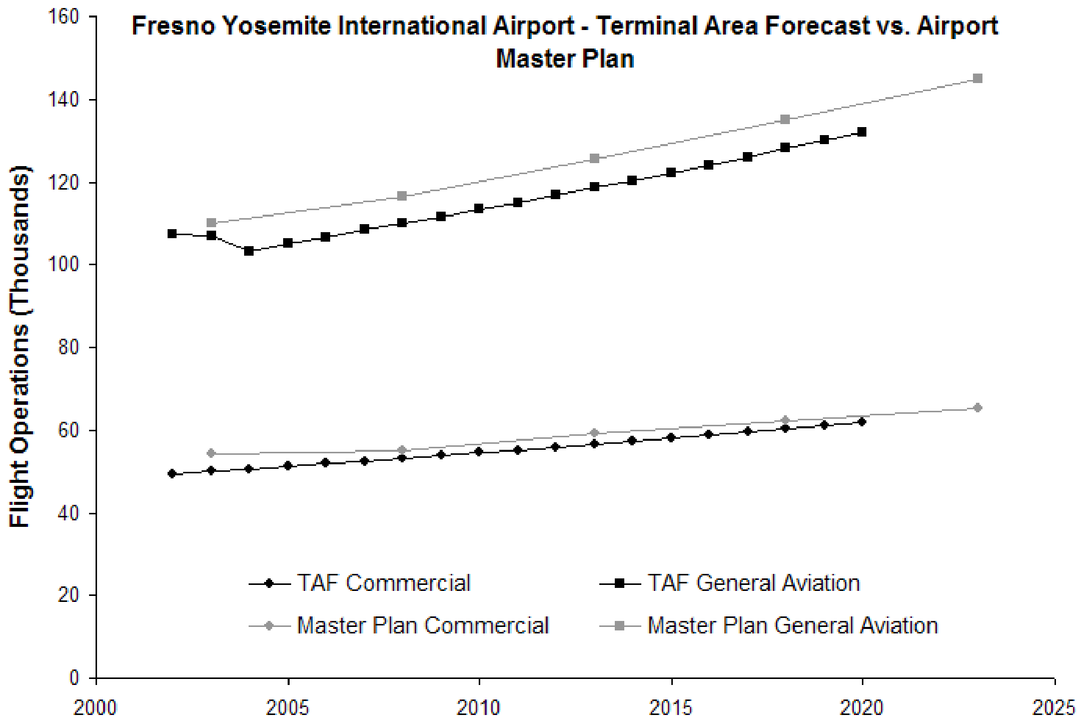
TAF operations data are segregated by aviation type: air carrier, commuter/air taxi, and general aviation.

- Commercial air carriers have a seating capacity of more than 60 persons.
- Commercial commuter planes and air taxis have a seating capacity of 60 or fewer persons.
- General aviation aircraft are non-commercial civil aviation aircraft.

Each aviation type was matched to a corresponding EIC to calculate historical and future growth surrogates.

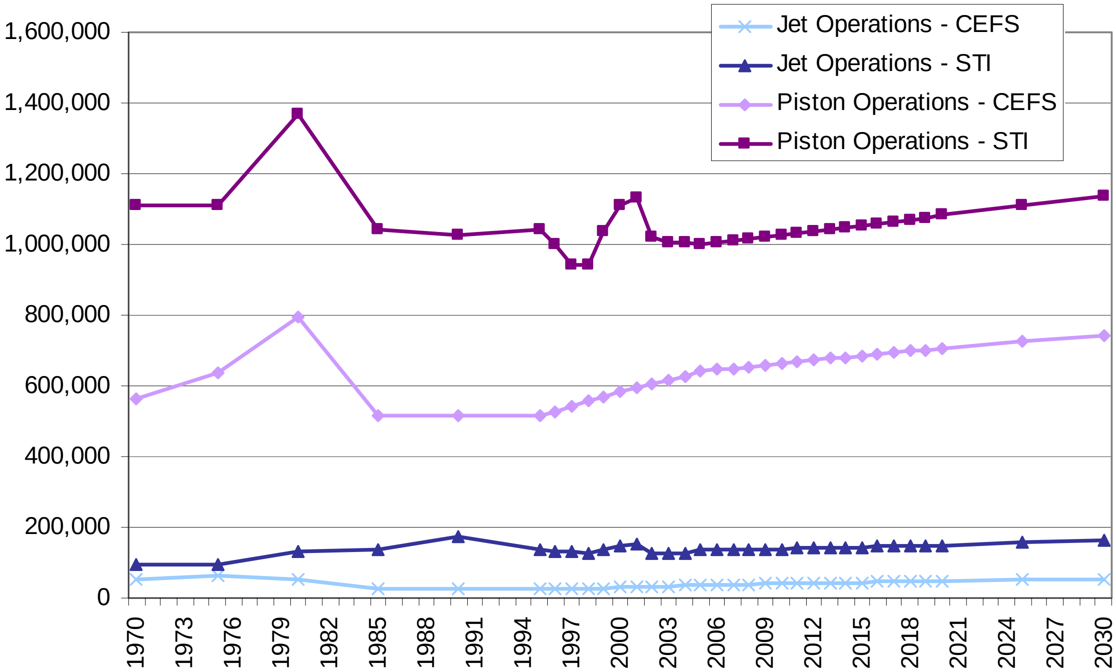
Forecast operations for the busiest airport in the District, Fresno Yosemite International Airport (FAT), were also available from the Fresno Yosemite International Airport Master Plan Update – March 2005 (URS Corporation, 2005). Figure 2 compares the projections for FAT from both the TAF and the Master Plan Update. The two data sets compare well, with a maximum of 8% difference and very similar projected slopes. This comparison suggests that the projections in the TAF are reasonable for other airports in the District. Because airport-specific projections are available for FAT, they were used in place of the projections from the TAF.

Figure 2. Projected operations for FAT from the TAF and the Fresno Yosemite International Airport Master Plan Update – March 2005.



The growth activity data currently contained in CEFS for civilian aircraft were derived from a 1994 study of non-road mobile source activities in California conducted for CARB by California State University, Fullerton (Puri and Kleinhenz, 1994). Collected for this study were activity data for three categories of civil aircraft: jet, turboprop, and piston. These data were based on FAA flight operations for towered airports from 1970-1992 and FAA flight operations forecasts out to 2020. Figure 3 shows a comparison of District flight operations for jet and piston aircraft between the CEFS activity data and the activity data collected by STI (CEFS data for piston and turboprop operations were combined for comparison purposes). Figure 3 shows that the overall trends of the two data sets are similar, but the activity levels developed by STI are higher for both jet and piston aircraft, which may be due to the fact that STI treated landings and takeoffs as distinct operations. The STI data also show more variations in activity between 1992 and 2004, years for which STI collected historical activity data (while CEFS utilized activity forecasts).

Figure 3. Comparison of CEFS and STI aircraft operations data.



Locomotives

Background

Growth activity data were collected for line-haul locomotives, which are used by freight railroad lines and Amtrak passenger rail service in the District, and switching locomotives, which are used at railyards by freight rail lines. Freight railroad lines are classified as Class I, Class II, or Class III on the basis of average annual operating revenues. Two Class I railroads operate in the District: Burlington Northern and Santa Fe Railroad (BNSF) and Union Pacific Railroad (UPRR), as well as several Class III railroads. In addition, Amtrak operates a passenger rail system within the District. Table 1 shows statewide fuel consumption by railroad type; the fuel consumption for Class III railroads is negligible compared with the fuel consumption of Class I and passenger railroads, constituting only 1.5% of the total (California Air Resources Board, 2004). Therefore, STI focused on activity data collection for locomotives operated by BNSF, UPRR, and Amtrak. A map of the service routes for these railroads within the District is shown in Figure 4 (note that Amtrak operates on the rail lines owned by BNSF). Also, Table 2 shows a count of switcher engines operated at the various railyards within the District.

Table 1. California locomotive fuel consumption – annual average for 2001-2003.

Railroad Type	Fuel Consumption (10^6 gallons)	Percentage
Class I	193.8	89.1%
Passenger	20.4	9.4%
Class III	3.3	1.5%

Figure 4. District railyards and rail service routes.

Table 2. 2003 switcher counts by railyard.

County	Railyard	Number of Switchers		
		BNSF	UPRR	Total
San Joaquin	Stockton	4	–	4
San Joaquin	Lathrop	–	3	3
Stanislaus	Riverbank	6	–	6
Fresno	Fresno	6	1	7
Kern	Bakersfield	6	3	9

Fuel consumption was selected as the recommended surrogate for trends in line-haul and switcher locomotive activity. Fuel consumption is directly related to the production of emissions, and fuel usage data for freight and passenger locomotives can be readily combined into a single set of activity data for line-haul locomotives operating in the District (data are also available on Class I freight shipments measured in ton-miles, but no corresponding data set exists for passenger rail service).

Activity Trends for Freight Locomotives (line-haul)

County-level fuel consumption data for line-haul locomotives were obtained directly from BNSF for 1999 through 2004 and from UPRR for 2003. For historical years back to 1970 for which the railroads could not provide data, national-level Class I railroad fuel usage data were obtained from the Bureau of Transportation Statistics (BTS) and disaggregated to the District counties based on the fraction of national fuel usage occurring in the District during years for which county-level data were available.

For future years (2005 through 2030), statewide[1] forecasts for growth in key economic sectors were used as surrogates for growth in freight rail activity. Table 3 shows that products of the manufacturing, petroleum refining, and agricultural industries dominate the freight rail cargo shipped in California (Bureau of Transportation Statistics, 2004). Therefore, forecasts for manufacturing employment, petroleum refining capacity, and agricultural productivity were weighted according to the breakdown of freight rail shipments shown in Table 3 to develop growth estimates for freight rail activity.

Table 3. BTS 2002 commodity flow survey data for California.

Economic Sector	Commodity	2004 Ton–miles (%)
Manufacturing	*Other prepared food stuffs, fats, and oils*	*28.5%*
	Non-metallic minerals	*11.1%*
	Wood products	*9.4%*
	Articles of base metal	*7.5%*
	Alcoholic beverages	*7.2%*
	Milled grain products and bakery products	*6.2%*
	Total manufacturing	69.9%
Petroleum Refining	Coal and petroleum products	16.3%
Agriculture	Agricultural products	13.8%

Manufacturing employment forecasts were available from the Caltrans 2002-2020 Economic Forecast (California Department of Transportation, 2002). Table 4 shows a slow and steady increase in manufacturing employment for the state, amounting to a total growth of 12% between 2005 and 2020. Between the years 2009 and 2020, a steady growth rate of about 0.7% was observed, and it was assumed that this rate would hold constant between the years 2020 and 2030.

[1] Statewide forecasts were used rather than District-only data because both BNSF and UPRR ship cargo through the San Joaquin Valley that originates or terminates in other parts of California, such as Los Angeles or the Bay Area.

Table 4. Forecasted California manufacturing employment, 2005-2020.

Year	Manufacturing Employment Forecasts	Annual Percent Change
2005	24,431	—
2006	24,713	1.2%
2007	24,979	1.1%
2008	25,241	1.0%
2009	25,443	0.8%
2010	25,637	0.8%
2011	25,802	0.6%
2012	25,944	0.6%
2013	26,108	0.6%
2014	26,289	0.7%
2015	26,469	0.7%
2016	26,651	0.7%
2017	26,813	0.6%
2018	26,978	0.6%
2019	27,142	0.6%
2020	27,317	0.6%

For petroleum refining forecasts, a 0.3% annual growth rate from 2004 forward was assumed based on statewide forecasts in petroleum refining capacity published by the California Energy Commission in its report titled, *An Assessment of California's Petroleum Infrastructure Needs* (California Energy Commission, 2005a). Agricultural productivity was held constant (no growth) across all future years because, while a slight decrease of about 0.2% per year in irrigated acreage is anticipated for the San Joaquin Valley (Wilson et al., 1998), this loss in agricultural productivity is likely compensated by the agriculture industry's plans to increasingly favor rail transportation over trucking transportation (Cunha, 2005).

Figure 5 shows the resulting fuel consumption estimates for line-haul locomotives by county and by year. When combined, Kern and San Joaquin Counties account for about 40% of the total District fuel usage each year. Figure 6 shows total District fuel consumption for line-haul locomotives by year and compares the estimated trends with the data for this source category currently incorporated into CEFS. The CEFS data do not vary by county and are provided in the form of unitless growth factors that represent a percentage increase from a base year of 1990. The CEFS trend line of Figure 6 represents the growth in fuel consumption by year that would occur if these growth factors were applied to the actual fuel consumption estimates provided by BNSF and UPRR. Figure 6 shows that agreement is good for most years, although the STI data are "flatter" overall, and, unlike the CEFS data, the STI data do not show a marked drop-off prior to 1990 or a sharp increase after 2019.

Figure 5. Annual line-haul locomotive fuel consumption by county.

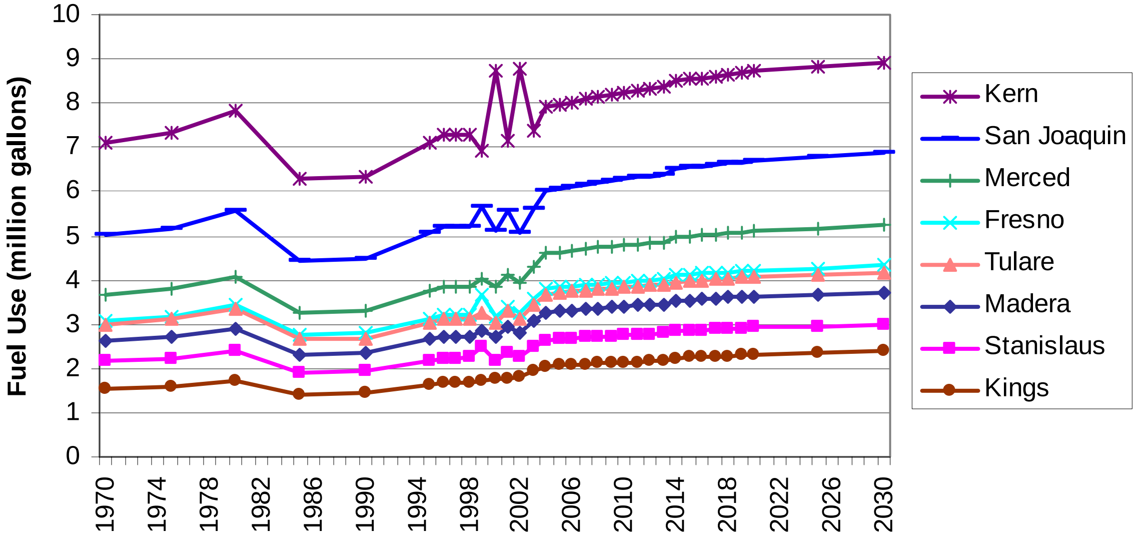
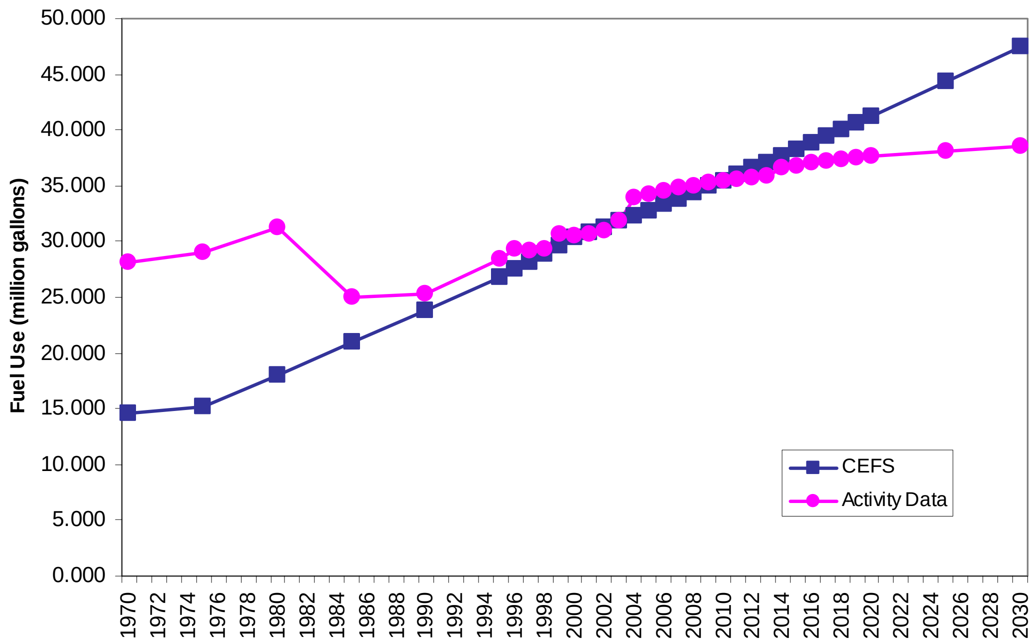


Figure 6. Comparison of CEFS data to STI-prepared line-haul activity data.



Activity Trends for Passenger Locomotives

For passenger rail lines, Amtrak's fuel consumption from 1971 through 2014 was estimated according to data presented in Caltrans' 2004 California State Rail Plan (California Department of Transportation, 2005). This document provided details on Amtrak's historical route expansions in the District and forecasted that by 2014, Amtrak will add daily round-trips to the Oakland-Bakersfield and Sacramento-Bakersfield routes, increasing service to five and three daily round-trips, respectively. On average, it was determined that new Oakland-Bakersfield and Sacramento-Bakersfield round-trips are added or projected to be added every 9 years and every 14 years, respectively. This trend was used to create anticipated route expansions in the District through 2030.

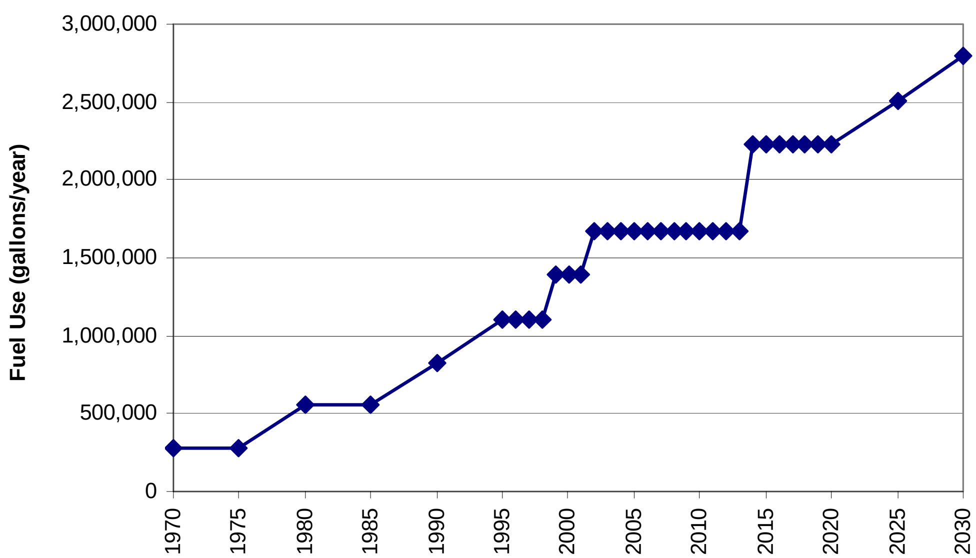
Table 5 shows a schedule of Amtrak's historical and projected route expansion plans in terms of the number of trips per route, as well as estimated annual fuel usage for each route. Fuel usage estimates were calculated as the product of the number of daily round-trips, the average hours per round trip, and the average fuel use per hour (76.5 gal/hr) (Paul, 2005). National Transportation Atlas Database (NTAD) rail network data were used to spatially allocate route mileage and fuel consumption data to the county level. Future-year fuel consumption estimates were based on projected Amtrak route expansions in the District, and no growth was assumed for years in which no expansions were anticipated. Figure 7 shows the historical and projected annual fuel consumption for Amtrak line-haul locomotives operating in the District.

Table 5. Amtrak annual activity estimates.

Year	Route	Number of Daily Round-trips	Average Number of Hours per Round-trip	Average Fuel Use per Day (gallons)[a]	Average Fuel Use per Year (gallons)[b]
1971	Oakland-Bakersfield	1	12.5	956	349,031
1980	Oakland-Bakersfield	2	12.5	1,913	698,063
1989	Oakland-Bakersfield	3	12.5	2,869	1,047,094
1992	Oakland-Bakersfield	4	12.5	3,825	1,396,125
1999	Sacramento-Bakersfield	1	11.2	860	1,710,131
2002	Sacramento-Bakersfield	2	11.2	1,721	2,024,137
2014	Oakland-Bakersfield	5	12.5	4,781	2,373,168
2014	Sacramento-Bakersfield	3	11.2	2,581	2,687,174
2025	Oakland-Bakersfield	6	12.5	5,738	3,036,205
2030	Sacramento-Bakersfield	4	11.2	3,441	3,350,211

[a] Based on an annual fuel usage of 76.5 gallons/hour.
[b] Based on route operations of 365 days per year.

Figure 7. Amtrak historical and projected trends in fuel consumption.



Activity Trends for Switching Locomotives

County-level fuel consumption estimates for switching locomotives were obtained directly from BNSF for 2002 through 2004 and from UPRR for 2003. For years for which the railroads could not provide data, information from a locomotive emission study conducted by Booz-Allen & Hamilton, Inc. (BAH) on behalf of CARB (1991) and growth factors contained in CEFS for switching locomotives were used to estimate fuel consumption. The BAH study correlated switching locomotive activity to freight movements and indicated that railroad operations have become far less switching intensive over time as railyards modernized operations and reduced delays (see Figure 8). These changes are captured in the growth trends for switching locomotive activities found in CEFS, which are based on rail freight shipments in ton-miles and are provided in terms of unitless growth factors that indicate a percentage change from a base year of 1990 (see Figure 9). These growth factors were renormalized to a base year of 2003 and applied to known fuel consumption estimates for that year to generate fuel consumption estimates for years for which BNSF and UPRR did not provide data.

Figure 8. Changes in Class I rail carrier switching activity.

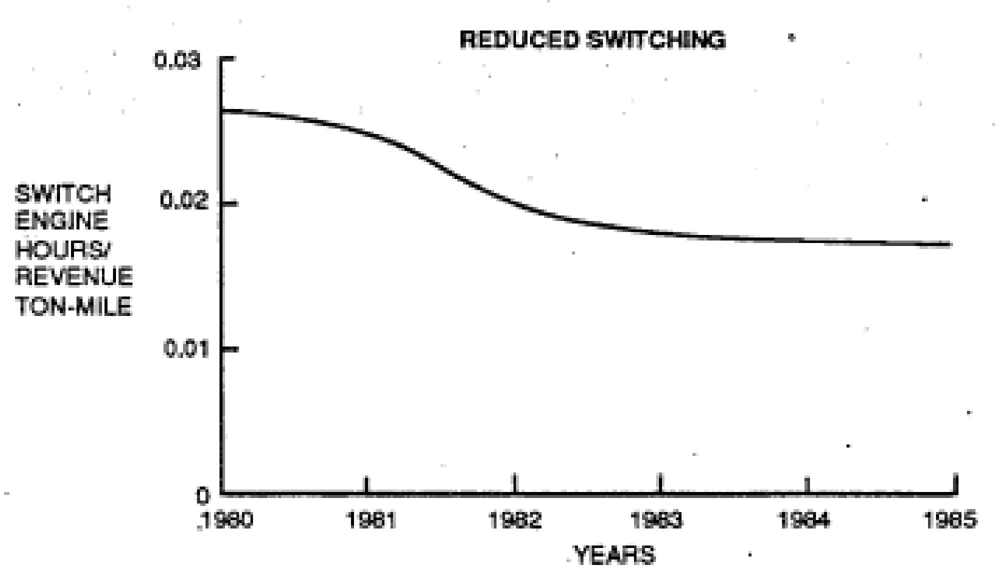
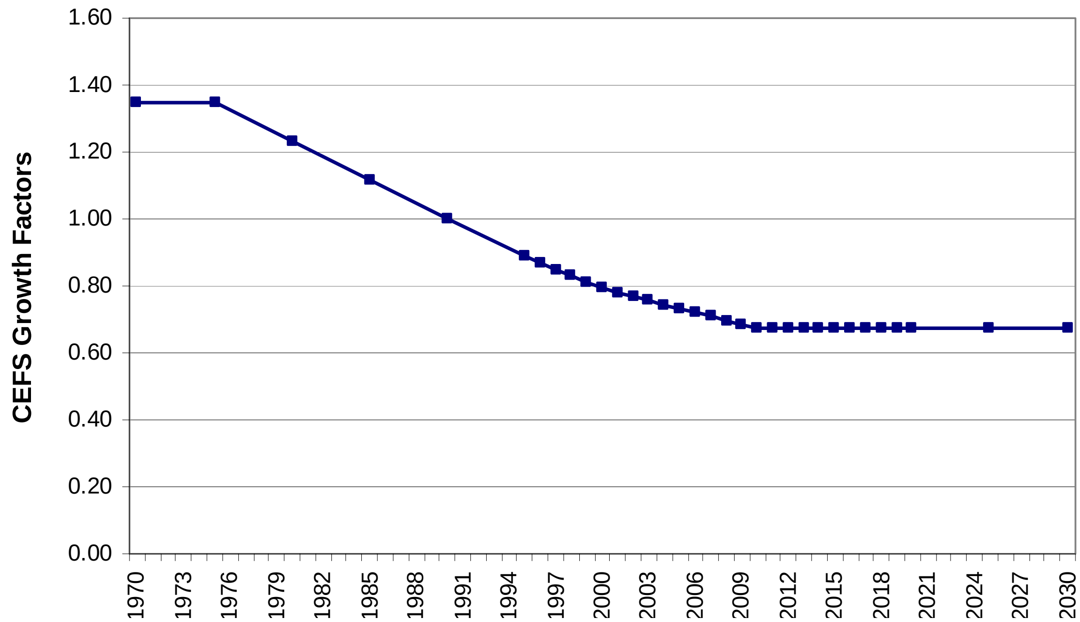


Figure 9. CEFS growth factors for switching locomotive activity.



Petroleum Refineries

Background

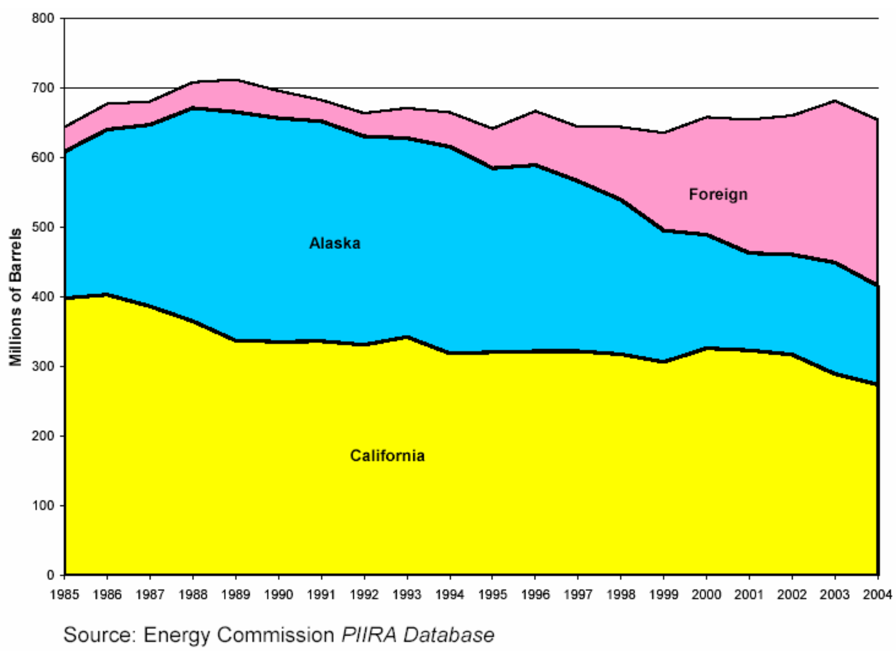
Six petroleum refining facilities are located in Kern County (listed in Table 6). The data in Table 6 were queried from the CARB Facility Search Tool (FST) and represent all facilities in the District with a SIC code of 2911-Petroleum Refining (California Air Resources Board, 2003).

Table 6. Summary of petroleum refineries in the District as reported in the CARB's Facility Search Tool.

Petroleum Refinery Name	Facility Address	County	Facility Id.
Kern Oil & Refining Co.	Panama Lane & Weedpatch Hwy.	Kern	37
Las Palmas Oil & Dehydration	3121 Standard St.	Kern	35
San Joaquin Refining Co.	Standard & Shell St.	Kern	36
Lone Star Gas Liquids	7th Standard and Beech	Kern	71
Big West Oil	6451 Rosedale Hwy.	Kern	n/a
Tricor Refining	4100 Airport Dr.	Kern	46

While the sources of crude oil refinery receipts (volumes of crude oil received by refineries) have shifted over time, the total amount of crude oil receipts has remained fairly constant over the past 20 years. This point is illustrated in Figure 10, which shows crude oil receipts by source from 1985 to 2004 (California Energy Commission, 2005a).

Figure 10. Crude oil receipts by source from 1985 to 2004 (California Energy Commission, 2005a).



Activity Trends

Oil production in California, a substantial portion of which occurs in the SJV, is expected to decline by an average of 1% to 3% over the next 20 years. However, increased oil imports are anticipated to allow refinery inputs to grow slightly, as shown in Figure 11 (California Energy Commission, 1999). The three major refineries in Kern County are Big West, San Joaquin Refining, and Kern Oil and Refining. These three facilities combined have the capacity to accept approximately 115,300 barrels of crude oil per day, or about 42 million barrels per year, which represents approximately 6% of total crude capacity in the state. Historical refinery capacity data obtained from the Energy Information Administration (EIA) indicates that capacity at these three refineries has grown by about 15% since 1994 but has remained constant in recent years. Overall, refinery capacity in the District has decreased by about 5% since 1994 due to the closure of two facilities: Sunland Refining Corp. in 1995 and Tricor Refining (formerly Golden Bear Oil Specialities) in 2001 (see Figure 12). The closure of these refineries resulted in a combined loss of 22,000 barrels per day of refining capacity.

Figure 11. Historical and projected California oil extraction, inputs, and imports (California Energy Commission, 2005a).

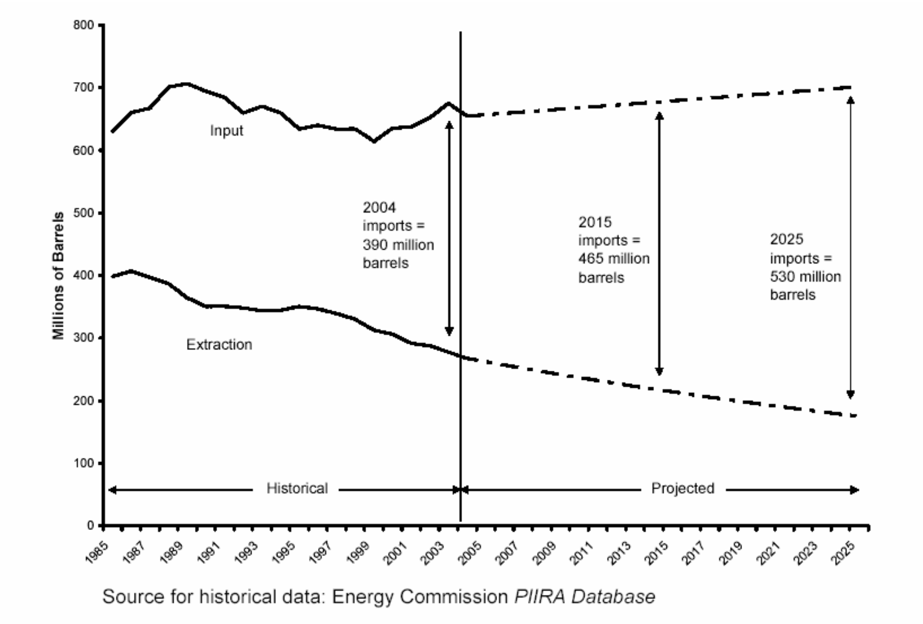
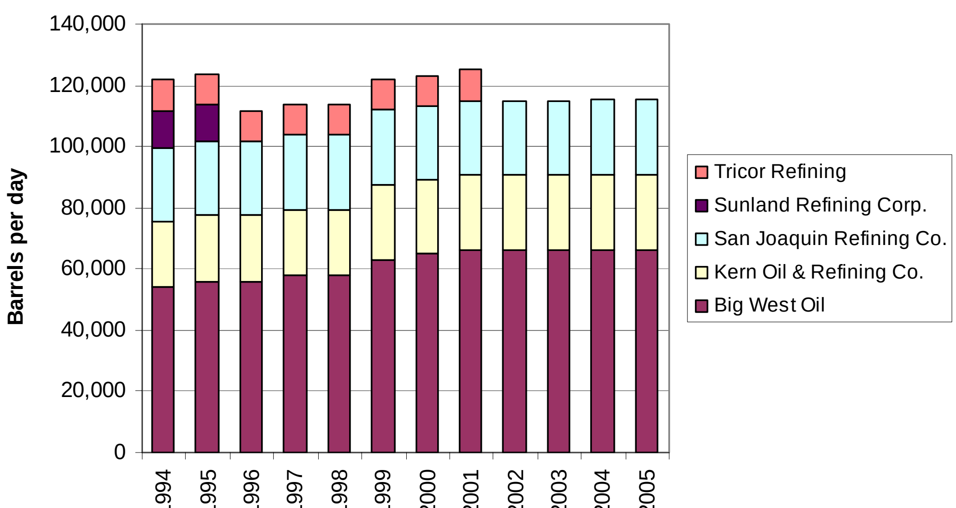


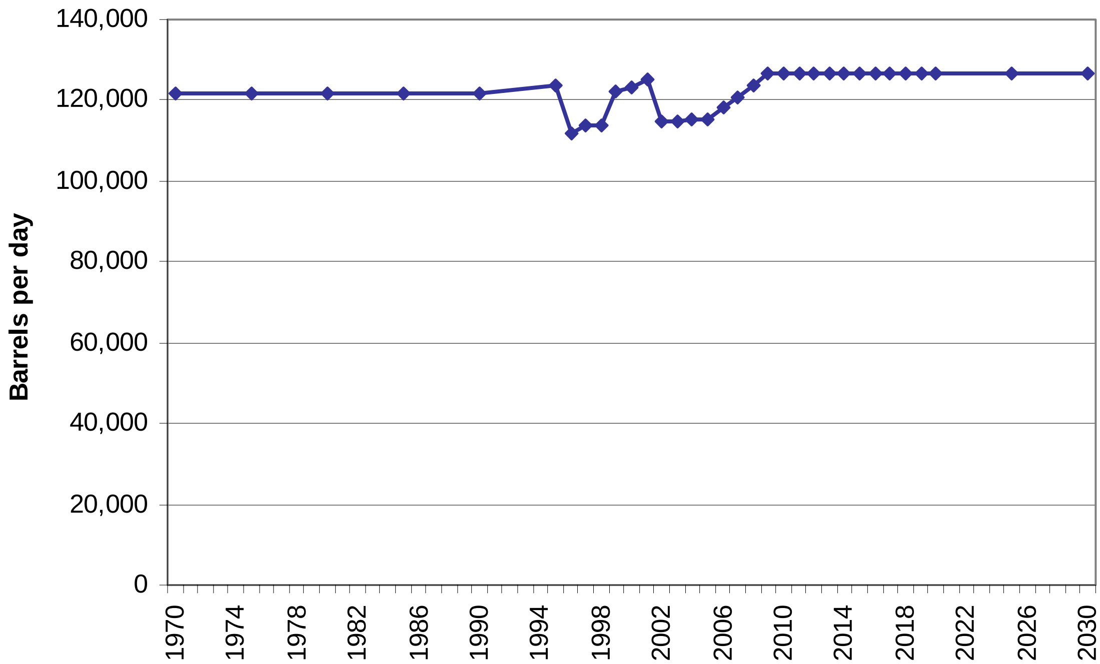
Figure 12. SJV refining capacity, 1994-2005.



One near-future refinery expansion project is currently under consideration in the District at the former Shell refinery in Bakersfield, which has recently been sold to Big West Oil, LLC, a subsidiary of Flying J, Incorporated. The Big West refinery supplies the equivalent of 2% of the state's gasoline production and 6% of its diesel fuel production and is considering an expansion project to increase gasoline and diesel fuel production by 10,000 to 12,000 barrels per day (California Energy Commission, 2005a). Big West currently has the capacity to refine approximately 66,000 barrels of fuel per day. If undertaken, the project will increase Big West's output to approximately 77,000—a 17% increase—and require between 24 and 48 months to complete. The expansion project is likely to involve the installation of a fluid catalytic cracker, which converts gas oils into lighter products, such as gasoline. The refinery sells most of the gas oils it currently produces to refineries that utilize this technology (Waldner, 2005). The expansion project will not impact Big West's crude input capacity; it will only affect its ability to output more product.

EIA historical data on refinery capacity in the District and information on the anticipated expansion at the Big West refinery were used to generate growth activity data for oil refining in Kern County for the period from 1970 through 2030. Due to a lack of available data, refining capacity for the years 1970 through 1994 was held constant at 1994 levels. For future years, the anticipated 17% increase in refining capacity at the Big West facility was spread evenly over the years 2006 through 2009 to allow for the maximum project completion estimate of 48 months. Figure 13 shows the changes in Kern County refinery capacity over time; reductions brought about by the refinery closures in 1995 and 2001 can be seen, as well as the increase in capacity between 2006 and 2009 in anticipation of the Big West expansion. At present, the CARB's CEFS assumes a no-growth scenario for petroleum refining in the District for the period from 1970 through 2030.

Figure 13. Total refinery capacity for Kern County, 1970-2030.



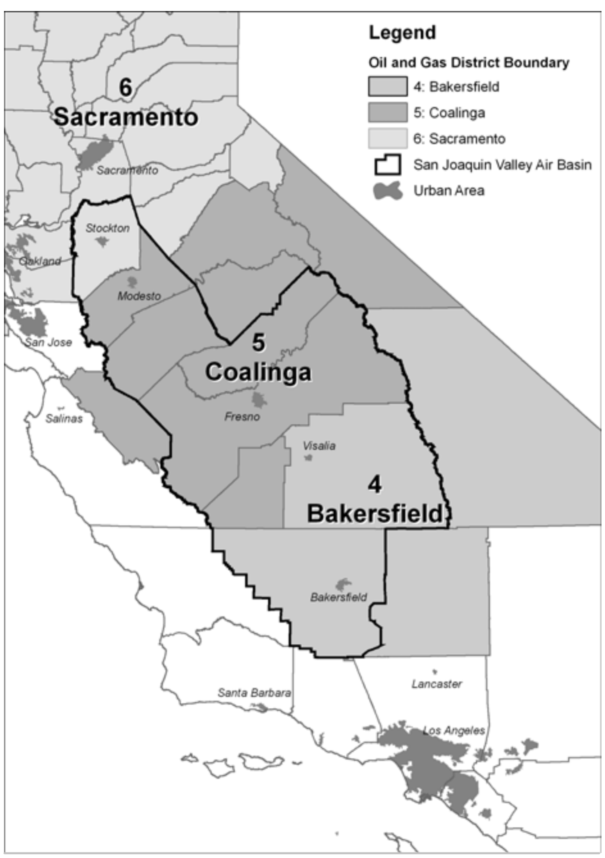
Oil & Gas Production

Background

Emissions sources associated with oil and natural gas production include all processes utilized during the exploration and extraction of oil and natural gas (including transport and storage of crude oil and natural gas products) and processing of natural gas. The natural gas used by consumers is composed almost entirely of methane. Natural gas produced at the wellhead, though also composed almost entirely of methane, is by no means as pure. Raw natural gas comes from three types of wells: oil wells, gas wells, and condensate wells. Natural gas from oil wells is termed “associated gas”. This gas can exist separately (free gas) from the co-produced crude oil or dissolved in the oil (dissolved gas). Natural gas from gas and condensate wells, in which there is little or no crude oil, is termed “non-associated gas”. Gas wells typically produce raw natural gas only, while condensate wells produce free natural gas along with a semi-liquid hydrocarbon condensate. Whatever the source of natural gas, once it is separated from crude oil (if present), it usually exists as a mixture of methane with other hydrocarbons, principally ethane, propane, butane, and pentanes (Natural Gas Supply Association, 2004). Natural gas processing consists of separating all the various hydrocarbons and fluids from pure natural gas to produce what is known as “pipeline quality” dry natural gas. While the ethane, propane, butane, and pentanes must be removed from natural gas, they are not waste products but are sold for a variety of different uses. These natural gas processing by-products are called natural gas liquids, or NGLs (Natural Gas Supply Association, 2004).

The California Department of Conservation Division of Oil, Gas, and Geothermal Resources (DOGGR) defines oil and gas districts throughout California. DOGGR Districts 4, 5, and 6 encompass all oil and natural gas wells and oil fields in the San Joaquin Valley (SJV) and eastern-central California. Figure 14 shows a map of DOGGR Districts 4, 5, and 6 and the District’s boundaries. As shown in Figure 14, DOGGR Districts 4 and 5 extend beyond the District to the east and west; however, little or no oil or gas production occurs in these areas. Therefore, DOGGR Districts 4 and 5 may be assumed to represent oil and gas production activity in the District for Kern, Tulare, Fresno, Madera, Stanislaus, and Kings Counties. DOGGR District 6 includes San Joaquin County.

Figure 14. Map of DOGGR oil and gas Districts 4, 5, and 6 within the District’s boundaries. Note that little or no oil and gas activity occurs in the areas of Districts 4 and 5 that lie outside the District and that San Joaquin County is part of DOGGR District 6.

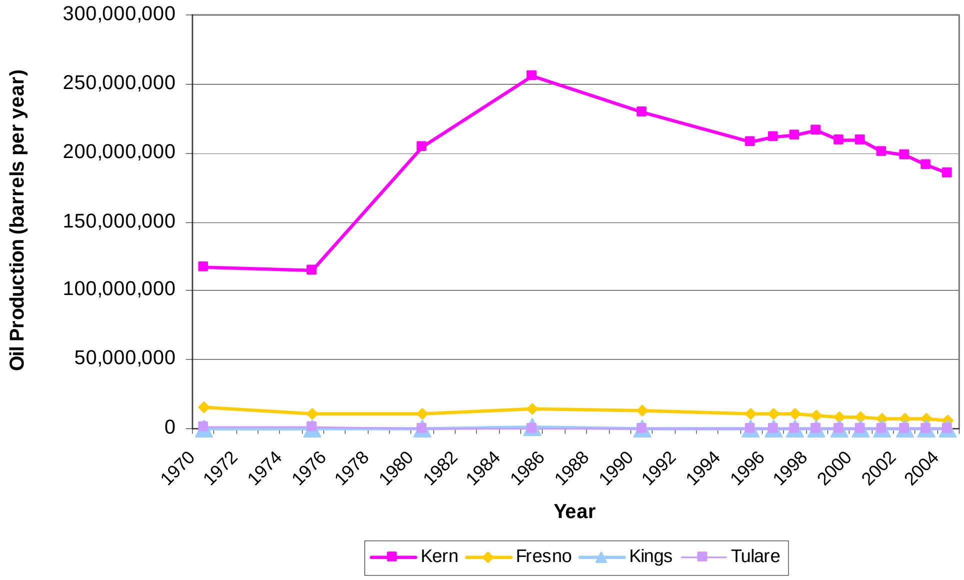


According to the DOGGR, 176 active fields in DOGGR Districts 4, 5, and 6 produced approximately 192 million barrels of oil and yielded approximately 259 billion cubic feet of natural gas in 2004. These figures represent approximately 80% and 94% of California's total production of crude oil and natural gas, respectively. Approximately 95% of crude oil and natural gas production in DOGGR Districts 4 and 5 occurred in Kern County (California Department of Conservation, 2005). The remaining counties of the District—Fresno, Stanislaus, Kings, Madera, Tulare, and Merced—lie within DOGGR District 5 and San Joaquin County lies within DOGGR District 6.

Activity Trends

Historical countywide crude oil and natural gas production data were acquired for 1970 through 2004 (Figures 15 and 16). The data show a gradual downward trend in crude oil and natural gas production since 1998. Far more oil and gas production activity occurs in District 4 than in District 5. Very little oil production activity occurs in District 6, but the level of natural gas activity is substantial.

Figure 15. Historical oil production levels for Kern, Fresno, Kings, and Tulare Counties from 1970 to 2004. Note that no oil production occurs in Merced, Madera, San Joaquin, and Stanislaus Counties.



Forecasts of crude oil and natural gas production in California were obtained from the CEC. The CEC forecasts begin in 2003 and extend to 2025. The forecasts were extrapolated to 2030 assuming the same growth trend from 2020 to 2025. Figure 17 shows the CEC's forecasts from 2003 to 2025 and extrapolated to 2030. The forecasts anticipate a gradual decline in production over the next two decades.

Figure 16. Historical gas production for all counties in the District from 1970 to 2004.

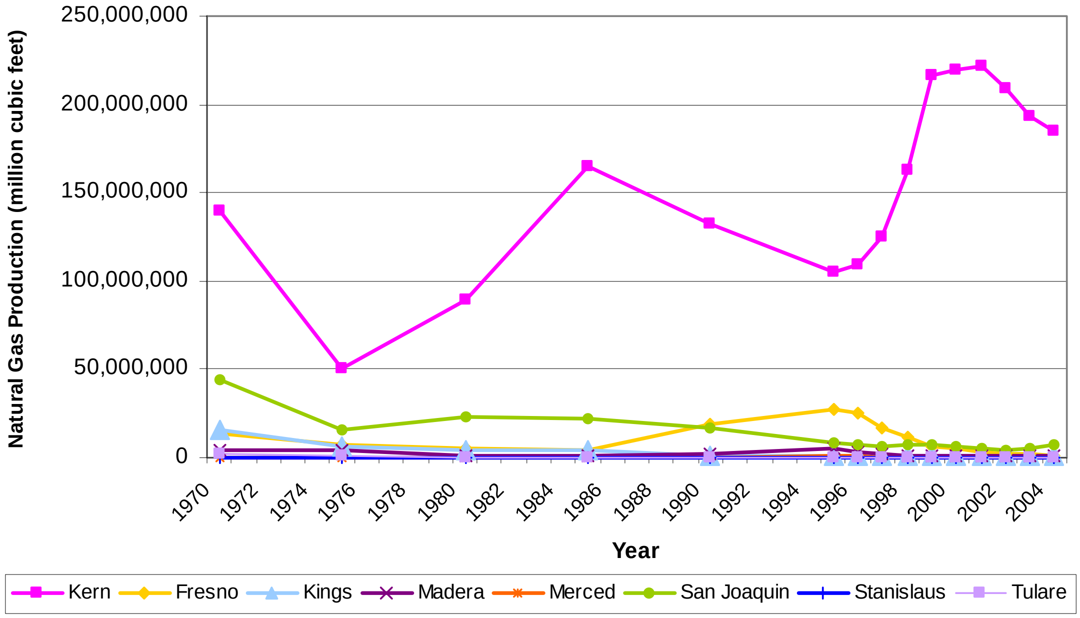
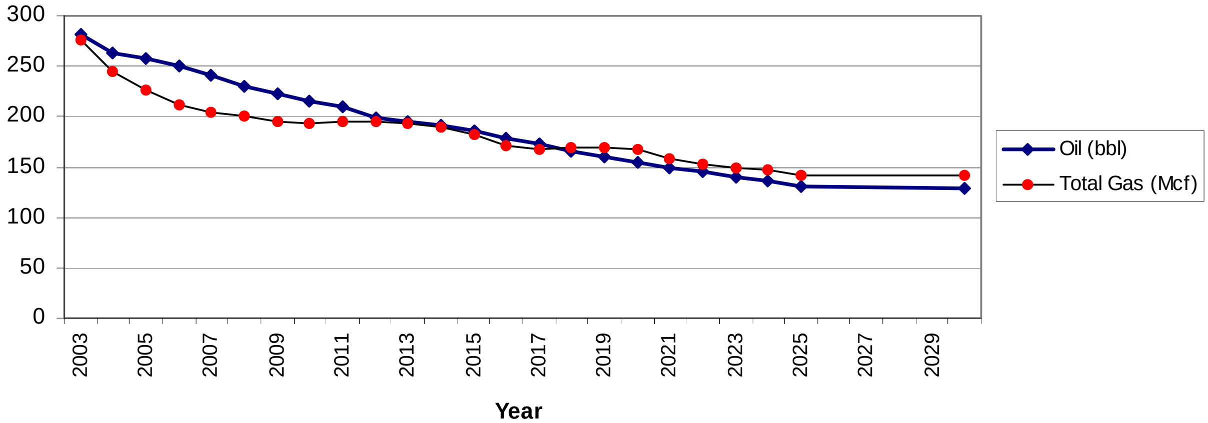


Figure 17. CEC forecasts of California on-shore oil and gas production from 2003 to 2025. Note that from 2025 to 2030, the data were extrapolated using the same growth trend from 2020 to 2025.



Trends for crude oil and natural gas production were developed from the DOGGR's historical production data and the CEC's forecasts. Figures 18 and 19 show the resultant historical and future trends in crude oil and natural gas production by county, respectively.

Existing activity data for oil and natural gas production were obtained from the CEFS database and compared with the activity data produced for this study (see Figures 20 and 21). ARB's CEFS forecasts were developed on the basis of the Regional Economic Model, Incl (REMI) socioeconomic modeling, regression analysis, and adjustments (Bollman, 2001). The CEFS forecasts also use industry fuel consumption forecasts to predict future oil production activity. The data in the CEFS database are similar to the data developed for this study for years prior to 2000, indicating that the same source of oil and gas production data was used for historical activity estimates. However, for future years, the two data sets are quite different—the CEFS data indicate steady growth in gas production and a modest decline in oil production, while the data from this study show significant declines in both oil and gas production. In forecast year 2030, the CEFS data indicate gas production of 250 million cubic feet, more than double the gas production of 100 million cubic feet that the data developed for this study indicate.

Figure 18. Historical oil production data for Fresno, Kern, Kings, and Tulare Counties grown to 2030, based on the CEC forecasts of future-year oil and gas production.

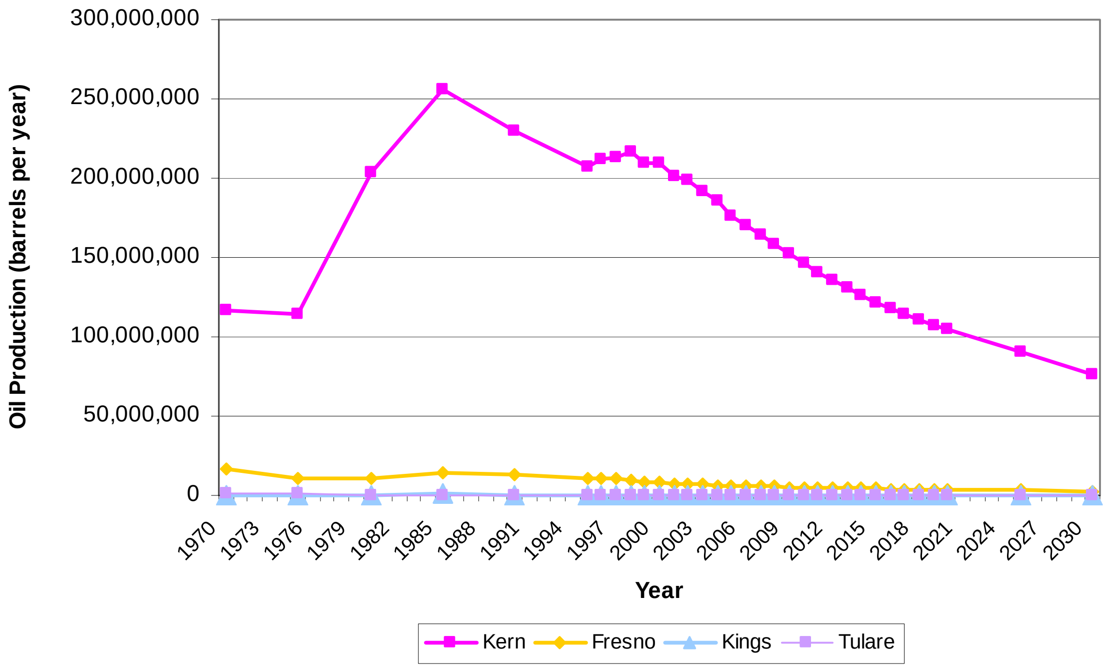
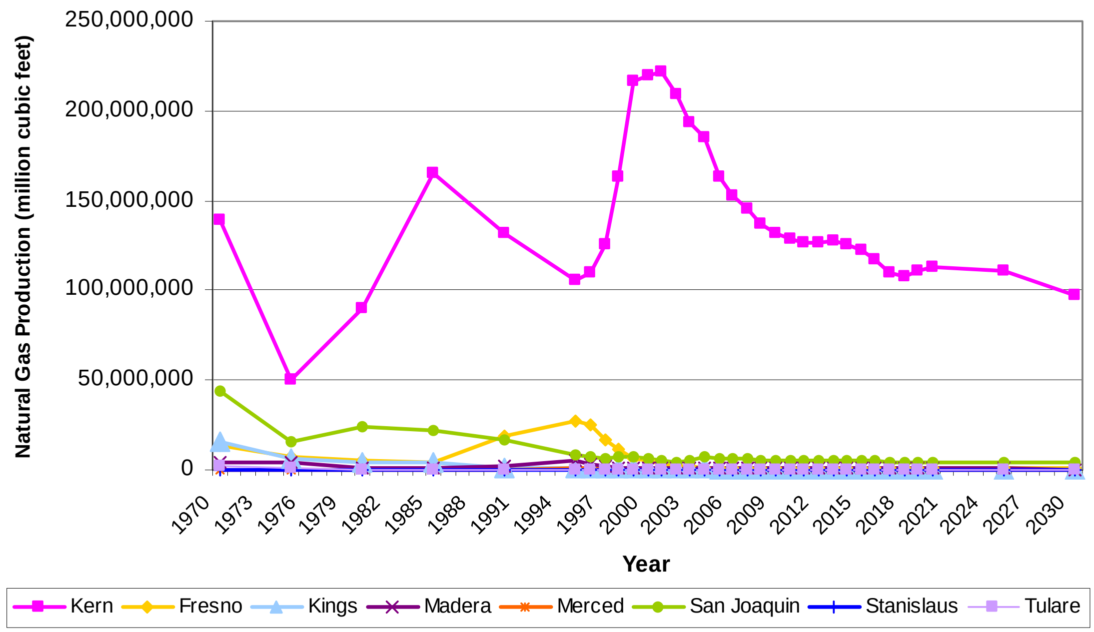


Figure 19. Historical gas production data for all counties in the District through 2030, based on the CEC forecasts of future-year gas production.



Cogeneration

Background

Certain energy intensive industries (such as oil refineries) and institutions (such as universities) generate electricity on site and recover waste heat for productive use through cogeneration. These operations are also known as combined heat and power (CHP) systems because the thermal by-products of electricity generation are captured and used for process or space heating. Several technologies are used for CHP in California, including reciprocating engines, steam turbines powered by boilers, and combustion turbines. Cogeneration capacity in 2004 totaled 9,180 megawatts (MW) in California and 3,242 MW in the District. In both California and the District, about 90% of this capacity resided in large systems with site capacities of over 20 MW (see Figure 22). Emissions from cogeneration units are estimated by facility operators and incorporated into the District's point source inventory.

Figure 20. Comparison between the CARB CEFS activity data for oil production and activity data developed for this study for Kern County.

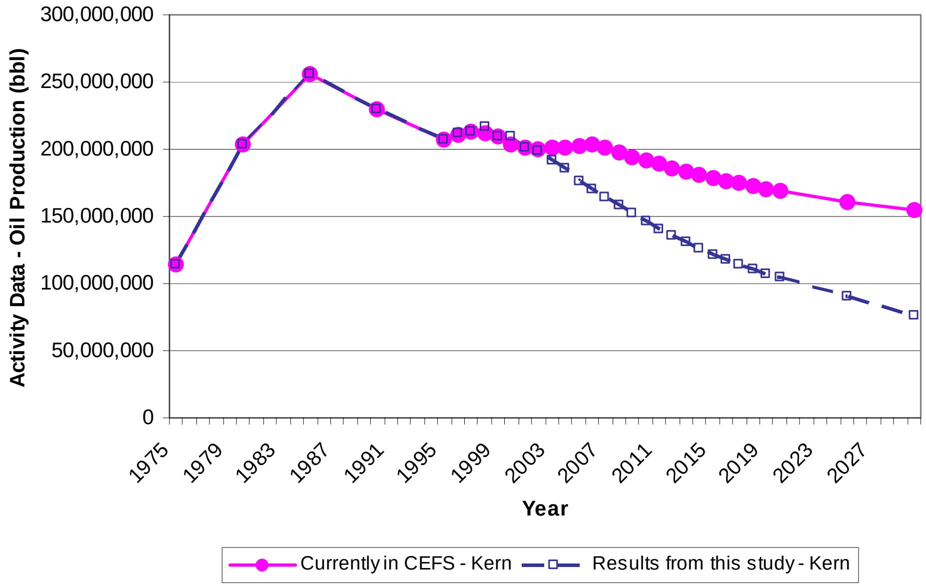
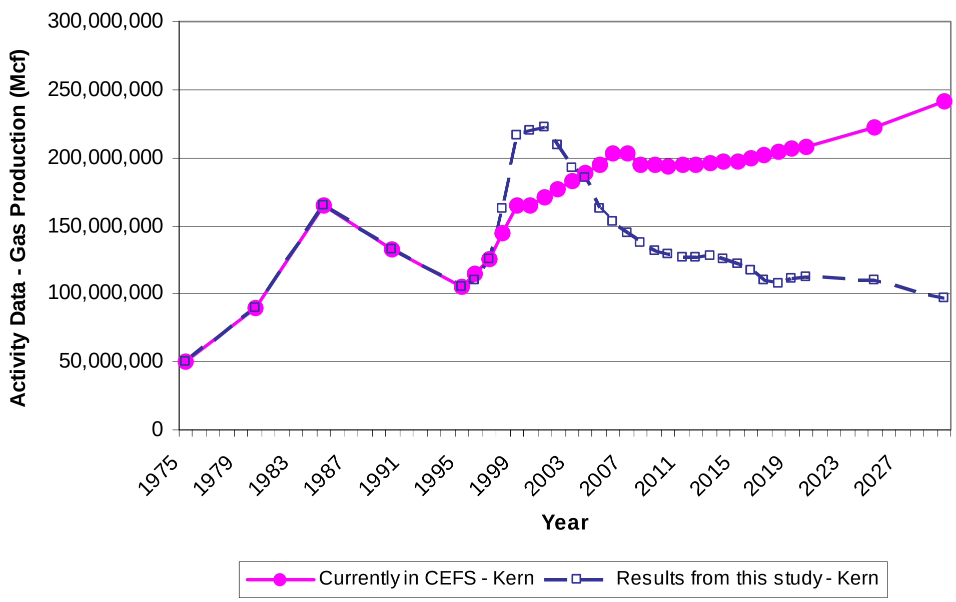


Figure 21. Comparison between the CARB CEFS activity data for gas production and activity data developed for this study for Kern County.



In the District, 76% of cogeneration capacity is currently utilized for oil and gas extraction; food-processing operations account for another 9% of capacity. About 80% of the current cogeneration capacity is located in Kern County, and an additional 9% of capacity is located in San Joaquin County (see Figure 23).

Figure 22. 2004 cogeneration capacity by size bin.

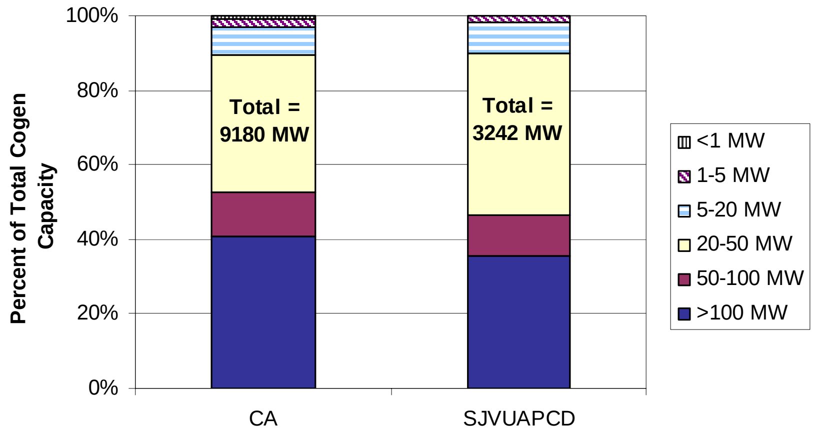
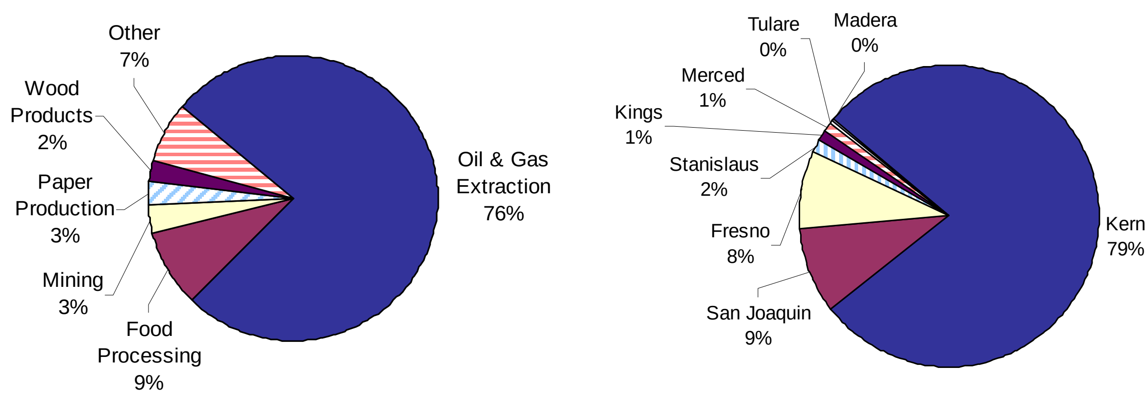


Figure 23. 2004 cogeneration capacity by industry and county for the District.



Prior to 1978, cogeneration was confined to large industrial facilities like oil refineries, and only 9 cogeneration units were operating in California. However, passage of the federal Public Utilities Regulatory Policy Act (PURPA) of 1978 mandated that electric utilities interconnect with all qualifying CHP units, leading to a nationwide annual growth rate of over 5% in CHP capacity since that time (California Energy Commission, 2000). In California, the number of cogeneration units grew from 9 to over 700 between 1978 and 2004, and 132 of California's current cogeneration units operate in the SJV.

At present, the growth activity data assigned to cogeneration source category codes within CEFS are based primarily on a combination of REMI socioeconomic data and fuel-specific energy consumption projections prepared for the EIA's Annual Energy Outlook (AEO). This approach takes county-level SIC code-based output data from REMI's models and adjusts for the national change in the intensity of energy use for various fuel types as projected in the AEO. For cogeneration units associated with an SIC code of 4931, however, data from the CEC on fuel use by electric utilities were used as a growth surrogate (E.H. Pechan & Associates, 2001).

Activity Trends

The ideal growth surrogate for cogeneration emissions would be directly related to activity and emissions, such as fuel consumption data. However, cogeneration units are utilized by a variety of industries and institutions in the District, including oil and gas production, school districts, and hospitals. While statewide fuel consumption data by fuel type are available from the EIA for broad commercial and industrial sectors, no clear way exists to separate cogeneration-related fuel consumption from these data. Therefore, it is proposed that total cogeneration capacity in MW be used as a growth surrogate for cogeneration operations in the District. Historical data on cogeneration capacity is available from Energy and Environmental Analysis, Inc. (EEA), which maintains a CHP installation database for the entire United States. This database was assembled from the following sources (Energy and Environmental Analysis, 2004):

- An independent power database developed by Hagler Bailly/PA Consulting.
- EIA databases of non-utility power plants.
- Personal contacts with manufacturers, developers, gas utilities, etc. (important for identifying smaller sites with capacity less than 1 MW).

For each cogeneration unit, the database provides a facility name, facility location (city), associated industry, year of installation, capacity (kilowatts), prime mover type (boiler, reciprocating engine, etc.), and fuel type. This database was used to determine the annual growth in total cogeneration capacity statewide and in the District between 1970 and 2004. Figure 24 shows that cogeneration capacity in the District grew rapidly between 1984 and 1990, increasing by more than 1,500%. However, the growth in cogeneration capacity in the District since 1990 has been only 31%, with total capacity in 2004 amounting to just over 3,200 MW. A similar trend exists in statewide cogeneration capacity between 1970 and 2004. The historical trend in cogeneration capacity in the District shows good agreement with the historical emissions data for cogeneration units contained in CEFS. Figure 25 shows that both emissions and capacity increase sharply between 1985 and 1990 and level off after 2000, though a spike in emissions in 1995 is not reflected in the capacity trend. Also, CEFS reports about 4 tons of NO_x emissions per day from cogeneration units in the District in 1975, but the EEA database does not contain any pre-1980 units for the District.

This historical capacity data was broken down by county and EIC using information from the EEA database on the location, prime-mover, and fuel-type for each cogeneration unit in California. County- and EIC-specific capacity data then served as the growth parameter data for historical cogeneration activity in the District.

For future years (2005-2030), growth in cogeneration capacity was estimated based on a recent study sponsored by the CEC (California Energy Commission, 2005b). This study assessed the market potential for cogeneration in California and developed forecasts in five-year increments out to 2020 for increased cogeneration capacity in the state. Forecasts were developed for a base-case scenario reflecting expected future gas and electric prices and existing incentive programs, emission requirements, and technology costs, as well as seven alternative scenarios that included the removal of existing cogeneration incentives and the adoption of various additional incentives. Because it is unclear which, if any, additional cogeneration incentives will be adopted in the future, the base-case scenario was selected for estimating cogeneration growth in the District.

Figure 24. Total cogeneration capacity, 1970-2004.

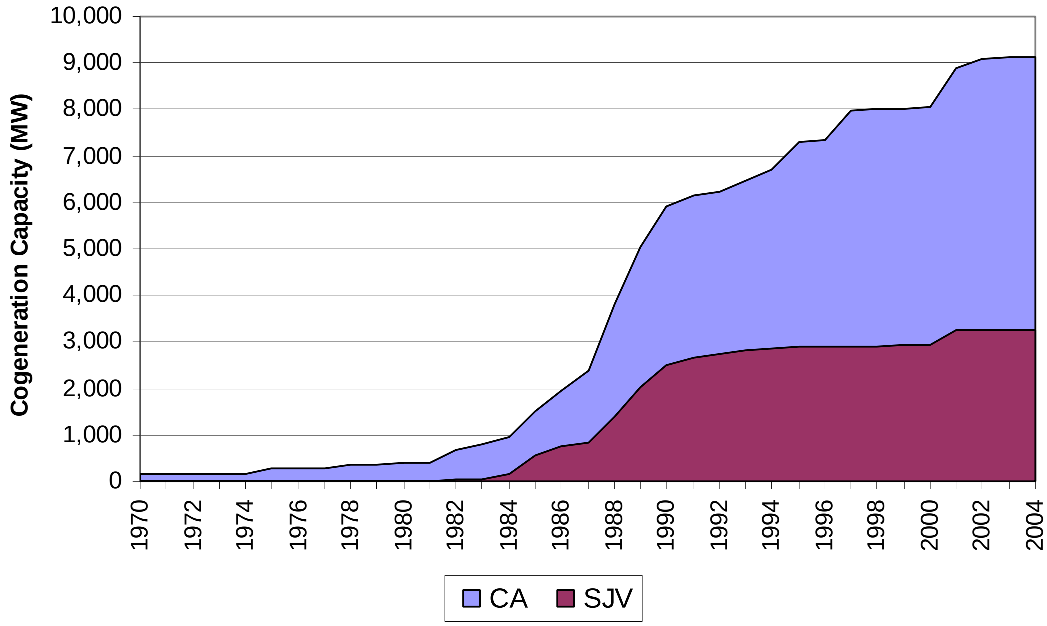
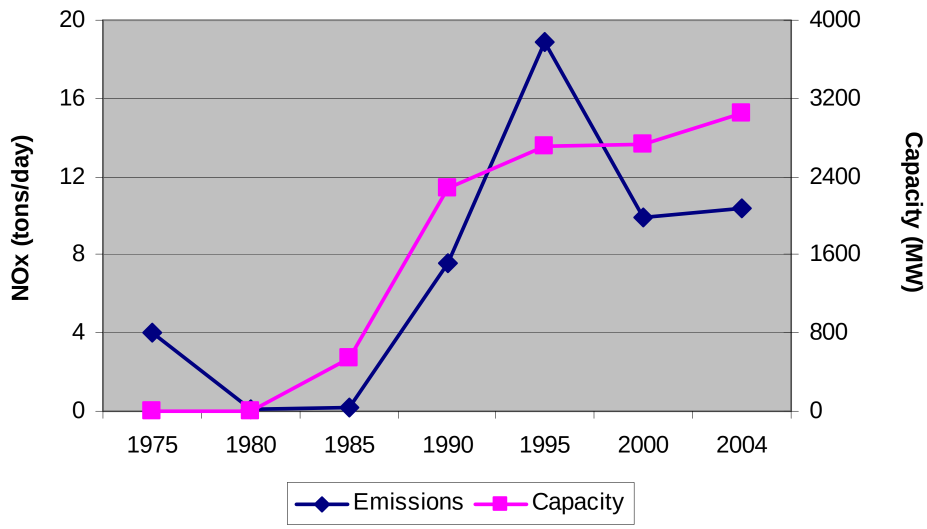


Figure 25. District trends in cogeneration emissions and capacity.



According to CEC forecasts, the additional cogeneration market penetration for the base-case scenario is anticipated to be 1,966 MW statewide and 357 MW within the District by 2020. Table 7 shows the growth in District cogeneration capacity by year and county (District-wide growth was apportioned to individual counties based on each county's year-2004 contribution to District cogeneration capacity by size bin). Total growth from a base year of 2004 equals 2% by 2010, 7% by 2015, and 10% by 2020. Growth from 2004 through 2020 in individual counties of the District ranges from 1% to 57%.

Table 7. Growth in cogeneration capacity by year and county.

County	2004	2010		2015		2020	
	Capacity (MW)	Capacity (MW)	%Growth	Capacity (MW)	%Growth	Capacity (MW)	%Growth
Fresno	268	281	5.0%	315	17.7%	346	29.0%
Kern	2,538	2,571	1.3%	2,641	4.0%	2,711	6.8%
Kings	34	35	2.1%	37	7.4%	39	13.4%
Madera	10	11	8.1%	13	30.9%	16	56.6%
Merced	33	36	7.4%	42	27.7%	49	48.2%
San Joaquin	297	312	5.1%	348	17.2%	376	26.8%
Stanislaus	49	50	0.4%	50	0.8%	50	1.3%
Tulare	12	12	2.0%	13	6.7%	13	11.0%
Total	3,242	3,307	2.0%	3,459	6.7%	3,600	10.0%

Figure 26 shows a breakdown of District cogeneration capacity by year and county from 1970 to 2020. To develop growth activity data for individual years between 2005 and 2020, a linear interpolation was performed on existing capacity data for 2005, 2010, and 2020. To develop growth activity data for 2025 and 2030, an extrapolation was performed on existing cogeneration capacity projections for the period from 2005 to 2020. The resulting growth activity data for each county in the District is shown in Figure 27 (Kern County) and Figure 28 (counties other than Kern). Figure 27 also shows the trend in Kern County cogeneration activities for data derived from CEFS activity data, which is based on output in the oil and gas production sector (the dominant industry utilizing cogeneration in Kern County).

Figure 26. Year-by-year changes in District cogeneration capacity.

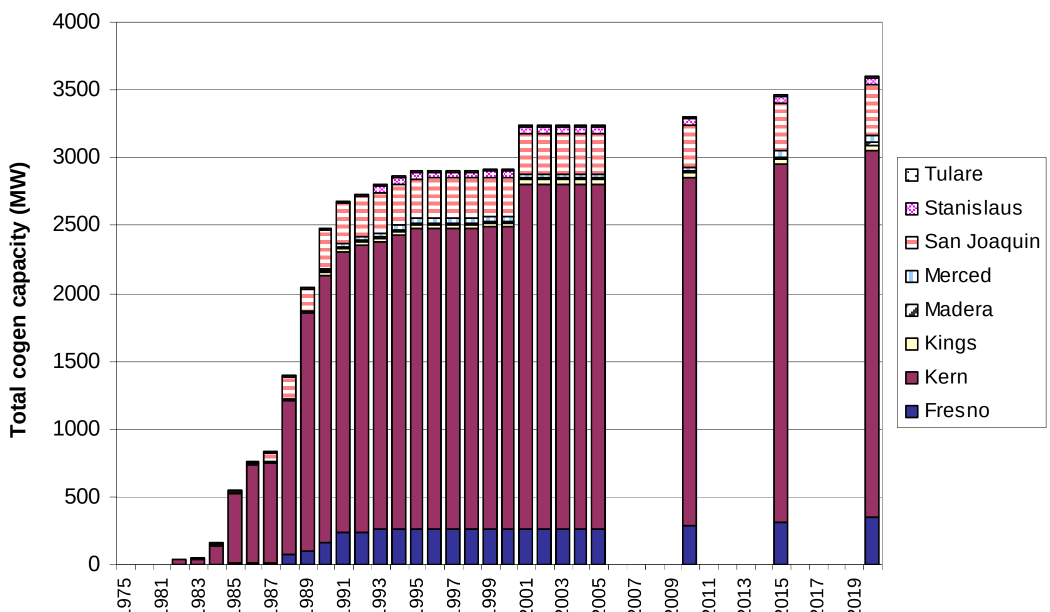


Figure 27. Comparison of STI and CEFS cogeneration activity trends for Kern County.

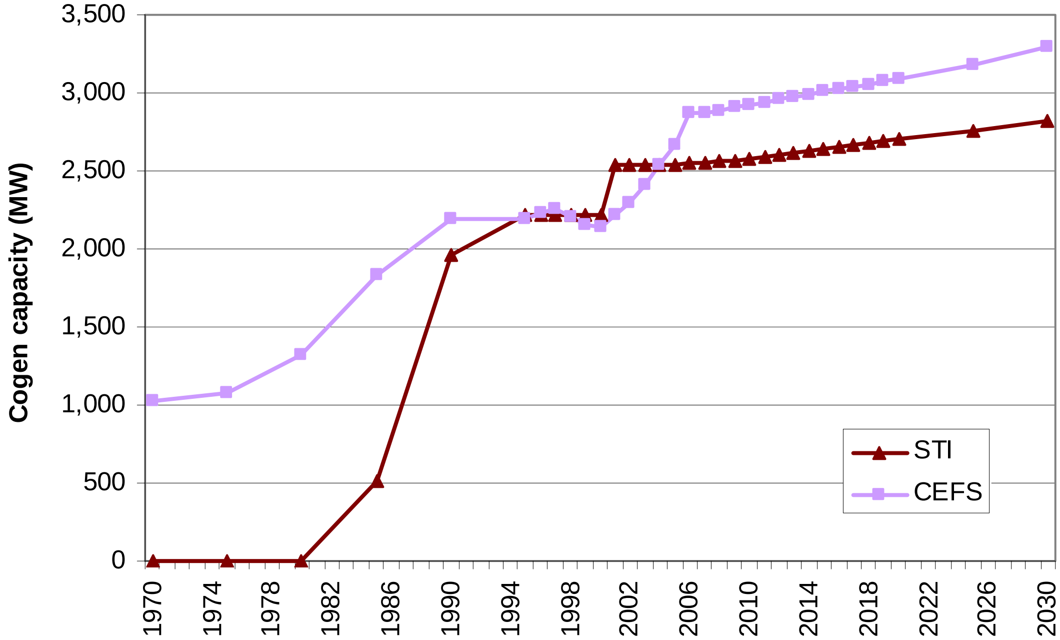
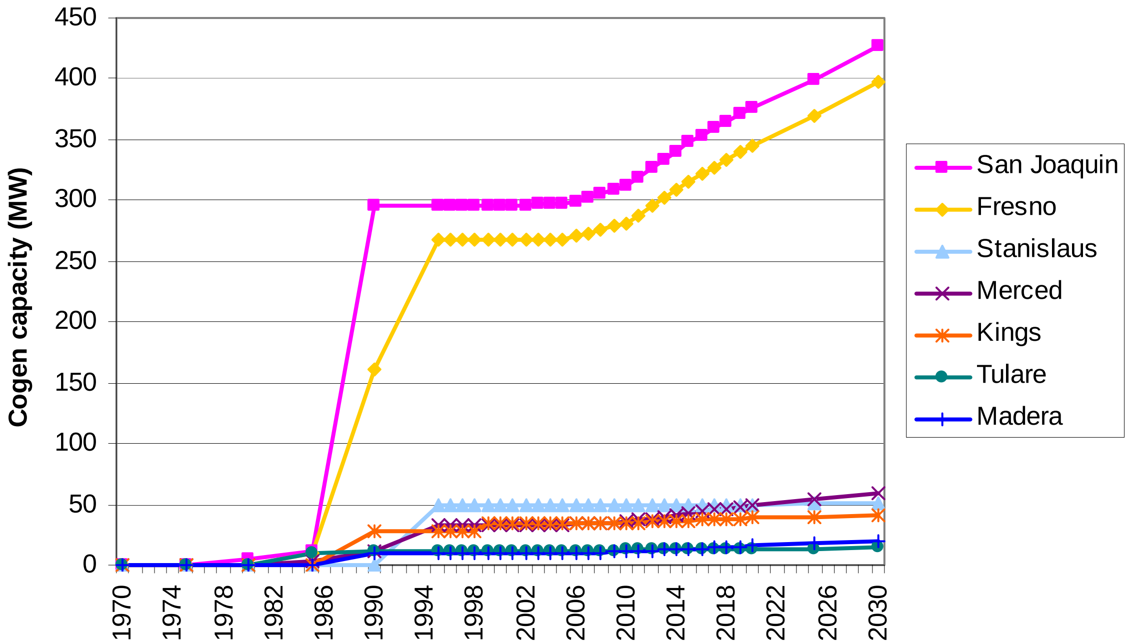


Figure 28. Cogeneration capacity by year and county for District counties other than Kern County.



CONCLUSIONS

The results of this project showed that the facility- and industry-specific activity data forecasts collected by STI differed significantly from the growth activity forecasts currently incorporated into CEFS, many of which are based on the outputs of a regional economic model. In general, updated activity data collected by STI produced lower future-year emissions forecasts than the data currently incorporated into CEFS. Table 8 lists the growth surrogate selected for each source category addressed in this paper, as well as the data sources used to generate historical growth activity data and future-year growth activity forecasts. Table 9 shows a comparison between growth activity data collected for this project and current CEFS growth activity data.

Table 8. Growth surrogate assignments by source category.

Source Category	Growth Surrogate	Surrogate Description/Units	Data Sources
Civilian Aircraft	Aircraft operations	Landing, take-off, or touch-and-go	Individual airports, Federal Aviation Administration (FAA) Terminal Area Forecasts (TAF), Bureau of Transportation Statistics (BTS) Air Carrier Summary database
Locomotives	Locomotive fuel consumption	Gallons consumed by line-haul and switching engines	Individual railroads, BTS freight and fuel consumption data, BTS Commodity Flow Survey, California Department of Transportation economic forecasts
Petroleum Refineries	Refinery capacity	Barrels of fuel produced	Individual refineries, California Department of Conservation Division of Oil, Gas, and Geothermal Resources (DOGGR) historical refinery capacity data
Oil Production	Crude oil production	Barrels of crude oil produced	DOGGR historical production data, California Energy Commission (CEC) forecasts
Natural Gas Production	Natural gas production	Million cubic feet of gas produced	
Cogeneration	Electrical generation capacity	Megawatts	Energy and Environmental Analysis, Inc. (EEA) cogeneration capacity database, CEC forecasts

Table 9. Comparison of CEFS and STI growth activity data.

Source Category	CEFS Activity Data			STI Activity Data			% Change 2002 to 2020		% Growth Per Year 2002 to 2020	
	2002	2020	Units	2002	2020	Units	CEFS	STI	CEFS	STI
Civilian Aircraft	639,088	752,720	Annual aircraft operations	1,147,801	1,232,009	Annual aircraft operations	17.8%	7.3%	1.0%	0.4%
Locomotives	1.315	1.734	Unitless growth factors (based on freight shipments)	31,025,545	37,679,351	Gallons of fuel	31.9%	21.4%	1.8%	1.2%
Petroleum Refining (Kern County)	1	1	Unitless (no growth)	115,000	126,300	Barrels per day	0.0%	9.8%	0.0%	0.5%
Oil Production	2.09E+08	1.76E+08	Million barrels	2.06E+08	1.08E+08	Million barrels	-15.8%	-47.6%	-0.9%	-2.6%
Natural Gas Production	1.98E+08	2.39E+08	Million cubic feet	2.18E+08	1.19E+08	Million cubic feet	20.9%	-45.2%	1.2%	-2.5%
Cogeneration (Kern County)	0.902	1.216	Output in the oil and gas extraction sector (billions of 1992 dollars)	3240.5	3600.2	Cogeneration capacity (megawatts)	34.8%	11.1%	1.9%	0.6%

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KEY WORDS

Emission inventories
Emission projections
Growth activity data
Growth surrogates
Future year forecasts
San Joaquin Valley
California