Smaller, Closer, Dirtier

DIESEL BACKUP GENERATORS IN CALIFORNIA

environmental defense
finding the ways that work

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Cover photo: Diesel backup generator. Photo by Kate M. Larsen

Our mission
Environmental Defense is dedicated to protecting the environmental rights of all people, including the right to clean air, clean water, healthy food and flourishing ecosystems. Guided by science, we work to create practical solutions that win lasting political, economic and social support because they are nonpartisan, cost-effective and fair.

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The opinions expressed in this report, and any error of fact or interpretation, are ours alone.

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Executive summary

Late one Thursday afternoon in March, a massive power outage darkened much of the University of California's Berkeley campus. Classes ended abruptly, students were herded out of darkened dormitories, and the campus server went down. But the lights did not stay off everywhere on campus. Tucked away in basements and behind buildings was a secret weapon, 40 backup generators or BUGs, 29 of them diesel-fired. During the blackout all but one were switched on to protect sensitive laboratory experiments, power dining facilities, and light hallways. Their service came at a steep cost, however. Toxic diesel exhaust from the Berkeley BUGs wafted across the busy campus and into nearby residential and commercial areas. Alarmed to see plumes of smoke from exhaust outlets, several staff and students dialed 911.

Although there wasn't a fire, there was still plenty to worry about. BUGs are large diesel engines, similar to those found in Greyhound buses, eighteen-wheel trucks, or locomotives. Because they are intended to operate only in the rare event of a power failure, they lack even rudimentary pollution controls. BUGs expose people living, working, and going to school nearby to high levels of toxic diesel emissions. Diesel BUGs emit smog-forming chemicals, fine particles and cancer-causing compounds at many times the rate of newer diesel engines with pollution controls. At their worst, BUGs pollute up to 100 times as much as conventional power plants. This report analyzes the health impacts of BUGs and provides recommendations on how these impacts can be lessened.

BUGS and California's recent electricity supply shortages

The California Air Resources Board (ARB) estimates there are more than 11,000 diesel BUGs in the state. Regulators' records indicate that BUG use increased substantially from December 2000 to May 2001, when rolling blackouts occurred.

Faced with the threat of recurring outages, the administration of Governor Gray Davis developed a plan to use California's largest diesel BUGs as blackout "busters," a function for which they were never approved. Under the plan, BUG owners would have received cash payments to operate BUGs when power supplies got tight. Legislation was even proposed to roll back restrictions on BUG use and provide taxpayer-financed cash incentives for companies to purchase BUGs. Fortunately Californians were spared the predicted nightmare scenario of frequent summer blackouts, and these plans were never implemented. But some experts predict California could face more shortages. If they're right, BUGs could once again emerge as an under-regulated, highly polluting antidote.

BUGS remain a serious health threat

Even if the shortages do not materialize, California's newly expanded crop of BUGs still poses a significant public health threat that merits greater oversight. Five influential governmental or scientific bodies have designated diesel exhaust as a probable or potential human carcinogen. Recent studies have found that diesel exhaust contributes more than 70% of the cancer risk from air toxics in the United

States.[1] The cancer risk from diesel exhaust is about ten times higher than all other toxic air pollutants combined.[2]

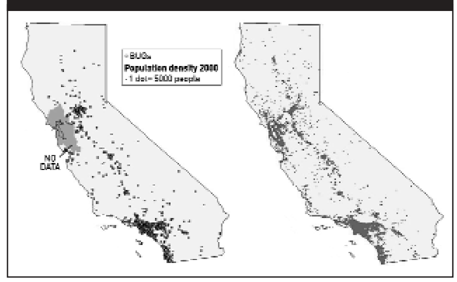
Diesel exhaust also has numerous acute and chronic noncancer effects, involving the respiratory, neurological and immunological systems.[3] Diesel exhaust contains or creates nitrogen oxides (NOx) and volatile organic compounds (VOCs), both precursors to ground-level ozone, or smog; carbon monoxide (CO); and particulate matter (PM).

Especially worrisome is the fact that diesel BUGs emit fine particles at extremely high rates. Studies have linked fine particles to many adverse health effects, including asthma, cardiovascular and respiratory problems, strokes, and heart attacks.[4] Researchers estimate that as many as 60,000 Americans die prematurely each year because of exposure to fine particles.[5] Children, the elderly, and the ill (especially those who have existing respiratory problems) are particularly vulnerable.

California is swarming with BUGs

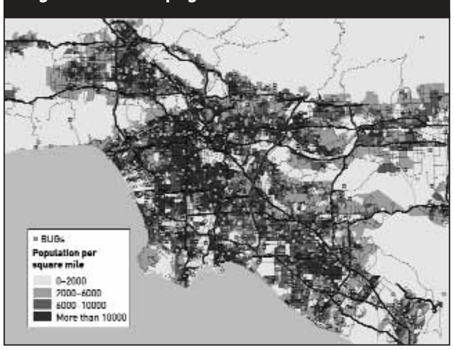
There are likely many more BUGs in California today than the 11,000 estimated by the Air Resources Board before the electricity shortages. Regulators can only make informed guesses about the number of BUGs, because until recently some air districts did not even require BUG owners to get a permit. Regulators not only had no way of knowing who had a BUG, they could not conduct inspections to detect and penalize unauthorized use.

Figure 3-2. See page 10 for full-color version.



Air quality regulators need to know where the BUGs are, especially as BUG owners everywhere face growing incentives for unauthorized use. Foremost among these incentives are demand-response programs, which compensate customers across the nation for cutting their use of grid power when electricity supplies are tight. While these programs can save consumers money and reduce the threat of power outages, they also tempt BUG owners to reap incentive payments by substituting dirty BUG power for much cleaner grid power. The complex utility rates for large commercial and industrial customers can create additional financial incentives for unauthorized BUG use.

Figure 3-3. See page 10 for full-color version.



Using data from the California Energy Commission (CEC) inventory of nearly 4,000 large BUGs, Environmental Defense found that most California BUGs are clustered near where people live, work, and go to school, as illustrated in Figure 3-2, page 10. Even within heavily urbanized regions BUGs are likely to be found where populations are most dense, as is the case in Los Angeles (see Figure 3-3, page 10). That means the potential health damage caused by BUGs is compounded.

The CEC BUG database, compiled in 2001, is based on permitting records from 27 of the state's 35 local air districts. The Bay Area air district and some rural districts were unable to provide the necessary data because they did not require BUG owners to obtain permits, so they are not included in the database. The inventory documents the owner, location, and specifications of each BUG 300 kilowatts and larger. The CEC inventory is the most complete record of BUGs in California.

How close is too close: The Risk Zone

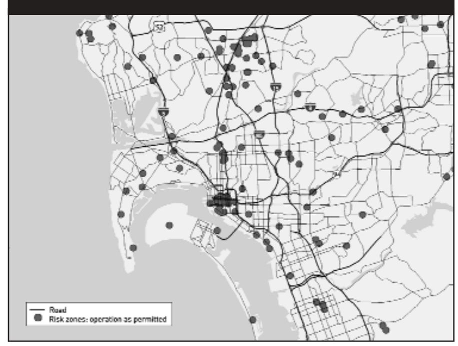
People in close proximity to BUGs are exposed to more harmful diesel emissions than those living and working further away. In this report, Environmental Defense has attempted to determine the "risk zone" for BUGs, or the area surrounding a BUG in which people are exposed to concentrations of diesel pollution that result in unacceptably high health risks. We chose as a threshold a cancer risk of one per million, consistent with regulatory benchmarks. Our analysis focused on five cities where most BUGs are located-San Francisco, Los Angeles, San Diego, Fresno, and Sacramento.

Even if BUGs are operated as little as 100 hours per year—the limit of typical permits—the surrounding risk zone ranges from 63 to 118 acres. That's 10 to 20 average city blocks. In general, the more BUGs are used, the larger the risk zone. Since BUGs are concentrated in densely populated areas, expanding the risk zone means increasing the number of people exposed to unacceptably high levels of pollution.

BUG HOT SPOTS ARE COMMON IN MAJOR CALIFORNIA CITIES

Our risk zone analysis also demonstrates that many BUGs are located close enough to each other that their risk zone circles overlap. Health risks may increase considerably when individuals are exposed to emissions from more than one BUG. Figure 8-5, page 52, shows that in the San Diego area, BUG clusters occur both inside and outside the core downtown area. We found many similar BUG hot spots throughout California in cities such as Los Angeles, Fresno, and Sacramento.

Figure 8-5. See page 52 for full-color version.



THE BURDENS FALL DISPROPORTIONATELY ON THE POOR, ELDERLY, AND MINORITIES

By integrating demographic data with the CEC BUG inventory, we show that in each of the districts we analyzed, the population within the BUG risk zone is more likely to be low income, elderly, and of a racial minority. While absolute differences are sometimes small, they are generally statistically significant, and the pattern of disparities is consistent across districts. In some instances the proportional differences are substantial: For example in the Sacramento metropolitan air district the proportion of elderly residents within the risk zone is 26% higher than for the entire district. BUG areas also tend to have higher existing background concentrations of diesel pollution, so emissions from BUGS affect a population that is already disproportionately burdened.

BUGs affect the health of over 150,000 schoolchildren

To better analyze the impact on children, who are most vulnerable to developing asthma or other respiratory ailments from air pollution, we examined the proximity of primary and secondary schools to BUGs in the four surveyed districts. We found that over 200 schools are within the boundaries of a BUG risk zone (see "School children's exposure to BUG emissions, operation as permitted," below). Based on this mapping exercise and the average enrollment of a California school,[6] we estimate that over 150,000 school children may be exposed to unacceptably high emissions from BUGs in just the four districts studied. Statewide figures would be significantly higher.

Schoolchildren's exposure to BUG emissions, operation as permitted

Air district	Schools within Risk Zone	Estimated children enrolled
South Coast	140	96,600
San Diego	27	18,630
San Joaquin Valley Unified	34	23,460
Sacramento Metro	18	12,420

Policy recommendations

California's recent electricity shortages highlighted the critical role BUGs play during outages, but also illuminated regulatory gaps and potential abuses. The California Air Resources Board (ARB) and many of the local air districts already have taken several important steps to remedy these problems.

Following are Environmental Defense's recommendations to reduce toxic emissions from diesel BUGs.

- **Adopt uniform permitting requirements for BUGs**
  All California air districts should require BUGs of 50 hp and larger to have permits so that local air regulators will know how many BUGs are in their districts, where they are located, and who owns them. This information will make it possible for the districts to enforce appropriate restrictions on BUG use.

- **Confine BUG use to emergencies**
  Air districts should ensure that BUG use is confined to true emergencies—those rare occasions when natural disasters or other events cause a loss of grid power *at the site where the BUG is located.* All air districts should adopt the ARB definition of an emergency: "when electrical or natural gas service fails or emergency pumping for fire protection or flood relief is required."[7] Air districts also should make clear that compensated curtailments do not justify BUG operation. All load-shedding programs should explicitly forbid using BUGs to meet

curtailment calls or respond to price signals. Program operators should require BUG owners to inform the local air district of their participation in real-time pricing programs, interruptible rates or other load-shedding programs.

- **Require pollution controls on BUGs**
  The California Air Resources Board's staff has proposed tough new emissions standards for BUGs to take effect in 2004. These call for BUG owners to reduce emissions of diesel PM by 85% and to comply with a 0.15 g/bhp-hr diesel PM emission rate or to replace any existing BUG with one that meets the requirements for new BUGs. New or rebuilt BUGs greater than 50 bhp would be required to meet an emissions standard of at least 0.15 g/bhp-hr. Environmental Defense supports adoption of these proposed standards by the Board. In particular, the oldest engines-for which no retrofit technology is available to meet the new emissions standards-must not be grandfathered. A strict timeline needs to be established for replacing or retiring these BUGs.

- **Adopt effective enforcement measures**
  Even if emissions limits are implemented, effectively enforcing restrictions on operating hours will be essential to guarantee that emissions remain below acceptable levels. Because BUGs are expected to run only a few dozen hours per year, the proposed new standards allow BUGs to emit fine particles at *15 times* the rate allowed for prime engines, which typically run for hundreds of hours. The different emissions limits make sense only if BUGs stay within their allotted annual operating hours.

  In addition to the ARB's recommendation that air districts require run-time meters, BUG owners should be required to maintain records of hours of operation, purpose of operation (i.e. testing, maintenance, emergency), and the nature of emergency hours. This data should be reported once a year and made available to the public.

  To ensure honest reporting, the air districts should conduct routine inspections of meters and run-time logs. Once emissions limits are implemented, inspectors should verify that control equipment has been installed. At large facilities, regular inspections should be expanded to include BUGs. The majority of BUGs, however, are located at facilities that would not otherwise be inspected. To provide an effective deterrent, a program of random inspections should be instituted for these facilities, with severe penalties for violations.

- **Use financial incentives to reduce pollution from BUGs**
  The legislature should consider providing direct financial incentives to retrofit or retire the dirtiest diesel BUGs. In fact, $14 million allocated to lessen the impacts of increased BUG use during last year's electricity shortages was axed from the budget in the first round of cuts. It should be restored.

- **Encourage alternative backup power sources**
  Cleaner options for backup power exist or are being developed. Although some on-site fuel storage considerations must be addressed, fuel cells are an especially promising alternative. Because fuel cells are a relatively new technology, operating experience must be gained to ensure they are an efficient

and reliable option. Facilities planning backup power upgrades should introduce fuel cells to provide this experience.

- **Protect the public's right to know about risks from BUGs**
  The ARB plans to expand the inventory to include all BUGs. In addition to data on engine characteristics and type of use, Environmental Defense recommends that the inventory include information on engine location, ownership and retrofit status. The legislature should allocate sufficient funds to ensure that the inventory will be comprehensive and that ARB can update it as new BUGs are permitted and retrofits are completed. The inventory should be available in an easy to access form on ARB's Web site so that Californians can find out if there is a BUG near where they live, work, or go to school. In addition, the air districts should collect and make available data on BUG run-times.

Conclusion: The health risks of BUGs are too high to ignore

By keeping essential functions running during an emergency, backup generators provide a critical service. But BUGs are the dirtiest form of power generation available, and their use threatens the health of millions in California and across the nation. These engines especially impact the health of the most vulnerable: children, the elderly, and low-income and minority groups. Increased reliance on BUGs sets a dangerous precedent. Standards to reduce pollution from BUGs are critically needed. In addition, BUG use should remain confined to true emergencies and cleaner alternatives should be put in place to protect the health of all citizens.

CHAPTER 1

Introduction

More than 11,000 diesel backup generators, or BUGs, can be found at California factories, offices, data centers, government buildings, hospitals, sewage treatment plants, and other facilities. BUGs are large diesel engines similar to those found in Greyhound buses, 18-wheel trucks, or even locomotives. Because they are intended to operate only in the rare event of a power failure, they lack even rudimentary pollution controls. When BUGs do operate—during emergencies but also for routine testing and maintenance—their smokestacks belch out a highly toxic brew of smog-forming chemicals, fine particles, and cancer-causing compounds. The height of a typical BUG stack is no more than a few feet, so the people living, working, and going to school nearby are the most affected. Eventually a BUG's emissions are dispersed, adding to the already excessive exposure to diesel pollution that most Californians face.

Before California's recent electricity supply shortages, policymakers paid little attention to BUGs. Indeed, many of the local air districts, which have primary jurisdiction over BUGs, did not even require their owners to have permits. The crisis that began with surging wholesale electricity prices in the summer of 2000 and progressed to recurring rolling blackouts between December 2000 and May 2001 created new notions of what constituted an emergency. Facing dire predictions of dozens to hundreds of hours of outages during the upcoming summer, some California leaders looked to BUGs for salvation. Lawmakers and regulators drew up proposals to systematically dispatch BUGs during stage 2 and 3 alerts and even to provide new financial incentives for businesses to buy BUGs. Suddenly it appeared likely that these very dirty engines, which previously had operated only during rare events like earthquakes, fires, and severe storms, might run for hundreds of hours. Making matters worse, these measures would have increased BUG pollution during the summer afternoon hours when California's smog problems were already at their worst.

Fortunately, Californians were spared the nightmare scenario of frequent summer blackouts that many experts had predicted. But even before it became clear that conservation and new federal price caps would get them through the summer, California air regulators, progressive legislators, and environmental groups banded together to prevent the implementation of such extreme measures. Plans by the administration of Governor Gray Davis to dispatch BUGs were quietly shelved, and proposed legislation to provide tax credits for BUG purchasers died in committee. But thousands of new BUGs were installed at facilities throughout California, and the available evidence indicates that on average, BUGs were used more often during the energy crisis.

Depending on which expert you consult, today California is either emerging from the woods or in the eye of the hurricane. Optimists point to the host of new power plants that have already come on line or are in various stages of regulatory review or construction. Pessimists worry about the difficulty that power plant developers currently face in financing new projects or note that federal price controls are set to expire later this year, once again exposing California to the ravenous power marketers increasingly seen as the architects of last year's crisis. If the pessimists are right, shortages could soon return, and BUGs could once again emerge as the antidote. Even if shortages do not materialize, California's newly expanded fleet of BUGs still poses a significant public health threat that merits greater oversight.

This report presents the results of a comprehensive study of California BUGs conducted by Environmental Defense. Our analysis looks both backward and forward. Looking back to the summer of 2001, we ask what might have happened if BUGs had been systematically dispatched as planned; what the health consequences would have been. Looking ahead, we evaluate the risks of both routine testing and maintenance and the more extended operation of BUGs as distributed, or small scale, power sources. Although the regular operation of BUGs to replace grid power is illegal, they may be used anyway, because the air districts' limited enforcement capabilities mean that the detection and punishment of permit exceedances are highly unlikely.

We also look at how the health risks of BUG emissions are distributed throughout California, using a detailed inventory of large BUGs developed by the California Energy Commission (CEC). By combining the CEC inventory with detailed demographic, land use, exposure, and health status data in an integrated database, we were able to examine the environmental justice implications of the increased use of BUGs.

The remainder of the report is organized as follows: Chapter 2 introduces the kinds of engines typically used for emergency generation and offers a statistical overview of California's BUG population. Chapter 3 analyzes the types of facilities at which BUGs are located and presents the findings on the geographic distribution of BUGs. Chapter 4 describes the regulation of BUGs in California. Chapter 5 outlines the policy issues relating to BUGs, those that arose during California's electricity shortages as well as emerging concerns. Chapter 6 summarizes the scientific literature on the health risks of exposure to emissions from diesel engines like BUGs. Chapter 7 describes the findings from the original research that Environmental Defense commissioned, quantifying the public health risks of various scenarios of BUG operation. Chapter 8 details the results of Environmental Defense's geostatistical analysis of the distribution of health risks from near-field exposure to emissions from BUGs. Finally, chapter 9 concludes the report with Environmental Defense's policy recommendations for California lawmakers and regulators.

CHAPTER 2

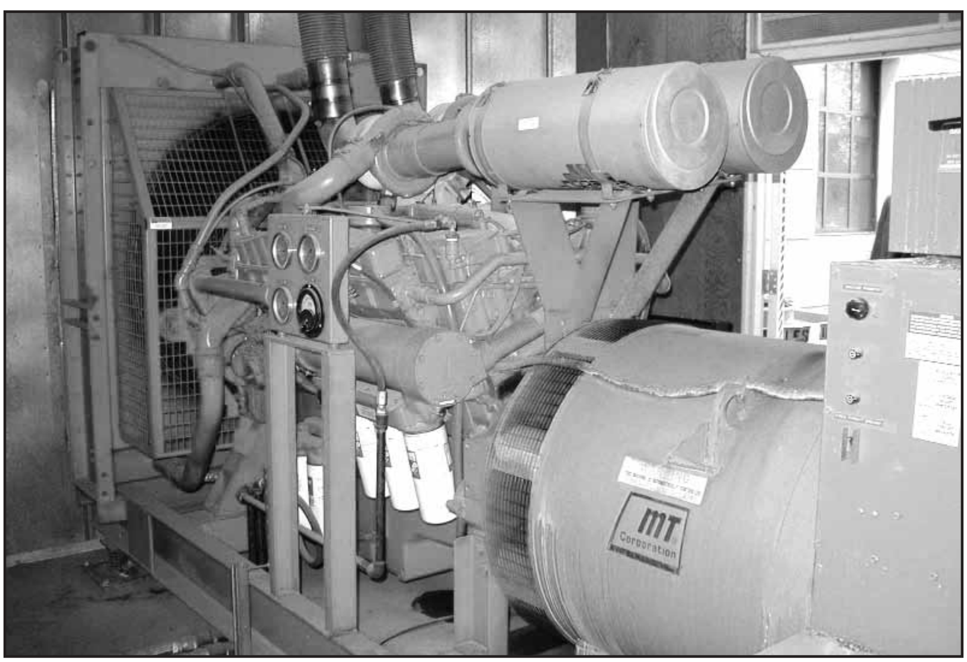
What is a BUG?

Diesel generators are a common source of emergency backup power in California and across the United States. A combination of low capital costs, quick start-up, and high overall efficiency have made diesel BUGs a popular option for both business and residential consumers.[8] Because BUGs are intended to operate only infrequently, they lack even basic pollution controls, making them the dirtiest form of distributed power. Other sources of backup power exist, or are currently being developed, that will provide comparable efficiency and reliability in the case of a power failure, without jeopardizing the health and safety of those who live nearby.

Most people have seen the dirty black plume of exhaust spewed out by diesel trucks or construction equipment. Diesel backup generators are similar to these engines in size, but because they lack even basic controls, they emit more dangerous pollution (see Figure 2-1). The average BUG in the CEC inventory is about 600 horsepower (hp), or about 450 kilowatts (kW),[9] just slightly larger than the engine of an 18-wheel truck. Although the majority of BUGs in California are under 300 kW, some diesel BUGs are as large as 2000 to 4000 hp (1.3 to 2.6 MW), the same size range as locomotive engines. Figure 2-2 gives an idea of the size range of BUGs compared with other engine types.

BUGs represent just one subsection of a larger category of diesel engines. Diesel engines can be divided into *stationary* sources, those that generally remain in one location for their entire lifetime, and *mobile* sources, those that move from location to location. Mobile sources include on-road engines, or all vehicles on the road that run on diesel fuel, and off-road engines. This category includes vehicle equipment, such as cranes and bulldozers, and portable generators, many of which

FIGURE 2-1
A diesel BUG



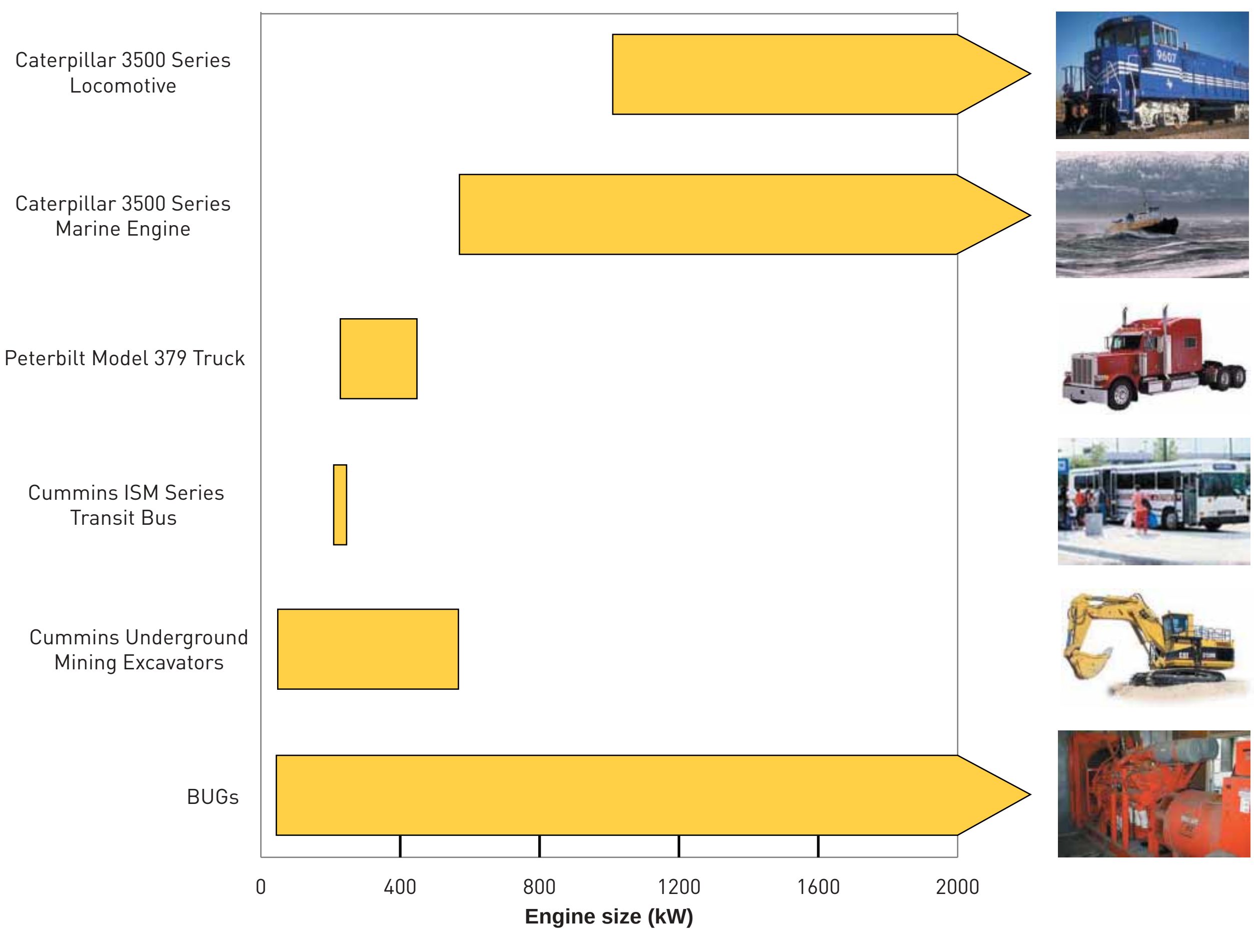
are used in construction and moved from one work site to the next. Portables can also be used as backup generators. BUGs fall under the stationary engine category, along with prime engines. Prime engines differ from BUGs in that they are permitted to run on a regular basis, usually to supplement or substitute for energy from the power grid.

The greater dependence of businesses and public services on an uninterrupted source of power and the current unstable energy situation in California has caused the purchase and use of BUGs to grow (see Chapter 5). Indeed, because diesel BUGs and other forms of backup power often are vital to maintaining public health and safety, providing hospitals and other public services with a constant supply of power, many of these facilities are required by building codes or other local ordinances to have some form of backup generation on site in case of emergency.

Except for routine maintenance and testing, BUGs are usually permitted to run only during emergencies, which, in most air districts, means during an unforeseen failure of the regular electric power supply from the grid or of on-site equipment (see chapter 4 for details of district regulations). When this happens, a BUG owner is allowed to operate the engine for as long as the facility is without power. In the event of an earthquake, flood, or fire, BUGs are also allowed to run, serving as

FIGURE 2-2

Size of BUGs relative to other common diesel engines



a power source for services such as pumping water and emergency lighting.[10] BUGs are not required to meet the more stringent emission controls that apply to longer-running prime and off-road engines. Prime stationary and nonroad engines are required to be equipped with pollution control equipment that will allow them to pass federal Clean Air Act requirements for new or modified sources of air pollution. Most air districts have established standards for nitrogen oxide (NOx) and carbon monoxide (CO), although they have not set standards for diesel particulate matter (PM).[11] BUGs are not required to meet such standards. The California Air Resources Board (ARB) has proposed airborne toxic control measures (ATCM) for emissions of PM from all stationary engines, whether prime or emergency.

California's BUG population

The California Air Resources Board estimates that at present, more than 16,000 diesel engines are located throughout the state, including both emergency standby and prime engines.[12] Using district permitting records and extrapolating from census population data when district permit data were not available, the ARB estimated that more than 11,300 of these engines were BUGs. The ARB also estimated the diesel PM and NOx emissions for all engines and found that the emissions levels of the 4,804 prime engines were three times higher than those of the 11,300 BUGs. Note that these numbers are estimated, not measured, and assume that all engines are operated as permitted. Diesel prime engines, which run longer hours, are believed to have significantly higher aggregate emissions than BUGs. However, with the large number of BUGs in California, even a small increase in the number of these engines' annual operating hours would mean a dramatic increase in their total emissions.

In 2001, the California Energy Commission (CEC) compiled an extensive and detailed inventory of diesel BUGs in the state, based on permitting records from 27 of the state's 35 local air districts[13] (see Table 2-1). The Bay Area Air Quality Management District (AQMD) and some rural districts were unable to provide the necessary data because until 2001 they did not require BUG owners to obtain permits.[14] This inventory documents the owner, location, and physical specifications of each BUG of 300 kW and larger that was permitted in the state before April 2001.

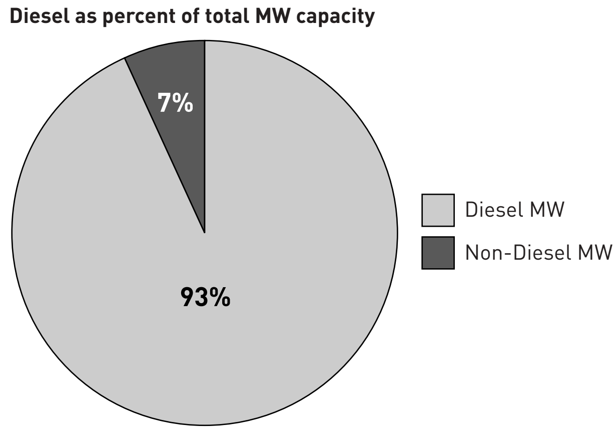
TABLE 2-1

Summary of the California Energy Commission's BUG inventory

	NUMBER OF BUGS			
Source	**Diesel**	**Non-Diesel**	**Total**	**Total diesel generating capacity (MW)**
South Coast AQMD	1,967	67	2,034	1,694
San Diego County APCD	478	5	483	324
San Joaquin Valley Unified APCD	302	11	313	219
Sacramento Metro AQMD	281	5	286	223
Monterey Bay Unified APCD	111	1	112	76
Mojave Desert AQMD	59	3	62	35
Yolo/Solano AQMD	58	1	59	47
All Other Air Districts	215	69	284	215
Total	**3,471**	**162**	**3,633**	**2,833**

* Only very limited data are available from the Bay Area AQMD. No data exist for Calaveras, Siskiyou, Modoc, Lassen, Tuolumne, Northern Sonoma, or Northern Sierra Air Districts. Since these data are incomplete, they are omitted from this summary.

FIGURE 2-3
The majority of BUG generating capacity is diesel-fueled



Source: Derived from California Energy Commission, "BUGS 1: Database of Public Back-up Generators (BUGS) in California," August 15, 2001.

Although there are many BUGs smaller than 300 kW across the state, the CEC inventory was originally compiled in order to catalog the larger BUGs available for dispatch to avert rolling blackouts during the energy crisis. Because the CEC inventory is the most complete record of BUG locations across the state, we chose to use it as the basis for our analysis and will refer to it throughout this report. It is important to note that the CEC inventory is only a partial snapshot of California's BUGs in early 2001 and does not include the new BUGs acquired since that time.

The South Coast Air Quality Management District, which includes Los Angeles and surrounding communities, is home to more than half the BUGs in the state. Almost one-third of the state's BUGs are in San Diego, San Joaquin Valley, and Sacramento. The majority of the documented BUGs in the state are diesel engines. Of the total number of BUGs listed in the CEC inventory, 96 percent use diesel fuel, and 93 percent of the megawatts are produced by diesel engines (see Figure 2-3).

PORTABLE ENGINES

Portable engines, often referred to as off-road engines, are used all over California for agricultural irrigation, commercial construction, dredging, drilling, and military tactical support activities. Although they operate much like diesel BUGs, these engines often are smaller and mounted on wheels for added mobility. The ARB estimates that more than 49,000 portable diesel-fueled engines are operating statewide.[15] Approximately 85 percent of the state's portable engines are located in the five air districts surveyed in this report, with 16,000 in the South Coast district alone. Most portable engines are used for short-term activities in various locations. Some facilities, however, regularly use portable engines, such as aircraft ground support at major airports, dredging equipment at harbors, waste reduction equipment at landfills, and oil and gas well drilling at oil and gas fields. Portable generators are regulated at the district level by local registration and regulation programs and also a voluntary statewide registration program.[16] During California's recent power shortages, portable engines were widely used for backup electricity supply.

Cleaner alternatives to BUGs

Although diesel-fueled generators are the most widely used sources of distributed generation in California, other technologies provide the same reliability and power benefits without the high levels of air pollution associated with diesel. Figure 2-4 shows the differences in polluting emissions from various distributed generation technologies, of which diesel BUGs and their alternatives are a subset. For every pollutant listed, diesel engines clearly rank the highest, with four times more CO and five times more NOx emissions than natural gas engines, the second highest polluter.

Only a few sources of distributed generation are cleaner alternatives to diesel generators for backup power.[17] Some technologies, such as alternative-fuel IC engines, are already commercially available. Emerging technologies, such as fuel cells, whose availability is currently limited, will be more widely accessible in the coming months and years.

ALTERNATIVE-FUEL INTERNAL COMBUSTION ENGINES

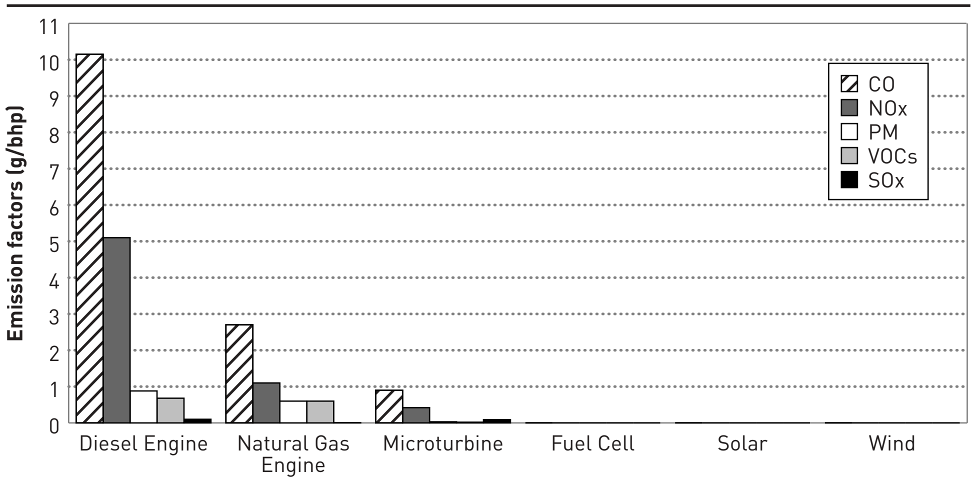
Internal combustion (IC), or reciprocating engines, are the most common distributed generation technology. Although IC engines run primarily on diesel, they can also use cleaner-burning fuels like natural gas, propane, gasoline, and landfill gas. Although most IC engines require pollution controls, their emissions rank the highest of the distributed generation technologies. IC engines fueled by natural gas, despite its being much cleaner than diesel, emit comparatively high levels of dangerous air pollutants.

FUEL CELLS

Fuel cells, first used as an energy source for U.S. spacecraft in the 1960s, have recently been developed for use as distributed generation. Only one of the three types of fuel cells is now commercially available, but given the recent technological improvements and the large investments by NASA, auto companies, and utilities, the market for this technology is growing rapidly.[18]

FIGURE 2-4

Polluting emissions from distributed generation technologies



Source: Distributed Utility Associates, prepared for the California Air Resources Board, Air Pollution Emissions Impacts Associated with Economic Market Potential of Distributed Generation in California. June 2000.

A *fuel cell* converts hydrogen and oxygen into electricity and heat.[19] It is much like a battery that can be recharged while power is being drawn from it. But instead of being recharged by using electricity, a fuel cell uses hydrogen and oxygen. Because natural gas is the primary source of this hydrogen, fuel cells have fewer emissions than from any other fossil fuel-burning technology. Besides the emissions associated with turning natural gas into hydrogen, the emissions from fuel cells are mainly CO_2 and water. With further development, especially in resolving difficulties with on-site fuel storage, fuel cells will be able to supply an emissions-free source of hydrogen.

CHAPTER 3

Where are the BUGS found?

BUGs can be found in commercial and office buildings, hospitals, and government facilities all over California, most often in or near urban centers where the majority of Californians live, work, and go to school.

California is swarming with BUGs

Figure 3-1 shows that BUGs exist in every air basin but that most are found in the South Coast and San Francisco air basins. Moreover, BUGs are not evenly distributed across California or even within the air basins. Some are at isolated sites on mountaintops or in the desert, but most are concentrated in densely populated areas. Figure 3-2 charts the correlation between population density and BUG location in California. Urban centers like Los Angeles, San Diego, and Sacramento have the most BUGs. In sum, BUGs are where the people are.

This pattern is consistent within cities as well. Using the CEC inventory, we overlaid the location of BUGs in major urban areas on population density data from the 2000 U.S. Census. Figure 3-3 shows that in the Los Angeles area, BUGs tend to be clustered in the darkest shaded areas where the population is most dense. This makes sense because BUGs are used in office buildings and commercial centers. We observed similar patterns for other major California cities.

Land use is important to consider when determining the types of people and places affected by BUG emissions. To better understand the distribution of BUGs

FIGURE 3-1
CARB estimates of the number of diesel BUGs by air basin: 2000

Air basin	No. of BUGs
South Coast	5350
San Francisco	2021
San Joaquin Valley	964
San Diego	877
Southeast Desert	548
Sacramento Valley	544
South Central Coast	428
North Central Coast	207
Mountain Counties	197
North Coast	95
Lake Tahoe	44
Lake County	32
Northwest Plateau	28
Great Basin Valley	9
Total	**11344**

Source: California Air Resources Board, "Diesel Risk Reduction Plan: Appendix 2 Stationary and Portable Diesel-Fueled Engines." page II-13, 2000.

FIGURE 3-2

Population density and diesel BUGs in California

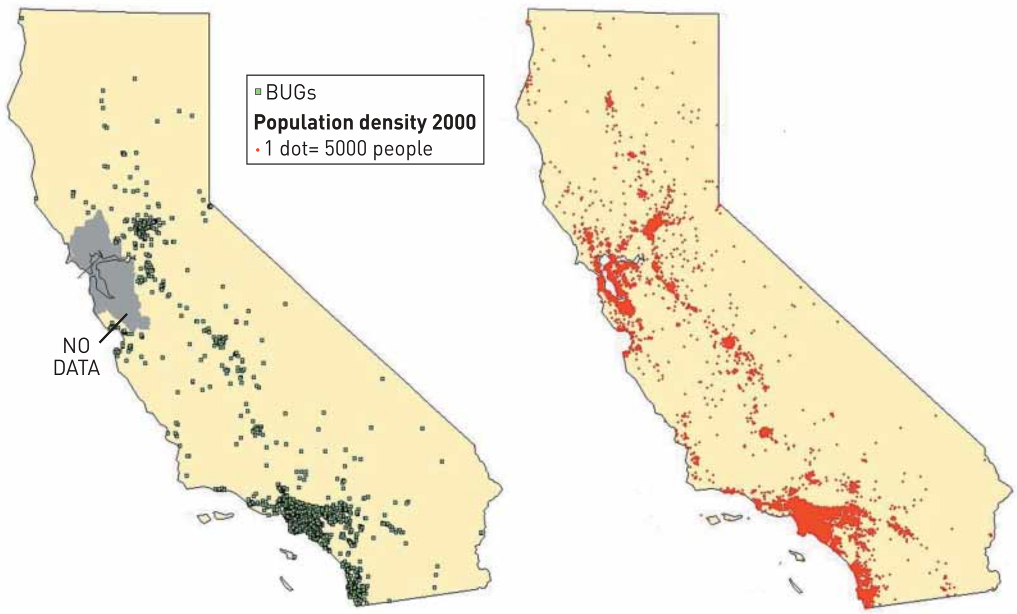


FIGURE 3-3

Population density and diesel BUG location in the Los Angeles region

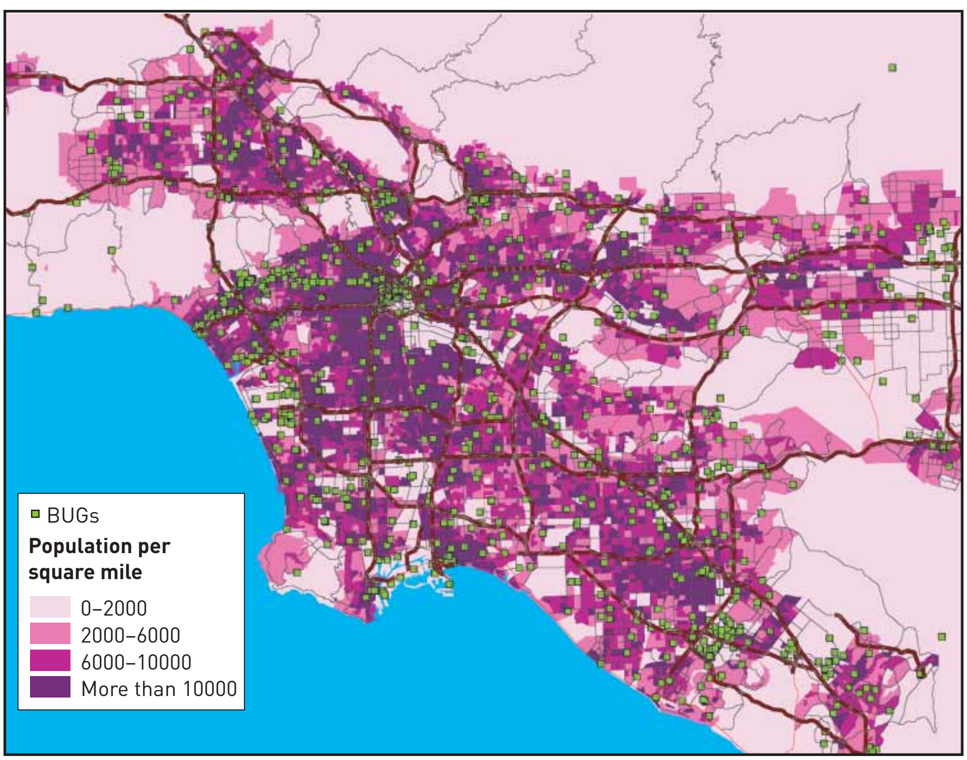


FIGURE 3-4

Land use and diesel BUG location in the Los Angeles region

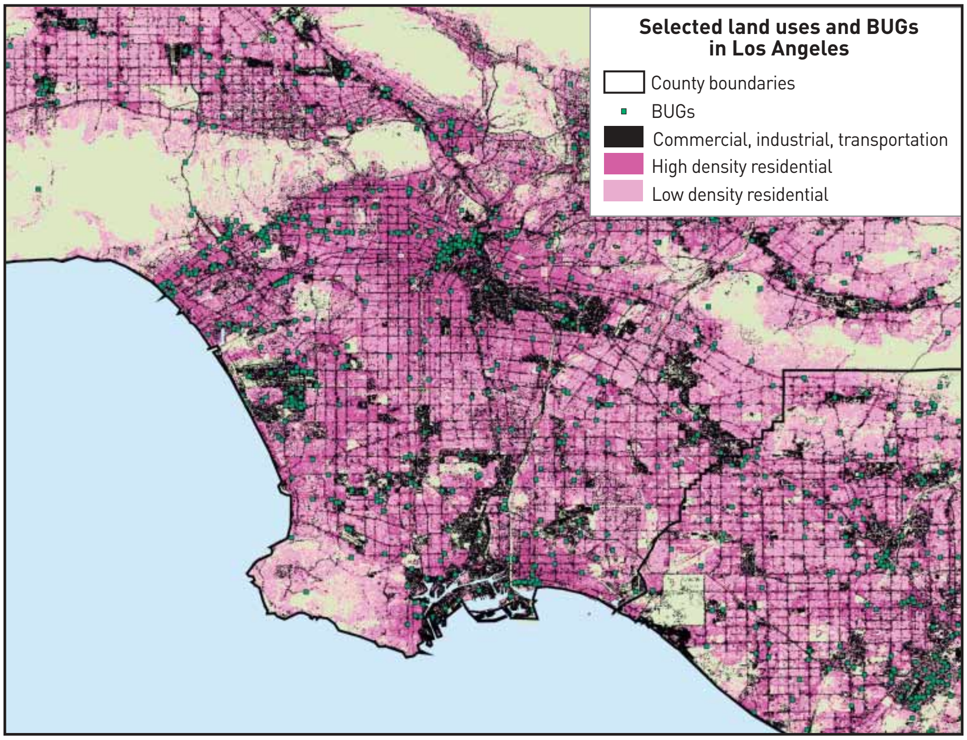


FIGURE 3-5

Employment density and diesel BUG location in Los Angeles County

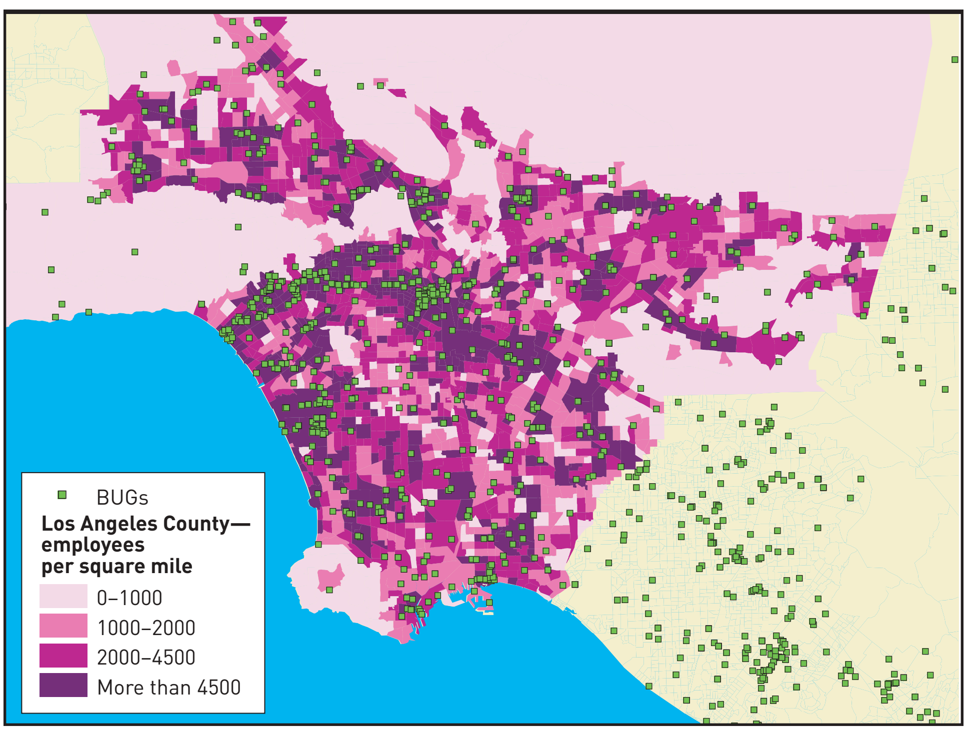
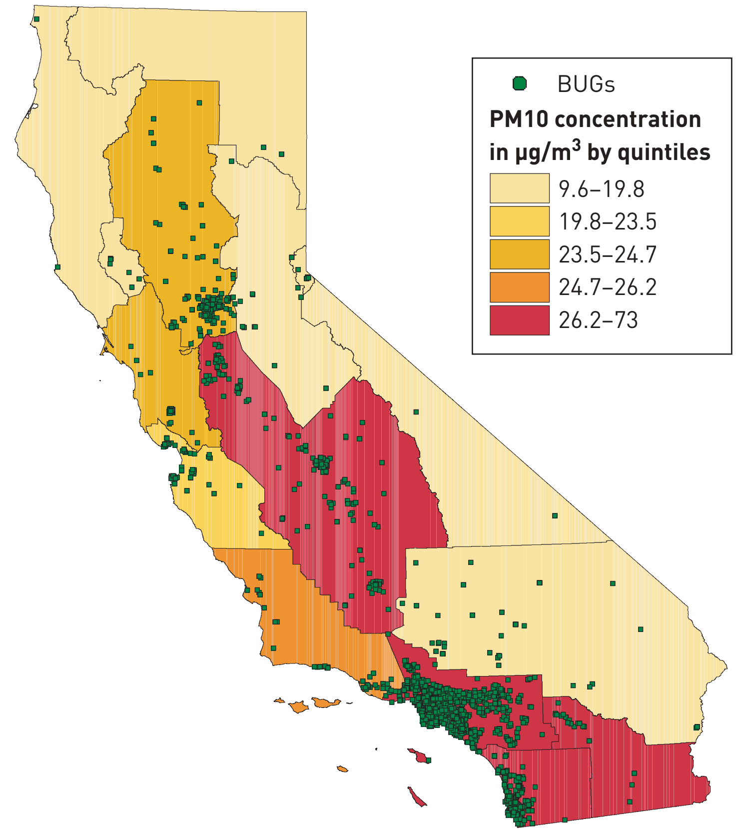


FIGURE 3-6

PM10 concentration and diesel BUGs by air basin



The 2002 California Almanac of Emissions and Air Quality, Appendix B: Air Quality Trend Data by Pollutant: Ozone, PM10, CO, NO_2, SO_2

for different land uses, we used U.S. Geological Survey (USGS) land coverage data to differentiate commercial, industrial, and transportation zones and high- and low-density residential areas from regions where other land uses predominate.[20] Figure 3-4 lays out our analysis of Los Angeles. When the city's BUG population is overlaid on the land use map, most of the area's BUGs are found in areas used for commerce, industry, or transportation. But as the map also shows, these areas are closely surrounded by high- and low-density residential areas. This means that even though most BUGs inhabit nonresidential areas, they still are very near where people live. Similar patterns were evident for other California cities.

Because BUGs are used mostly during business hours, we next looked at not only where people live but also where they work. Figure 3-5, which overlays the BUG locations on a map of worker density (employees per square mile) in Los Angeles County, shows that BUGs are also concentrated in areas where people work,[21]representing an additional risk to people working in urban and commercial centers who are already heavily exposed to dangerous pollutants.

BACKGROUND EXPOSURES

Most BUGs are found in areas of California where air pollution is already a serious problem. According to Figure 3-6, the greatest concentration of BUGs is in

Hospitals

Medical facilities, including hospitals, health clinics, and medical centers, make up approximately 16 percent of classified BUG facilities from the CEC inventory. Today's hospitals depend on electricity more than ever before. Almost every aspect of patient care, especially monitoring and critical life support systems, depend on increasingly large supplies of reliable power.

National and state electrical codes have been upgraded to reflect the growing need for an uninterrupted power supply. Regulations developed by several authorities, ranging from the National Fire Protection Association (NFPA), the Joint Commission on Accreditation of Healthcare Organizations (JCAHCO), to the state of California, cover almost all hospitals that have emergency diesel generators. The National Electric Code 517-13 and the California Electrical Code require all hospitals and critical care facilities to have backup power systems that can be running at full capacity within ten seconds after power failure.

Several leading hospitals are looking for alternatives to traditional diesel generators, and fuel cells have proved to be clean and reliable. The major benefit of a fuel cell system is its extremely low emissions. In addition, its design provides greater protection against failure than does the average hospital diesel unit.

Many hospitals in California are currently upgrading their facilities to meet new seismic requirements as well as the requirement of the Office of Statewide Health Planning and Development (OSHPAD) that they have three days of backup generation in place. While switching completely to fuel cells may not be feasible at present, the decision to introduce fuel cells slowly into the backup power mix at certain facilities will increase their operating experience and eventually lead to a wider range of options for cleaner, less polluting backup technologies.

Source: Clean Energy Group, Materials from "Draft Report on Fuel Cell and Health Care Project," 2002.

air basins with the highest particulate matter (PM) exposures. A growing body of research has shown that particulate matter contributes to asthma, allergies, cardiopulmonary disease, and premature death. Even though the contribution of BUGs to California's overall particulate matter is small, incremental exposures from BUGs in these already heavily polluted areas should be avoided.

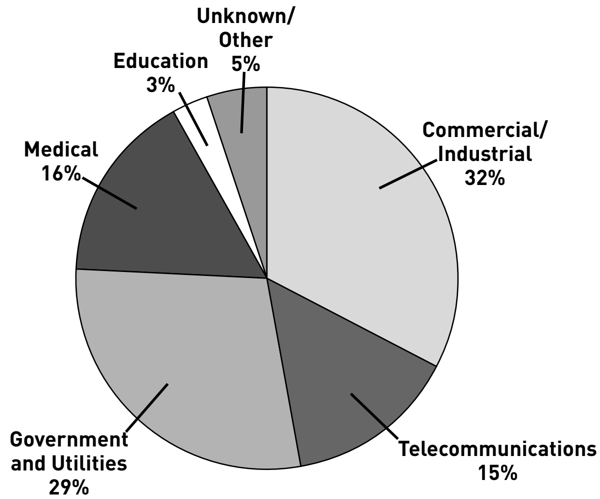
FACILITIES WITH BUGS

Our analysis of the CEC's BUG inventory revealed that BUG ownership is highly diverse. Because the CEC's database provided the name of the facility where each inventoried BUG is located, we were able to classify the BUGs by facility type: commercial/industrial, government and utilities, medical, telecommunications, and educational (see Figure 3-7).

Many BUGs are located at facilities where backup power is essential to, and required for, saving lives or protecting public health and safety. For example, 16 percent are located at medical facilities, mostly hospitals. Facilities classified as government and utilities account for almost a third of the classified BUGs and include city, county, and state government buildings and offices; prisons, police services, and military facilities. Facilities classified as utilities are municipal water districts, sanitation facilities, and municipal or public utility providers.

Almost half the classified BUGs are located at facilities owned by private companies, which we assigned to the commercial and industrial or telecommuni-

FIGURE 3-7
Classification of facilities with BUGs



cations categories. Commercial and industrial facilities include hotels; entertainment, manufacturing, electronics, financial, and insurance corporations; and communications. Many rely on backup generation to safeguard against business disruptions and the consequent financial losses.

Server farms, or data centers, are a prime example of a business that cannot afford to let the lights go out. Clustered mostly in Silicon Valley and parts of the Los Angeles metropolitan area, they require enormous amounts of electricity to run their computers. To ensure a reliable power supply, many have installed diesel BUGs. According to the CEC inventory, one company, Exodus Communications, has 30 BUGs located at three different server farm facilities in the Los Angeles area.

CHAPTER 4

How are BUGs regulated?

The primary responsibility for regulating diesel BUGs in California belongs to the 35 local air quality management districts. Because no emissions controls are now required for BUGs, the districts are concentrating on limiting the BUGs' annual number of operating hours and enforcing compliance with these limits. Until the California Air Resources Board draws up new emissions standards for BUGs and the BUGs are retrofitted or replaced, how well the local air districts can regulate the operation of diesel BUGs will determine the impact of BUG emissions on public health and the environment.

Air quality management districts

While district permit requirements for most internal combustion engines require controls on emissions of criteria air contaminants, most districts exempt diesel BUGs from such controls.[22] Because BUGs are expected to operate purely in the event of an emergency, or for basic testing and maintenance purposes, the districts do not require them to meet the same strict standards as those engines permitted to run more frequently.

Environmental Defense surveyed the permitting regulations of the five air districts that account for more than three-quarters of California's BUG population: the South Coast AQMD, San Diego AQMD, Sac Metro AQMD, Bay

TABLE 4-1

BUG regulations and enforcement in the five surveyed air districts

District	Minimum hp requiring permit	Year permits first required	Max annual hours of operation	Max annual hours for testing and maintenance	Run-time meters required?
Bay Area AQMD	50 hp	2001	Unlimited emergency situation hours	100 hours (200 for essential services)	Required for all BUGs>50hp but not all equipped
SAC Metro AQMD	50 hp	1977	200 hours	100 hours	Required for all post-1991 BUGs; almost all engines equipped.
South Coast AQMD	50 hp	1988	200 hours	50 hours	Required for all new BUGs; older engines (pre-1990) not required.
San Diego AQMD	50 hp	1995	Unlimited emergency situation hours	52 hours	Required on all post 11/00 engines and by 2002 for all other engines.
San Joaquin Valley APCD	50 hp	1991	Unlimited emergency situation hours	200 hours	Not required for BUGs.

Area AQMD, and San Joaquin Valley APCD. As outlined in Table 4-1, the basic regulations for diesel BUGs are fairly consistent throughout the districts. Only BUGs 50 hp and larger are required to obtain a permit to operate[23] but the districts did not always require BUGs of even this size to obtain a permit. In San Diego, BUGs smaller than 500 hp were not regulated until 1995, and in the Bay Area, all engines smaller than 250 hp were exempt from regulation until May 2000.[24]

Hours of operation

Because their emissions are not now controlled, the pollution released from diesel BUGs is limited by the amount of time they run. The main permit condition for diesel BUGs is a ceiling on the annual number of hours of operation. All the districts we surveyed cap the number of hours that a BUG may run for testing and maintenance purposes. South Coast and San Diego set the limit at 50 to 52 hours per year, respectively. The Sacramento Metro and Bay Area AQMDs set the limit at 100 hours, and the San Joaquin area's BUGs and those located at essential public service facilities, such as hospitals and police stations in the Bay Area, are allowed to run up to 200 hours for testing and maintenance.[25]

Of the five air districts surveyed, only the Sacramento and South Coast districts place an upper limit on the annual number of hours of BUG operation. The 200-hour annual maximum limit set by both districts is equivalent to running a BUG for more than half an hour a day, every day, for a year.

The critical determinant of overall run time, and ultimately the total amount of emissions from diesel BUGs, is the districts' definition of what constitutes an emergency. Most air districts define an emergency as an unforeseen failure of regular electric power supply from the serving utility or of on-site equipment or of emergency water pumping in the event of a fire or flood.[26]

Enforcement and monitoring

Determining exactly when and for how long it is safe to run diesel BUGs is the first step in regulating their operation. It is the second step, enforcing these regulations and monitoring BUGs to ensure compliance, that is vital to preventing the serious health risks caused by diesel BUG emissions.

METERS

For its run time to be tracked accurately, a BUG must be equipped with a meter that measures its hours of operation. Most BUGs purchased within the last few years come with a nonresettable meter that clocks its operation hours, just as the odometer on a car records the number of miles driven. But because many of the older engines are not equipped with such meters, their run time cannot be reliably monitored. Neither the Sacramento Metro nor the South Coast AQMD requires that engines purchased before 1990 have meters. Those bought before 1990 in San Diego are required to install meters this year. The Bay Area AQMD, which until now had no meter requirements, requires that beginning this year, all BUGs in its district be equipped with meters. And even though many BUGs in the San Joaquin Valley do have meters, the district still has no meter requirements. This lack of strict and uniform metering requirements throughout the state illustrates the difficulty of ensuring compliance.

INSPECTION

Another important aspect of enforcing permit restrictions is the districts' inspection and reporting systems. At all five of the air districts surveyed, inspection is supposed to be annual, but the staff at most districts admitted that BUGs were often inspected only once every two years or even less frequently. In many districts, the number of engines is far greater than the number of available inspectors, who must inspect both emergency generators and all engines permitted in the district. Consequently, some districts extend the required time between inspections; for example, the San Joaquin Valley APCD inspectors review smaller engines only once every three years.

During inspections, district personnel review the BUG owners' records of the annual number of hours of operation. The BUG owners are required to keep these records for up to two years and to make them available to district inspectors upon request. Little is known, however, about the general frequency and length of BUG use, as most districts have no centralized aggregate reporting of BUG run time. Instead, the districts use the number of hours permitted to calculate the total number of hours run. Some districts are currently conducting studies to get a better idea of BUG run time. It is important to note, however, that without run-time meters, inspection cannot consistently verify the number of run time hours reported in operating logs.

When inspectors do find that a BUG has been run more than the number of hours allowed by the operating permit, they can impose penalties on the owner, usually a monetary penalty, which can be up to $1,000 per day. In the Bay Area and South Coast districts, BUGs consistently run more than the permitted hours lose their emergency standby status and are required to be retrofitted to meet the stricter emissions standards of a prime engine.

State and Federal policies for BUGs

The districts directly manage the permitting and enforcement of BUGs' operation, but they also incorporate the state and federal permitting requirements and guidelines in their programs. Federal regulation focuses on controlling mobile sources of diesel exhaust, and the U.S. Environmental Protection Agency (EPA) has established diesel fuel registration and formulation regulations that affect the fuels used by BUGs in California. Another federal regulation that applies to California's diesel engine population is the federal Clean Air Act amendments of 1990 (CAA), which preempt state and local authorities' control of emissions from new farm equipment under 175 hp. Because local air districts do not require diesel engines used as farm equipment to obtain a permit, their operation and emissions are virtually unregulated.[27]

The state's air pollution regulator, the California Air Resources Board, has more influence on diesel BUG regulation than the EPA does. Although the ARB's central responsibility is to control emissions from mobile sources of diesel exhaust, it also is responsible for guiding the local districts on setting standards and establishing permitting requirements for stationary sources. The ARB's Diesel Risk

Reduction Plan also provides support in reducing particulate emissions from diesel-fueled engines.

California's Diesel Risk Reduction Plan

In 1998, following a ten-year review, the ARB identified particulate matter (PM) from diesel exhaust as a toxic air contaminant. Because of the high risk associated with PM, the ARB directed its staff to create a plan to significantly reduce diesel emissions. The Diesel Risk Reduction Plan (DRRP) proposes to reduce, in three steps, diesel PM emissions by about 85 percent from current levels. The first step sets new regulatory emission standards for all *new* on-road, off-road, and stationary diesel-fueled engines and vehicles. The second requires that *existing* on-road, off-road, and stationary engines and vehicles be retrofitted with pollution controls when it is determined to be technically feasible and cost effective. And third, new diesel fuel standards will be established to reduce the sulfur content of diesel fuel to ensure the best result from advanced diesel PM emission controls.

The DRRP also recommends the development of airborne toxic control measures (ATCMs) to define emissions control requirements for emergency backup generators. The plan places separate limits on PM emissions from new BUGs and on those already in use, treating them as two distinct categories. Although it still is in draft form, the proposed ATCMs require both new and existing BUGs to meet strict PM standards of 0.15 g/bhp-hr by 2004.[28] In contrast, existing prime engines will be required to meet a PM standard of 0.01 g/bhp-hr or to be replaced with a new engine that meets the stricter standards.[29] The more stringent requirements for prime engines are based on the assumption that they operate for more hours than BUGs do. The ARB staff hopes to achieve the planned reduction of up to 105 tons of diesel PM by 2010, reducing PM emissions by at least 85 percent.

CHAPTER 5

What constitutes an emergency?

California's more than 11,000 diesel BUGs were originally intended to be used only in emergencies such as fires, floods or earthquakes that caused a loss of grid power on site. But in 2001, the collapse of California's restructured electricity market and the utilities' ensuing financial crises led to a near constant state of emergency and new notions of what constituted an emergency. Rolling blackouts across the state and the extensive curtailment of those customers that opted for interruptible rates during the winter and spring of 2001 confronted BUG owners with more (in some cases, a lot more) hours of service interruptions than experienced in a typical year, leading to an increased use of BUGs.

As summer approached, these unprecedented circumstances led policymakers to consider paying businesses to run diesel BUGs during peak load periods to prevent further rolling blackouts. Some local air quality management districts revised their restrictions on diesel BUGs' run time to facilitate their use as blackout "busters." Although blackouts and the systematic dispatch of diesel BUGs were averted last summer, neither threat has been eliminated: although power supplies appear sufficient this summer, California's notorious transmission bottlenecks may cause local shortages at any time of year. More ominously, the recent cancellations of several power plant construction projects raise the possibility that the boom-bust roller coaster of California's electric generation sector may again bring blackouts. Furthermore, electricity rate schedules for large customers and new load-shedding programs may provide financial incentives for unauthorized BUG use in excess of permitted levels.

THE PROLIFERATION OF BUGS DURING THE ENERGY CRISIS

With blackouts looming on the horizon, retailers, manufacturers, e-commerce firms, and local governments scrambled to make sure that service interruptions would not disrupt their operations. Even though many businesses and communities made significant efforts to conserve energy, for some avoiding the blackouts also meant buying or renting BUGs. In January 2001, a Bay Area Caterpillar dealer reported that the backlog for his $400,000, 2 MW generators had grown from two months to five months, and a Southern California generator retailer observed that inquiries from frightened business people had increased three- to fourfold.[30]

Newspaper accounts of the energy crisis frequently described businesses' and local governments' plans to acquire diesel BUGs. For example, Costco was reported to be considering buying or leasing BUGs for its more than 75 California stores,[31] and high-tech firms Sun Microsystems, WorldCom, and Web site host Verio all received permits for BUGs from the Bay Area AQMD.[32] Municipal utilities also turned to BUGs to keep the power flowing when the independent systems operators (ISOs) could not deliver the juice. Alameda's public utility leased four tractor trailer-size portable 1.5 MW diesel BUGs. Healdsburg, Santa Clara, and Palo Alto initiated similar backup plans for their municipal utilities.[33] Municipalities bought or rented diesel BUGs to ensure that their offices[34] and vital facilities such as sewage treatment facilities could operate during a blackout.[35]

Home owners, too, sought insurance against anticipated blackouts. Home Depot saw a surge in sales of portable, manual generators. "The sales are comparable to the Y2K scare," said a Corona Home Depot sales representative, noting that sales of portable generators had doubled since the onset of the crisis.[36]

The rush to acquire BUGs translated into a surge in permit applications submitted to California's local air regulators. In late 2001, the California Air Pollution Control Officers' Association (CAPCOA) surveyed its members to assess the effects of the crisis on BUG ownership and operation and found that "a significant number of new engines were permitted and registered in California."[37] Twelve air districts, including the five most populous, responded to a survey of new permits for BUGs. These 12 districts reported that 3,064 new diesel BUGs had been permitted since the start of the crisis, in most cases at least a 400-percent increase over previous permit activity. The CAPCOA was unable to obtain data on the use of portable generators but noted that "district inspectors have widely reported an increased presence of the registered engines in the field."

EXISTING BUGS MAY HAVE RUN MORE HOURS

Due to the lack of centralized reporting of BUGs' operating hours, less is known about how much longer BUGs ran as a result of the crisis. From the available statistical and anecdotal evidence, it appears that the average run time did increase during this period, for two reasons. First, between June 2000 and December 2001, California experienced a total of 103 hours of rolling blackouts, 796 hours of stage 3 emergencies, and 650 hours of stage 2 emergencies,[38] and many BUG owners turned to backup power during blackouts or in anticipation of them. BUGs also may have been used more often because of the ISOs frequent shutdowns of customers that had opted for the lower rates of interruptible power. Another reason that BUG use may have increased during the crisis is that their owners began testing their engines more frequently to ensure that they would be available when a blackout actually occurred.

When power supplies first became tight during the summer of 2000, the California ISOs began relying on a little known tool—interruptible contracts—to keep the lights on. Interruptible contracts are special deals usually offered to large industrial and commercial customers that agree to cut their electricity use for a limited number of hours per year in exchange for lower utility rates. Participants who fail to turn off their power when called are assessed penalties. After years of few or no curtailments, the utilities' interruptible customers were called as many as 20 times during the summer of 2000, and these calls resumed with increased frequency in December 2000 when the market meltdown began in earnest. Indeed, by February 2001 Pacific Gas & Electric (PG&E) had shut down the power of its interruptible customers so many times that it had already reached the program's annual ceiling of 100 hours. Southern California Edison (SCE) had used 50 percent of its annual limit of 25 events or 150 hours.[39] Pointing to the many years of discounted rates that these customers had received, the California Public Utilities Commission (CPUC) asked them to continue heeding the ISOs' curtailment calls voluntarily.

The ISOs' extensive reliance on the interruptible contracts, however, turned California's power shortages into a financial emergency for these customers, which were confronted with difficult choices. Some accepted the business disruptions; others simply ignored the calls and accrued penalties; and some counted on their BUGs to help them weather the service interruptions. For example, airplane parts manufacturer Moog Inc.'s Torrance operations plant first responded to SCE's curtailment calls by sending its 350 workers home, then accumulated thousands of dollars in fines, and finally looked to BUGs for economic salvation. The company leased a 1500 kW diesel generator to supplement its existing 500 kW unit. Plant operations manager Dan Aynesworth told the *Los Angeles Times*, "If we really get into a bind, we'll run the damn generators whether the air quality management district likes it or not. We won't be the only ones in this boat. I'm hoping that the gravity of this situation will allow the AQMD to relax the permitting requirements."[40]

Such choices were especially hard for local governments and other public entities participating in SCE's interruptible program. Enticed by discounts and the perception that outages were unlikely, many of them had enrolled in the program, even though they lacked the necessary operating flexibility. The result was a poor compliance rate.[41]

Faced with non-compliance penalties of $13,000 per hour, Ventura County endured 27 voluntary outages between June 2000 and February 2001.[42] The blackouts disrupted work in county offices, delayed trials and crippled the main jail. Ventura County supervisors voted in May 2001 to purchase additional diesel generators to supplement existing BUGs and ensure that back-up generation was enough to keep the county's Government Center running at 100% during the voluntary shutdowns. The generators enabled the county to stay on the discounted interruptible rate, avoiding penalties or quitting the program, which would have obliged the county to repay the more than $300,000 in discounts it received during 2001.[43]

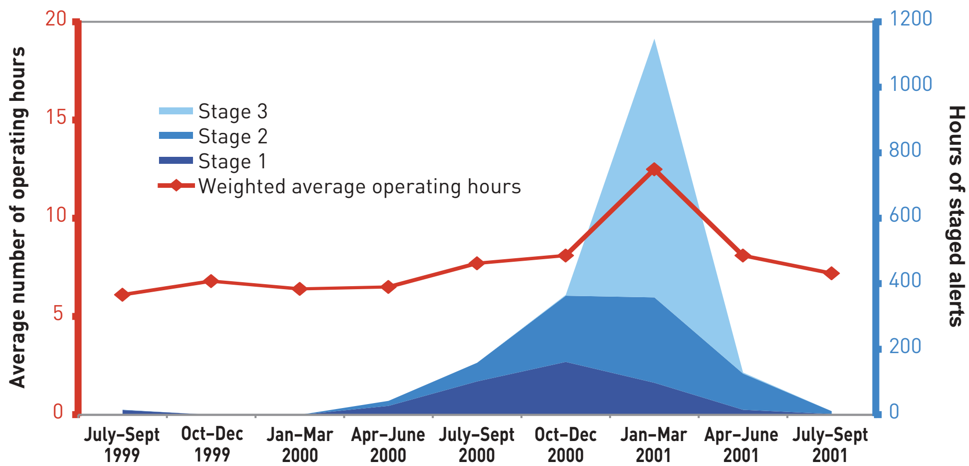
Evidence assembled by the CAPCOA and the South Coast AQMD strongly suggests that BUGs did run more hours during the crisis. The CAPCOA surveyed its members on changes in diesel fuel consumption, and the South Coast AQMD assembled a sample of data on engine run time between July 1999 and September 2001. The CAPCOA concluded that as a result of the crisis, "existing engines experienced higher than baseline use."[44] Eight of the 11 air districts that responded to the survey reported that diesel fuel use at stationary sources had risen during the crisis. The greater use of BUGs by customers in the utilities' interruptible programs may have accounted for some of the increase. CAPCOA noted anecdotal evidence that "the sources reporting the largest increases in BUG use over the baseline have these contracts in place."[45] The survey also uncovered anecdotal evidence of longer run times and operation inconsistent with permits:

Districts have also identified other examples of increased engine operation, based on reports from field inspectors, complaint investigation, and isolated observances. Examples include hospital operation to cut energy costs, banks running BUGs to guarantee secure systems, increased municipal use of BUGs for a variety of reasons, and load shedding and peak-shaving at industrial and commercial facilities, as well as residential uses.[46]

Consistent with this anecdotal evidence, the CAPCOA also noted a 15 percent statewide increase in the production and sale of CARB diesel[47], which they concluded was "significant during what is clearly an economic downturn."[48]

FIGURE 5-1

BUGs operated more during California electricity shortages, summer 2001



Source: South Coast AQMD, California, ISO.

Our analysis of the South Coast AQMD's sample of engine run-time data confirms that BUG use was higher throughout the crisis.[49] Figure 5-1 contrasts the average number of hours of BUG operation with the number of hours of stage 1, 2, and 3 alerts by quarter for July 1999 through September 2001. During each three-month period from July 2000 to June 2001, the average number of hours of BUG use was at least 20 percent higher than that during the corresponding period 12 months earlier, before the crisis started. In the first three months of 2001, the average number of hours of operation was nearly double that of the same period in 2000. January to March 2001 was the worst period of the crisis when 85 hours of rolling blackouts occurred[50] and interruptible customers were shut down most frequently. The South Coast AQMD data show that although most engines operate no more than a few dozen hours a year, a few engines run much more. A handful of engines reported operating for more than 300 hours that year. The South Coast AQMD's survey also revealed that many BUG owners do not consistently maintain the records required for enforcement, that almost one-third of the permittees reported no data for at least one quarter.

BUGS AS BLACKOUT BUSTERS

As the summer of 2001 approached, genuine supply shortages loomed, and experts predicted as many as 260 hours of rolling blackouts.[51] State government officials scrambling to secure all available electricity generation resources looked to a systematic dispatch of BUGs as a means of avoiding outages. In May 2001, Governor Gray Davis was reported to be considering issuing an executive order that would have paid BUG owners to operate during stage 3 alerts.[52] S. David Freeman, one of Davis's advisers, outlined the governor's plan: "The backup generators will help us get through the summer."[53]

In preparation for this initiative, Governor Davis directed the California Energy Commission (CEC) to investigate the generating capacity that BUGs could contribute to the grid. The CEC's investigation resulted in the creation and publication of the inventory of large (> 300 kW) BUGs that is the basis for the GIS analysis contained in this report. The inventoried BUGs, which account for fewer than a third of all the BUGs statewide, have a total generating capacity of 3233 MW, equivalent to three nuclear reactors or ten new base-load gas-fired power plants. Portable BUGs of more than 300 kW numbered 969 and added another 825 MW to the total.

Governor Davis was not alone in looking to BUGs to supplement the state's generating resources. On May 3, 2001, San Diego Gas & Electric (SDG&E) sought permission from the California Public Utilities Commission (CPUC) for a new program that would pay customers to operate their BUGs during stage 3 emergencies. The idea was that when the independent systems operators asked SDG&E to reduce its load during stage 3 emergencies, it could call on participants to switch on their BUGs instead of instituting rolling blackouts. While the program would have reduced the number of unexpected outages for San Diegans, it also would have led to the systematic operation of participating BUGs, thereby significantly increasing the surrounding population's exposure to harmful diesel emissions. The San Diego AQMD filed comments with the CPUC supporting the program.

Despite opposition from the ARB and environmental groups, the CPUC approved a modified version of SDG&E's plan, dubbed the Rolling Blackout Reduction Program.[54] By August 2001, SDG&E reported to the CPUC that it had enrolled 35 customers in the program. These customers owned 136 engines with a total potential load reduction (and hence BUG capacity) of 73.56 MW.[55]

Although most air quality regulators tried to curb BUG use during the crisis, some legislators attempted to weaken their authority and make it easier for the BUGs to run longer. In February 2001, State Senator Rico Oller (R, Granite Bay) introduced a bill that would have suspended any state or local regulations that restricted BUG operation during stage 1, 2, and 3 emergencies. This bill could have allowed hundreds of hours of BUG operation, as there were more than 500 hours of staged alerts between July and December of 2000,[56] and the shortages were expected to be much worse in 2001. Oller's proposed legislation would not only have exposed Californians to much higher BUG emissions, it would also have made taxpayers pay for the privilege. In addition, the bill would have created new incentives for Californians to buy BUGs, by providing a 100 percent tax credit for the cost of buying and installing one.[57] Fortunately, Oller's bill stalled in committee and never became law.

THE RESPONSE OF LOCAL AIR QUALITY REGULATORS

The blackout threat and financial pressures faced by interruptible customers shone a spotlight on the local air districts, which have primary jurisdiction over BUGs. The air regulators faced intense pressure to relax restrictions on the BUGs' operations to facilitate their use as blackout busters. But with a few exceptions, the districts generally held the line against an unconventional use of BUGs (to the extent permitted by their limited enforcement resources) and also helped discourage implementation of some of the more extreme measures proposed at the height of the crisis.

Some districts did, however, temporarily expand the definition of an emergency to allow BUGs to operate for extended hours. Executive orders issued by the Sacramento Metro and South Coast AQMDs allowed essential services (e.g., hospitals, police, prisons, schools) to operate their BUGs for 400 and 500 hours, respectively, during actual or imminent blackouts.[58] The San Diego AQMD and the San Joaquin Valley APCD altered their diesel BUG regulations to include independent systems operators' stage 3 emergencies, in which their operating reserve falls to less than 1.5 percent, as an acceptable circumstance for BUG operation. The South Coast AQMD expanded its emergency allowance to include both ISO stage 2 and 3 electrical emergencies and actual or imminent blackouts. These modifications of district regulations, although temporary, greatly expanded the allowance for diesel BUG operation throughout California during the summer of 2001.

DEMAND RESPONSE PROGRAMS COULD LEAD TO WIDER BUG USE

New programs being devised to prevent last year's shortages may create new incentives for the unconventional and greater use of BUGs. Many of the studies of California's energy crisis stressed the importance of expanding programs that make electricity demand more responsive to short-term price fluctuations.[59] The common theme of all these programs is creating incentives or imperatives for participating customers to curtail their electricity consumption when supplies are tight and spot prices soar. Such programs can yield both financial and environmental benefits to all ratepayers by lowering utilities' power procurement costs, reducing the operation of polluting peaking plants and deferring the building of new generating facilities.

Without proper safeguards, program participants may simply substitute energy from dirty BUGs for costly but cleaner central station power. Apparently at least some interruptible customers fired up their BUGs last year when asked to curtail their grid power use. Environmental advocates and air quality regulators recognized this risk in 2001 when the California independent systems operators were designing their summer 2001 demand relief program, which offered cash payments in exchange for load reductions during periods of peak demand. California air quality regulators successfully dissuaded the ISOs from recruiting BUG owners to participate in the demand response programs, but concerns remained that the programs might create new incentives for unauthorized BUG operation. Most California air districts do not consider compensated curtailments to be emergencies justifying BUG operation, but the ISOs' confidentiality agreements with program participants have stymied their enforcement. Air regulators have no way of knowing which permittees are participating in the ISOs' programs. ISO senior operations engineer Ali Amirali explained that "generation owners have the responsibility to work with local air districts. We leave the onus on them."[60] But CAPCOA chair Fred Thoits countered that the program created incentives that encouraged BUG owners to gamble that they wouldn't get caught, noting that "the ISO's incentives to run dwarf our fines."[61]

The role of backup generation remains a critical concern in designing demand response programs in California and elsewhere. Many utilities and independent system operators throughout the country now operate or are planning to operate such programs. Two recent studies of existing utility programs and tariffs found that customers with on-site generation (which includes, but is not limited to, BUGs) were more likely to participate in them.[62] An analysis of Duke Power's dynamic pricing program found that "customers with self-generation respond significantly to electricity prices above a threshold point at which self-generation becomes economical."[63] In a recent survey of 627 North American businesses by Primen, the market intelligence affiliate of the Electric Power Research Institute, 94 percent of those respondents who considered themselves strong candidates to acquire on-site generation in the next two years said that they "would be willing to dispatch their generators during peak demand if given the proper incentives." Among the likely adopters (more than 10 percent of those sampled), 54 percent admitted that diesel generators were their "preferred technology."[64] Unless BUG owners are explicitly prohibited from participating or air quality regulators are apprised of who they are, an increase in unauthorized BUG operation remains a potential drawback of these otherwise beneficial programs.

BUGS COULD BE USED AS "UNDER THE RADAR" DISTRIBUTED GENERATION

In addition, some BUG owners may be operating their BUGs to save money on their utility bills. The complex rate structure for the large industrial and commercial customers that are most likely to own BUGs includes both energy and demand charges. Just as it is on residential and small commercial customers' bills, the month's total energy use (measured in kilowatt-hours) is multiplied by an energy charge. Energy charges for large customers are lower than for small users, because their bills also include one or more demand charges which are calculated based on their maximum rate of consumption during peak hours. Demand charges can account for a substantial component of large customers' monthly utility bills. Within a range of realistic assumptions about fuel prices, the cost of generating electricity with a diesel BUG exceeds the energy charges for large customers. But BUG owners may be able to save by shaving their peak demand—and hence their demand charge—if they routinely run their BUG during hours when they expect their energy use to be highest. Savings are especially likely if a facility's peak energy use predictably occurs on summer afternoons, when system-wide demand is greatest and demand charges are highest. This would be the case for large office complexes whose summer demand for electricity is driven by the use of air conditioning. Large customers with sophisticated energy management systems may understand their consumption patterns well enough to devise such strategies.

CHAPTER 6

What are the health risks from BUGs?

Diesel exhaust is a significant health concern. Formed mostly in the engines' combustion process, diesel exhaust is a complex mixture of particles and hundreds of gases. Five influential governmental or scientific bodies have designated diesel exhaust as a probable or potential human carcinogen; the U.S. Environmental Protection Agency (EPA) is considering labeling it a probable human carcinogen.[65] In 1998, the California Air Resources Board (ARB) listed diesel exhaust as a toxic air contaminant (TAC).[66] Because the EPA's health assessment still is in draft form, this chapter relies on the California assessment as the most credible review to date of the health effects of diesel exhaust.

Recent studies have found that diesel exhaust contributes more than 70 percent of all cancer risk from air toxics in the Los Angeles air basin,[67] in California,[68] and in the entire United States.[69] The risk from diesel exhaust is about ten times greater than that from all other toxic air pollutants combined.[70] Diesel exhaust also has numerous acute and chronic noncancer effects on the respiratory, neurological, and immunological systems of the human body.[71] In addition, diesel exhaust contains or creates four of the six criteria air pollutants: nitrogen oxides (NOx) and volatile organic compounds (VOCs), both precursors to elevated ground-level ozone, or smog; carbon monoxide (CO); and particulate matter (PM).

By far the largest sources of diesel exhaust are mobile sources (cars, trucks, trains, etc.), but a nonnegligible fraction of diesel particulate matter is emitted from stationary engines. This category includes engines used for agricultural pumping, industrial processes, and backup electrical generation, or BUGs.[72] Because most BUGs are located in densely populated urban areas and their emissions of pollutants are relatively high, BUGs could have an amplified effect on the health risks for people living or working nearby. This chapter surveys the evidence for a range of the health effects from exposure to diesel exhaust.

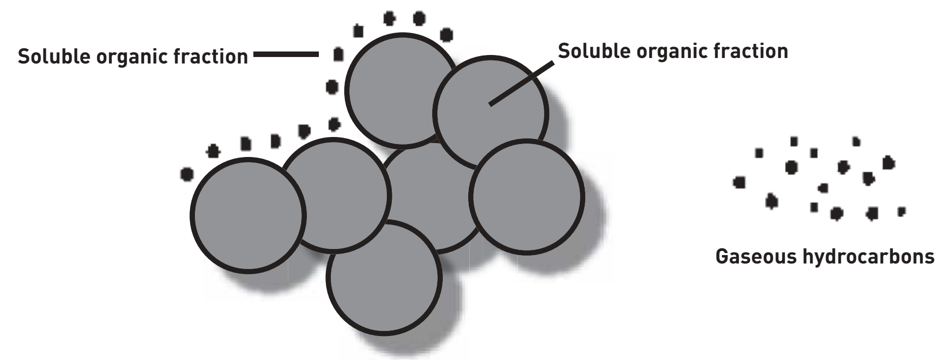
WHAT IS DIESEL EXHAUST?

Diesel exhaust occurs as a gas, liquid, or solid and is a result of the combustion of diesel fuel in a compression ignition engine. Its composition varies depending on the type of engine, the operating conditions, and the presence of a control system,[73] but it always contains both particulate matter and a complex mixture of hundreds of gases. The principal gases are nitrogen, oxygen, carbon dioxide, and water vapor, but diesel exhaust also contains carbon monoxide, nitrogen oxides, volatile hydrocarbons, and low-molecular-weight polycyclic aromatic hydrocarbons (PAH) and PAH-derivatives, some of which are known or suspected to cause cancer.[74]

Diesel particulate matter (DPM) is actually not one solid particle but groups of spherical carbon particles clustered together to form irregular shapes (see Figure 6-1). The elemental carbon core can also contain small amounts of trace metals.

By the time the diesel exhaust is released into the atmosphere, some of the gases are present as vapors ("Gaseous Hydrocarbons" in Figure 6-1), while others stick onto the surface of the particles (the "Soluble Organic Fraction"). Because of its large surface area, DPM can adsorb large amounts of organic materials, some of which have been identified as mutagenic or carcinogenic.

FIGURE 6-1
Schematic of diesel particulate matter



Sources: California Office of Environmental Health Hazard Assessment/Air Resources Board, "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant," P. ES-5.

Particles are released from diesel vehicles about 20 times faster than those emitted by comparable gasoline-powered vehicles,[75] a rate that may also apply to stationary diesel-powered engines. DPM is typically fine (< 2.5 microns) or ultrafine (< 0.1 micron) in size; most of diesel exhaust particle mass has a diameter of less than 10 microns, 94 percent less than 2.5 microns, and 92 percent less than 1.0 microns.[76] While most of the mass of DPM ranges from 0.1 to 1.0 microns, the majority of the particles (by number) are smaller than 0.1 micron. These "ultrafine" or "nanoparticles" have a greater surface area for a given mass and thus affect a larger surface area of lung tissue than does an equal mass of larger particles.[77] Because of the preponderance of small particles, DPM is easily inhaled deep into the lungs' bronchial and alveolar regions, where their clearance is slow compared with that of particles deposited on airways.[78] Exposure to diesel exhaust is mainly a result of inhalation, with an undetermined but likely insignificant fraction from ingestion or through the skin.

More than 40 gaseous and particulate constituents of diesel exhaust are listed as hazardous air pollutants by either the U.S. Environmental Protection Agency or the California Air Resources Board as toxic air contaminants (see Table 6-1). At least 21 of these substances are listed by the state of California as known carcinogens or reproductive toxicants.

HEALTH EFFECTS OF VARIOUS COMPONENTS OF DIESEL EXHAUST

An uncontrolled diesel engine emits 30 pounds of nitrogen oxides per megawatt-hour of electricity produced (lbs/MWh), whereas a comparable natural gas engine without controls emits 5.9 lbs/MWh.[79] Diesel engines also contribute significantly to particulate pollution. In California, diesel exhaust contributes 3 and 8 percent of the total statewide inventories of PM10 and PM2.5, respectively.[80] Of this amount, stationary and portable diesel electricity generators—the category that includes BUGs—account for approximately 7 percent.[81] Because of the low number of hours that BUGs are allowed to operate, they are estimated to contribute only 0.5 percent of the total. But BUGs' contribution to the overall health impacts of diesel pollution may significantly exceed their share of emissions because they tend to be located in densely populated areas.

TABLE 6-1

Toxic air contaminants and hazardous air pollutants found in diesel exhaust

Acetaldehyde*	Chlorine	Methyl ethyl ketone
Acrolein	Chlorobenzene	Naphthalene*
Aluminum	Chromium compounds*	Nickel*
Ammonia	Cobalt compounds*	4-nitrobiphenyl*
Aniline*	Copper	Phenol
Antimony compounds*	Cresol	Phosphorus
Arsenic*	Cyanide compounds	POM (including PAHs)
Barium	Dibenzofuran	Propionaldehyde
Benzene*	Dibutylphthalate	Selenium compounds*
Beryllium compounds*	Ethyl benzene	Silver
Biphenyl	Formaldehyde*	Styrene*
Bis [2-ethylhexyl]phthalate*	Hexane	Sulfuric acid
Bromine	Lead compounds*	Toluene*
1,3-butadiene*	Manganese compounds	Xylene isomers and mixtures
Cadmium*	Mercury compounds*	Zinc
Chlorinated dioxins*	Methanol	

*This compound or class of compounds is known by the state of California to cause cancer or reproductive toxicity. See California EPA, Office of Environmental Health Hazard Assessment, "Chemicals Known to the State to Cause Cancer or Reproductive Toxicity," May 31, 2002.

Note: This list of toxic air contaminants either have been identified in diesel exhaust or are presumed to be in the exhaust, based on observed chemical reactions and/or presence in the fuel or oil. See California Air Resources Board, "Toxic Air Contaminant Identification List Summaries, Diesel Exhaust," September 1997, available online at http://www.arb.ca.gov/toxics/tac/factshts/diesex.pdf.

While much of the recent regulatory attention has focused on "whole diesel exhaust" and DPM, many of the individual components of diesel exhaust have health impacts worth noting. Diesel exhaust is found in ambient concentrations of NOx and VOCs, both of which are harmful to the respiratory system.[82] With the addition of sunlight, these chemicals combine to form ground-level ozone, or smog, a known lung irritant linked to asthma attacks and respiratory illnesses.

Particles with a median aerodynamic diameter of less than 10 micrometers (PM10) have been epidemiologically associated with many adverse health effects, including asthma attacks in patients with preexisting asthma; admission to hospitals for cardiovascular and respiratory causes; and deaths from heart attacks, strokes, and respiratory causes.[83] Other studies have shown that the association between PM exposure and premature death is stronger for particle diameters of less than 2.5 microns (PM2.5) than for PM10.[84] Researchers estimate that as many as 60,000 Americans die prematurely each year because of exposure to fine particles.[85] Because diesel BUGs emit fine particles at extremely high rates, these findings are especially worrisome for those exposed to high concentrations of diesel particulate matter.

HEALTH EFFECTS OF WHOLE DIESEL EXHAUST AND DIESEL PARTICULATE MATTER

Although the toxic contribution of each of the gaseous components of diesel exhaust is substantial, the EPA concluded that the total carcinogenic effect estimated for all these compounds does not account for the complete carcinogenic effect of whole diesel exhaust.[86] Only 50 to 90 percent of the mutagenic potency of whole diesel exhaust, however, is associated with DPM.[87] While neither the gas phase nor the solid phase alone explains the potency of diesel exhaust, studies often use DPM as a surrogate measure for exposure to whole diesel exhaust. Thus, depending on the study cited, the concentration of either whole diesel exhaust or DPM is used as the exposure metric.

Acute health effects

Even a brief exposure to diesel exhaust can have immediate respiratory, neurological, and immunological effects. Healthy volunteers exposed to diesel exhaust for one hour showed a significant increase in airway resistance and increases in eye and nasal irritation.[88] Other symptoms caused by exposure to diesel exhaust include coughs, headaches, light-headedness, and nausea.[89] Epidemiological studies of occupationally exposed individuals (e.g., bus garage workers and miners) found decreased lung function, increased cough, labored breathing, chest tightness, and wheezing.[90] Although all epidemiological studies of workers have limitations—especially in regard to information about their exposure—they consistently show respiratory impairment and corroborate similar findings in animal studies.[91]

Some experts believe that air pollution in general and DPM in particular may be a cause of the greater incidence of asthma and other allergic respiratory disease.[92] Furthermore, exposure to DPM can induce allergic reactions and localized inflammation in humans.[93] Even more interesting, simultaneous exposure to DPM and ragweed pollen causes an allergic response greater than that from exposure to either pollutant alone; similar results were found with Japanese cedar pollen in animals.[94] There also is some evidence that DPM exposed to ozone (at levels similar to those found in polluted urban air) has an enhanced inflammatory effect on rat lungs compared with DPM not exposed to ozone.[95] If confirmed, this result could mean that DPM in polluted regions, like many in California, is much more potent than previously believed.

Chronic noncancer health effects

A number of chronic health effects have been associated with exposure to diesel exhaust, although the evidence for humans is more limited than it is for acute effects. Some studies have found that long-term exposure in occupational settings produced a greater frequency of bronchitic symptoms, cough, phlegm, and reductions in lung function.[96] Test animals provided additional results, including chronic inflammation of lung tissue and reduced resistance to infection in rats, as well as significant noncarcinogenic pulmonary effects from long-term exposure in rats, mice, rabbits, guinea pigs, and primates.[97] Based on the animal studies, the EPA established a chronic inhalation reference concentration (RfC) of 5 micrograms per cubic meter ($\mu g/m^3$); California's Reference Exposure Level (REL) is set at the same concentration. An RfC or REL is the concentration below which no noncancer adverse health effects are likely to occur from a lifetime exposure (70 years), taking into account sensitive populations.

Carcinogenicity

Numerous governmental agencies and scientific bodies have determined the cancer-causing potential of exposure to diesel exhaust. Even though all acknowledge the

TABLE 6-2
History of determinations of the carcinogenicity of diesel exhaust

Agency	Year	Determination
National Institute for Occupational Safety and Health (NIOSH)	1988	Potential occupational carcinogen
International Agency for Research on Cancer (IARC)	1989	Probable human carcinogen
State of California (under provisions of Proposition 65)	1990	Known by the state to cause cancer
Health Effects Institute (HEI)	1995	Potential to cause cancer
American Council of Government Industrial Hygenists (ACGIH) (proposed)	2001	Suspected human carcinogen
World Health Organization International Programme on Chemical Safety (WHO-IPCS)	1996	Probable human carcinogen
California Air Resources Board (ARB)	1998	Toxic air contaminant (determination based substantially on the cancer risk to humans)
U.S. Environmental Protection Agency (EPA) (proposed)	2000	Probable human carcinogen
U.S. Department of Health and Human Services National Toxicology Program (U.S. DHHS/NTP)	2000	Reasonably anticipated to be human carcinogen

Sources:
National Institute for Occupational Safety and Health, "Carcinogenic Effects of Exposure to Diesel Exhaust," *Current Intelligence Bulletin* 50 (August 1988). Available online at http://www.cdc.gov/niosh/88116_50.html.
International Agency for Research on Cancer (IARC), *Diesel and Gasoline Engine Exhausts and Some Nitroarenes*. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, no. 46 (Lyons: World Health Organization, 1989), pp. 41–185.
California Environmental Protection Agency, Chemicals Known to the State to Cause Cancer or Reproductive Toxicity (Proposition 65, 1997), revised May 31, 2002.
Health Effects Institute, *Diesel Exhaust: A Critical Analysis of Emissions, Exposure and Health Effects* (Cambridge, MA: Health Effects Institute, 1995). Available online at http://www.healtheffects.org/Pubs/diesum.htm, accessed on January 20, 2002.
American Conference of Governmental Industrial Hygienists, "Documentation of the Threshold Limit Values and Biological Exposure Limits, Notice of Intended Changes," 2001.
International Programme on Chemical Safety, World Health Organization, "Diesel Fuel and Exhaust Emissions," *Environmental Health Criteria* 171 (1996).

need for further research, especially on humans, the emerging consensus is that on the basis of limited human studies and more robust animal findings, diesel exhaust is a probable human carcinogen (see Table 6-2).

Dozens of epidemiological studies have found evidence consistent with a causal relationship between diesel exhaust exposure and lung cancer.[98] These studies formed the basis for most of the determinations cited in Table 6-2, including that of the California ARB. Two metanalyses statistically examined the results of 23 to 30 epidemiological studies[99] and concluded that the increased risk of lung cancer associated with long-term, occupational exposures was, on average, 40 percent,[100] with higher risks in more heavily exposed subgroups.[101] While this level of elevated risk is considered weak evidence for causality, after extensive evaluation in their review of the toxicity of diesel exhaust, the California Office of Environmental Health Hazard Assessment (OEHHA) determined that the association was unlikely due to bias, confounding (e.g., cigarette smoking), or chance.[102] However, because most of these studies used inadequate measures of exposure, uncertainties remain as to whether diesel exhaust fully explains the cancer incidence observed.[103]

The composition of diesel exhaust and the results of animal and bioassay studies provide additional evidence of its carcinogenicity. For example, DPM or extracts from DPM are mutagenic in bacteria and mammalian cell systems.[104] Many other studies have shown that diesel exhaust causes mutation in chromosomes and damage to DNA, processes that are believed to be important to the causation of cancer.[105] The carcinogenicity of diesel exhaust has been demonstrated in test animals based on inhalation bioassays in the rat and, with less certainty, in mice.[106] But even though rats show a consistent lung tumor response, mice and hamsters have not demonstrated the same response.[107] Because of uncertainties in extrapolating results in animals to humans and in the animal results themselves, OEHHA decided to base its risk estimates on the human data.[108]

SPECIAL RISKS TO VULNERABLE SUBPOPULATIONS

Even more susceptible to the health effects of diesel exhaust are vulnerable groups, such as children, the elderly, the infirm (especially those who have existing respiratory problems), and those who have predisposed their lungs to increased particle retention (e.g., from smoking, high particulate burdens from nondiesel sources).[109] Recently, many researchers explored why children are an especially sensitive subpopulation. Air pollution affects children more than adults because they inhale more pollutants per pound of body weight and have a more rapid rate of respiration, narrower airways, and a less mature ability to metabolize, detoxify, and excrete toxins.[110] Children also spend more time outdoors engaged in vigorous activities;[111] athletes are similarly susceptible for this reason. Exposures that occur in childhood are of special concern because children's developmental processes can easily be disrupted and the resulting dysfunctions may be irreversible.[112] In addition, exposures that occur early in life appear more likely to lead to disease than do exposures later in life.[113]

HEALTH RISK ASSESSMENTS

The health risks of exposure to diesel exhaust are great. In fact, OEHHA stated that the "long-term exposure to diesel exhaust particles poses the highest cancer risk of any toxic air contaminant evaluated by OEHHA."[114] The first major study to investigate the contribution of diesel exhaust to people's exposures to toxic air pollutants was the Multiple Air Toxics Exposure Study (MATES-II), conducted by the South Coast Air Quality Management District in 1998 and 1999. The results were alarming: fully 70 percent of the cancer risk from air toxics for those living in the Los Angeles air basin (one of the most polluted in the country) was due to diesel particulate emissions alone.[115] As a result of this finding, the ARB expanded the study to include all of California. The findings were similar: about 70 percent of the total inhalation cancer risk from air toxics for the average Californian is due to diesel exhaust (see Table 6-3). This result is slightly lower than the estimate for the United States as a whole: 80 percent of the total cancer risk from all hazardous air pollutants is associated with the inhalation of diesel exhaust.[116]

A concentration below which no carcinogenic effects are anticipated has not been determined.[117] Based on the California exposure estimates, OEHHA calculated the range of cancer unit risk to be 1.3×10^{-4} to 2.4×10^{-3} $(\mu g/m^3)^{-1}$, with 3×10^{-4},

TABLE 6-3

Estimated statewide average potential cancer risk from outdoor ambient air levels of air toxics for the year 2000

Compound	Potential cancer risk* excess cancers/million	Percent contribution to total risk
Diesel exhaust PM10	540	71.2
1,3-Butadiene	74	9.8
Benzene	57	7.5
Carbon tetrachloride	30	4.0
Formaldehyde	19	2.5
Hexavalent chromium	17	2.2
Para-dichlorobenzene	9	1.2
Acetaldehyde	5	0.7
Perchloroethylene	5	0.7
Methlene chloride	2	0.3
TOTAL	758	100.0

*Diesel exhaust PM10 potential cancer risk is based on 2000 emission inventory estimates. All other potential cancer risks are based on air toxics network data: 1997 data were used for para-dichlorobenzene, and 1998 monitoring data were used for all others. Measured concentrations are assumed to be equivalent to annual average concentrations, and the duration of exposure is 70 years, inhalation pathway only.

Source: California Air Resources Board, "Diesel Risk Reduction Plan," October 2000, p. 16.

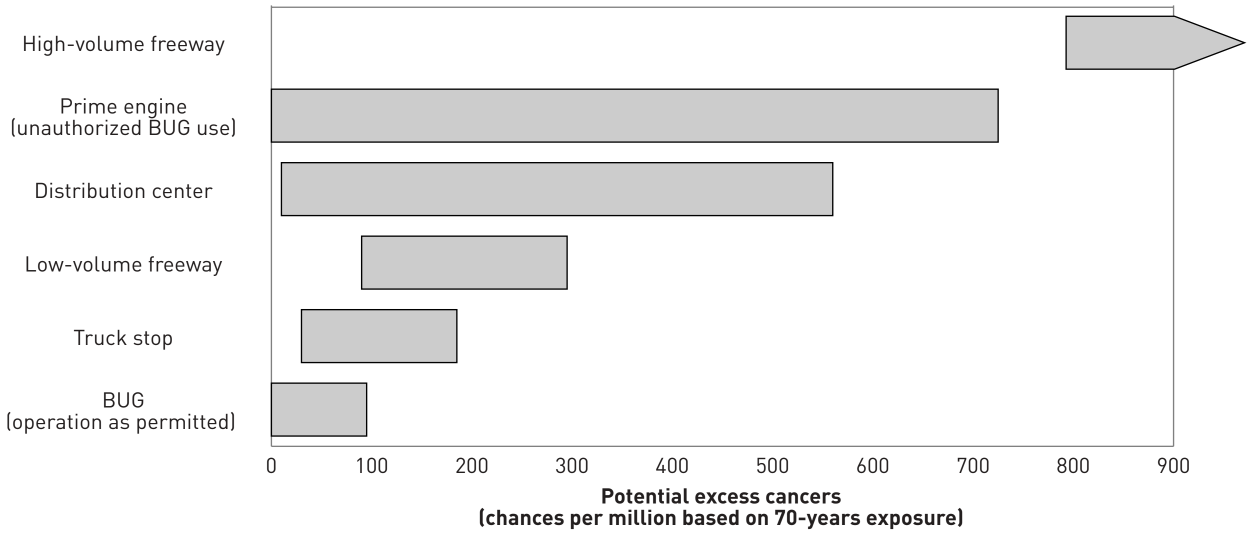
or, equivalently, 300 cases per million per (μg g/m^3), as a reasonable point estimate.[118] A cancer unit risk represents the probability of a person's contracting cancer (at the 95 percent upper confidence limit) as a result of constant exposure to an ambient concentration of diesel exhaust of one microgram per cubic meter over a 70-year lifetime.

The population time-weighted average diesel exhaust exposure concentrations across all environments (both indoors and outdoors) in California is estimated by OEHHA to be 1.54 μg/m^3 in 1995 (2.2 μg/m^3 outdoors and 1.5 μg/m^3 indoors).[119] OEHHA acknowledges that its analysis underestimates the true exposure because of the lack of data for areas with elevated exposures. An organization of air quality control officers used the California data to estimate the concentration of diesel exhaust throughout the country and found that on average, other metropolitan areas would have concentrations one-half that of Los Angeles, and nonmetropolitan areas, one-tenth that of Los Angeles.[120]

Based on their exposure concentration estimates, OEHHA estimates that the number of potential additional cancer cases in California is 200 to 3,600 per year (assuming a 70-year lifetime exposure to diesel exhaust) at the exposure concentrations that it calculated.[121] State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officers (STAPPA/ALAPCO) used their national estimates of the exposure concentrations along with the California unit risk factor and estimated that across the United States, 125,000 additional cancers are caused by exposure to diesel exhaust.[122]

These cancer-risk figures are derived from averages and, as such, do not represent individuals' actual exposures, nor do they take into account the greater susceptibility of some groups, such as children, those with preexisting conditions, and the elderly. In 1989, the National Institute for Occupational Safety and Health (NIOSH) estimated that 1.35 million workers were occupationally exposed to

FIGURE 6-2
Potential cancer risk range for activities using diesel-fueled engines



Source: California Air Resources Board, *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles*, app. 5, p. 17, October 2000.

diesel exhaust, many at significantly elevated levels.[123] Owing to population and economic growth, the numbers exposed today are probably much higher. Concentrations of diesel exhaust PM10 near freeways can reach as high as 10 μg g/m^3,[124] and concentrations in occupational and other near-source settings may be even higher.[125] Thus, individuals can be exposed to much greater cancer and noncancer risk depending on where they live and work.

The ARB analyzed seven typical activities in which diesel-fueled engines are used and calculated the potential range of excess cancer risks; the results can be seen in Figure 6-2.[126] They wanted to find out whether the operation of certain diesel-fueled engines could expose nearby individuals to locally elevated DPM concentrations. Their estimates assumed a 70-year exposure by the maximally exposed individual at current concentrations. Ranges in the results are the result of variations in assumptions of operating durations, stack parameters, facility sizes, and meteorological conditions, among other things. As can be seen from these results, being exposed to emissions from diesel BUGs could lead to an additional 100 cancers per year in a population of 1 million people, or 1 in 10,000; if those same diesel engines were operated as prime engines (increasing their hours of operation from less than 100 to several hundred hours per year), the excess cancer risk would increase nearly tenfold.

CHAPTER 7

How close is too close?

When a BUG is running, the people nearby are exposed to more harmful diesel emissions than are the people living and working farther away. Our initial GIS analysis, presented in Chapter 3, showed that BUGs tend to be clustered in parts of California where both residential and worker populations are most dense. A question that naturally follows is, how close is too close? Put in another way, how large is the "risk zone" (the area surrounding a BUG in which people will be exposed to incremental concentrations of diesel pollution that result in acceptably high health risks)? Other questions are, what are the most important health risks inside the risk zone, and how important are they? This chapter presents the results of studies commissioned by Environmental Defense that explored these questions.

While exposures to fine particles—and health risks—are greatest in the immediate vicinity of a BUG, its emissions are dispersed into the atmosphere and contribute to the background, or ambient, concentration of diesel pollution in the air basin in which it is located. A second question that Environmental Defense examined was how much the increased operations of BUGs would contribute to the overall exposure to diesel particulate matter and the associated mortality statewide. This analysis concluded that even if the run time of California's more than 11,000 BUGs averaged as few as 25 hours per year, at least 20 deaths per year would be attributable to BUG emissions. Many more deaths would result each year with an increase in the annual average number of operating hours, which could result from the systematic dispatch of BUGs as a peaking resource or from the extended (i.e., by several hundred hours) operation of a few BUGs in violation of permit restrictions.

METHODS

The health risk from toxic air contaminants emitted from diesel BUGs can be estimated as the product of three elements: (1) the quantity of contaminant released, (2) the increase in exposure concentration per unit release, and (3) the risk of adverse effect per unit increase in exposure concentration. The first element is determined by multiplying an emission factor by the amount of engine use. The emission factor indicates the amount of pollutant emitted per unit of engine use. Air dispersion models are used to evaluate the second element, which is based on information about the emission's characteristics and meteorology. The third element is addressed by toxicity values, which quantify the risk of an adverse health outcome's occurring because of exposure to toxic substances such as diesel particulate matter (DPM) and its constituents.

Government data on emissions factors and a regulatory-approved air dispersion model were used to estimate exposures from BUG operations. Environmental Defense commissioned Air Resource Specialists (ARS) from Fort Collins, Colorado, to conduct air dispersion modeling of generic BUGs using weather data from five California cities. Emission factors (EFs) were taken from the EPA's compilation of emission factors, known as AP-42.[127] The specialists used a standard air dispersion model, Industrial Source Complex (ISC),[128] to predict the increases in the ambient concentration of diesel pollutants owing to atmospheric emissions from individual diesel BUGs. ISC is a regulatory-approved model typically used (e.g., when permitting new sources) to determine the impact of emissions on the surrounding community. Additional information on dispersion modeling and the analysis performed by ARS is contained in Appendix B.[129]

Toxicity factors were derived from government sources and academic publications. The initial phase of this process was a screening analysis of the various health risks associated with exposure to BUG emissions. The purpose of this preliminary screening was to review the published literature on health risks from diesel emissions in order to (1) identify the substances and health end points for which the risk from BUG operations was greatest, and (2) determine toxicity factors for these substances and end points to use in the health risk assessment. This analysis was performed by researchers from the University of California at Berkeley, who also conducted the health risk assessment described later in this chapter.[130] Their findings are summarized next and described in greater detail in Appendix B.

The screening analysis encompassed three health risks typically considered in a health risk assessment for toxic air contaminants and that have associated toxicity values: acute, chronic cancer, and chronic noncancer risks. *Acute health risks* are those resulting from short-term exposure, usually defined as less than 14 days, whereas *chronic health risks* are associated with long-term exposures, usually defined as longer than three months. The screening analysis also included an assessment, based on recent epidemiological evidence, of a new category: direct mortality effects due to the inhalation of particulate matter. A growing body of scientific literature has demonstrated that elevated ambient PM levels correlate with increased rates of morbidity and mortality in exposed populations.

This screening analysis determined that the direct PM mortality risk poses the single largest concern for the health effects of diesel BUG emissions. In addition, of the three types of health risks typically considered in a risk assessment (acute, chronic cancer, and chronic noncancer), chronic cancer risk poses the largest public health concern. This finding was based on a comparison of published values for chronic cancer and chronic noncancer toxicity. The most stringent constraint appears to be the cancer risk for diesel particulate matter, which is a mixture of many different chemical species. Based on the available data—which are quite limited—acrolein was identified as the specific chemical constituent of diesel exhaust most likely to cause acute health effects.

A toxicity value for direct PM mortality risk was derived using information from peer-reviewed literature for populationwide exposure surveyed in an article by the chairperson and the chief deputy executive officer of the California Air Resources Board (Lloyd and Cackette 2001). Based on Lloyd and Cackette's estimated health outcome of 3,566 deaths/year in California owing to average ambient levels of 1.8 $\mu g/m^3$ of direct PM2.5, and a state population of 33 million, Environmental Defense's consultants estimated that the toxicity was 60 deaths per million per year per $\mu g/m^3$.[131] Lloyd and Cackette based their estimates of the health effects from DPM on epidemiological studies that investigated the link between ambient PM2.5 and population mortality. Given the size and chemical composition of DPM, it is probably more toxic than ambient PM2.5. Thus, while the studies that Lloyd and Cackette cited probably represent the best available evidence of the risk of direct mortality effects from DPM exposure, the values they used were based on studies of ambient PM2.5, and they therefore may have underestimated the true hazard posed by DPM. The values that Lloyd and Cackette derived represent the risk to the general public. But the risks to sensitive populations are likely to be even greater than for the general public. For diesel PM, we expect the list of sensitive populations to include young people, the elderly, and the infirm. It is important to note that this mortality risk is *in addition to* the other effects calculated in this report (e.g., the chronic cancer risk).

Toxicity for chronic cancer risk is typically expressed as the lifetime (70 years) risk of excess cancer cases per unit of exposure concentration. This value is multiplied by the lifetime average exposure concentration to obtain the incremental cancer risk. According to the California EPA, the cancer risk potency of diesel exhaust is 300 per million per $\mu g/m^3$. This means that chronic exposure to one $\mu g/m^3$ would yield a lifetime excess cancer risk of 300 cases per million people so exposed.

An important difference between the direct PM mortality risk and the chronic cancer risk is that the former is calculated based on one year of exposure, whereas the later is calculated based on 70 years of exposure. While the PM2.5 risk value of 60 per million per $\mu g/m^3$ appears to be five times lower than the DPM chronic cancer toxicity (300 per million per $\mu g/m^3$), the former occurs after only one-seventieth of the exposure, and thus after only one-seventieth of the intake. Therefore, the direct mortality risk is estimated to be 14 times higher than the chronic cancer risk (60 $\mu g/m^3$ x 70 years of exposure equals 4,200 deaths per million exposed per $\mu g/m^3$, which is 14 x the chronic cancer risk of 300 per million exposed per $\mu g/m^3$).

PARTICULATE MATTER EXPOSURE FROM BUG OPERATION

ARS conducted air dispersion modeling for Fresno, Los Angeles, Sacramento, San Francisco, and San Diego to find ground-level concentrations of PM10 on a grid surrounding a generic BUG.[132] Then ARS developed three sets of results for each model run:

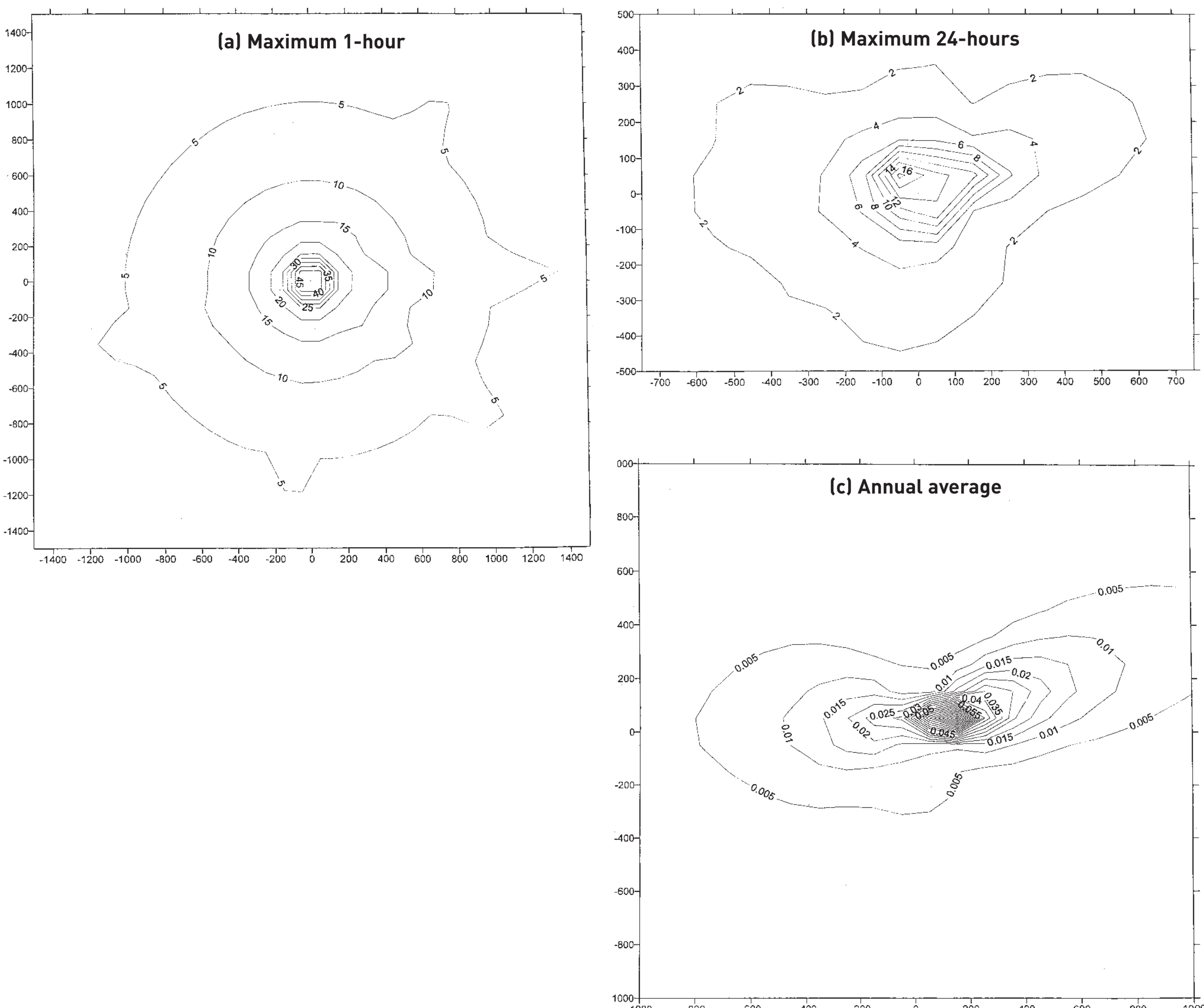
- The *annual average*, which is used to evaluate the chronic cancer risk from exposure to diesel particulate matter. These results were also used to estimate the direct mortality risk of PM2.5 exposure. Other chronic cancer and chronic noncancer risks were not evaluated because the available evidence indicated that they were less stringent than the chronic cancer risk from DPM.
- The *maximum 24-hour average*, which is used to evaluate the likelihood of exceeding the state of California's 24-hour PM10 standard of 50 $\mu g/m^3$.
- The *maximum 1-hour average*, which is used to evaluate acute risks for acrolein and total PAH.

As illustrated in Figure 7-1, the results of air dispersion modeling are typically presented as isopleth maps. Like a topographic map, which uses contour lines to represent a three-dimensional landscape in two dimensions, isopleth maps show how the average concentration of a pollutant diminishes when moving away from the source.

Panels A, B, and C of Figure 7-1 present isopleth maps for PM10 emissions from a 500 hp engine located in Los Angeles for 1-hour, 24-hour, and 1-year averaging periods, respectively. The 1-year averages represent *average* modeled concentrations, and the 1-hour and 24-hour concentrations represent the *highest* modeled concentration of PM10 at each point on the receptor grid. Note that the maximum modeled concentrations at various points on the receptor grid may occur at different days or hours, so the isopleth maps do not represent a snapshot of concentrations for any particular day or hour. Instead, panels A and B summarize extreme conditions over time and so are useful for determining whether regulatory limits for maximum exposures may be exceeded at the site. Panel C, an annual average isopleth map, represents the average conditions in the vicinity of a BUG over all hours in a year. This type of map is most useful for understanding the contribution of cumulative exposures to chronic health effects.

Note that even though the figures are for the same location, they differ markedly in both shape and orientation. The isopleths of maximum 1-hour and 24-hour concentrations occur in a roughly circular shape around the BUG. The

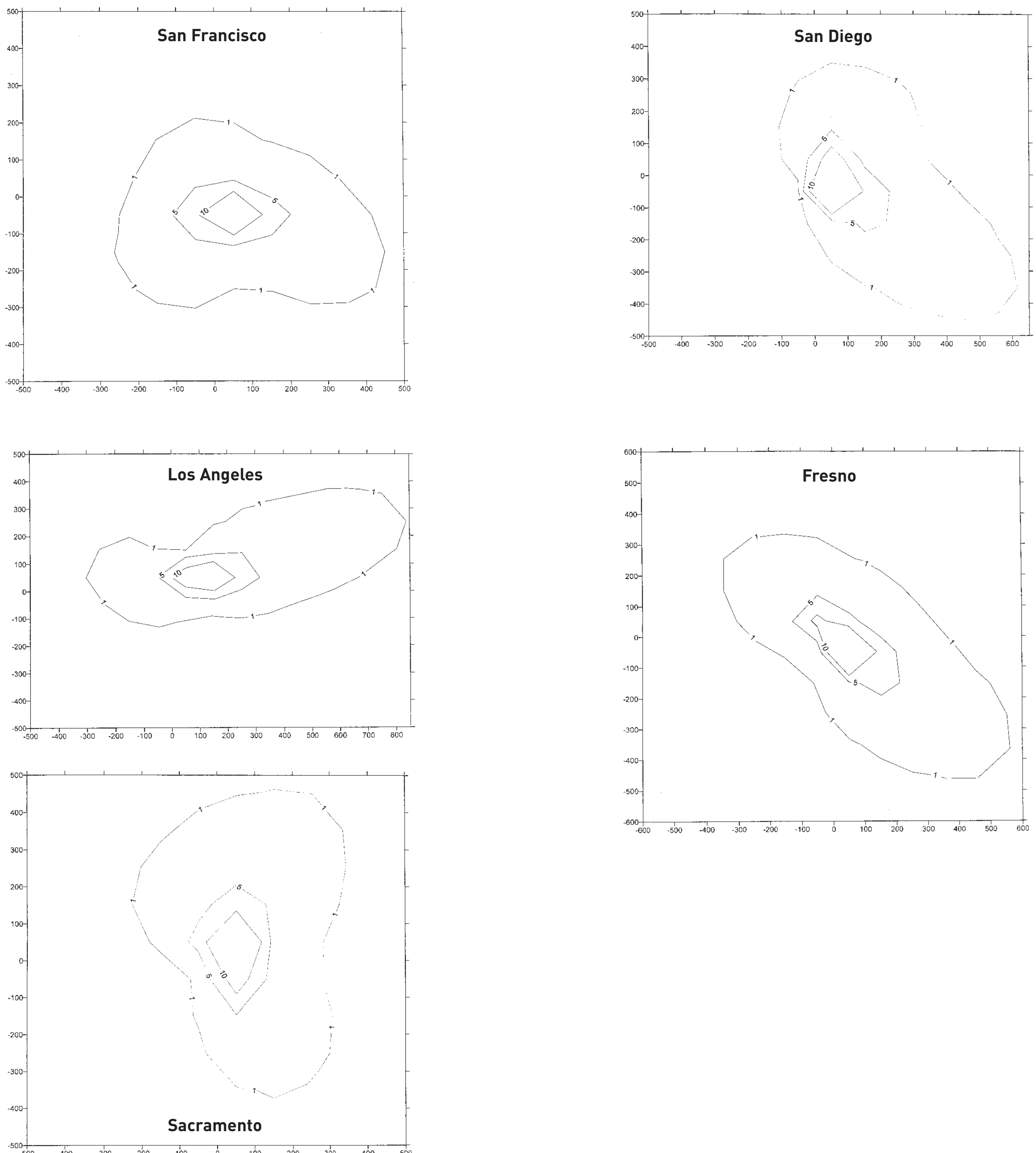
FIGURE 7-1
PM concentration (μg/m³) isopleths for a generic 500hp BUG in Los Angeles



Note: Grid measures distance from BUG in meters.

FIGURE 7-2

Cancer risk isopleths for a generic 500hp BUG running 100 hours per year



Notes: (1) Grid measures distance from BUG in meters. (2) Isopleth lines show incremental cancer risk per million resulting from BUG operation.

upwind and downwind concentrations are similar because the meteorology that leads to the maximum 1-hour and 24-hour concentrations at a given distance is likely to occur at least once during a year when the wind is blowing from any direction. In contrast, the annual average concentrations tend to be higher in the prevailing downwind direction. The reason is that the meteorology at a specific location tends to follow consistent patterns over the course of a year. The case illustrated in panel C of Figure 7-1 shows that the winds in Los Angeles blow most often from west to east but that the next most common direction is east to west. Therefore, the risks from chronic exposures in this region are concentrated in a west-to-east corridor in the vicinity of the emissions.

BOUNDING THE RISK ZONE

By combining the results of the dispersion modeling with toxicity factors for DPM, ARS was able to address the question, how close is too close? To summarize the results of the dispersion modeling and facilitate its integration with the GIS-based BUG inventory, Environmental Defense used the concept of a risk zone.

A *risk zone* is defined as the farthest distance away from the BUG when the incremental chronic cancer risk from the BUG's operation exceeds one per million. This definition of the risk zone is consistent with existing regulatory benchmarks, which establish the risk level that is small enough to be considered insignificant, or *de minimus*. For example, the California EPA defines *de minimus* to be one per million or fewer for chronic cancer risks,[133] and OEHHA uses a risk of one per million to define risk zones in analyzing urban-air toxic "hot spots."[134] The 1990 Clean Air Act allows sources to be exempt from regulation and residual risk to be considered negligible when posing a risk of fewer than a one in a million to the most exposed individual.[135] In some instances, though, even a chronic cancer risk of less than one per million may not be considered insignificant.[136]

To determine the extent of the risk zones, it was necessary to translate the results from the dispersion modeling, which are expressed as the concentration of DPM in the vicinity of the modeled BUGs (measured in $\mu g/m^3$), into chronic cancer risk. This was accomplished by multiplying the modeled annual-average concentration of DPM by OEHHA's toxicity factor of 300 excess cancer cases per million per $\mu g/m^3$ of DPM. Figure 7-2 illustrates the results of this calculation for a 500 hp BUG running 100 hours per year during business hours (7:00 A.M. to 7:00 P.M.). The figures present isopleth maps for five California cities expressed in terms of excess chronic cancer risk. In each diagram the contour line labeled "1/million" represents the boundary of the area in which the incremental cancer risk from BUG operation under that scenario is *at least* one per million. This means that within that area, operation of the BUG increases each exposed individual's preexisting probability of contracting cancer by a factor of 1/1,000,000 over a 70-year lifetime. It is important to note that the overall health risk in this area is actually much greater than one in a million, because the direct PM mortality risk is so much greater than the chronic cancer risk.

As illustrated in Figure 7-2, the risk zone may extend hundreds of meters downwind of a BUG. Table 7-1 shows that the size of the risk zone depends on how a BUG is operated, which varies among air districts because of the differences in meteorology. The table summarizes the risk zone parameters for a 500 hp engine for the five cities and three operating scenarios. In general, the risk zone grows larger as the number of operating hours rises. The reason is that the cumulative annual emissions climb in proportion to the number of hours of operation, raising the total annual exposure at each point around the BUG. As annual exposures increase at every point on the receptor grid, people farther and farther from the BUG receive greater exposures, and the distance to a *de minimus* exposure lengthens. Appendix B contains a table summarizing this risk zone analysis for additional operating scenarios for both 500 and 1500 hp engines.

Operating BUGs for more than 200 hours per year is not typical, nor is it generally consistent with permit restrictions. However, as discussed in Chapter 5, the systematic dispatch of BUGs to avert blackouts during California's recent electricity shortages may have meant that some BUGs ran as long as 500 hours, mainly during summer afternoons. Furthermore, the available evidence suggests that some BUG owners have, and in some instances responded to, economic incentives to substitute energy from their BUG for grid power. The systematic operation of a BUG as distributed generation would mean that BUGs would run for hundreds or more hours a year. This case is represented in Table 7-1 as Operation as Distributed Generation. Note that while the downwind distance to the risk zone boundary increases with the number of operating hours, this trend does not occur in the upwind direction. The reason is that the scenarios differ in both the number of operating hours and when those hours occur.[137]

In order to extrapolate this analysis to the entire BUG inventory for each air district analyzed,[138] Environmental Defense developed a simplified summary measure of the risk zone. As illustrated in Figure 7-3, we substituted offset circles for the irregularly shaped one-per-million contour lines shown in the isopleth maps. The circles are offset in the direction of the prevailing wind direction, and their diameter equals the sum of the distance to the one-per-million contour line in the upwind and downwind directions. Although the risk zone circles in some places lie outside the one-per-million cancer risk boundary (since these tend to be somewhat elliptical), much if not all of the area they contain still has much more than a one-per-million overall health risk owing to the added risk of direct PM mortality.

TABLE 7-1
Risk zone radii, or distance to one per million risk in meters

	South Coast		San Francisco		San Joaquin Valley		San Diego		Sacramento	
	Downwind	Upwind	Downwind	Upwind	Downwind	Upwind	Downwind	Upwind	Downwind	Upwind
Scenario/wind direction	NE	SW	SE	NW	SE	SW	SE	NW	NE	SW
Operation as permitted 100 hours, per year 7 A.M.—7 P.M.	410	160	410	220	660	120	650	120	500	90
Summer 2001 BUG dispatch 500 hours per year 12—6 P.M. June—Sept. only	720	0	1100	110	1500	220	1300	0	1300	140
Operation as distributed generation 1,000 hours per year 7 A.M.—7 P.M.	1400	660	1400	860	2600	600	2600	540	1700	500

The risk zone parameters for the Operation as Permitted scenario provide the basis for the geostatistical analysis presented in Chapter 8, which compares the demographic composition and cumulative exposures of the population within the risk zone to the district at large.

Developing this simplified representation of the risk zones also enabled Environmental Defense to investigate the issue of BUG clusters, in which BUGs are close enough to one another that people are exposed to emissions from more than one BUG. Clustering could lead to a total impact from BUGs on a person or community that is higher than the impact from a single BUG. Chapter 8 also presents the results of the analysis of BUG clusters.

INSIDE THE RISK ZONE

The cancer risk for people living or working inside the risk zone may be much higher than one per million. Indeed, in that case, the isopleth maps depicted in Figure 7-2 show that the cancer risk exceeds ten per million within approximately

FIGURE 7-3

Example of deriving risk zones for geostatistical analysis (100 annual hours), 500 hp engine

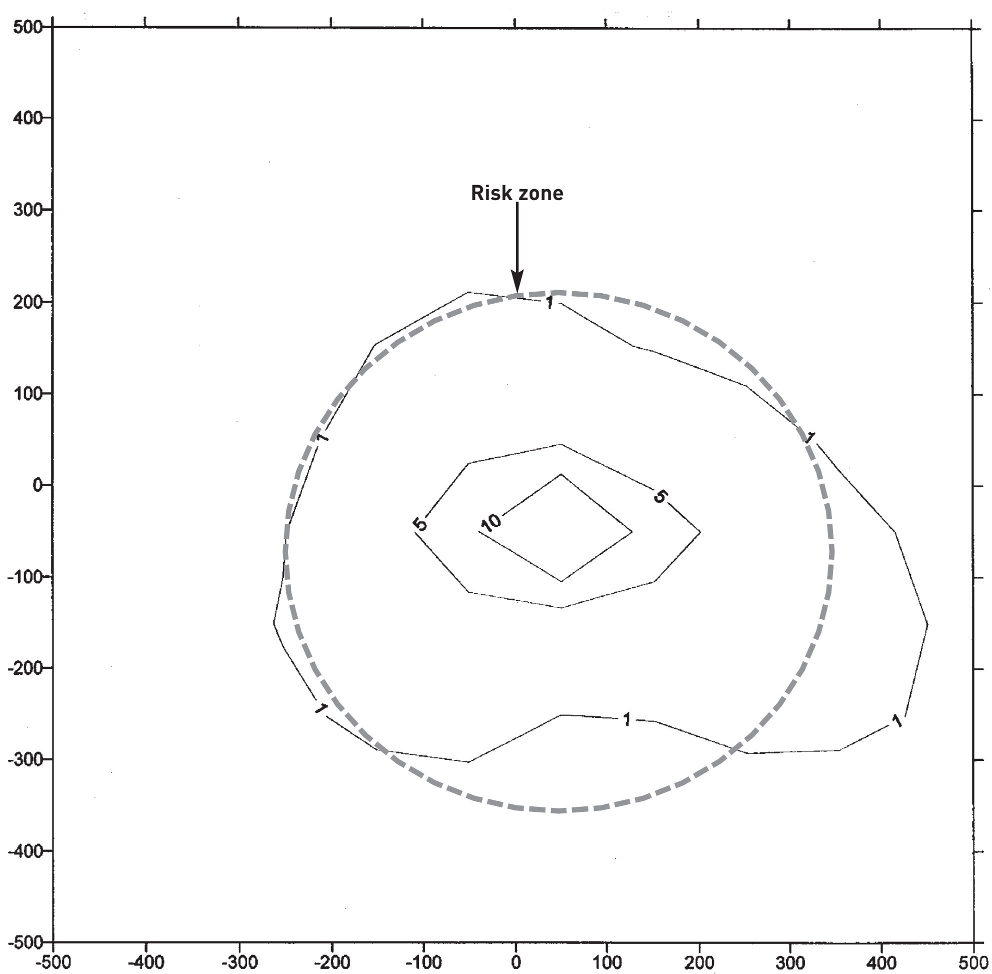
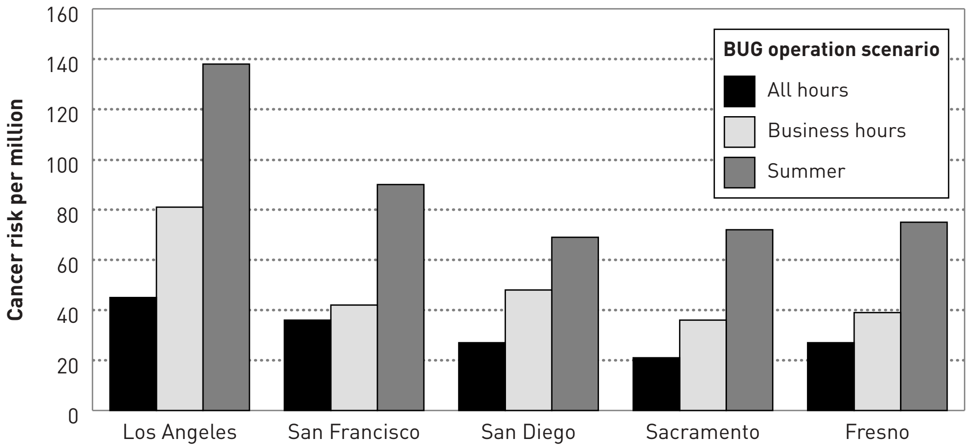


FIGURE 7-4

Maximum cancer risk from PM exposure, operation as permitted (100 annual hours), 500 hp engine



100 meters of the modeled BUG. In the majority of cases analyzed, the modeled concentrations yield chronic cancer risks at or above ten per million within close proximity of the BUG. In many instances, risks are this high even when BUGs are expected to run as few as 50 hours per year. This is significant because emissions leading to risks in excess of ten per million trigger California's Proposition 65, which requires that businesses[139] provide a "clear and reasonable" warning before knowingly exposing people to carcinogenic chemicals.[140] Since 1990, diesel engine exhaust has been included on the list[141] of chemicals known to the state of California to cause cancer, birth defects, or other reproductive harm.

Regulatory decisions are often made based on the risk at the location of a hypothetical maximally exposed individual (MEI). The analysis indicates that long-term health risks to the MEI from BUG operation are greatest on summer afternoons, precisely when they would have operated had they been dispatched to avert rolling blackouts during the summer of 2001. Figure 7-4 shows the estimated cancer risk for each city and modeling scenario, assuming 100 annual hours of operation. This metric—the maximum ground-level concentration for annual average conditions—represents the long-term risk for the MEI who spends all his or her time at the location of maximum average impact. In all five cases, the risk based on the maximum-modeled concentration is much higher for the *summer*

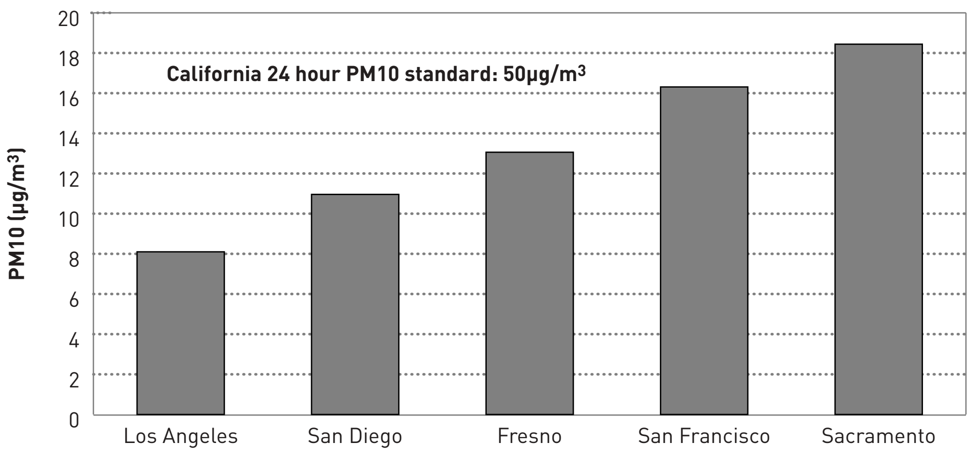
TABLE 7-2

Number of violations of the State of California's 24-Hour PM10 standard: 1999

Air basin	Number of violation days
Sacramento Valley	66
San Diego	126
San Francisco	36
San Joaquin Valley	174
South Coast	258

FIGURE 7-5

Maximum 24-hour concentration of PM10, 500 hp BUG operating 12:00–6:00 PM summer afternoons



modeling scenario than for either the *business hours* or *all-hours* scenarios. Two features of summer meteorology, increased air turbulence and more consistent wind direction, cause this pattern.[142]

Particle emissions from BUGs are high enough that extended BUG operation could cause local exceedances of California's existing 24-hour standard for PM10. The modeled concentrations presented in this report represent incremental increases in concentration attributable to a generic BUG. In reality, as shown in Table 7-2, BUG emissions take place in already polluted urban areas, where these health-based standards are already routinely exceeded. BUG operation on days when there already are exceedances will exacerbate exposures, especially in the immediate vicinity of the BUG where the PM concentrations are most elevated. As illustrated in Figure 7-5, the maximum modeled 24-hour concentrations can be quite high. Although not high enough to lead to local exceedances of the 24-hour standards owing only to BUG emissions, these concentrations would be added to existing ambient concentrations, greatly raising the possibility that a BUG would cause localized exceedances of the 24-hour PM10 standard. This risk would be compounded in cases in which two or more BUGs in close proximity are operating simultaneously.

In addition to fine particulate matter, diesel exhaust also includes specific toxic chemicals, such as acetaldehyde, acrolein, 1,3-butadiene, benzene, formaldehyde, and polycyclic aromatic hydrocarbons, many of which have been found to be carcinogenic or to cause acute health effects.[143] Little is known about the rates at which these chemicals are emitted by stationary engines (such as BUGs), and knowledge of their toxicities is also quite limited. A preliminary screening analysis identified acrolein as the chemical most likely to pose an acute health risk from BUGs. Using the available data on emissions factors and toxicity values, Environmental Defense's consultants tentatively concluded that the modeled 1-hour average concentrations of acrolein do not exceed acceptable exposure levels for specific chemical compounds. This conclusion is tentative, because the data are incomplete regarding emission factors and toxicity values for the whole suite of toxic air contaminants emitted from BUGs.

Statewide Health Risk: Intake Fraction Analysis

As Chapter 3 explained, BUGs tend to be concentrated in densely populated areas where the air quality is already degraded. These are also the parts of the state where exposure to DPM is the highest. We have already used the results of dispersion modeling to show how health risks in the immediate vicinity of a BUG would be affected by increased operation. Even though the relatively small number of people who live or work closest to a BUG will experience the greatest impact from increased BUG operation, the entire population of the air basin will be affected as the increased emissions elevate their exposure to ambient concentrations of DPM. Now we use a novel method, the intake fraction approach,[144] to quantify the populationwide health risks of operating BUGs. This approach focuses on the chronic cancer and direct mortality risks resulting from increased exposure to DPM. Unlike the risk zone analysis present earlier in this chapter, here we consider the health risks that would likely result from higher levels of photochemical smog caused by emissions of oxides of nitrogen from BUGs.

An intake fraction approach summarizes the impact of BUG emissions on the total population's intake of DPM and the incremental risk based on this exposure.[145] Three pieces of information are needed to calculate the excess population-wide health-effect burden using an intake fraction approach: the intake-based toxicity, the total amount of emissions from the source, and the intake fraction for the source. This analysis employs the same toxicity factors discussed earlier in this chapter. The total amount of emissions from all California BUGs were estimated for various operating scenarios using the AP-42 emissions factors just described and the engine size and population data from the California ARB and CEC inventories. The intake fraction for DPM emitted by BUGs was derived using public data from the California ARB on emissions and ambient concentrations of DPM in California's most populous air basins.

The *intake fraction* is the fraction of emissions from a source that are breathed (taken in) by the exposed population. It is calculated as the ratio of the total intake, summed over all people, and divided by the total emissions. The intake fraction (iF) for inhalation of atmospheric emissions depends on three main factors:

TABLE 7-3

Estimated annual excess cancer and PM mortality per year of BUG operation

Average annual operating hours per BUG	Chronic cancer cases per year of BUG operation	PM mortality per year of BUG operation
25 hours	1	20
50 hours	3	40
100 hours	5	70
250 hours	10	180
500 hours	30	360
1000 hours	50	720

Notes:
1. The mortality values in this table have been rounded from those in appendix 4 of the Health Risk Assessment Study by Nazaroff and Marshall.
2. These estimates assume BUGs operate at full capacity. If the BUG idles or runs at less than full load, emissions and health risks may be lower.
3. Based on the ARB estimate of 11,344 BUGs in California.

- The *proximity* between the source and those exposed.
- The size of the *population* that is exposed to a source (and their breathing rate).
- The *persistence* of the pollutant in the environment.

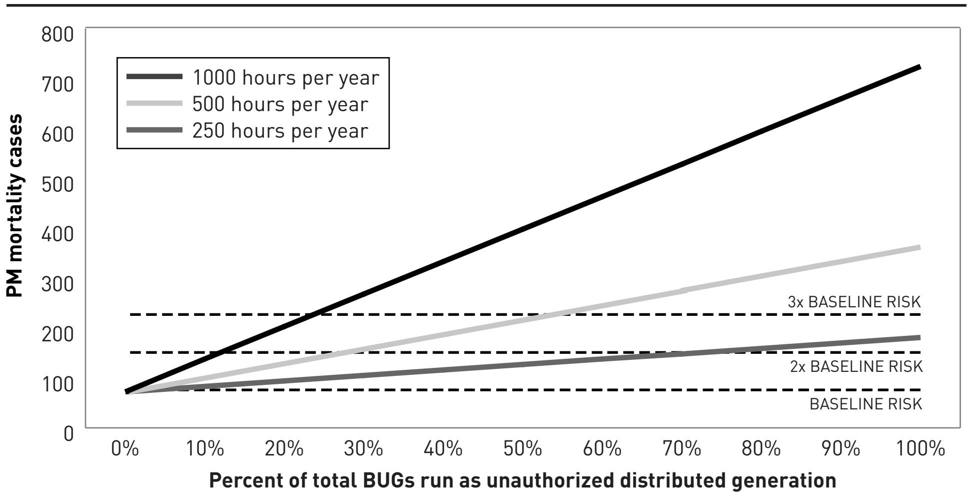
Most DPM derives from mobile sources, which, like BUGs, are widely distributed throughout California's air basins. Whether emitted by a mobile or a stationary source, DPM is nonreactive on the time scale of airflow through a basin and thus equally persistent for the purposes of the iF analysis. Appendix C presents the data and calculations used to derive the iF used here.

For the DPM from BUGs, the estimated statewide average intake fraction is 15 per million. This means that 15 grams of DPM are inhaled for every million grams (metric tonnes) emitted by BUGs. This estimate is consistent with intake fractions of 7 to 31 per million previously calculated from similar data for primary nonreactive pollutants from well-distributed sources in major California air basins[146] (South Coast, San Francisco Bay Area, San Diego, San Joaquin Valley, and Sacramento Valley).

Table 7-3 shows that the number of chronic cancer cases and PM mortality from each year of BUG operation go up as the average annual number of run hours rises. Even an average annual run time of just 25 hours (which is consistent with the South Coast AQMD's precrisis data discussed in chapter 5) would lead to nearly two dozen deaths statewide each year based on the ARB's estimate of 11,344 BUGs in California. A fairly conservative regimen of running an engine half an hour per week for testing and maintenance would lead to 25 operating hours per year. As the South Coast AQMD's data and other anecdotal reports suggest, many BUGs ran much longer during last year's crisis, and the results presented in Table 7-3 show that the higher number of run hours would have led to many additional deaths. The widespread dispatch of BUGs—as the Davis administration considered doing—could have caused dozens of extra deaths owing to

FIGURE 7-6

PM mortality from BUGs with increasing unauthorized operation as distributed generation



Annual operating hours for BUGs run as distributed generation. This analysis assumes that all other BUGs operate 100 hours per year.

operations in 2001 alone.[147] It is important to note that the emission factors on which these estimates are based assume operation at full load/capacity. But if a BUG is idling, its emissions are smaller, and therefore so is the risk.

Although BUGs are permitted only for use during emergencies, the local air districts' limited policing resources means that some owners may operate their BUGs for other purposes with little fear of detection and punishment. For example, BUG owners participating in a demand-response program or facing a real-time pricing tariff could substitute on-site power from the BUG for grid power during a curtailment call or a period of high prices. Or BUG owners with a sufficient understanding of their facility's energy usage patterns could devise a strategy of systematically running their BUG to shave their peak demand and lower their utility bill.

Figure 7-6 shows that if even a small number of BUGs were used regularly as distributed generation (instead of only for emergency standby operation), the overall run time, emissions, and mortality could still rise significantly. For example, assume that BUGs used for distributed generation run for 1,000 hours annually. If just 10 percent of the entire BUG population is operated as distributed generation, the PM mortality will almost double. Although not illustrated here, the number of cancer cases would also be expected to double in this example. This analysis underscores the importance of ensuring that California's air districts have adequate means to verify compliance with permits and that penalties for noncompliance are commensurate with both the rewards of cheating and the risks of getting caught.

CHAPTER 8

Who bears the risks?

People living, working, and going to school close to BUGs are most heavily exposed to their toxic diesel emissions. Even under routine operating conditions individuals within a few hundred meters of a BUG experience an unacceptable cancer risk and may also be exposed to short-term concentrations of five particles that exceed the state's 24-hour standard. This chapter integrates the results of the health assessment with Environmental Defense's GIS database to examine how these risks are distributed within each of four air districts that have high numbers of BUGs.

Our geostatistical analysis examines the impact of BUGs from an environmental justice (EJ) perspective, asking how the burden of increased BUG emissions is distributed among residents of these districts. We employ specific demographic variables, which have been shown to be reliable indicators of communities in which a disproportionate pollution impact may exist. These variables include measures of race and ethnicity, age, and income level.[148] Youth and elderly residents are especially vulnerable to air pollution and they have been shown, like racial minorities and low-income families, to lack adequate access to health care and political and economic power. In addition this analysis explores the impact of BUGs relative to cumulative exposures to air pollution and assesses the potential for BUG hot spots.

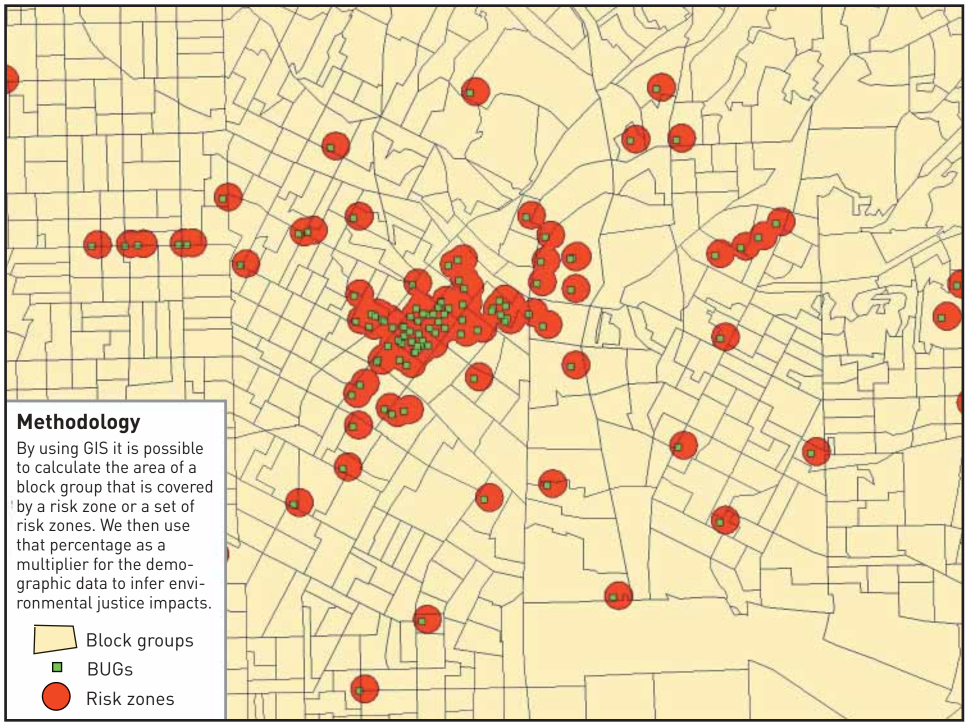
By integrating demographic data with the CEC BUG inventory we show that in each of the districts we analyzed the population exposed is more likely to be low income, elderly, and of a racial minority than the larger population. We also find that BUGs are clustered in the more densely populated areas of each district. The areas where BUGS are located also tend to have higher existing background concentrations of diesel pollution, so emissions from BUGS affect a population that is already disproportionately burdened with diesel exhaust.

Demographic analysis

Using results from the risk assessment described in Chapter 7, we created risk zone circles around each BUG. The diameter of a risk zone circle equals the sum of the down and upwind distances in which a person would be exposed to a one-in-a-million or greater cancer risk from PM emissions.[149] Each of the four cities in our analysis has a unique risk zone because of differences in wind patterns. Using Geographic Information Systems (GIS) mapping, we drew risk zone circles around each BUG in the CEC inventory, offset in the downwind direction to account for prevailing wind patterns. As shown in Figure 8-1, we then overlaid the risk zone circle on demographic data from the 2000 U.S. Census.[150]

For the purposes of this analysis, the term risk zone refers to the entire non-contiguous area covered by the risk zone circles. Combining these data enabled us to compare the demographic characteristics of the exposed population (i.e. within the risk zone) with the general population of each air district. To determine the percentage of different groups residing within the risk zone, we multiplied the percent of each subpopulation in each census block group by the percentage of its area covered by the risk zone. We then compared this figure with the corresponding percentages for the entire air district.

FIGURE 8-1
Illustration of risk zone methodology used in environmental justice analysis



For this analysis we looked at race and ethnicity in terms of white (non-Hispanic) versus nonwhite as defined by the U.S. Census Bureau.[151] We also broke the nonwhite category down into individual minority groups: African-American, Asian-American, and Hispanic or Latino. In addition, we focused on low-income households, which we define as those earning $25,000 or less a year. Finally, we looked at age, focusing on the young (under 18) and the elderly (65 and older). Both groups are especially vulnerable to adverse health impacts from air pollution. In the discussion below we use the term "EJ individuals" to refer to members of any of these demographic groups.

We found that in almost all cases there is a statistically significant[152] disproportionate impact on EJ individuals within the risk zone in all four districts. At the 5 percent level of significance, and even at the 1 percent level, we found a statistically significant difference between the risk zone and the district as a whole for the three main EJ factors of race, age, and income. Although the absolute differences are fairly small, they are sometimes proportionately large. To facilitate comparisons between the demographic makeup of the risk zone and the district, we created an "EJ Index," which is a ratio of the percent of EJ individuals within the risk zone divided by the percent in the district as a whole. When the EJ Index is greater than one, the proportion of EJ individuals within the risk zone is greater than the in the entire district; this indicates a disproportionate impact from BUGs. As shown in Table 8-1, in all but two cases (African-Americans in the South Coast, and Asian-Americans in Sacramento) the EJ Index was greater than one.

EJ FACTORS

Race and ethnicity

For the four districts we surveyed, South Coast, San Joaquin, Sacramento, and San Diego, we found that a slightly higher percentage of nonwhite residents live within the risk zones than in the districts as a whole. The EJ Index ranges from about 1.04 in Sacramento to 1.13 in San Diego. When the nonwhite category was broken down into individual minority groups, the results were less consistent, but an overall slight and consistent pattern remained. In some cases the discrepancy is quite large. In the San Joaquin Valley for example, the EJ Index for Asian-Americans is 1.46, meaning those living inside the risk zone are nearly twice as likely to be Asian-American as those living outside of it. In Sacramento, the risk zone population is almost a third more African-American than the rest of the district, with an EJ Index of 1.27.

Age

In our risk zone demographic analysis, we found no disproportionate impact on those under 18 years old. We did, however, consistently find a higher percentage

TABLE 8-1

Risk zone demographic analysis

Air district	EJ variable	Percent of population in Risk zone	Percent of population in Entire district	z statistic	EJ index
South Coast	Nonwhite	62.9%	60.3%	5.50**	1.04
	African-American	7.4%	7.4%	–0.46	0.99
	Asian-American	11.4%	11.0%	2.46**	1.04
	Hispanic/Latino	43.8%	41.7%	5.10**	1.05
	Over 65	12.3%	10.4%	8.34**	1.18
	Household income < $25,000	3.8%	3.3%	6.87**	1.13
San Diego	Nonwhite	50.2%	44.7%	5.77**	1.13
	African-American	7.3%	6.0%	3.48**	1.21
	Asian-American	11.4%	10.1%	3.46**	1.13
	Hispanic/Latino	31.1%	28.1%	4.17**	1.11
	Over 65	13.2%	11.8%	2.28*	1.12
	Household income < $25,000	4.3%	3.6%	6.74**	1.20
Sacramento	Nonwhite	41.3%	39.8%	1.92*	1.04
	African-American	11.2%	8.8%	5.57**	1.27
	Asian-American	10.3%	12.1%	–2.34	0.86
	Hispanic/Latino	18.8%	18.1%	1.21	1.04
	Over 65	14.3%	11.4%	5.08**	1.26
	Household Income < $25,000	4.6%	4.3%	0.18	1.06
San Joaquin Valley	Nonwhite	56.3%	51.5%	3.62**	1.09
	African-American	4.8%	4.1%	1.29	1.16
	Asian-American	11.6%	8.4%	8.00**	1.37
	Hispanic/Latino	56.3%	51.5%	0.38	1.09
	Over 65	12.0%	10.0%	4.64**	1.20
	Household Income < $25,000	6.7%	5.8%	5.32**	1.16

$$\text{EJ Index} = \frac{\text{percent of EJ individuals in risk zone}}{\text{percent of EJ individuals in entire district}}$$

* Significant at the 5% level
** Significant at the 1% level

TABLE 8-2

School children's exposure to BUG emissions, operation as permitted

Air district	Schools within Risk Zone	Estimated children enrolled
South Coast	140	96,600
San Diego	27	18,630
San Joaquin Valley Unified	34	23,460
Sacramento Metro	18	12,420

of elderly residents (65 and older) living inside the risk zone. With an EJ Index ranging from 1.08 in San Diego to 1.21 in Sacramento, it is clear that the elderly face a somewhat disproportionate amount of risk from BUGs in the four districts we surveyed.

Income

In our risk zone demographic analysis we found that low-income populations, households earning $25,000 or less, are more impacted by BUG emissions. From Sacramento to San Diego, the EJ Index ranges from 1.08 to 1.22, showing a significant disproportionate impact on low-income households inside the risk zone.

Proximity of schools to BUGS

To better analyze the impact on young children, the age category most vulnerable to developing asthma or other respiratory ailments due to exposure to air pollution, we looked at the proximity of primary and secondary schools to BUGs in the four surveyed districts. Because the time children spend at school coincides with the hours BUGs are likely to run, it is important to consider the impact of BUG emissions on school-age children. More than 200 schools are located within the boundaries of a BUG risk zone in the four districts we analyzed (see Table 8-2). In the South Coast AQMD alone, 140 schools are located within

FIGURE 8-2

Comparative demographics, population density, risk zone vs. air districts

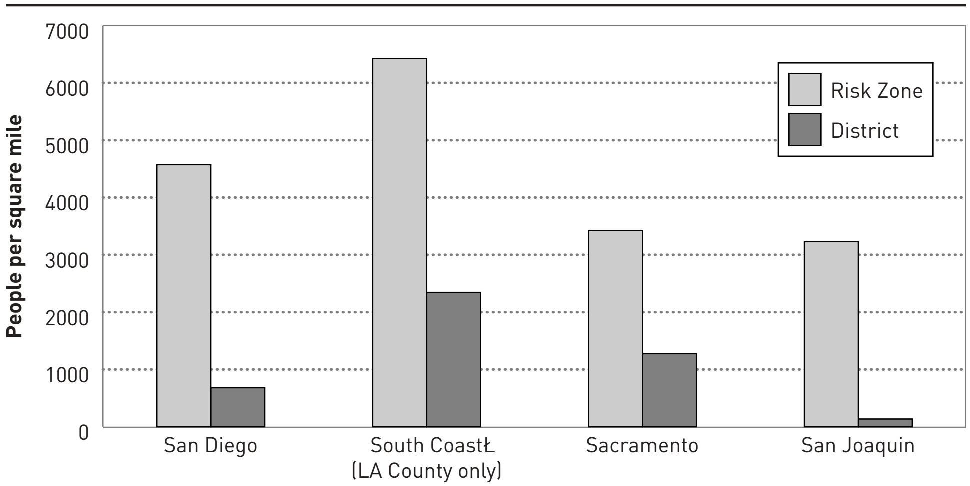
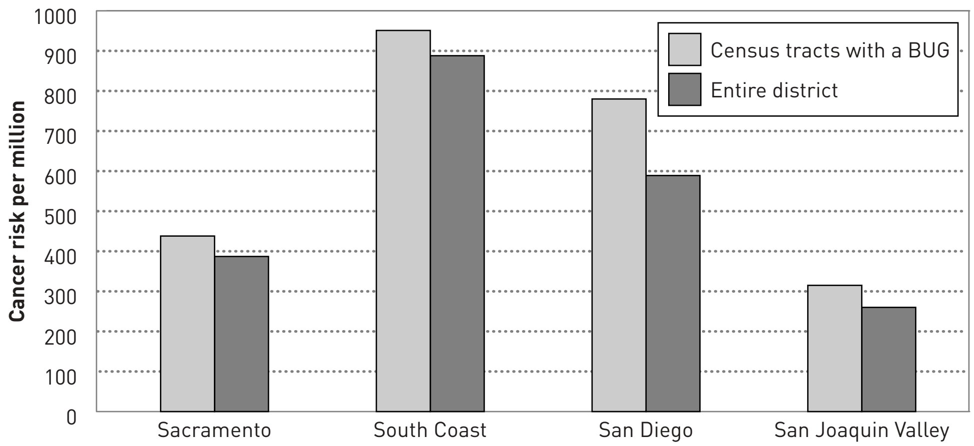


FIGURE 8-3

Cancer risk from background diesel PM concentrations, census tract averages



approximately 300 meters of a BUG, exposing children to high levels of harmful diesel emissions that carry an increased risk of cancer and PM mortality. Based upon this mapping exercise and the average enrollment of a California school,[153] we estimate that over 150,000 school children may be exposed to unacceptably high emissions from BUGs in just the four districts studied. Statewide figures would be much higher.

BUGs are concentrated in densely populated areas

Using 2000 Census data, we compared the population density inside the risk zone to the overall population density for the entire district. For each of the four districts we surveyed, the population density in the risk zone was more than twice that of the district as a whole. In the San Joaquin Valley, the risk zone was almost 25 times more densely populated than the district average. See Figure 8-2.

Cumulative exposures to PM

Emissions from BUGs can cause more significant risks when added to the already high background concentration of diesel exhaust in the surrounding air. Using methods similar to the demographic analysis, we looked at the background concentration of diesel PM emissions in census tracts in which a BUG is located and compared that to the average for each district as a whole.[154]

We found that in each of the four districts we analyzed, census tracts with at least one BUG have higher background concentrations of diesel PM emissions, and therefore higher cancer risk levels, than the district as a whole. In the San Diego AQMD, census tracts with BUGs had average cancer-risk levels from diesel concentrations that were over 30 percent higher than the district average, while in the San Joaquin Valley the risk level was 20 percent higher. Figure 8-3 shows the elevated cancer risk levels in census tracts with BUGs compared to the districts as a whole.

FIGURE 8-4

Risk Zone clusters in downtown Sacramento

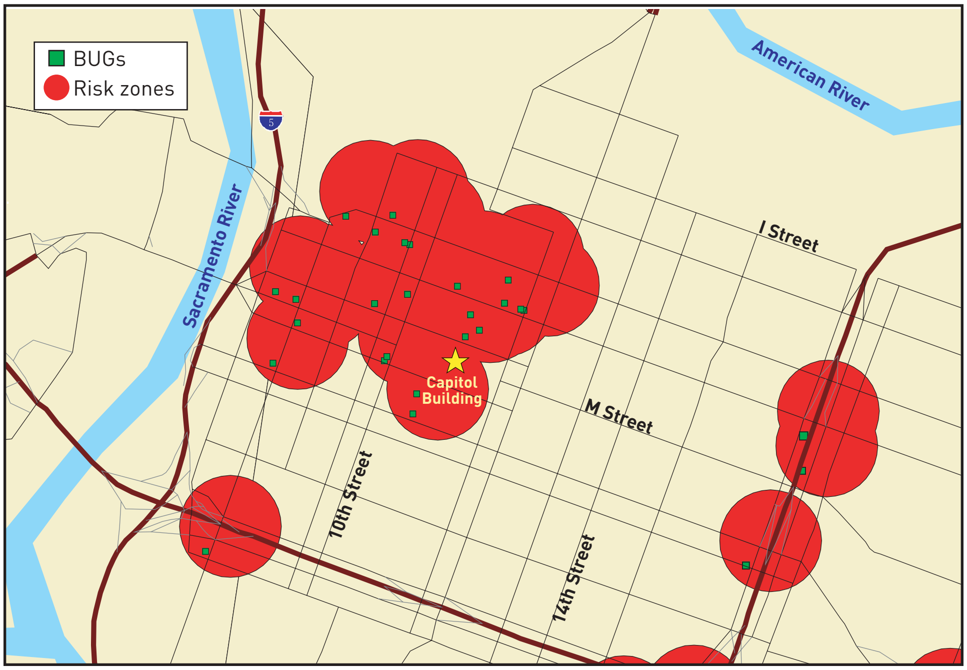
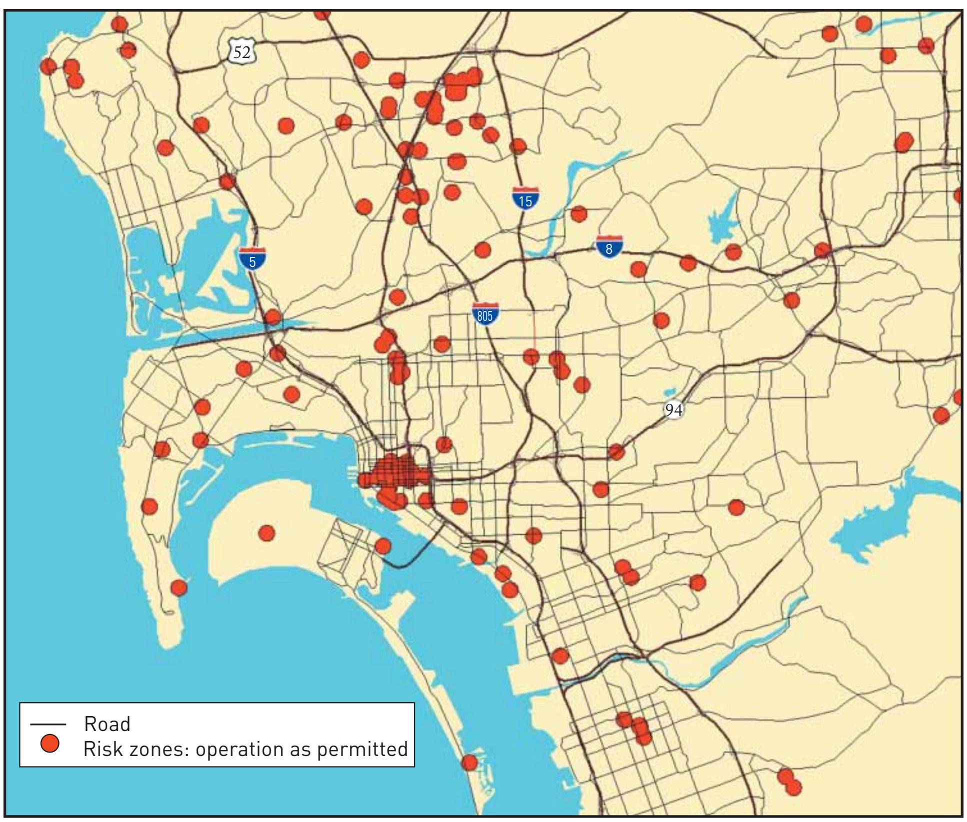


FIGURE 8-5

Risk zone clusters in the San Diego region



BUG hot spots are common in major California cities

Our risk zone analysis also demonstrates that many BUGs are located close enough together that their risk zone circles overlap. Health risks may increase considerably when individuals are exposed to emissions from more than one BUG. Figure 8-4 shows that a large portion of downtown Sacramento is at risk from exposure to multiple BUGs. We found many similar incidences of BUG hot spots in downtowns and other areas throughout California. Figure 8-5 shows BUG clusters in the San Diego area, inside and outside the downtown.

MULTIPLE BUGS AT SINGLE LOCATIONS

Many facilities in the CEC inventory have multiple BUGs at each location. One commercial facility in Irvine has 15 BUGs. In our geostatistical analysis we were unable to account for occasions when multiple BUGs are located at one facility address. For this reason, the actual cancer and PM mortality risk may be many times higher in locations with multiple BUGs.

CHAPTER 9

Policy recommendations

California's recent electricity shortages highlighted the critical role BUGs play during outages, but also illuminated regulatory gaps and potential abuses. The California Air Resources Board (ARB) and many of the local air districts already have taken several important steps to remedy these problems. Though the energy crisis apparently is waning and a new budget crisis is looming, necessary reforms should not be abandoned. This chapter summarizes Environmental Defense's recommendations for air regulators and the legislature to reduce Californians' exposure to toxic emissions from diesel BUGs.

Adopt uniform permitting requirements for BUGs

All California air districts should require BUGs of 50 hp and larger to have permits so that local air regulators will know how many BUGs are in their districts, where they are located, and who owns them. This information will make it possible for the districts to enforce restrictions on BUG use. Collecting permit fees will also provide the funding needed to finance enforcement efforts. When used as permitted, BUGs provide valuable benefits to their owners: It's only fair to ask BUG owners to help pay for enforcement to prevent abuses. In fact, requiring polluters to pay permitting fees that fund enforcement is a well-established regulatory principle of the federal Clean Air Act.

Ensure BUG use is confined to genuine emergencies

The local air districts also should ensure that BUG operation is confined to true emergencies—those rare occasions when natural disasters or other events cause a loss of grid power *at the site where the BUG is located.* Environmental Defense endorses the ARB's recommendation in its September 2001 Guidance for the Permitting of Electrical Generation Technologies that the local air districts define a situation as an emergency "when electrical or natural gas service fails or emergency pumping for fire protection or flood relief is required."[155] Air districts that have not already done so also should explicitly advise BUG owners that compensated curtailments—such as participating in interruptible rate programs or responding to price signals from real-time pricing or demand-bidding programs—do not justify BUG operation.

The California ISO, the California Power Authority, the CPUC, and the utilities can reinforce these regulations by ensuring that new load-shedding programs do not counteract permit restrictions. All load-shedding programs should explicitly forbid operation of BUGs to meet curtailment calls or respond to price signals. Program operators also should require BUG owners to inform their local air district of their participation in real-time pricing programs, interruptible tariffs or other load-shedding programs.

Require pollution controls on new and existing BUGs

The California Air Resources Board, as part of its comprehensive Diesel Risk Reduction Program, has proposed tough new emissions standards for BUGs. The draft regulations call for owners of in-use BUGs to reduce emissions of diesel PM by 85% and comply with a 0.15 g/bhp-hr diesel PM emission rate, or replace the engine with one that meets the requirements for new BUGs. New or rebuilt BUGs greater than 50 bhp would be required to meet an emissions standard of at least 0.15 g/bhp-hr. In addition, the proposed standards would mandate low-sulfur (CARB) diesel. The ARB expects to promulgate new regulations in early 2003, with the standards becoming effective in 2004.

Environmental Defense supports prompt implementation of the proposed guidelines with few exceptions. In particular, the oldest engines—for which no retrofit technology is available to meet the new emissions standards—must not be grandfathered. A strict timeline needs to be established for replacing or retiring these BUGs.

Adopt effective enforcement measures

Even if the ARB's proposed emissions limits are implemented, effective enforcement of restrictions on operating hours will be essential to guarantee that emissions from BUGs remain at acceptable levels. Because BUGs are normally expected to run only a few dozen hours per year, the ARB's proposed standards allow BUGs to emit fine particles at *15 times* the rate allowed for prime engines, which typically run hundreds of hours per year. The different emissions limits make sense only if BUGs stay within their allotted annual operating hours.

The essential ingredients of effective enforcement include metering, record keeping, inspections and penalties. Environmental Defense supports the ARB's recommendation that the air districts require non-resettable run-time meters on all BUGs. Like the familiar, tamper-proof odometers found in cars, the run-time meters provide basic data on the total hours of operation—the single most important aspect of BUG use. In addition, BUG owners should be required to maintain records tracking the number of hours of operation, the purpose of operation (i.e. testing, maintenance, or emergency), and the nature of emergency hours. The air districts should require this data to be reported once a year and should make it available on request. A simple Internet-based system would allow centralized reporting and record keeping of actual operating hours.

To ensure honest reporting, the air districts should conduct routine inspections of meters and run-time logs. Once emissions limits are implemented, inspectors should verify that control equipment has been installed. At large facilities, regular inspections should be expanded to include BUGs. The majority of BUGs, however, are located at facilities that would not otherwise be inspected. Since enforcement dollars are scarce, inspections at these facilities necessarily will be less frequent. To provide an effective deterrent, a program of random inspections should be instituted for these facilities, with severe penalties for violations.

Use financial incentives to reduce pollution from BUGs

When California emerges from its current budget crunch, the legislature should consider providing direct financial incentives to retrofit or retire the dirtiest diesel BUGs. A model for this is California's Carl Moyer Program, which provides grants to cover the cost of reducing NOx emissions from heavy-duty vehicles and equipment. In fact, the legislature allocated $14 million for air districts to mitigate the impacts of increased BUG use during last year's electricity shortages. This funding was axed from the budget in the first round of cuts. It should be restored.

Encourage alternative backup power sources

Cleaner options for backup power exist or are being developed. Fuel cells are an especially promising alternative. Because fuel cells are a relatively new technology, operating experience must be gained to ensure they are an efficient and reliable option. Facilities planning backup power upgrades, especially hospitals and other large facilities with multiple power sources, should introduce fuel cells into their backup mix to provide essential operating experience in these settings.

Protect the public's right to know about risks from BUGs

The CEC's BUG inventory paints only a partial picture. The ARB plans to expand the inventory to include all BUGs, using permitting data from the air districts. In addition to data on engine characteristics and type of use, Environmental Defense recommends that the inventory include information on engine location, ownership and retrofit status. The legislature should allocate sufficient funds to ensure that the inventory will be comprehensive and that ARB can update it as new BUGs are permitted and retrofits are completed. The inventory should be available in an easy to access form on ARB's Web site so that Californians can find out if there is a BUG near where they live, work, or go to school. In addition, the air districts should collect and make available data on BUG run-times.

Glossary of technical terms

Acute noncancer effects Any noncancer health effect that occurs over a relatively short period of time, such as two weeks. The term is used to describe brief exposures and effects which appear promptly after exposure.

Acute toxicity Involves harmful effects in an organism through a single or short-term exposure.

Air basin A land area with generally similar meteorological and geographic conditions throughout. To the extent possible, air basin boundaries are defined along political boundary lines and include both the source and receptor areas. California is divided into 15 air basins.

Air dispersion modeling A mathematical relationship between emissions and air quality which simulates on a computer the transport, dispersion, and transformation of compounds emitted into the air.

Ambient concentrations The concentration of a substance or pollutant within the immediate environs of an organism, related to the amount of possible exposure in that location.

Background concentration In exposure assessment, the concentration of a substance in a defined control area during a fixed period of time before, during, or after a data-gathering operation.

Bioassay A test to determine the relative strength of a substance by comparing its effect on a test organism with that of a standard preparation.

California's Proposition 65 The Safe Drinking and Toxic Enforcement Act of 1986. This Act, codified in California Health and Safety Code Section 25249.5, et seq., states "No person in the course of doing business shall knowingly discharge or release a chemical known to the state to cause cancer or reproductive toxicity without first giving clear and reasonable warning to such individual."

Carcinogen Any substance that can cause or aggravate cancer.

Chronic health effects An adverse effect on a human or animal in which symptoms recur frequently or develop slowly over a long period of time.

Chronic noncancer effects Any noncancer health effect that occurs over a relatively long period of time (e.g., months or years).

Chronic toxicity The ability of a substance or mixture of substances to cause harmful effects over an extended period, usually from repeated or continuous exposure, sometimes lasting for the entire life of the exposed organism.

Cogenerator unit The consecutive generation of useful thermal and electric energy from the same fuel source, in the same machine.

Criteria air pollutants As required by law, EPA has identified and set standards for six pollutants: ozone, carbon monoxide, total suspended particulates, sulfur dioxide, lead, and nitrogen oxide. These are known as "criteria" pollutants because

EPA is required to set or revise these standards based on the criteria of their potential health and welfare effects.

Cumulative exposures The sum of exposures of an organism to a pollutant over a period of time.

***De minimus* level** A risk level that is small enough to be considered insignificant

Demand-response program A program, usually voluntary, in which participants are offered a financial incentive to reduce energy consumption during a period of tight supply or high spot prices.

Distributed generation A distributed generation system involves small amounts of generation located on a utility's distribution system for the purpose of meeting local (substation level) peak loads and/or displacing the need to build additional (or upgrade) local distribution lines.

Dynamic pricing A real-time adjustment of prices based on supply, demand, and competitor's price fluctuations. A type of demand-response or load-shedding program.

Environmental justice The pursuit of equal justice and equal protection for all people under the environmental statutes and regulations. Environmental impacts do not fall equally on everyone in society. Studies have shown that chemical manufacturing plants, hazardous waste landfills, highways and other developments with negative environmental consequences are more likely to be located in low-income and minority communities. Low-income populations and minority populations are more likely to be exposed to physical displacement and adverse impacts on their cultural institutions, traditional forms of land use, community cultural character, religious practices, and financial well being. The idea behind environmental justice is to recognize these disproportionate impacts and try to avoid them.

Fine particles Particulate matter less than 2.5 microns in diameter, also referred to as PM2.5.

Gensets Diesel or gas-fired engines used for the purpose of generating electricity.

Horsepower A unit of power in the U.S. Customary System, equal to 745.7 watts or 33,000 foot-pounds per minute, often a standard measure of engine size.

Intake fraction The fraction of emissions from a source that is breathed by an exposed population. It is calculated as the ratio of the total intake, summed over all people, divided by the total emissions.

Interruptible contracts Electrical supply contracts that allow the supplier to curtail or stop service at times.

Load-shedding Reduction of peak demand through voluntary curtailment of electrical loads, often accomplished by simply turning off equipment.

Median aerodynamic diameter The average diameter of a particle of matter of a given type (e.g., diesel particulate matter), used for modeling and other purposes.

Meta-analyses The process or technique of synthesizing research results by using various statistical methods to retrieve, select, and combine results from previous separate but related studies.

Metabolize Processing of a specific substance by the living body. In the context of air pollution, this indicates a movement of particles out of the body or into fatty tissue.

Mobile sources Sources of air pollution such as automobiles, motorcycles, trucks, off-road vehicles, boats, and airplanes.

Mortality risk The expected likelihood of death from a particular exposure or series of exposures.

Mutagen An agent that causes a permanent genetic change in a cell other than that which occurs during normal growth.

Mutagenic potency The capacity of a chemical or physical agent to cause permanent genetic changes.

New Source Review The permittering process for new and modified stationary sources, mandated by the federal Clean Air Act.

Nitrogen oxide or NOx, is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. They form when fuel is burned at high temperatures, as in a combustion process. The primary sources of NOx are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.

Occupational exposure Exposure to compound or class of compounds through routine work performance. Of special concern due to the repeated, prolonged contact.

Off-road engines Any non-stationary device, powered by an internal combustion engine or motor, used primarily off the highways to propel, move, or draw persons or property, and used in the following applications: marine vessels, construction/farm equipment, locomotives, utility and lawn and garden equipment, and off-road motorcycles..

Particulate matter (PM2.5,PM10) A criteria air pollutant, particulate matter includes dust, soot and other tiny bits of solid materials that are released into and move around in the air. Particulates are produced by many activities, including burning of diesel fuels by trucks and buses, incineration of garbage, mixing and application of fertilizers and pesticides, road construction, industrial processes such as steel making, mining operations, agricultural burning (field and slash burning), and operation of fireplaces and woodstoves. Particulate pollution can cause eye, nose and throat irritation and other health problems. The number after PM refers to the diameter of the particles in microns.

Peaking capacity The maximum electrical output of a given facility.

Peaker Plant An electric generating unit used mainly or exclusively during periods of peak electrical demand.

Polycyclic Aromatic Hydrocarbons (PAHs) Organic compounds that contain carbon and hydrogen with a fused ring structure containing at least two benzene (six-sided) rings. PAHs may also contain additional fused rings that are not six-sided. The combustion of organic substances is a common source of atmospheric PAHs.

Portable generators An internal combustion engine which is designed and capable of being carried or moved from one location to another and does not remain at a single location for more than 12 consecutive months.

Prime engines Engines that are permitted to run on a regular basis, usually for hundreds or thousands of hours per year.

Real-time pricing The instantaneous pricing of electricity based on the cost of the electricity available for use at the time the electricity is demanded by the customer.

Receptor grid The division of a sampling location into defined, symmetric areas for the purpose of measuring the air pollution at the location.

Reference Exposure Concentration (RfC) An estimate derived by the U.S. EPA of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime of exposure. The RfC is derived from a no- or lowest-observed adverse effect level from human or animal exposures, to which uncertainty or "safety" factors are applied.

Reference Exposure Level A health risk value measure developed by the National Institute for Occupational Safety and Health to gauge exposure in the workplace; based on a time-weighted average for up to a ten-hour workday during a 40-hour work week.

Residual risk The quantity of health risk remaining after emissions controls are applied.

Retrofit Addition of a pollution control device without making major changes to the generating plant. Also called backfit.

Risk assessment The characterization of the potential adverse health effects of human exposures to environmental hazards.

Rolling blackouts A controlled and temporary interruption of electrical service. These are necessary when a utility is unable to meet heavy peak demands because of an extreme deficiency in power supply.

Run-time The number of hours an engine operates during the course of one year.

Self-generation A generation facility dedicated to serving a particular retail customer, usually located on the customer's premises. The facility may either be owned directly by the retail customer or owned by a third party with a contractual arrangement to provide electricity to meet some or all of the customer's load.

Small-scale generation Electric power generation systems from 1-kilowatt to 5-megawatt in capacity, such as fuel cells, engine/generator sets, advanced combustion turbines, and microturbines.

Stack parameters Limits on chimney, smokestack, or vertical pipe discharges of used air.

Stage 1 Alert Declared by the California independent systems operators when it is clear that an operating reserve shortfall is unavoidable or the operating reserve is forecast in real-time to be less than the minimum after using available resources.

Stage 2 Alert Declared by the California independent system operators when it is clear that an operating reserve shortfall (less than 5%) is unavoidable or the operating reserve is forecast in real-time to be less than 5 percent after dispatching all available resources.

Stage 3 Alert Declared by the California independent system operators when it is clear that an operating reserve shortfall (less than 1.5%) is unavoidable or the operating reserve is forecast in real-time to be less than 1.5 percent after dispatching all available resources.

Stationary source A place or object from which pollutants are released that does not move. Stationary sources include power plants, gas stations, incinerators, houses, etc.

Toxic air contaminant An air pollutant, identified in regulations by the ARB, which may cause or contribute to an increase in deaths or in serious illness, or which may pose a present or potential hazard to human health. TACs are considered under a different regulatory process (California Health and Safety Code Section 39650 et seq.) than pollutants subject to CAAQS. Health effects from TACs may occur at extremely low levels, and it is typically difficult to identify levels of exposure that do not produce adverse health effects.

Toxicity factor The degree to which a substance or mixture of substances can harm humans or animals.

Uninterrupted power supply A battery with sophisticated electronic control circuitry which switches to battery power when the main power fails so that there is no break in the electricity provided to equipment.

Sources:
EPA environmental glossary: http://www.epa.gov/OCEPAterms/intro.htm
CEC energy glossary: http://www.energy.ca.gov/glossary/index.html
Electric Power Industry glossary:
http://www.energycentral.com/sections/directories/glossary/

Abbreviations

ACGIH	American Council of Government Industrial Hygienists
APCD	Air Pollution Control District
AQMD	Air Quality Management District
ATCM	Airborne Toxic Control Measures
ATSDR	Agency for Toxic Substances and Disease Registry
BACT	Best Available Control Technology
BUG	Backup Generator
CAA	Clean Air Act
CAPCOA	California Air Pollution Control Officers' Association
CARB	California Air Resources Board
CO	Carbon monoxide
CEC	California Energy Commission
DG	Distributed Generation
DRRP	Diesel Risk Reduction Plan
DPM	Diesel Particulate Matter
EF	Emission Factor
EPA	Environmental Protection Agency
GIS	Geographic Information Systems
HEI	Health Effects Institute
HI	Hazard Index
IARC	International Agency for Research on Cancer
IC	Internal Combustion
iF	Intake Fraction
ISC	Industrial Source Complex
kW	Kilowatt
MEI	Maximally Exposed Individual
MRL	Maximum Risk Level
MW	Megawatt
NIOSH	National Institute for Occupational Safety and Health
NOx	Nitrogen Oxides
OEHHA	Office of Environmental Health Hazard Assessment
OSHPAD	Office of Statewide Health Planning and Development
PAHs	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
US DHHS/NTP	United States Department of Health and Human Services/National Toxicology Program
USGS	United States Geological Survey
VOCs	Volatile Organic Compounds
WHO (IPCS)	World Health Organization (International Programme on Chemical Safety)

APPENDIX A

GIS methodology and data sources

The BUG database was derived from the CEC BUG inventory. Facility addresses were geocoded using the Geographic Data Technology (GDT) Streetmap 2000 database extension and Arcview 3.2 software. Address information was available for the majority of BUGs in the inventory, except in the Bay Area AQMD PG&E data. Those BUGs with inaccurate, incomplete or missing facility addresses were not included in the GIS analysis.

In the geocoding process, complete street addresses were individually matched to latitude and longitude coordinates by the Streetmap program, which plots distances along a street line segment based on the address number. Each segment of each street line contains a code for the address number. Since all streets in the United States are standardized to have even addresses on one side and odd addresses on the other, the geocoder can plot points on the correct side of the street. This system is extremely accurate, especially in urban and suburban areas Dropping all BUGs without address data or those that did not match with street segment coordinates ensures the highest possible accuracy.

Of the 3,342 BUGs in the CEC database for which an address was available, 3,328 were successfully geocoded. An additional 451 BUGs without address information were excluded. We projected the resulting data set onto the state of California's official projection system: Albers Equal Area Conic along with all other data sets to facilitate overlay analysis.

GIS data sets and sources

BUG risk zones were derived from a general buffer program and shifted downwind from the location of each BUG. Following the detailed analysis of the wind patterns in each air basin, we derived a buffer radius congruent with the limit of the one in 1 million added cancer risk of the generators. These buffers were shifted a modeled distance downwind from each generator according to the prevailing winds of the air basin.

All demographic layers, including race, income, age, and population density were taken from 2000 U.S. census data. We used both the block group and tract levels of geography for overlay analysis with the risk zones. The block group data was the most appropriate level of geography and was used in most analyses.

Data layers of schools and parks were provided by Environmental Systems Research Institute (ESRI) but were originally derived from the Geographic Names Information System, a federal government resource.

For land-use data we used the National Land Cover Database, a product of the USGS based on satellite imagery.

Worker density data for Los Angeles was provided by the South Coast Area Governments (SCAG) Regional Transportation Plan. This data was only available for Los Angeles County by census tract for 1997.

Data on background exposures to diesel particulate matter were taken from the Environmental Defense Scorecard website (www.scorecard.org). The source for the Scorecard data is the U.S. Environmental Protection Agency's National-Scale Air Toxics Assessment.

Risk assessment methods

FIGURE B-1
General framework for evaluating environmental health risks

For toxic air contaminants emitted from diesel BUGs, the health risk can be estimated as the product of three elements: (1) the quantity of contaminant released; (2) the increase in exposure concentration per unit release; and (3) the risk of adverse effect per unit increase in exposure concentration. The first element is determined by multiplying an emission factor by the amount of engine use. The emission factor indicates the amount of pollutant emitted per unit of engine use. Air dispersion models are used to evaluate the second element, based on information about emission characteristics and meteorology. The third element is addressed by toxicity values, which account for acute, chronic cancer, and chronic noncancer effects, respectively.

The three elements summarize a more general framework, presented in Figure B-1, for evaluating risk from environmental sources.

Emission factors

Emission factors (EFs) indicate the mass of emissions that will occur per amount of BUG activity. Emission factors for the evaluations presented here were taken from the EPA's compilation of EFs, known as AP-42[156]. For diesel engines (such as BUGs) the EFs are expressed in terms of grams of pollutant emitted per horsepower-hour of electrical power generated by the engine. EFs for particulate matter with a mean diameter of 10 micrometers or less (PM10), in pounds per million BTU, are listed in AP-42 as 0.31 and 0.1, for small (<600 hp) and large (>600 hp) engines, respectively. Essentially all of the diesel particulate emissions are expected to be smaller than 2.5 micrometers in diameter. Thus, for this investigation the following terms may be considered to be synonymous: diesel particulate matter (DPM), diesel PM10, and diesel PM2.5.

Air dispersion modeling

To explore the health impacts of increased BUG operation on nearby populations Environmental Defense commissioned an analysis of predicted increases in ambient concentration of diesel pollutants owing to atmospheric emissions from individual diesel BUGs. Air Resource Specialists (ARS) conducted air dispersion modeling of generic BUGs using weather data from five California cities. ARS used a standard air dispersion model, Industrial Source Complex (ISC)[157]. ISC is a regulatory-approved model used to determine the impact of emissions on the surrounding community, for purposes such as permitting new sources. Using local weather data and information on how an engine is situated in relation to surrounding buildings, ISC models the ground-level concentration at a grid of discrete receptor points in the vicinity of the source. Wind speed and atmospheric stability are key determinants of how the plume of emissions from a source is dispersed. Wind speed determines how rapidly clean air dilutes the emissions. Atmospheric stability determines the rate of vertical mixing in the atmosphere. Unstable conditions lead to more rapid vertical mixing. This spreading or mixing dilutes the emissions, thereby decreasing the concentration while spreading it over a larger volume. ARS conducted air dispersion modeling using hourly meteorological data for San Diego, San Francisco, Fresno, Los Angeles, and Sacramento. Five years of historical meteorological data were used for each city. Because a generic BUG was modeled, researchers assumed it would run only a small proportion of hours each year, without knowing when those hours would occur. Different operating scenarios for BUGs would result in different seasonal and daily patterns of BUG operation. To support analysis of a plausible range of potential operating scenarios for BUGs, ARS conducted three separate modeling runs for each BUG:

- In the "All" scenario, which BUGs can operate at any time and any day of the year, and BUG use is randomly allocated to a fixed number of operating hours, selected from among 24 hours per day and 365 days per year (8,760 possible hours).
- In the "Business" scenario, BUGs operate only between 7 am and 7 pm, and BUG use is randomly allocated to a fixed number of operating hours, selected from among 12 hours per day and 365 days per year (4,380 possible hours).
- In the "Summer" scenario, BUGs only operate between noon and 6 pm during the months of June, July, August, and September, and BUG use is randomly allocated to six hours per day, 122 days per year (732 possible hours).

Results generated by these modeling scenarios were combined with assumptions about annual run-time to develop results by operating scenarios. ISC model results are expressed in terms of the highest one-hour concentration, the highest 24-hour concentration, and the annual average (for a specified number of operating hours and season/time of operation)[158].

Toxicity

The toxicity of a chemical indicates the risk of an adverse health outcome occurring because of exposure to that chemical. The three health risks that are typically considered in a health-risk assessment for toxic air contaminants and that have associated toxicity values are *acute, chronic cancer,* and *chronic noncancer* risks. In addition, we have estimated direct mortality effects due to PM2.5 using recent epidemiological evidence.

Based on our analysis, we conclude that the direct mortality risk poses the single largest concern for the health effects of diesel BUG emissions. Of the three health risks typically considered in a risk assessment (acute, chronic cancer, and chronic noncancer), chronic cancer risk is the largest public health concern.

Toxicity values for selected pollutants for acute, chronic cancer, and chronic noncancer risks are listed in Table B-1. These values have been peer-reviewed and approved by regulatory agencies. They are designed protect public health, meaning that they should include a margin of safety to protect children, the elderly, and the infirm.

TABLE B-1
Health risk values*

Chemical	Chronic Reference Exposure Level (REL)	Acute Reference Exposure Level (REL)
Acrolein	0.06	0.19
Formaldehyde	3	94
Propylene	3000	NA
Total PAHs	NA	NA
Benzene	60	1300
Acetaldehyde	9	NA
Butadiene	20	NA
Toluene	300	37,000
Xylenes	700	22,000
PM-10	NA	NA
Diesel exhaust	5	NA
Naphthalene	9	NA

*in micrograms per cubic meter
Source: Office of Environmental Health Hazard Assessment (OEHHA), May 2000.

The toxicity value for direct mortality risk is taken from peer-reviewed literature for populationwide exposure, based on an article by the Chairman and the Chief Deputy Executive Officer of the California Air Resources Board.

Acute toxicity

Acute health risks are those that result from short-term exposure, typically defined as less than 14 days, whereas chronic health risks are associated with long-term exposures, typically defined as longer than three months. The toxicity for acute and chronic noncancer is expressed in terms of a threshold concentration that should not be exceeded during a specified exposure period. The acute and chronic noncancer risk is often presented as a Hazard Index (HI), which is the actual concentration divided by the threshold concentration. For example, an HI of two indicates that the estimated exposure concentration is twice the threshold concentration.

The acceptable threshold concentrations for acute toxicity are given by the Reference Exposure Level[159] (REL) values maintained by the Office of Environmental Health and Hazard Assessment. To understand the significance of the one-hour maximum concentration results predicted for BUGs, they are presented as a fraction of the respective REL. This comparison provides a partial basis for assessing which chemicals pose the greatest acute hazards. Among those chemicals for which both emission factors and REL values are available, the chemical with the most stringent acute concentration limit for BUGs is acrolein. We determined this by comparing all chemicals for which we have an emission factor and an REL, and choosing the one with the highest EF/REL ratio.

Chronic cancer and noncancer risks

Toxicity for chronic cancer risk is typically expressed in terms of the lifetime risk of excess cancer cases per unit concentration. This value is multiplied by the concentration to obtain the incremental cancer risk. For example, if the average concentration increase of a certain chemical is 2 micrograms per cubic meter ($\mu g/m^3$), and the toxicity is 3 per million per $\mu g/m^3$, then the risk from that source is estimated to be 6 per million. This is interpreted to mean that if one million people were exposed to the given concentration for the duration of a 70-year lifetime, we would expect six people to contract cancer because of their exposure to this chemical from this source.

To determine whether a risk is large or small, one compares the estimated risk to respective benchmarks. One benchmark for comparison is a risk level that is small enough to be considered insignificant, or *de minimus.* The California Environmental Protection Agency (CalEPA) defines de minimus to be one per million or less for chronic cancer risks, and an HI of 0.2 or less for acute and chronic noncancer risks. The benchmark for chronic cancer risk is based on the 1990 Clean Air Act, which allows sources to be exempt from regulation and residual risk to be considered negligible when posing less than a one in a million risk to the most exposed individual. CalEPA considers an HI greater than 10 to be sufficient grounds for denial of an emissions permit for regulated emission sources. A chronic cancer risk greater than 10 times the *de minimus* level, or 10 per million, is large enough to warrant risk reduction actions. A risk greater than 100 times the *de minimus* level, or 100 per million, may be grounds for denying a permit.

Based on a comparison of published values for chronic cancer and chronic noncancer toxicity, the most stringent constraint appears to be the cancer risk for diesel exhaust. The cancer risk potency of diesel exhaust, according to CalEPA, is 300 per million per $\mu g/m^3$. This means that chronic exposure to one $\mu g/m^3$ would yield a lifetime excess cancer risk of 300 per million, i.e. 300 times the *de minimus* risk level. The incremental increase in chronic exposure concentration must be less than 0.0033 $\mu g/m^3$ to be below the *de minimus* risk level.

Mortality risk

Because most PM emissions from diesel engines are smaller than 1 (m in diameter, it is appropriate to consider all DPM as PM2.5. Recent evidence—summarized by Lloyd and Cackette (2001)[160]—concludes that the largest public health concern for PM2.5 is the mortality risk. Furthermore, current research[161] indicates that the risks from PM2.5 may be even greater than previously thought.

Lloyd and Cackette (2001) base their estimates of the toxicity of DPM on studies investigating the link between ambient PM and population mortality. Given the size and chemical composition of DPM, we would expect DPM to be more toxic than ambient PM2.5. Thus, while the studies that Lloyd and Cackette cite represent the best available evidence of DPM toxicity, the values they use are based on studies of ambient PM2.5, and may therefore underestimate the true toxicity of DPM.

Lloyd and Cackette provide four estimates of the short-term mortality and two estimates of the long-term (one-year) mortality attributable to direct (primary) DPM concentrations[162] of 1.8 $\mu g/m^3$. Each estimate is presented in terms of the mean, 5th percentile, and 95th percentile value, with mean values for short-term effects from 665 to 2,531 deaths/year, and mean values for combined short- and long-term effects[163] of 2,880 and 3,566 deaths/year. Because BUGs are installed to operate intermittently over periods of many years, it is appropriate to consider the combined short- and long-term effects of DPM exposure. We used the higher of the two mean values from Lloyd and Cackette (3,566 deaths/year)[164] for estimating direct mortality effects. Even this value may underestimate the toxicity of DPM, because these toxicity values are for ambient PM2.5 rather than DPM.

PM2.5 may be even more toxic than was thought at the time that Lloyd and Cackette completed their review article, and recent research[165] indicates a PM2.5 toxicity value approximately twice the value in Lloyd and Cackette (2001). Nevertheless, we have used the results from Lloyd and Cackette because they are more comprehensive and compare several studies.

Based on the estimated health outcome of 3,566 deaths/year in California owing to average ambient levels of 1.8 $\mu g/m^3$ of direct DPM, and a state population of 33 million, we estimate a toxicity of 60 deaths per million per ug/m3.[166] Note that this risk is *in addition to* the other effects calculated elsewhere in this report (e.g., the chronic cancer risk).

An important difference between the mortality risk and the chronic cancer risk is that the former is calculated based on a one-year exposure scenario, while the latter is calculated based on a 70-year exposure scenario. While the PM2.5 risk value of 60 per million per $\mu g/m^3$ appears to be five times lower than the DPM chronic cancer toxicity (300 per million per $\mu g/m^3$), the former occurs after only one-seventieth of the exposure, and thus after only one-seventieth of the intake. *Therefore the direct mortality risk is estimated to be 14 times higher than the chronic cancer risk.*

Unlike the REL toxicity values, which are designed to be protective of sensitive populations, the toxicity values used in Lloyd and Cackette (2001) represent the risk to the general public. The risks to sensitive populations will be even greater than is presented in this report. For diesel PM, we expect the list of sensitive populations to include young people, the elderly, and the infirm.

Intake fraction analysis approach

The first step in the analysis was to derive an estimate of the intake fraction for DPM emitted by BUGs. An estimated intake fraction of 15 grams inhaled per tonne of DPM emitted was derived from published data on the concentration and emissions of DPM in major California air basins. We start by converting the units used to express the toxicity of DPM. CalEPA uses a concentration-based toxicity of 0.000300 per $\mu g/m^3$ [167], meaning that if a person were exposed to 1 $\mu g/m^3$ of DPM for their entire 70-year lifetime, we would predict an excess cancer risk of 300 per million. This is converted to an intake-based toxicity of 0.00078 per million per gram of intake, meaning that if a person inhales 1 gram of DPM over the course of their entire 70-year lifetime, we would predict an excess cancer risk of 780 per million. Conversely, a population intake of 1.0 kg will be expected to lead to one cancer case. Similarly, a population intake of 0.07 kg per year is estimated to cause one excess death per year owing to the direct mortality effect of PM.

The final step in this calculation is to determine the total emissions from all BUGs. This calculation, which is presented in Table C-1, assumes that there are a total of approximately 11,000 BUGs in California[168] operating an average of 100 hours per year.[169] Consequently, the total run-time of BUGs is 1,100,000 hours. Using emission factors[170] of 0.0022 pounds (1 gram) of PM per horsepower-hour for smaller BUGs (ranging from 100 to 600 hp) and 0.0007 lb/hp-hr (0.32 grams) for larger BUGs (601 to 2100 hp), these 1.1 million hours of operation cause a total of 380 million grams (380 metric tonnes) of DPM emissions.[171]

- The data points are *Emissions,* 380 tonnes of PM emitted each year;
- *Intake fraction,* 0.015 kg inhaled per tonne emitted;
- *Toxicity,* one cancer case per 1.0 kg of DPM inhaled, and one death per 0.073 kg of PM inhaled.

The numbers are combined to yield a prediction of approximately five excess cancer cases per year and approximately 70 excess deaths per year due to BUG PM emissions.

In this intake fraction calculation, mortality is directly (i.e. linearly) proportional to average annual operating hours. To calculate mortality effects for different assumptions about operating hours, as presented in Table 7-3 and Figure 7-6, we simply scaled the above estimates. For example, increasing the number of annual operating hours from 100 to 200 doubles the expected number of deaths from both cancer and direct PM mortality.

TABLE C-4

Intake fraction, engine size distribution

BUG range size (kW)	Middle BUG size for this range (kW)	Number of BUGs in state	Annual run hours per engine	Total run hours	IF per million	EF (lb/hr)	Size (hp)	CHRONIC CANCER CASES (PER YEAR) 25	50	100	250	500	1000	PM MORTALITY 25	50	100	250	500	1000
0-100	50	2,269	100	226,933	14.6	0.15	67	0.05	0.11	0.22	0.54	1.09	2.18	0.76	1.52	3.0	7.6	15	30
101-200	150	2,269	100	226,933	14.6	0.44	201	0.16	0.33	0.65	1.63	3.27	6.54	2.28	4.55	9.1	22.8	46	91
201-300	250	2,269	100	226,933	14.6	0.74	335	0.27	0.54	1.09	2.72	5.45	10.90	3.79	7.59	15	37.9	76	152
301-400	350	118	100	11,839	14.6	1.03	469	0.02	0.04	0.08	0.20	0.40	0.80	0.28	0.55	1.1	2.8	6	11
401-500	450	868	100	86,822	14.6	1.33	603	0.19	0.38	0.75	1.88	3.75	7.51	2.61	5.22	10	26.1	52	104
501-600	550	688	100	68,764	14.6	1.62	738	0.18	0.36	0.73	1.82	3.63	7.27	2.53	5.06	10	25.3	51	101
601-700	650	588	100	58,838	14.6	0.61	872	0.06	0.12	0.23	0.58	1.17	2.34	0.81	1.63	3	8.1	16	33
701-800	750	255	100	25,473	14.6	0.70	1,006	0.03	0.06	0.12	0.29	0.58	1.17	0.41	0.81	1.6	4.1	8	16
801-900	850	508	100	50,826	14.6	0.80	1,140	0.07	0.13	0.26	0.66	1.32	2.64	0.92	1.84	4	9.2	18	37
901-1000	950	184	100	18,417	14.6	0.89	1,274	0.03	0.05	0.11	0.27	0.53	1.07	0.37	0.74	1.5	3.7	7	15
1001-1100	1,050	255	100	25,473	14.6	0.99	1,408	0.04	0.08	0.16	0.41	0.82	1.63	0.57	1.14	2.3	5.7	11	23
1101-1200	1,150	161	100	16,145	14.6	1.08	1,542	0.03	0.06	0.11	0.28	0.57	1.13	0.39	0.79	1.6	3.9	8	16
1201-1300	1,250	73	100	7,295	14.6	1.17	1,676	0.01	0.03	0.06	0.14	0.28	0.56	0.19	0.39	0.8	1.9	4	8
1301-1400	1,350	159	100	15,905	14.6	1.27	1,810	0.03	0.07	0.13	0.33	0.66	1.31	0.46	0.91	1.8	4.6	9	18
1401-1500	1,450	37	100	3,707	14.6	1.36	1,944	0.01	0.02	0.03	0.08	0.16	0.33	0.11	0.23	0.5	1.1	2	5
1501-1600	1,550	260	100	25,951	14.6	1.45	2,079	0.06	0.12	0.25	0.61	1.23	2.46	0.86	1.71	3	8.6	17	34
1601-1700	1,650	44	100	4,425	14.6	1.55	2,213	0.01	0.02	0.04	0.11	0.22	0.45	0.16	0.31	0.6	1.6	3	6
1701-1800	1,750	39	100	3,946	14.6	1.64	2,347	0.01	0.02	0.04	0.11	0.21	0.42	0.15	0.29	0.6	1.5	3	6
1801-1900	1,850	28	100	2,751	14.6	1.74	2,481	0.01	0.02	0.03	0.08	0.16	0.31	0.11	0.22	0.4	1.1	2	4
1901-2000	1,950	74	100	7,415	14.6	1.83	2,615	0.02	0.04	0.09	0.22	0.44	0.88	0.31	0.62	1.2	3.1	6	12
2001-2100	2,050	164	100	16,384	14.6	1.92	2,749	0.05	0.10	0.21	0.51	1.03	2.05	0.71	1.43	2.9	7.1	14	29
more	2,150	32	100	3,229	14.6	2.02	2,883	0.01	0.02	0.04	0.11	0.21	0.42	0.15	0.30	0.6	1.5	3	6
Total		**11,344**	**100**	**1,134,404**		**26.3**		**1.4**	**2.7**	**5.4**	**14**	**27**	**54**	**19**	**38**	**76**	**189**	**378**	**757**

EF (>600 hp)	0.0007	lb/hp-hr
EF (<600 hp)	0.0022	lb/hp-hr
Cancer cases per (run hr*IF*EF)	4.4E-07	
Excess deaths per (run hr*IF*EF)	6.2E-06	

EF weighted average (by # of BUGs) lb/hr	Total capacity (based on the # of BUGs) kW
335	113,467
1004	340,400
1674	567,333
122	41,438
1153	390,700
1116	378,203
359	382,449
179	191,045
406	432,019
164	174,960
251	267,463
174	185,663
86	91,187
202	214,724
50	53,756
378	402,241
69	73,010
65	69,063
48	50,886
136	144,584
315	335,868
65	69,422
8,349	4,969,880

Total generating capacity	**4,970**	**MW**
Total number of BUGs	**11,344**	**—**
Average BUG size	**438**	**kW**
Average BUG size	**587**	**hp**
Weighted average emission factor	**0.74**	**lb/hr**
Weighted average emission factor	**0.00125**	**lb/hp-hr**

Notes

[1] Environmental Defense Scorecard, 2002, calculated from 1999 EPA National Scale Assessment of Air Toxics data.

[2] Ibid.

[3] California Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section, "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant," *Health Risk Assessment for Diesel Exhaust* app. III, part B, as approved by the Scientific Review Panel, April 22, 1998. Available on-line at ftp://ftp.arb.ca.gov/carbis/regact/diesltac/partb.pdf, accessed on January 20, 2002.

[4] K. Donaldson, V. Stone, A. Clouter, L. Renwick, W. MacNee, "Ultrafine particles," *Occupational Environmental Medicine* 58 no. . (March 2001):199, 211-6. R.D. Morris, "Airborne Particulates and Hospital Admissions for Cardiovascular Disease: A Quantitative Review of the Evidence," *Environmental Health Perspectives* 109, supp. 4 (August 2001): 495–500.

[5] R. Wilson and J. Spengler, eds., "Particles in Our Air: Concentrations and Health Effects," (1999): 212.

[6] Available on-line at http://www.cde.ca.gov/resrc/factbook/fingertip.htm.

[7] California Air Resources Board, "Guidance for the Permitting of Electrical Generation Technologies," Sacramento, CA, September 2001, p. 10.

[8] California Energy Commission, "California Distributed Energy Resources: DER Equipment." Available online at http://www.energy.ca.gov/distgen/equipment/reciprocating_engines/strengths_weakness.html. 1/30/01.

[9] Derived from California Energy Commission, "BUGS 1: Database of Public Back-up Generators (BUGS) in California," August 15, 2001. Available online at http://www.energy.ca.gov/database/index.html#powerplants; and California Air Resources Board, "Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles," October 2000, app. 2, p. 13. Available online at http://www.arb.ca.gov/diesel/documents/rrpapp5.PDF

[10] California Air Resources Board, "Risk Reduction Plan," app. 2, p. 5.

[11] Ibid., app. 5, p. 5.

[12] Ibid., app. 2, p. 13.

[13] California Energy Commission, "BUGs 1: Database."

[14] The Bay Area AQMD now requires all BUGs greater than 50 hp to obtain a permit. Data on Bay Area permits will be included in future updates of the CEC inventory.

[15] California Air Resources Board, "Risk Reduction Plan," app. 2, p. 17.

[16] California Air Resources Board, Portable Equipment Registration Program. Available online at http://www.arb.ca.gov/perp/perp.htm.

[17] California Energy Commission, "California Distributed Energy Resources: DER Equipment." Available online at http://www.energy.ca.gov/distgen/equipment/equipment.html, January 30, 2002.

[18] Ibid. See, online, http://www.energy.ca.gov/distgen/equipment/fuel_cells/fuel_cells.html.

[19] California Energy Commission, "Distributed Energy Resources: DER Technologies: Fuel Cells." Available online at http://www.eren.doe.gov/der/fuel_cells.html, February 5, 2002.

[20] U.S. Geological Survey, "National Land Use, Land Cover Database. Landstat Imagery."

[21] GIS data for Los Angeles County employment density provided by South Coast Area governments. Maps can be viewed at Regional Transportation Plan 2001, Community Link 21, Employment Density Map, 1997. Available online at http://www.scag.ca.gov/rtp/maps/exhibit4.4.pdf.

[22] California Air Resources Board, "Risk Reduction Plan, " app. 2, p. 3.

[23] California Air Resources Board, "Air Resources Board Compilation of District Rules and Policies for Back-up Generators," 2002.

[24] E-mail correspondence with Bay Area AQMD staff.

[25] All information on district-specific rules and regulations of diesel BUGs was obtained from district officials in the five districts surveyed.

[26] California Air Resources Board, "Air Resources Board Compilation of District Rules and Policies for Back-up Generators," 2001.

[27] After a series of lawsuits brought against the U.S. EPA by environmental and community groups, the EPA must end California's permit exemption for agricultural operation under the Clean Air Act. In the settlement, the EPA agreed to withdraw its approval of California's Title V program, which exempted agricultural sources of air pollution. Until the California legislature amends the state law to remove the exemption, which it must do before November 2003 to avoid sanctions, the EPA will retain regulatory authority over agricultural sources.

[28] California Air Resources Board, "Draft Airborne Toxic Control Measure to Reduce Diesel Particulate Matter Emissions from New Stationary Diesel-Fueled Engines," April 4, 2002.

[29] Ibid.

[30] Leslie Berkman, "Generator Business Booming," *Press-Enterprise* (Riverside, CA), January 13, 2001, p. C-11.

[31] Ibid.

[32] Joseph Menn, "Silicon Valley Scrambling for Protection against Blackouts," *Los Angeles Times*, January 8, 2001, p. A-1.

[33] Matthew Yi, "Alameda Public Utility Rents Four Backup Generators," *San Francisco Chronicle*, April 19, 2001, p. A-18.

[34] Rich Saskal, "Annex Back-up Power Wanted," *Press Democrat* (Riverside, CA), February 13, 2001, p. B-01.

[35] Seema Mehta, "Black-outs May Test the Sewer Districts," *Los Angeles Times* (Orange County ed.), June 22, 2001, p. CA-1.

[36] Berkman, "Generator Business Booming."

[37] California Air Pollution Control Officers Association, "Operation of Diesel Engines during the Energy Crisis," mimeo, November 2, 2001, p. 1.

[38] California Independent Systems Operators, System Status Log. Available online at http://www.caiso.com/docs/09003a6080/08/8a/09003a6080088aa7.pdf.

[39] California Public Utilities Commission, "Energy Division's Report on Interruptible Programs and Rotating Outages," February 2001.

[40] Lois Hutchinson, "Energy Crunch Causes Flow of Conservation Dollars," *Energy User News*, July 1, 2001, p. 28.

[41] Energy Division's Report.

[42] Charles Levin, "Government Center Decides on Backup Diesel Generators," *Ventura County Star*, February 13, 2001, p. B01.

[43] David Montero, "County Could Have Power, Still Save on Electricity," *Ventura County Star*, May 5, 2001, p. A01.

[44] California Air Pollution Control Officers Association, "Operation of Diesel Engines during the Energy Crisis," p. 1.

[45] Ibid., p. 3.

[46] Ibid.

[47] CARB Diesel is a California-certified diesel fuel with significantly reduced sulfur and hydrocarbon content and emissions. California diesel regulations were adopted in 1988 and enacted in 1993. The regulation caps sulfur content at 0.5 percent, about one fifth the level of non-regulated diesel fuel. The lower sulfur content reduces emissions of both sulfur dioxide and particulate matter. The aromatic hydrocarbon content is capped at 10 percent, about one third the level of normal diesel fuel. The lower levels of aromatic hydrocarbons reduce emissions of both particulate matter and NOx. See http://www.arb.ca.gov/fuels/diesel/dieselfs.pdf for more information.

[48] CAPCOA memo, p. 3.

[49] South Coast Air Quality Management District, "Emergency Standby ICE Survey: Summary of Operating Hours 7-1-99 to 9-31-01." Available from the AQMD through public information request.

[50] California Independent Systems Operators, System Status Log.

[51] North American Electric Reliability Council, "2001 Summer Special Assessment: Reliability of the Bulk Electricity Supply in North America," May 2001, p. 11.

[52] Chris Bowman, "Davis to Push Backup Diesel," *Sacramento Bee*, May 24, 2001, p. A-1; and California Energy Markets n. 619, May 25, 2001, p. 12.

[53] Bowman, "Davis to Push Backup Diesel."

[54] California Public Utilities Commission, Decision 01-06-009 (Rulemaking 00-10-002), "Interim Opinion on Rolling Blackout Reduction Program," June 7, 2001.
[55] San Diego Gas & Electric Company, "August 2001 Report on Interruptible and Outage Programs," September 7, 2001.
[46] California Independent Systems Operators, System Status Log.
[57] Cal. Sen. 38, 2001-02 1st ex. sess., April 16, 2001.
[58] South Coast Air Quality Management District, Rule 118 Executive Order #01-01. Available online at http://www.aqmd.gov/news1/exec_order_01_01.htm.
[59] See, for example, Severin Borenstien, "The Trouble with Electricity Markets and California's Electricity Restructuring Disaster," POWER Working Paper no. PWP-081, University of California Energy Institute, Berkeley, CA, September 2001; Eric Hirst, "The California Electricity Crisis: Lessons for Other States," report prepared for the Edison Electric Institute, July 2001; and Justin A. Colledge, et. al., "Power by the Minute," *McKinsey Quarterly*, no. 1, 2002.
[60] Quoted in California Energy Markets, n. 588, October 13, 2000, p. 12.
[61] Ibid.
[62] Ahmed Faruqui, Joe Hughes, and Melanie Mauldin, "Real Time Pricing in California: R&D Issues and Needs," report prepared for the California Energy Commission, October 28, 2001; and Eric Hirst and Brendan Kirby, "Retail-Load Participation in Competitive Wholesale Electricity Markets," report prepared for Edison Electric Institute (Washington, DC) and Project for Sustainable FERC Energy Policy (Alexandria, VA), January 2001.
[63] Hirst and Kirby, "Retail-Load Participation in Competitive Wholesale Electricity Markets," p. 17.
[64] Primen, "Research Highlights: Distributed Energy Market Survey 2001." Available online at http://www.primen.com/about/pr_strong.asp.
[65] U.S. Environmental Protection Agency, "Health Assessment Document for Diesel Exhaust," SAB Review Draft, July 2000.
[66] California Air Resources Board, "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant, Initial Statement of Reasons for Rulemaking," as approved by the Scientific Review Panel, April 22, 1998.
[67] South Coast Air Quality Management District, "Multiple Air Toxics Study in the South Coast Air Basin (MATES-II)," March 2000. Available online at http://www.aqmd.gov/matesiidf/es.pdf, accessed on February 2, 2002.
[68] California Air Resources Board, "Diesel Risk Reduction Plan," October 2000.
[69] Scorecard, 2002, calculated from 1999 EPA National-Scale Assessment of Air Toxics data.
[70] Ibid.
[71] California Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section, "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant, app. 3, part B: Health Risk Assessment for Diesel Exhaust," as approved by the Scientific Review Panel, April 22, 1998. Available online at ftp://ftp.arb.ca.gov/carbis/regact/diesltac/partb.pdf, accessed on January 20, 2002.
[72] California Air Resources Board, "Risk Reduction Plan," app. 5, p. 5.
[73] U.S. Department of Health and Human Services, "Ninth Report on Carcinogens," National Toxicology Program, Research Triangle Park, NC, 2000. Available online at http://ehis.niehs.nih.gov/roc/ninth/rahc/diesel.pdf, accessed on February 2, 2002.
[74] California Office of Environmental Health Hazard Assessment and Air Resources Board, "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant." Available online at http://arbis.arb.ca.gov/toxics/dieseltac/finexsum.pdf, accessed on January 20, 2002.
[75] California Energy Commission, "BUGS 1: Database"; and California Air Resources Board, "Risk Reduction Plan," app. 2, p. 13.
[76] Air Resources Board, Emissions Inventory 1995, Technical Support Division, October 1997.
[77] A.C. Lloyd and T.A. Cackette, "Diesel Engines: Environmental Impact and Control," *Journal of the Air and Waste Management Association* 51 (June 2001): 809–47.
[78] J. Schwartz, D. Dockery, and L. Neas, "Is Daily Mortality Associated Specifically with Fine Particles?" *Journal of the Air and Waste Management Association* 46 (1996): 927–39.
[79] California Energy Commission, "Environmental Performance Report of California's Electric Generation Facilities," July 2001.

[80] California Air Resources Board, "Risk Reduction Plan," app. 5, p. 5.

[81] Ibid.

[82] California Energy Commission, "BUGS 1: Database"; and California Air Resources Board, "Risk Reduction Plan," app. 2, p. 13.

[83] K. Donaldson, V. Stone, A. Clouter, L. Renwick, and W. MacNee, "Ultrafine Particles," *Occupational Environmental Medicine* 58 (March 2001):211-16, 199; and R. D. Morris, "Airborne Particulates and Hospital Admissions for Cardiovascular Disease: A Quantitative Review of the Evidence," *Environmental Health Perspectives* 109 (August 2001, supp. 4): 495–500.

[84] Schwartz et al., "Is Daily Mortality."

[85] R. Wilson and J. Spengler, eds., "Particles in Our Air: Concentrations and Health Effects," 1999. p. 212.

[86] W. Pepelko and C. Ris, "Update on US Environmental Protection Agency Activities in the Assessment of Mobile Source Air Toxics: Emissions and Health Effects," proceedings of U.S. EPA/A&WMA International Specialty Conference, Air and Waste Management Association, 1992, pp. 193–200; and California Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section, "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant."

[87] California Energy Commission, "BUGS 1: Database"; and California Air Resources Board, "Risk Reduction Plan," app. 2, p. 13.

[88] Ibid.

[89] California Office of Environmental Health Hazard Assessment and American Lung Association, "Health Effects of Diesel Exhaust: A Fact Sheet," 2001.

[90] California Energy Commission, "BUGS 1: Database"; and California Air Resources Board, "Risk Reduction Plan," app. 2, p. 13.

[91] California Energy Commission, "California Distributed Energy Resources: DER Equipment."

[92] The Bay Area AQMD now requires all BUGs greater than 50 hp to obtain a permit. Data on Bay Area permits will be included in future updates of the CEC inventory. Brett Peterson and Andrew Saxon, "Global Increases in Allergic Respiratory Disease: The Possible Role of Diesel Exhaust Particles," *Annals of Allergy, Asthma, & Immunology* 77 (October 1996): 263–70.

[93] California Energy Commission, "BUGS 1: Database"; and California Air Resources Board, "Risk Reduction Plan," app. 2, p. 13.

[94] The Bay Area AQMD now requires all BUGs greater than 50 hp to obtain a permit. Data on Bay Area permits will be included in future updates of the CEC inventory.

[95] M.C. Madden et al., "Effect of Ozone on Diesel Exhaust Particle Toxicity in Rat Lung," *Toxicol. Appl. Pharmolcol* 168 (2000): 140–48.

[96] California Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section, "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant"; and California Air Resources Board, "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant."

[97] California Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section, "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant," app. 3, part B, and "Initial Statement of Reasons for Rulemaking."

[98] The Bay Area AQMD now requires all BUGs greater than 50 hp to obtain a permit. Data on Bay Area permits will be included in future updates of the CEC inventory.

[99] M. Lipsett and S. Campleman, "Occupational Exposure to Diesel Exhaust and Lung Cancer: A Meta-Analysis," *American Journal of Public Health* 89 (July 1999): 1009–17; R. Bhatia, P. Lopipero, and A. H. Smith, "Diesel Exhaust Exposure and Lung Cancer," *Epidemiology* 9 (January 1998): 84–91.

[100] Lipsett et al., "Occupational Exposure"; Bhatia et al., "Diesel Exhaust Exposure"; California Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section, "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant," app. 3, part B.

[101] California Air Resources Board, Portable Equipment Registration Program.

[102] The Bay Area AQMD now requires all BUGs greater than 50 hp to obtain a permit. Data on Bay Area permits will be included in future updates of the CEC inventory.

[103] California Air Resources Board, Portable Equipment Registration Program.

[104] The Bay Area AQMD now requires all BUGs greater than 50 hp to obtain a permit. Data on Bay Area permits will be included in future updates of the CEC inventory.

[105] Ibid.
[106] Ibid.
[107] California Air Resources Board, Portable Equipment Registration Program.
[108] The Bay Area AQMD now requires all BUGs greater than 50 hp to obtain a permit. Data on Bay Area permits will be included in future updates of the CEC inventory.
[109] South Coast Air Quality Management District, "Emergency Standby ICE Survey."
[110] American Academy of Pediatrics, "Ambient Air Pollution: Respiratory Hazards to Children, American Association of Pediatrics News," 1993. Available online at http://www.aap.org/policy/04408.html, accessed on February 9, 2002; and P. Landrigan et al., "Children's Health and the Environment: A New Agenda for Prevention Research," *Environmental Health Perspectives* 106 (1998, suppl. 3): 787–94.
[111] American Academy of Pediatrics, "Ambient Air Pollution."
[112] Landrigan et al., "Children's Health and the Environment."
[113] Ibid.
[114] Berkman, "Generator Business Booming."
[115] California Air Resources Board, "Risk Reduction Plan," app. 2, p. 5.
[116] Ibid., app. 2, p. 13.
[117] California Energy Commission, "BUGS 1: Database of Public Back-up Generators (BUGS) in California."
[118] The Bay Area AQMD now requires all BUGs greater than 50 hp to obtain a permit. Data on Bay Area permits will be included in future updates of the CEC inventory.
[119] Ibid.
[120] State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officers, "Cancer Risk from Diesel Particulate: National and Metropolitan Area Estimates for the United States," March 15, 2000. Available online at http://www.4cleanair.org/comments/cancerriskreport.pdf, accessed on February 2, 2002.
[121] The Bay Area AQMD now requires all BUGs greater than 50 hp to obtain a permit. Data on Bay Area permits will be included in future updates of the CEC inventory.
[122] U.S. Department of Health and Human Services, "Ninth Report on Carcinogens."
[123] U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluations, and Field Studies, Surveillance Branch, "National Occupational Exposure Survey, 1981-1983: Estimated Total and Female Employees, Actual Observation and Trade-Named Exposure to Products of Combustion—Diesel Fuels," unpublished database cited at http://www.cdc.gov/niosh/88116_50.html according to Number of Exposed Workers section.
[124] The Bay Area AQMD now requires all BUGs greater than 50 hp to obtain a permit. Data on Bay Area permits will be included in future updates of the CEC inventory.
[125] California Energy Commission, "California Distributed Energy Resources: DER Equipment."
[126] California Air Resources Board, "Risk Reduction Plan," app. 5, p. 5.
[127] AP-42 is available online at http://www.epa.gov/ttn/chief/ap42/.
[128] ISC is available online at http://www.epa.gov/ttn/scram/.
[129] A copy of ARS's report to Environmental Defense is available on request.
[130] This work was performed by Professor William Nazaroff, Department of Environmental Engineering, and Julian Marshall, graduate student in the Energy and Resources Group, University of California at Berkeley. A copy of their report to Environmental Defense is available on request.
[131] Lloyd and Cackette's estimate of annual PM mortality includes the effects of $1.8 \mu g/m^3$ of primary particles and $0.81 \mu g/m^3$ of secondary particles, meaning particles formed in the air from precursor emissions. Note that while the present report focuses on diesel BUGs, Lloyd and Cackette look at all diesel engines in aggregate, including on-road, off-road, and stationary diesel engines. By using their results, we are implicitly assuming that the formation of secondary PM2.5 nitrate calculated by Lloyd and Cackette for all diesel engines also applies to diesel BUGs. This is correct only if the ratio of PM emissions to NOx emissions is the same for BUGs as for the diesel engines considered by Lloyd and Cackette. But this is not necessarily the case.
[132] Actual BUG operating conditions such as engine load, exhaust temperature, volumetric flow rate, and meteorology affect the exposure from BUG emissions. Some of the assumptions made in this report for dispersion-modeling purposes, for example, assuming that BUGs operate at

full-load conditions rather than at no load or low load, may result in an overestimation or underestimation of the actual exposure impact.

[133] Risk Assessment Advisory Committee, *A Review of the California Environmental Protection Agency's Risk Assessment Practices, Policies, and Guidelines.* Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, 1996), p. A-4.

[134] Office of Environmental Health Hazard Assessment, "Air Dispersion Modeling: Technical Support Document for Exposure and Stochastic Analysis," chap. 2, September 2000. Available online at http://www.oehha.ca.gov/air/hot_spots/pdf/chap2.pdf.

[135] A chronic cancer risk ten times greater than the *de minimus* level, or ten per million, is large enough to warrant risk reduction actions. A risk greater than 100 times the *de minimus* level, or 100 per million, may be significant grounds for denying a permit.

[136]For example, the ARB's Risk Management Guidance for the Permitting of New Stationary Diesel-Fueled Engines (http://www.arb.ca.gov/diesel/documents/rmg.htm), recommends that the best available control technology be applied if the risk is greater than or equal to one in a million and that reasonably available control technology be applied when the risk is less than one in a million.

[137] In the coastal regions of the California, the prevailing winds tend to blow more consistently in the downwind direction. This causes average annual exposures in the downwind direction to be lower when operation is confined to the summer months, as in the Summer 2001 Dispatch scenario.

[138] The isopleth maps for each air district illustrate the influence of prevailing local weather conditions at one location in each district (usually the largest airport) for a hypothetical BUG. Actual dispersion patterns and health risks vary from one location to another within an air district based on a number of factors, including microclimate effects, individual BUG characteristics, topography, and configuration of neighboring buildings.

[139] Businesses employing fewer than ten persons and all government agencies are exempt from this law.

[140] Further information on this regulation is available online from http://www.oehha.org/prop65.html.

[141] Available online at http://www.oehha.org/prop65/prop65_list/12502LSTA.pdf.

[142] There are two reasons that the summer hours have higher maximum annual averages. First, in some locations, the wind direction is more consistent during summer afternoons than during the whole year. This means that emissions from different hours are more likely to affect the same location under the Summer scenario than under the All scenario. Second, vertical dispersion is relatively strong during summer afternoons because the sunlight warms the ground and causes unstable atmospheric conditions. Far away from the BUG, the greater mixing caused by this instability produces lower concentrations; however, in the immediate vicinity of the BUG, increased dispersion causes the plume to mix down to the ground rapidly, leading to high local concentrations.

[143] See online http://www.nrdc.org/air/transportation/ebd/chap2.asp#table1.

[144] For an introduction and illustration of the intake fraction approach, see D. H. Bennett et al., "Defining Intake Fraction," *Environmental Science & Technology* 36 (2002): 207A–211A.

[145] For an introduction to the intake fraction approach, see W. Nazaroff et al., "Environmental Health Implications of Electricity Generation Choices: Pollutants of Concern and Exposure Issues," paper presented to the second Haagen-Smit Symposium, Lake Arrowhead, CA, April 9–12, 2002.

[146] The results of the analysis were presented at the Haagen-Smit Symposium; see Nazaroff et al., "Environmental Health Implications."

[147] Some of the mortality effects, for example, for cancer, would not be expressed in the same year as the exposure.

[148] J.L. Sadd, M. Pastor, T. Boer, and L.D. Snyder, "'Every Breath You Take...': The Demographics of Toxic Air Releases in Southern California," *Economic Development Quarterly*. Vol. 13, No. 2 (1999):107–123. Rachel Morello-Frosch, M. Pastor, and J.L. Sadd, "Environmental Justice and Southern California's 'Riskscape' The Distribution of Air Toxics Exposures and Health Risks Among Diverse Communities," *Urban Affairs Review*, Vol. 36, No. 4 (March 2001): 551–578. V. Brajer and J.V. Hall, "Recent Evidence on the Distribution of Air Pollution Effects," *Contemporary Policy Issues*, Vol. 10 (1992): 63–71.

[149] See figure 7-3 for an illustration of how the risk zone circles were derived from the modeling results used in the health risk assessment.

[150] The resolution of U.S. Census data used was the block group. Within major California cities, a block group typically covers 10 to 25 square miles.

[151] The U.S. Census Bureau's definition of "white" includes some Hispanics who do not identify with another race. For the purposes of this study, we included all Hispanics in the nonwhite category.

[152] We assessed statistical significance using a one-tailed test, one-sample test. Since the district-level data are population statistics derived from the U.S. Census, we treated the mean and variance of the proportion of EJ individuals in the entire district as population parameters and the variances of the risk zone proportion as unknown. Under the null hypothesis, which holds that the composition of the risk zone's population differs systematically from the district at large, the variance of the risk zone is expected to be less than that of the district. Using the district level variance in our z-statistic therefore imparts a conservative bias to the test, making it less likely that EJ impacts will be found to be statistically significant.

[153] Available online at http://www.cde.ca.gov/resrc/factbook/fingertip.htm.

[154] Scorecard Background Diesel PM Data. Online at http://www.scorecard.org.

[155] California Air Resources Board, *Guidance for the Permitting of Electrical Generation Technologies*, Sacramento, CA, Sepetmber 2001, p. 10.

[156] AP-42 is available online at http://www.epa.gov/ttn/chief/ap42/.

[157] ISC is available online at http://www.epa.gov/ttn/scram/.

[158] The annual averages in this report are the average of five annual averages (from five years of meteorological data).

[159] Reference Exposure Level (REL) values are available online through the OEHHA website: http://www.oehha.org/air/acute_rels/index.html

[160] AC Lloyd and TA Cackette. "Diesel Engines." For a more detailed look at the health effects of diesel, the reader may wish to review an analysis by the ARB and OEHHA, "Review of the California Ambient Air Quality Standards For Particulate Matter and Sulfates," Public Review Draft, November 30, 2001. As this latter document is currently in the draft stage, we do not use it in our analysis.

[161] Pope et al. "Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution." *Journal of the American Medical Association.* 2002; 287:1132–1141. While Lloyd and Cackette (2001) only provide estimates of total mortality, Pope et al. provide results based on the cause of death. Their four categories for cause of death are all causes (i.e., total mortality), lung cancer, cardiopulmonary, and all causes other than lung cancer and cardiopulmonary.

[162] Lloyd and Cackette estimate that each 1.8 $\mu g/m^3$ of direct (primary) PM2.5 causes 0.18 $\mu g/m^3$ of indirect (secondary) PM2.5. Thus, the health effects due to primary and secondary PM2.5 are 10% greater than the health effects of only primary PM2.5. The health effects presented here as attributable to each 1.8 $\mu g/m^3$ of direct PM2.5 are the combined effects of direct and indirect PM2.5.

[163] Lloyd and Cackette label the combined short- and long-term effects as "long-term exposures mortality," and then point out in a footnote that this category includes both short- and long-term effects.

[164] Note that the value we used (3,566 deaths/year) is lower than the 95th percentile estimates, which were 4,341 and 5,257 deaths per year, respectively, for the two long-term studies.

[165] Pope *et al.* op. cit.

[166] Lloyd and Cackette estimate that each 1.8 $\mu g/m^3$ of direct (primary) PM2.5 corresponds to 0.81 $\mu g/m^3$ of indirect (secondary) PM2.5 nitrate formation attributable to NOx emissions. Thus, the combined health effects due to primary and secondary PM2.5 are 45% greater than the health effects of only primary PM2.5. The health effects presented here as attributable to each 1.8 $\mu g/m^3$ of direct PM2.5 are the combined effects of direct and indirect PM2.5. Note that while the present report focuses on diesel BUGs, Lloyd and Cackette look at all diesel engines in aggregate, including on-road, off-road, and stationary diesel engines. By using their results, we are assuming that the formation of secondary PM2.5 nitrate calculated by Lloyd and Cackette for all diesel engines applies to diesel BUGs. This will only be correct if the ratio of PM emissions to NOx emissions is the same for BUGs as for the diesel engines considered by Lloyd and Cackette. This is not necessarily the case. If the NOx-to-PM ratio is significantly higher for BUG engines than for those engines considered by Lloyd and Cackette, there will more secondary PM2.5 formed by BUGs than Lloyd and Cackette calculate. Similarly, if the NOx-to-PM ratio is significantly lower for BUGs than for those engines considered by Lloyd and Cackette, then less secondary PM2.5 will be formed by BUGs than Lloyd and Cackette calculate. Detailed analyses of the PM-to-NOx ratio for BUGs and other engines, and of secondary

PM2.5 nitrate formation from NOx emissions from BUGs, are beyond the scope of this work. The EPA's compilation of emissions factors, called AP-42, does not distinguish between the end use of the diesel engine (e.g., BUGs versus on-road engines), implying that differences between engine uses (i.e., diesel BUGs versus other diesel engines) are not overly important. Note that the value we used (3,566 deaths/year) is lower than the 95th percentile estimates, which were 4,341 and 5,257 deaths per year, respectively, for the two long-term studies. Because of lack of available information, we have not investigated the potential for synergistic effects between DPM, other PM, and other air pollutants.

167 300 per million per $\mu g/m^3$is the same as 0.000300 per $\mu g/m^3$.

168 Taken from the CARB Diesel Risk Reduction Plan Appendix II: Stationary and Portable Diesel-Fueled Engines. Available online at http://www.arb.ca.gov/diesel/documents/rrpapp.htm.

169 A survey of permitting regulations for BUGs indicates that most California air quality management districts allow 100-250 hours of operation per year.

170 Taken from EPA's Compilation of Air Pollutant Emission Factors AP-42. Available online at http://www.epa.gov/ttn/chief/ap42/index.html.

171 This analysis uses information from the California Energy Commission's BUGs database about the number of BUGs in various ranges of generating capacity. The results, presented in CEC Appendix 4-3, indicate that the average BUG size, weighted by the number of BUGs in each category, is approximately 590 hp.

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