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Evaluation of Air Pollution Regulatory Strategies for Gasoline Marketing Industry

Executive Summary

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OFFICE OF AIR QUALITY PLANNING AND STANDARDS
AND
OFFICE OF MOBILE SOURCES

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Washington, DC 20460

July 1984

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Preface

This report contains an executive summary of a regulatory strategies analysis performed by the Environmental Protection Agency. Also, this report refers the reader to other chapters and appendices that are contained in the complete regulatory strategies document. Interested persons should read the regulatory strategies document (EPA-450/3-84-012a) for a more comprehensive discussion of the methodology and assumptions used in the analysis, and the results of the analysis. The complete regulatory strategies document can be obtained from the EPA library and NTIS (see page ii, for address).

1.0 EXECUTIVE SUMMARY

The purpose of the study was to evaluate the air pollution regulatory strategies available to reduce emissions from gasoline marketing operations of benzene (Bz), ethylene dibromide (EDB), ethylene dichloride (EDC), and gasoline vapors (GV). Gasoline vapors or volatile organic compound (VOC) emissions contribute to ambient ozone concentrations and, thus, in some areas contribute to a failure to attain the national ambient air quality standard for ozone. Benzene is a known carcinogen, which has been listed as a hazardous air pollutant under Section 112 of the Clean Air Act and is present in varying amounts in gasoline. In addition, EDB, EDC and gasoline vapors each have been shown to cause cancers in laboratory animals. EDB and EDC are generally added to leaded gasoline, but are not present in unleaded gasoline. The following segments of the gasoline marketing industry were considered: bulk terminals (including storage tanks and tank trucks), bulk plants (including storage tanks and tank trucks) and service stations (both inloading of underground storage tanks and refueling of vehicles). The regulatory strategies examined controls on all segments of the industry, both with and without selected size cutoffs for small facilities, as well as controls onboard the vehicle to reduce refueling emissions.

As noted, there are still areas of the country which have not yet attained the national ambient air quality standard (NAAQS) for ozone. The Clean Air Act requires that all areas achieve the NAAQS by December 31, 1987. Some States, as part of their State implementation plans to meet the statutory requirement, are considering control of gasoline marketing sources, especially the refueling of motor vehicles. Thus, an analysis of gasoline marketing regulatory strategies must address the need to attain the ozone NAAQS in selected areas. However, the emissions from gasoline marketing sources may induce public health risks which require control on a national basis. The analysis evaluated regulatory strategies which address both the more limited nonattainment issue in part of the country and the broader question of the need for a national control program to limit potential hazardous exposure.

1.1 OPERATIONS, EMISSIONS AND CONTROL TECHNOLOGY

This section briefly outlines the operations and emissions of each source category and major associated type of facility in the gasoline marketing industry, as well as the commonly used control techniques. The segments of the gasoline marketing industry analyzed in this study include all elements and facilities that move gasoline starting from the bulk terminal to its end consumption. Gasoline produced by refineries is distributed by a complex system comprised of wholesale and retail outlets. Figure 1-1 depicts the main elements in the marketing network. The flow of gasoline through the marketing system is shown from the refinery, through bulk terminals, and sometimes bulk plants, to retail service stations or commercial or rural dispensing facilities, primarily via pipeline and tank truck. The wholesale operations storing and transporting gasoline including delivery and storage in a service station underground tank are commonly called Stage I operations. Retail-level vehicle refueling operations are commonly termed Stage II.

The baseline nationwide VOC emission estimates are also given for the various source categories on Figure 1-1. VOC emission factors for the individual point source operations at each source category were estimated. Emissions at baseline were calculated based on the gasoline throughput and current regulations for each source category in each county in the nation. Emission estimates for the other pollutants (Bz, EDB, EDC) were calculated using a ratio of the vapor pressures and thus, vapor emission rates.

1.1.1 Bulk Terminals

Bulk gasoline terminals serve as the major distribution point for the gasoline produced at refineries. Gasoline is most commonly delivered to terminal storage tanks by pipeline with no emissions. Gasoline is stored in large aboveground tanks and later pumped through metered loading areas, called loading racks, and into delivery tank trucks, which service various wholesale and retail accounts in the marketing network.

Most tanks in gasoline service at terminals have an external or, less commonly, an internal floating roof to prevent the loss of product through evaporation and working losses. Floating roofs rise and fall with the liquid level preventing formation of a large vapor space

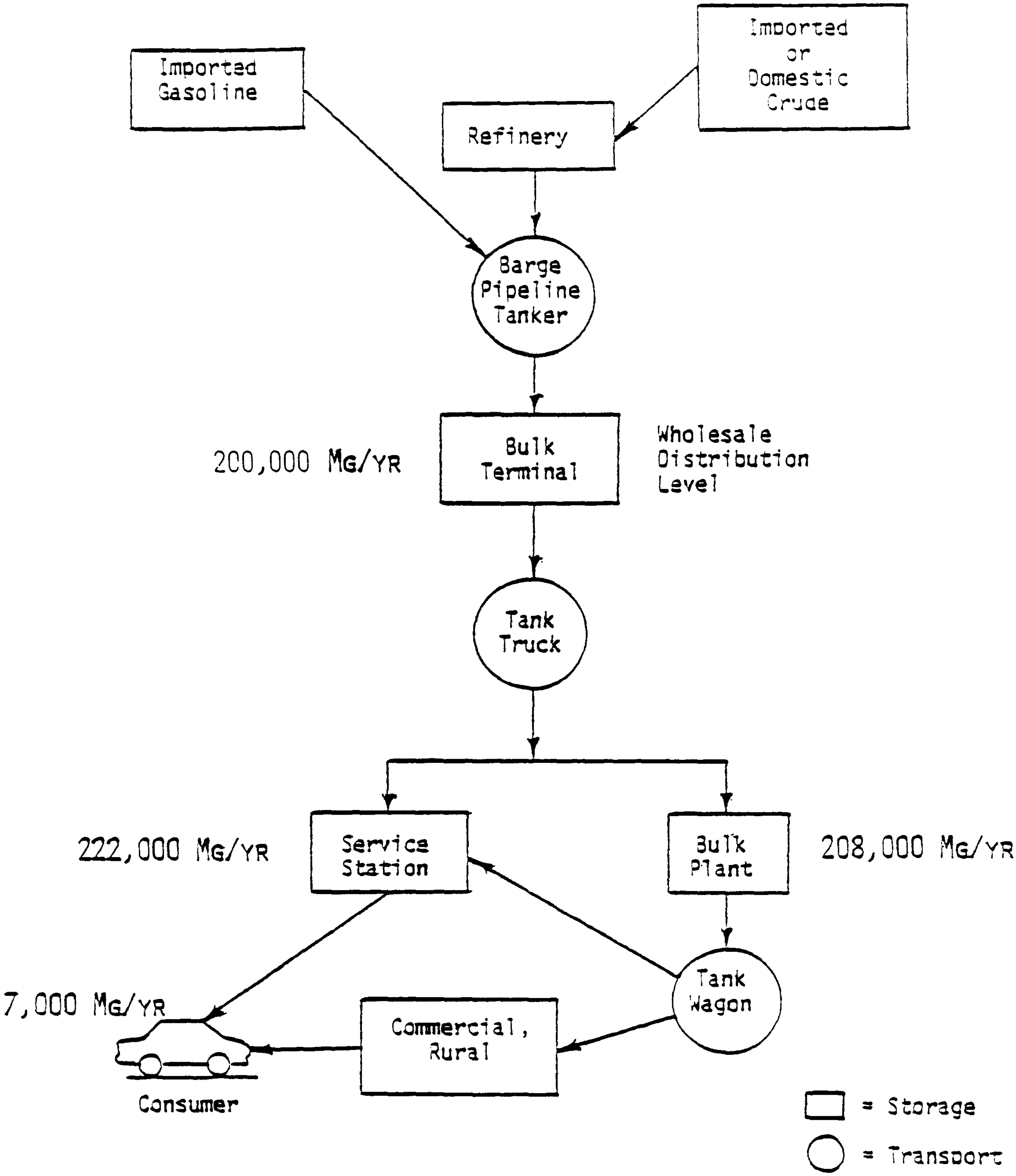

Figure 1-1. Gasoline Marketing in the U.S.
(1982 Baseline VOC Emissions)

and resulting emissions. Fixed-roof tanks, which are still used for gasoline in some areas, use pressure-vacuum (P-V) vents to control the smaller breathing losses and may use processing equipment to control the much greater working (filling and emptying) losses. Breathing losses result from volume variation due to daily changes in temperature and barometric pressure. Emptying losses occur when air drawn into the tank during liquid removal saturates with hydrocarbon vapor and expands beyond the vapor space of a fixed-roof tank. Filling losses occur when the vapors in the fixed-roof tank are displaced by the incoming liquid and forced to the atmosphere. The largest potential source of losses from external floating-roof tanks is an improper fit between the seal and the tank shell. Withdrawal loss from exposed wet tank walls is another source of emissions from floating-roof tanks.

Emissions from the tank truck loading operations at terminals occur when the product being loaded displaces the vapors in the delivery truck tank and forces the vapors to the atmosphere. In order to control these loading emissions, the displaced vapors can be ducted to a vapor processor such as a carbon adsorber, thermal oxidizer, or refrigerated condenser for recovery or destruction. The quantity of emissions generated during loading a tank truck are dependent on the type of loading. Splash loading from the top of the truck creates considerable turbulence during loading and can create a vapor mist resulting in higher emissions. Top submerged loading, which uses an extended fill pipe, or bottom loading admit gasoline below the liquid level in the tank and can be used to reduce turbulence and emissions (about a 60 percent reduction). The recently promulgated bulk terminal new source performance standards (NSPS), as well as a large number of State regulations, currently require the use of vapor processors and submerged loading at bulk terminals. Most State regulations limit truck loading emissions to 80 mg/liter transferred (equivalent to about 90 percent reduction) and require the tank truck to be vapor tight. The NSPS is more stringent and requires a lower emission limit of 35 mg/liter.

1.1.2 Bulk Plants

Bulk gasoline plants are secondary distribution facilities that typically receive gasoline from bulk terminals via truck transports, store it in aboveground storage tanks, and subsequently dispense it via smaller account trucks to local firms, businesses and service stations. As discussed in the previous section, vapors can escape from fixed-roof storage tanks at bulk plants due to breathing losses even when there is no transfer activity. The majority of bulk plants already use top or bottom submerged loading, largely in response to State regulations. Vapor balancing is required by many State regulations, primarily for incoming loads, but also for outgoing loads in some instances. Vapor balancing enables the vapors from the tank being filled to be transferred via piping to the tank being emptied. Thus, the vapors are not forced to the atmosphere, and as a result, working losses are greatly reduced (by 90 percent or greater).

1.1.3 Tank Trucks

Gasoline tank trucks are normally divided into compartments with a hatchway at the top of each compartment. Loading can be accomplished by top splash or submerged fill through the hatch, or by bottom filling. The majority of trucks have dual capability. Either top or bottom loading can be adapted for vapor collection. However, the trend is toward bottom loading because of State vapor recovery regulations and operating and safety advantages. The vapor collection equipment is basically composed of vapor domes enclosing each top hatch along with various connectors and pipes (some removable) that enable the vapors from the tank being filled to be transferred to the tank being emptied of liquid. Tank trucks with vapor collection equipment can become a separate source of emissions when leakage occurs (estimated to average about 30 percent of potentially captured emissions). Many States require gasoline tank trucks equipped for vapor collection to pass an annual test of tank vapor tightness and pressure limits for the tanks and vapor collection equipment (reducing average leakage to about 10 percent).

1.1.4 Service Stations

Gasoline handling operations, emissions, and controls at service stations are basically divided into two steps: the filling (or inloading) of the underground storage tank, commonly called Stage I, and vehicle refueling, commonly called Stage II. The filling of underground tanks at service stations ends the wholesale gasoline marketing chain. The automobile refueling operation at service stations is the part of the marketing chain that interacts directly with the general public.

Emissions from underground tank filling operations at service stations can be reduced significantly (by about 95 percent) by the use of a vapor balance system. Instead of being vented to the atmosphere, the vapors are transferred into the tank truck unloading at the service station and, ultimately, to the terminal vapor processor for recovery or destruction. Such controls have been incorporated into many State regulations.

Vehicle refueling emissions are another major source of emissions, attributable to spillage and to vapor displaced from the automobile tank by dispensed gasoline. The two basic vehicle refueling regulatory strategies are: (1) control systems on service station equipment (termed Stage II controls), and (2) control systems on vehicles and trucks (termed onboard controls). Stage II controls consist of either vapor balance systems or assisted systems. Assisted systems use a variety of means to generate a more favorable (negative or zero) pressure differential at the nozzle-vehicle interface so that a tight seal is not necessary between the vehicle and the nozzle "boot" (a flexible covering over the nozzle which captures the vapor for return to the underground tank via a vapor hose). Stage II controls are currently being used in 26 counties in California and the District of Columbia and are being considered for other ozone nonattainment areas. Onboard vapor controls consist of a fillpipe seal and a carbon canister that adsorbs the vapors displaced from the vehicle fuel tank by the incoming gasoline. The onboard system has undergone only limited testing to date. It is unclear what design problems could be encountered if onboard were required for the entire vehicle fleet; however, the technology is an extension of a system already installed on light-duty cars and trucks. Since 1971, new cars have been equipped with similar carbon canister systems for collecting evaporative emissions (breathing losses caused by temperature changes in the vehicle tank and carburetor).

Both Stage II and onboard controls can be highly effective (as high as 95 and 98 percent, respectively). However, these high theoretical efficiencies are likely to be somewhat reduced in-use (to as low as 56 percent for Stage II programs under a minimal enforcement scenario considering a 20 percent rate of noncompliance, and to about 92 percent for onboard controls with the expected level of tampering).

It should be noted that vehicle refueling controls not only reduce ambient concentrations of VOC and hazardous emissions dispersed from the service station, but also reduce the much higher exposures to hazardous pollutants during self-service refueling (as discussed later). In addition, it has been found that the present canisters for controlling evaporative emissions on many models of new vehicles are undersized. The expansion of the onboard system to control refueling emissions could achieve additional evaporative emission reductions roughly equal to the emission reductions achieved through refueling control. The estimate of excess evaporative emissions is preliminary because EPA testing is not yet complete.

1.2 ANALYSES OF REGULATORY STRATEGIES

The regulatory strategies selected for this evaluation were assessed with regard to their air pollution emissions, health-risk and cost impacts. Impacts analyses were conducted using a model plant approach for most industry segments and source categories, along with certain key assumptions. Economic impacts were also assessed, as were the effects of various enforcement levels on in-use effectiveness of the vehicle refueling control systems. The following sections summarize the regulatory strategies and analytical methods and assumptions used.

1.2.1 Regulatory Strategies, Model Plants, and Projections

A total of 14 industry-wide regulatory strategies were selected for evaluation. These strategies, which are presented in Table 1-1, are composed of a mixture of control options for the individual source categories. For the strategies calling for additional controls assessment was made of the relative emissions, risks, costs, and cost effectiveness of:

(1) nationwide control of Stage I sources,

TABLE 1-1. GASOLINE MARKETING REGULATORY STRATEGIES[a]

No Additional Controls (Baseline)
Stage II - Selected Nonattainment Areas (NA*)[b]
Stage II - All Nonattainment Areas (NA)[c]
Stage I - Nationwide
Stage II - Nationwide
Stage I and Stage II - Nationwide
Onboard - Nationwide
Stage II - Selected Nonattainment Areas & Onboard - Nationwide
Stage II - All Nonattainment Areas & Onboard - Nationwide
Stage I & Onboard - Nationwide
Stage II - All Nonattainment Areas and Stage I & Onboard - Nationwide
Stage II & Onboard - Nationwide
Stage I & Stage II & Onboard - Nationwide
Benzene Reduction in Gasoline[d]

[a] Facility Size Cutoffs:
Stage I:
(1) bulk plants with throughputs <4000 gal/d from balance controls on outgoing loads; and
(2) service stations with throughputs <10,000 gal/mon.
Stage II:
(1) all service stations with throughputs <10,000 gal/mon; and
(2) all independent service stations with throughputs <50,000 gal/mon.

[b] Ozone nonattainment areas needing vehicle refueling controls to help meet their ozone attainment goals by 1987.

[c] Areas predicted by State or EPA to be nonattainment for ozone in 1982.

[d] Benzene reduction:
A. removal of 94.5 percent of Bz from reformate fraction for total reduction of 62.4 percent;
B. removal of 94.5 percent of Bz from reformate and fluid catalytic cracker (FCC) fractions for total reduction of 81.3 percent.

(2) nationwide control of vehicle refueling emissions (Stage II controls, onboard controls, or both),

(3) ozone nonattainment area control of vehicle refueling emissions (selected or all ozone nonattainment areas), and

(4) combinations of the above.

The regulatory strategies consider these approaches either singly or in combination, both for controlling all facilities and for including size cutoffs for some facilities. The facility size cutoffs were assumed based on the relatively higher costs of control for small facilities, existing size cutoffs under State and local regulations, and statutory requirements for small and medium throughput independent service stations under Section 325 of the Clean Air Act (section titled "Vapor Recovery for Small Business Marketers of Petroleum Products"). If a Section 112 standard is pursued requiring Stage I or Stage II controls, the actual size cutoffs could vary from these assumptions based upon a more thorough economic analysis for small businesses and an assessment of whether Section 325 applies to Section 112 standards. For the purposes of the analysis, initial installation of Stage I and II control equipment was assumed to occur in 1986 for the nonattainment area strategies, in 1987 for nationwide strategies, and on new vehicles beginning with the 1988 model year for onboard controls. All of the strategies were compared with a baseline reflecting 1982 Federal, State, and local regulations. The base year of 1982 was selected because this represented the final implementation year for many State regulations affecting gasoline marketing sources, and because at the beginning of the analysis the most recent complete data reflected 1982 totals.

A number of model plants were developed to represent the entire spectrum of facilities in the analyses. Four model plants were used for both bulk terminals and bulk plants while five model plants were used for service stations. The model plants for each source category were differentiated on the basis of size, in terms of gasoline throughput. Estimates of typical costs, emissions, and resultant health-risks could then be generated for each model plant and, thus, for the entire population spectrum of each facility type.

Because onboard controls would be installed only on new vehicles (this analysis did not consider a retrofit option), the onboard regulatory strategies take a number of years after initial implementation to control the entire vehicle fleet. Therefore, in order to evaluate the comparison of onboard with other controls during both phase-in and full implementation, the analyses examined the time period from 1986 (when the first controls would begin to be implemented) through 2020. Thus, the projection of certain basic parameters was necessitated.

Total and leaded gasoline consumption were extrapolated to the year 2000, based on the projections by EPA through 1990 for the phasedown of lead in gasoline (47 FR 49329). Due to a lack of confidence in extrapolating beyond 15 years, gasoline consumption was assumed to remain constant from the year 2000 to the year 2020. The number and fuel consumption of onboard controlled vehicles in a given year were estimated based on projections of new vehicles, retirement rates, fuel economy, and mileage accrual rates through the year 2000. These parameters were also assumed constant from 2000 through 2020. Although the number of bulk plants and service stations have been decreasing, no quantitative data was readily available with which to project facility populations. Therefore, the numbers and size distributions of facilities were assumed to remain constant at the values estimated for the base year of 1982. However, the throughputs per facility and corresponding recovery credits were decreased in proportion to the projected decline in nationwide gasoline consumption. The economic effects of alternative assumptions (e.g., constant gasoline consumption, declining marketing facilities, etc.) are examined in Chapter 8.

A summary of major analytical considerations that should be noted in assessing the results is given in Table 1-2. Both costs and emissions were summed to a cumulative value, and also were discounted (at 10 percent) to a net present value in 1986 (by summing the equivalent worth in 1986 of each annual amount). Discounting was necessary because impacts are not uniform over the time period analyzed due to: 1) the slower phase-in period of onboard controls compared to Stage I and II equipment; 2) the respective useful lives of service station and onboard control equipment; and 3) the declining gasoline consumption which directly influences the

TABLE 1-2
MAJOR ANALYTICAL CONSIDERATIONS

- A standard exposure lifetime of 70 years was used for exposure to ambient concentrations (i.e., those away from the immediate vehicle fueling area). A period of 50 years was used for self-service fueling exposure because one would not be expected to operate a vehicle for a complete lifetime.

- Because of the different phase-in times for Stage II and onboard, and to analyze the impact of the strategies after onboard was fully implemented, the analysis covered a period from 1986 to 2020.

- In this analysis, it was assumed that a national Stage II program would be in place in 1989, and that 1988 model year vehicles would be the first to incorporate onboard controls. It is expected that it will take about 20 years to convert the entire vehicle fleet to onboard control.

- Both costs and emissions capture over the 35-year analysis period were discounted at 10 percent to calculate cost effectiveness. This was done to address the difference in phasing-in Stage II and onboard controls.

- Due to the number of sources and lack of siting data, simplifying assumptions were required. These included:
  - Model Plants
  - Typical Locations of Plants
  - Number of Facilities Within Source Categories
  - Distribution of all Sources

- Sources were distributed by best estimate considering size and population densities.

- Risk is assumed to be linearly related to dose (concentration x duration of exposure) and combinations of concentration and duration yielding the same dose are assumed to be equivalent for risk estimation purposes.

- The impacts of exposure to other substances beyond benzene, EDC, EDB, and gasoline vapor are not addressed. Health Effects other than cancer are not explicitly addressed.

- Total gasoline and leaded gasoline consumption is based on EPA's lead phase-down projection extrapolated to the year 2000. The consumption estimate for the year 2000 is assumed for all years from 2001 to 2020.

- Fleet average cost estimate of onboard systems used in this analysis was approximately $15 per vehicle. Recent studies by API and Ford Motor Company estimate average onboard costs of $13 and $53 per vehicle, respectively.

- The average capital costs (equipment and installation costs) per station for Stage II control systems used in this analysis are $5,700, $6,100, $6,600, $9,800 and $14,800 for 5, 20, 35, 65, and 185 thousand gallon per month throughput stations, respectively.

recovery cost credits. Cost effectiveness was calculated using the discounted costs and emissions values.

1.2.2 Air Pollution Emissions, Health-Risk, and Control Cost Analyses

Several underlying methods and assumptions were made in all of the emissions, health-risk, and control cost analyses, in addition to the projections noted in the previous section. Generally, emissions and health-risk impacts of the various regulatory strategies (including baseline, which reflects current controls) were estimated for a base year (1982) and then extrapolated to the years 1986 through 2020 in proportion to the total (for benzene and gasoline vapors) or leaded (for EDB and EDC) gasoline throughput for each source category. In addition, the phasing-in of control installations with time were considered in accordance with statutory requirements. All affected facilities were assumed to install controls (linearly with time) within one year for a CTG and within 2 years for a NESHAP except for independent service stations, which may be allowed up to 3 years in accordance with Section 325 of the Clean Air Act. Capital costs were attributed to the year of installation.

Estimates of annualized costs, emissions, and subsequent health-risks during phase-in periods were based on the number of facilities and corresponding gasoline throughput controlled for an entire year. The impacts of vehicles with onboard controls in each year were calculated based on the vehicle fleet projections noted previously. After nearly the entire vehicle fleet was projected to be equipped with onboard controls (in about 2002-2003), Stage II controls were not replaced, but instead gradually phased out after the completion of useful equipment lives for those strategies combining Stage II and onboard.

The health-risk analysis estimated both annual cancer incidences nationwide and lifetime risk from high exposure, assuming a linear dose response relationship with no threshold. The term "lifetime risk from high exposure" is conceptually similar to the term "maximum lifetime risk" which has been presented in other EPA documents, including those on benzene sources regulated or considered for regulation under Section 112 of the Clean Air Act. The term "lifetime risk from high exposure" rather than "maximum lifetime risk" is used in presenting the risk calculations for the gasoline marketing study because EPA is less certain in this case that the assumptions used result in the maximum exposure to any single person or group. For example, high exposure from self-service was assumed to occur to a person pumping 40 gallons per week. To the extent that some people may pump more gas than that, risks may be underestimated.

The estimates of risk, in terms of individual lifetime risk from high exposure and aggregate incidence, are applicable to the public in the vicinity of gasoline marketing sources and those persons who refuel their vehicles at self-service pumps. This analysis did not examine the risk to workers from occupational exposure (e.g., terminal operators and service station attendants). The lifetime risk from high exposure for these workers is probably substantially higher than for the general public. In addition, the estimates of aggregate incidence would be higher if such worker populations were included in the analysis. Of course, any controls to reduce gasoline marketing emissions would reduce exposure for workers as well as for the general public.

The unit risk factors used in the analysis for the four pollutants, presented in Table 1-3, were developed by the EPA's Carcinogen Assessment Group based on available health studies. Two values of unit risk are shown for gas vapors - a "maximum likelihood estimate" and a "plausible upper limit." Both values are used in the analysis to provide a broader base for evaluating the impacts of exposure to gasoline vapors. For a detailed description of the derivation of the gasoline vapors unit risk numbers, see the EPA staff paper "Estimation of the Public Health Risk from Exposure to Gasoline Vapor Via the Gasoline Marketing System", June 1984. The risk factor for benzene is based on studies of humans occupationally exposed to benzene. The risk factors for gasoline vapors, EDC, and EDB are based on animal studies only. Because of the significance of the gasoline vapor animal studies, conducted for the American Petroleum Institute, they are examined in detail in the EPA staff paper cited above. The staff paper was submitted on June 22, 1984, to the EPA Science Advisory Board for review.

There can be substantial uncertainty in unit risk factors. Reasons for this uncertainty include extrapolations which must be made from

TABLE 1-3. UNIT RISK FACTOR SUMMARY

Pollutant	Unit Risk[a] (probability of cancer given lifetime exposure to 1 ppm)	Health Effects Summary	Comments
Gasoline Vapor		Kidney tumors in rats, liver tumors in mice.	Gasoline test samples in the animal studies were completely volatilized, therefore may not be completely representative of ambient gasoline vapor exposures.
Plausible Upper Limit:[b]			
Rat Studies	3.5×10^{-3}		
Mice Studies	2.1×10^{-3}		
Maximum Likelihood Estimates:			
Rat Studies	2.0×10^{-3}		
Mice Studies	1.4×10^{-3}		
Benzene	2.2×10^{-2}	Human evidence of leukemogenicity. Zymbal gland tumors in rats, lymphoid and other cancers in mice.	EPA: listed as a hazardous air pollutant, emission standards proposed. IARC[c]: sufficient evidence to support a causal association between exposure and cancer.
Ethylene Dibromide	4.2×10^{-1}	Evidence of carcinogenicity in animals by inhalation and gavage. Rats: nasal tumors; Mice: liver tumors.	EPA: suspect human carcinogen; recent restrictions on pesticidal uses.
Ethylene Dichloride	2.8×10^{-2}	Evidence of carcinogenicity in animals. Circulatory system, forestomach, and glands; Mice: Liver, lung, glands, and uterus.	EPA: Suspect human carcinogen. Draft health assessment document released for review March 1984.

[a] Unit Risk Factor is in terms of the probability of a cancer incidence (occurrence) in a single individual for a 70-year lifetime of exposure to 1 ppm of pollutant.

[b] The plausible upper limit is calculated as the 95 percent upper-confidence limit of the incremental risk due to exposure to 1 ppm of gasoline vapor, using the multistage dose-response model for low-dose extrapolation.

[c] IARC: International Agency for Research on Cancer.

workers or animals to the general population and from the higher concentrations found in studies to the lower concentrations found in the ambient air.

Estimates of risk due to exposures from bulk terminals, bulk plants, service stations, and self-service vehicle refueling were generated for each of the four pollutants. In order to calculate community exposure to emissions (and the resultant risk) from bulk terminals and plants, assumptions were made concerning their geographical distribution. The fundamental assumption was that facilities were located in proportion to the gasoline throughput for an area--for example, the largest model plants would be located in large urban areas where throughput (and population density) were highest. Further, each model plant type in each source category (bulk terminals and bulk plants) was distributed over a range of ten urban area sizes. The largest terminals, for instance, were assumed to be located in cities ranging in size from New York City to Des Moines, Iowa; the smallest terminals were assumed to be located in cities ranging in size from Spokane to Effingham, Illinois. Estimates were also made of the extent of existing control at these terminals. Most of those in the large cities (likely to be ozone nonattainment areas) were considered controlled, based upon existing regulations, with proportionately fewer facilities controlled in the smaller areas.

Thus, for both terminals and bulk plants, there were 40 model plant locations (four model plant sizes each distributed to 10 representative areas) for which estimates of ambient concentrations, population exposure and incidence were made. Total national incidence was calculated by multiplying the model plant incidence by the number of facilities represented by each model plant. In somewhat similar fashion, model service stations were allocated to 35 localities (multi-county metropolitan areas or single counties) and grouped by seven population size ranges. The model plants were selected to be representative of total national service station distribution. The localities and seven population size ranges were selected to be representative of the total national population distribution.

Ambient concentrations, exposure, and incidence for bulk terminals, bulk plants and service stations were calculated using the SHEAR version of the EPA Human Exposure Model (HEM). The HEM is a model capable of estimating ambient concentrations and population exposure due to emissions from sources located at any specific point in the contiguous United States.

Annual incidence due to self-service vehicle refueling was estimated based on benzene and VOC concentrations in the region of the face of a person filling the tank, as measured in a study for the American Petroleum Institute (API).* API selected thirteen gas stations in 6 cities in which samples were collected to characterize typical exposures to total hydrocarbons, benzene and eight other compounds. Samples were collected using MSA-type battery operated pumps operated at a one liter per minute flow rate and analyzed using a gas chromatograph. Results were expressed as mg/m^3 air and ppm (vol.).

The lifetime risk analysis was designed to estimate high exposures of the four pollutants. The Industrial Source Complex (ISC) dispersion model was used to calculate annual concentrations in selected years at a number of receptors in the vicinity of a bulk terminal complex, a bulk plant complex, and a service station complex. Meteorological data for several cities expected to produce high concentrations were used. The highest concentration at any receptor under a given regulatory strategy was used to estimate the risk over a 70-year lifetime. The lifetime risk due to self-service exposure was estimated based on the API measurements and an assumed lifetime exposure pattern of an individual using a relatively high amount of gasoline (i.e. traveling salesman): the risk was based upon an assumed exposure to four 10-gallon self-service refuelings per week for a working lifetime (estimated as 50 years).

The control cost estimates were developed using a method similar to that for emissions. Capital and operating cost data were obtained (largely from previous EPA studies) and developed on a per facility

*Clayton Environmental Consultants, Inc. Gasoline Exposure Study for the American Petroleum Institute. Job No. 18629-15. Southfield, Michigan. August 1983.

basis for each model plant size of each source category. These per facility costs were then combined with data on the number of facilities requiring controls within each source category. Capital costs over the 35 years of the analysis were incorporated during the initial phase-in years and then repeated in the years in which the economic life of the equipment ended if replacement equipment was required. Annualized costs reflected the capital costs and also were adjusted each year, as appropriate, to reflect reduced recovery credit due to the assumed decreases in gasoline throughput.

1.3 RESULTS OF REGULATORY STRATEGY ANALYSES

Although only results of strategies involving size cutoffs are given in this summary, all strategies are discussed in detail in Chapters 2 through 9. The estimated risks from the various source categories are given in Table 1-4 for baseline (no additional controls) and when controlled. Table 1-4a contains estimated risks using the plausible upper limit unit risk factor for gasoline vapors and Table 1-4b contains the estimates using the maximum likelihood estimate unit risk factor for gasoline vapors.

The lifetime risk from high exposure estimates the probability that exposure by an individual to a relatively high ambient concentration throughout his lifetime would result in a cancer incidence. The lifetime risk from high exposure to bulk terminal emissions is higher than the lifetime risk from high exposure to uncontrolled emissions from any of the other source categories.

The average annual incidence for each regulatory strategy is the sum of the estimated average annual incidences from each industry segment expected to result from exposures during a given year. (The estimated annual incidences decrease during the study period in proportion to a projected decrease in gasoline consumption.) The average annual incidences given are estimates of cancer incidence due to benzene and gasoline vapors; for the latter, results are shown based on both mice and rat health studies. Subsequent incidence numbers in this Executive Summary will be given in terms of rat data only (for both plausible upper limit and maximum likelihood estimates) as the rat numbers are higher and the tables can be simplified. The incidences due to EDB and

TABLE 1-4a. ESTIMATED RISKS FROM GASOLINE MARKETING SOURCE CATEGORIES (USING PLAUSIBLE UPPER LIMIT UNIT RISK FACTOR FOR GASOLINE VAPORS)

A. BASELINE

Source Category	Lifetime Risk from High Exposure (probability of effect) Bz(GV[a])	Average Annual Incidence Over 35 years (1986-2020) Bz(GV[a])
Bulk Terminals	1.2×10^{-4}(2.4 or 3.9×10^{-3})	0.07(1.3 or 2.2)
Bulk Plants	6.4×10^{-6}(1.2 or 2.0×10^{-4})	0.04(0.68 or 1.1)
Service Stations	2.4×10^{-6}(4.4 or 7.2×10^{-5})	0.19(3.3 or 5.5)
Self-service	1.1×10^{-5}(5.5 or 9.0×10^{-5})	3.2(19 or 31)

B. CONTROLLED WITH SIZE CUTOFFS[b]

Source Category	Lifetime Risk from High Exposure (probability of effect) Bz(GV[a])	Average Annual Incidence Over 35 years (1986-2020) Bz(GV[a])
Bulk Terminals	2.0×10^{-5}(3.9 or 6.4×10^{-4})	0.05(0.92 or 1.5)
Bulk Plants	1.7×10^{-6}(3.2 or 5.3×10^{-5})	0.02(0.32 or 0.53)
Service Stations[c]		
Stage I controls only	1.6×10^{-6}(2.9 or 4.7×10^{-5})	0.17(3.0 or 4.9)
Stage II controls only	1.3×10^{-6}(2.5 or 4.2×10^{-5})	0.11(1.9 or 3.2)
Onboard controls only	1.6×10^{-6}(2.9 or 4.8×10^{-5})	0.10(1.8 or 3.0)
Self-service[c]		
Stage II controls only	5.1×10^{-7}(2.5 or 4.1×10^{-6})	1.2(6.8 or 12)
Onboard controls only	7.6×10^{-8}(4.4 or 7.2×10^{-7})	1.1(5.9 or 9.8)

[a] Bz = benzene, GV = gasoline vapors (mice or rats studies). Incidences and lifetime risk due to gasoline vapors are presented to reflect the two unit risk factors (for liver cancer in mice or for kidney cancer in rats).

[b] Based on theoretical control efficiencies.

[c] Indicates reduction of lifetime risk from high exposure for controlled sources.

TABLE 1-4b. ESTIMATED RISKS FROM GASOLINE MARKETING SOURCE CATEGORIES (USING MAXIMUM LIKELIHOOD ESTIMATE UNIT RISK FACTOR FOR GASOLINE VAPORS)

A. BASELINE

Source Category	Lifetime Risk from High Exposure (probability of effect) Bz(GV[a])	Average Annual Incidence Over 35 years (1986-2020) Bz(GV[a])
Bulk Terminals	1.2×10^{-4}(1.6 or 2.2×10^{-3})	0.07(0.90 or 1.3)
Bulk Plants	6.4×10^{-6}(8.2×10^{-5} or 1.1×10^{-4})	0.04(0.46 or 0.64)
Service Stations	2.4×10^{-6}(2.9 or 4.1×10^{-5})	0.19(2.2 or 3.1)
Self-service	1.1×10^{-5}(3.7 or 5.1×10^{-5})	3.2(13 or 18)

B. CONTROLLED WITH SIZE CUTOFFS[b]

Source Category	Lifetime Risk from High Exposure (probability of effect) Bz(GV[a])	Average Annual Incidence Over 35 years (1986-2020) Bz(GV[a])
Bulk Terminals[b]	2.0×10^{-5}(2.6 or 3.7×10^{-4})	0.05(0.62 or 0.86)
Bulk Plants	1.7×10^{-6}(2.2 or 3.0×10^{-5})	0.02(0.22 or 0.30)
Service Stations[c]		
Stage I controls only	1.6×10^{-6}(1.9 or 2.7×10^{-5})	0.17(2.0 or 2.8)
Stage II controls only	1.3×0^{-6}(1.7 or 2.4×10^{-5})	0.11(1.3 or 1.8)
Onboard controls only	1.6×10^{-6}(2.0 or 2.8×10^{-5})	0.10(1.2 or 1.7)
Self-service[c]		
Stage II controls only	5.1×10^{-7}(1.7 or 2.3×10^{-6})	1.2(4.8 or 6.6)
Onboard controls only	7.6×10^{-8}(3.0 or 4.1×10^{-7})	1.1(4.0 or 5.6)

[a] Bz = benzene, GV = gasoline vapors. Incidences and lifetime risk due to gasoline vapors are presented to reflect the two unit risk factors (for liver cancer in mice or kidney cancer in rats.

[b] Based on theoretical control efficiencies.

[c] Indicates reduction of lifetime risk from high exposure for controlled sources.

EDC only increase the incidences due to benzene by less than 3 percent in most cases and by 5 percent or less in all cases. Because the estimated incidences due to EDB and EDC are relatively small, they were omitted from the summary tables. The average annual incidence from self-service refuelings at service stations contributes about 80 percent of the total incidence from all source categories. The annual incidences due to service stations without any additional controls are approximately 3 for benzene and from about 15 to 36 for gasoline vapors, considering both community exposures to ambient concentrations and individual exposures to self-service refueling concentrations.

1.3.1 Nonattainment Area Strategy Results

The effects of vehicle refueling controls in nonattainment areas are shown in Table 1-5. The primary focus of the nonattainment area strategies is to reduce VOC emissions in order to attain the national ambient air quality standard (NAAQS) for ozone; reduction of risk due to hazardous pollutants is an added benefit. If onboard controls nationwide under Section 202(a)(6) of the Clean Air Act are used to replace or supplement nonattainment area regulatory strategies, in addition to the primary aim of reducing VOC emissions in some or all nonattainment areas, VOC and hazardous emissions are also reduced nationwide. It should be noted that the strategy of Stage II controls in all nonattainment areas also includes the costs, emissions, and risk reductions for Stage I controls at service stations in two non-attainment areas (Atlanta and Phoenix) where they currently are not installed.

The average annual baseline level of VOC emissions (and zero additional control cost) from service stations of 91,300 Mg/yr is given in parentheses in Table 1-5. The average annual VOC emission reduction from the baseline, net present value of control costs, and discounted cost effectiveness due to Stage II refueling controls were estimated to be 20,600 Mg/yr, $210 million, and $940/Mg VOC, respectively, for the "selected nonattainment areas" (NA*) strategy and 60,900 Mg/yr, $570 million, and $870/Mg VOC, respectively, for the "all nonattainment areas" (NA) strategy. The costs and cost effectiveness values for strategies involving onboard controls are much higher (costs about $2

TABLE 1-5. VEHICLE REFUELING CONTROLS IN NONATTAINMENT AREAS

Regulatory Strategy	Average Annual VOC Emission Reduction[a], In Nonattainment Areas, Mg (1986 - 2020)	Net Present Value of Costs, $Million (1986 - 2020)	Discounted Cost Effectiveness $/Mg VOC	Nationwide Service Station Average Annual Incidence[b] (1986 - 2020), Bz (GV)[c]
BASELINE				
Service Station Emissions	(91,300)[d]	--	--	3.4(21 or 36)
REGULATORY STRATEGIES				
Stage II in Selected Nonattainment areas (NA* with size cutoffs)[e]	20,600	210	940	3.1(19 or 33)
Stage II in all Nonattainment areas (NA with size cutoffs)[f]	60,900	570	870	2.6(16 or 28)
Onboard Nationwide[g]	56,300[g]	1,900	4,760[h]	1.2(7.3 or 13)
Stage II in Selected Nonattainment areas (with size cutoffs),[e] Onboard Nationwide	60,900[g]	2,100	4,130[h]	1.1(6.8 or 12)
Stage II in All Nonattainment areas (with size cutoffs)[f], Onboard Nationwide	69,100[g]	2,400	3,440[h]	1.0(6.1 or 11)

[a] Emission reductions from vehicle refueling only assuming theoretical efficiencies.

[b] From community exposure to ambient concentrations from service stations and from exposure of individuals during self-service vehicle refueling considering theoretical efficiencies.

[c] GV = Gasoline vapors (rat data only), two numbers given represent estimates using maximum likelihood estimate unit risk factor and plausible upper limit unit risk factor, respectively.

[d] Baseline emission level for vehicle refueling in nonattainment areas.

[e] Selected Nonattainment Areas (NA*) - areas needing Stage II to meet their attainment goals by 1987.

[f] All Nonattainment Areas (NA) - areas predicted by State or by EPA to be nonattainment for ozone in 1982. Includes Stage I for two metropolitan areas currently without Stage I in place.

[g] Onboard emission reductions in nonattainment areas only. Total nationwide average annual emission reductions (Mg/yr): Onboard - 197,000, Stage II (NA*) + Onboard - 203,000, Stage II (NA) + Onboard - 211,000.

[h] Cost effectiveness based on total nationwide emission reductions are: Onboard - 1,360, Stage II (NA*) + Onboard - 1,370, Stage II (NA) + Onboard - 1,410.

billion and cost effectivenesses about $5,000/Mg VOC) when considering only the emission reductions in the affected nonattainment areas and nationwide costs for onboard controls. The annual average incidences presented are the cumulative nationwide cancer incidences expected to result from service station community and self-service exposures during the 35-year period under the given regulatory strategy averaged over the 35 years. As can be seen from Table 1-5, the incidence reduction due to Stage II controls in nonattainment areas are relatively small (less than one incidence per year due to benzene) compared with that associated with onboard controls nationwide (more than two incidences per year due to benzene reduced). The results shown in Table 1-5 are based on theoretical control efficiencies and do not account for reduced efficiency in-use.

1.3.2 Nationwide Strategy Results

The issues involved in gasoline marketing operations do not relate to ozone attainment only -- there is concern for hazardous exposure also. This section presents summaries of the results of analyses of alternative nationwide regulatory strategies and combined nationwide/nonattainment strategies. Table 1-6 shows the estimated baseline annual average incidence for benzene and gasoline vapors, and the residual incidence and cost for each of the three primary nationwide strategies: Stage I, Stage II and onboard. The baseline benzene incidence attributable to vehicle operations emissions (tailpipe and evaporative) is also shown; this incidence is more than twice as large as that from gasoline marketing operations. In addition, the baseline incidence from possible additional evaporative emissions is shown separate from vehicle operations. This value was separated because of its uncertainty, being based on preliminary test results. Controls on gasoline marketing sources will not reduce incidences associated with vehicle operations.

For gasoline marketing sources, the average annual reduction in benzene incidence is estimated to be 0.1 with Stage I controls, 2.1 with Stage II controls and 2.3 with onboard. For gasoline vapors, the comparable numbers are 1.0 or 1.8, 12 or 22, and 14 or 24. Only limited benzene incidence reduction is achieved by removing benzene from gasoline (2.4-3.2 per year). This reduction primarily results from reduced exposure from gasoline marketing sources. Benzene tailpipe

TABLE 1-6. CONTROL OF BENZENE AND GASOLINE VAPORS FROM GASOLINE MARKETING SOURCES

Regulatory Strategy	Average Annual Incidence Of Cancers Expected From Exposures Over 35 years (1986-2020) Bz (GV[a])	Cost Impacts of Strategies ($Billion)	
		1986 NPV[b] of Costs (1986 - 2020)	Total 1982 Dollars Spent (1986 - 2020)
BASELINE			
Gasoline Marketing	3.5 (23 or 40)	--	--
Vehicle Operations[c]	9.7 (NA[d])	--	--
Evap. Emissions Not Captured[e]	0.2 (4.0 or 7.0)		
Total	13 (NA)	--	--
IMPACTS AFTER SELECTED[f] NATIONWIDE STRATEGIES	AVERAGE ANNUAL INCIDENCE REDUCTION		
Stage I - Nationwide (with size cutoffs)	0.1 (1.0 or 1.8)	0.9	3.2
Stage II - Nationwide (with size cutoffs)	2.1 (12 or 22)	1.6	6.3
Onboard Controls Nationwide			
- w/o Evap	2.3 (14 or 24)	1.9	9.7
- w/ Evap	2.5 (18 or 31)	1.9	9.7
Benzene Reduction in Gasoline		7.4-22	30-90
Gasoline Marketing	2.2-2.9 (0 or 0)		
Vehicle Operations[c]	0.18-0.23 (NA)		
Evap. Emissions Not Captured	0.09-0.12 (1.5 or 3.3)		

[a] GV = gasoline vapors (rat data only), two numbers given represent estimates using maximum likelihood estimate unit risk factor and plausible upper limit unit risk factor, respectively.

[b] NPV = Net Present Value.

[c] Incidences due to exhaust and evaporative benzene emissions during vehicle operations were estimated using an area source approach similar to that used for service stations. Unanticipated evaporative emissions were not considered here (see Footnote e).

[d] Not applicable.

[e] Based on preliminary estimate of possible emissions not captured by the existing evaporative emissions control system on vehicles. Reduction in such incidence is account for under "Onboard Controls, Nationwide, w/Evap."

[f] Impacts based on theoretical control efficiencies.

emissions are not affected substantially by benzene removal, since benzene is formed in the combustion process.*

Costs of additional controls beyond baseline are presented both as the net present value of cost (discounted at 10 percent to 1986) and the cumulative value of the estimated expenditures from 1986 through 2020 (all in 1982 dollars). The costs of all available nationwide strategies are greater than $800 million net present value of costs or $3 billion cumulative costs. The cost of benzene reduction in gasoline is a factor of 2 to 10 greater than for the next most costly strategy.

Table 1-7 summarizes the estimates of average annual incidence, emission reductions, cost, and cost effectiveness for the nationwide control strategies (with size cutoffs) evaluated. These impacts also are based on theoretical control efficiencies. This table presents more detailed results: average annual incidence under the strategy, cumulative VOC and benzene emission reductions, net present value of costs, and discounted cost effectiveness for both basic regulatory strategies and combinations of strategies. Although Stage I controls result in large emission reductions at relatively low cost, they result in substantially less incidence reduction than Stage II or onboard. Strategies with either Stage II or onboard refueling controls achieve greater incidence reductions because of their effect on self-service emissions.

Table 1-8 presents costs, emission reductions, incidence reduction and cost effectiveness with theoretical and in-use efficiencies for Stage II and onboard, and gives two levels of enforcement for Stage II. The in-use efficiency of Stage II programs is highly dependent on the level of enforcement used, varying from 56 percent with no inspections to 86 percent with annual inspections. Enforcement costs are not included in the cost-effectiveness figures given (their impact is addressed in Chapter 8). Although average annual enforcement costs for Stage II nationwide with annual inspections are about $7.7 million, including

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* Black, F.M., L.E. High, and J.M. Lang. Composition of Automotive Evaporative and Tailpipe Hydrocarbon Emissions. Journal of the Air Pollution Control Association. 30:1216-1221. November 1980.

Table 1-7. SUMMARY OF THEORETICAL IMPACTS FOR SELECTED REGULATORY STRATEGIES

Regulatory Strategies (with size cutoffs)	Average Annual Incidence (1986 - 2020) Bz (GV[a])	Average Annual VOC Emission Reduction, Mg (1986 - 2020)	Average Annual Bz Emission Reduction, Mg (1986 - 2020)	Net Present Value of Costs[b], $Million (1986 - 2020)	Discounted Cost Effectiveness[c] $/Mg VOC
Baseline(No Additional Controls)	3.5(23 or 40)	[710,000][d]	[4,400][d]	--	--
Stage II - Nationwide	1.4(10 or 18)	163,000	1,100	1,600	1,040
Onboard - Nationwide	1.3(9.2 or 16)	197,000	1,300	1,900	1,360
Stage II NA* Areas, Onboard Nationwide	1.2(8.7 or 15)	202,000	1,300	2,100	1,380
Stage II NA Areas, Onboard Nationwide	1.1(8.0 or 14)	210,000	1,400	2,400	1,390
Stage I - Nationwide	3.4(22 or 38)	217,000	1,300	860	410
Stage II and Onboard Nationwide	0.8(6.7 or 12)	228,000	1,500	3,500	1,700
Stage I and Stage II - Nationwide	1.4(9.3 or 16)	380,000	2,300	2,500	680
Stage I and Onboard-Nationwide	1.2(8.1 or 14)	414,000	2,500	2,780	790
Stage I, Stage II, Onboard - Nationwide	0.8(5.7 or 9.9)	446,000	2,700	4,350	1,040

[a] GV = gasoline vapors (rat data only), two numbers given represent estimates using maximum likelihood estimate unit risk factor and plausible upper limit unit risk factor, respectively.

[b] Net present value of costs is the sum of the present worth of each year's annualized cost (discounted at 10 percent).

[c] Discounted cost effectiveness is the net present value of costs divided by the net present value of emissions, both discounted at 10 percent.

[d] Average annual emissions at baseline control levels.

TABLE 1-8. IMPACTS BASED ON "IN-USE" EFFECTIVENESS FOR STAGE II AND ONBOARD CONTROLS (1986 - 2020)

Regulatory Strategies (% Control Efficiency)	Average Annual Emission Reduction of Benzene (Gasoline Vapors) (10^3Mg)	Net Present Value of Annual Costs, $ Billion	Discounted Cost Effectiveness, $/Mg of VOC	Average Annual Incidence Reduction Bz(GV[a])	Average Annual Enforcement Resources Person-years/$ Million
STAGE II NATIONWIDE (No size cutoffs)					
o Theoretical (95%)	1.6(237)	4.9	2,130	2.9(18 or 31)	-
o In-use . Annual Inspections (86%)	1.4(214)	5.0	2,380	2.6(16 or 28)	815/24.3
. No Inspections (56%)[c]	0.9(140)	4.0	2,950	1.6(9.8 or 17)	-
STAGE II NATIONWIDE (w/size cutoffs)					
o Theoretical (95%)	1.1(163)	1.6	1,040	2.1(12 or 22)	-
o In-use . Annual Inspections (86%)	1.0(146)	1.7	1,200	1.9(11 or 20)	260/7.7
. No Inspections (56%)[c]	0.6(94)	1.4	1,570	1.1(6.7 or 12)	-
ONBOARD					
o Theoretical (98%) . w/o Additional Evaporative Control	1.3(197)	1.9	1,360	2.2(14 or 24)	-
. w/Additional Evaporative Control	2.5(374)[b]	1.9	720	2.5(18 or 31)	-
o In-use (92%) . w/o Additional Evaporative Control	1.2(183)	1.9	1,460	1.8(11 or 20)	4.9/0.1
. w/Additional Evaporative Control	2.3(346)[b]	1.9	770	2.1(15 or 27)	4.9/0.1

[a]GV = gasoline vapors (rat data only), two numbers given represent estimates using maximum likelihood estimate unit risk factor and plausible upper limit unit risk factor, respectively.

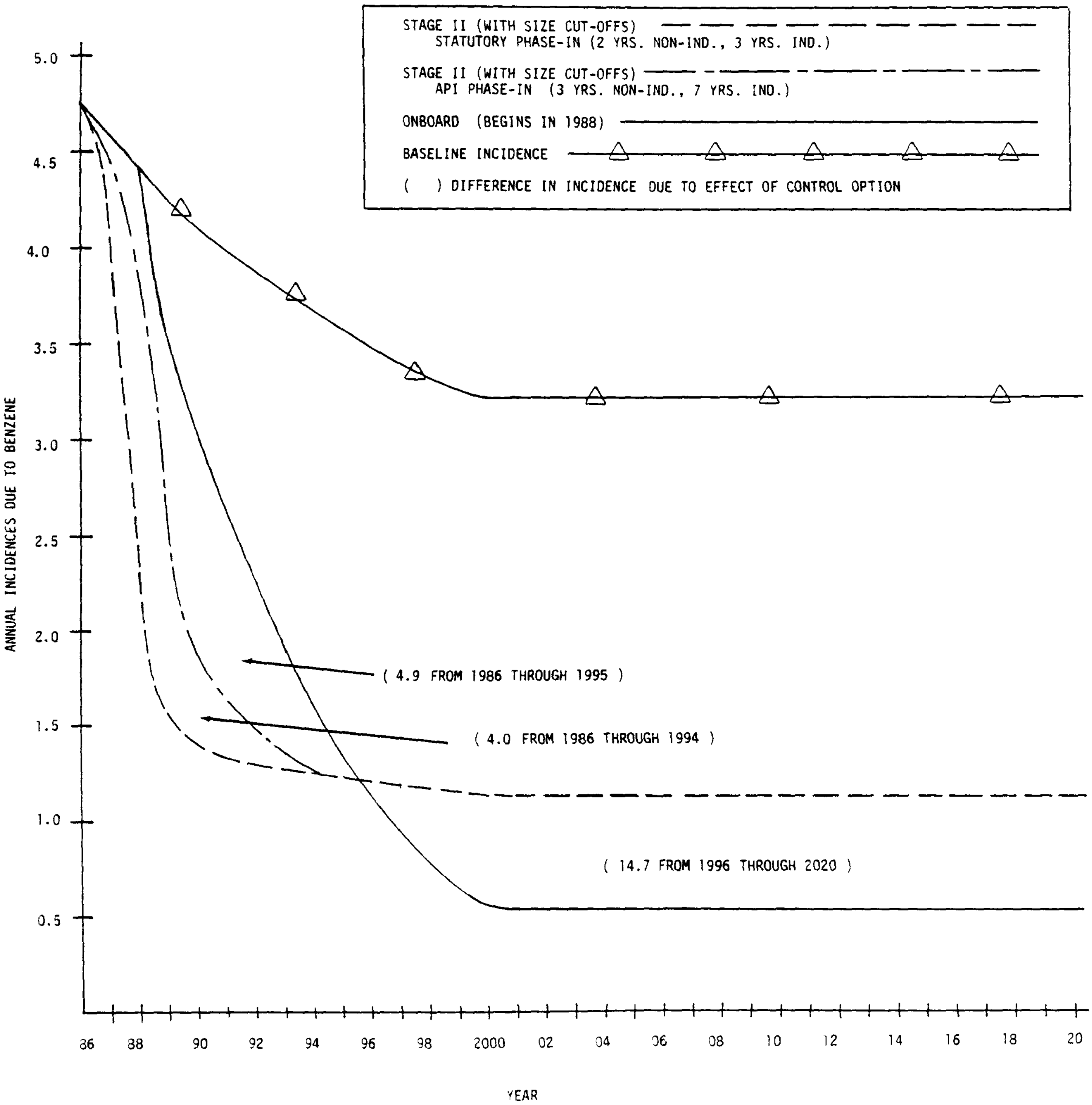
[b]Based on preliminary data.

[c]Program efficiency reduces to 56 percent when the rate of noncompliance (20 percent) is considered. Actual average control efficiency of installed recovery systems is estimated at 70 percent.

them would cause only a slight increase in cost effectiveness. The in-use efficiency of onboard controls is expected to be about 92 percent (based on current levels of tampering to use leaded gasoline, disregarding the phase-out of leaded gasoline). The enforcement costs for onboard are lower than Stage II (average annual cost of $0.1 million) since they are for the incremental cost above the current certification and in-use testing program, and the incremental costs of inspecting onboard rather than evaporative control systems on selected vehicles at the assembly line.

Figure 1-2 graphically depicts annual incidences due to benzene with either Stage II or onboard regulatory strategies and with no additional controls (baseline). Estimated incidence with Stage II is shown both for the assumed statutory phase-in requirements and for an alternative phase-in schedule suggested by the American Petroleum Institute (API). The assumed statutory phase-in requirements used in this analysis are installation within 2 years for non-independents under a NESHAP (Section 112) and 3 years for independents assuming Section 325 of the Clean Air Act applies to CTG's and Section 112 standards. The API phase-in schedule assumes 3 years for nonindependents and 7 years for independents. Installation of Stage II controls was assumed to begin in 1987 for both the statutory and API phase-in scenarios. Onboard controls were assumed to be installed on new vehicles beginning with the 1988 model year. Therefore, all of the strategies shown begin at baseline levels of about 4.8 incidences expected from 1986 benzene emissions from the entire gasoline marketing system. The baseline (no further controls) levels of annual incidence also decrease with time in proportion to the projected decrease in gasoline consumption. The Stage II strategies reduce incidence more rapidly than the onboard strategy. The numbers in parentheses on the graph indicate the differences in cumulative incidence before or after 1995 when the onboard strategy is projected to reduce incidence to below the level reached by the Stage II strategies. Thus, although Stage II can achieve incidence reduction sooner than onboard, by 2020 the cumulative incidence reduction with onboard controls has surpassed the cumulative reduction with Stage II controls, since the steady-state levels of annual benzene incidence are about 1.2 for Stage II versus 0.5 for onboard.

Figure 1-2. Effect of Onboard and Stage II Controls on Benzene Incidence (Based on Theoretical Efficiencies)



The control costs associated with each of the regulatory strategies are assumed in this study to be passed on by producers to consumers of gasoline and vehicles in the form of higher prices. The magnitude of these price increases for components of nationwide regulatory strategies with size cutoffs are presented in Table 1-9. Most show gasoline price increases of less than half a cent per gallon of gasoline. Price increases for benzene reduction strategies range from 1.5 to nearly 5 cents per gallon. These are average figures; in practice they would vary both with location and over time.

Consumer resistance to these price increases can reduce the sale of vehicles and gasoline. Estimates of the reductions in the rate of consumption are displayed in percentage terms in Table 1-9. The estimated reduction in gasoline consumption ranges from 38 million gallons a year for Stage I to 128 million gallons a year for a combination of Stage I, Stage II, and onboard controls, and to over 1,200 million gallons a year for the most costly benzene reduction option. For regulations involving onboard controls, annual LDV and LDT rate of sales are estimated to decline by 17.7 and 5.3 thousand vehicles, respectively.

Other economic impacts of the regulatory strategies were also examined. These included an analysis of the sensitivity of cost calculations to underlying assumptions and consideration of distributional impacts of the regulatory strategies by firm size. Results are summarized in Table 1-10.

1.3.3 Cost Per Incidence Reduction

An analysis was performed to determine the residual costs expended per cancer incidence avoided for selected nationwide and nonattainment area regulatory strategies. The residual costs were determined by obtaining the annualized costs of the controls associated with the regulatory strategy and subtracting a range of assumed benefit values per megagram of VOC emissions reduced. The assumed VOC benefits are those in addition to cancer prevention, such as reduction in non-cancer health effects and agricultural damage due to ozone. The residual cost per incidence was then calculated by dividing residual costs by the appropriate amount of cancer incidences avoided.

TABLE 1-9. ECONOMIC IMPACT OF REGULATORY STRATEGIES BASED ON THEORETICAL EFFICIENCIES[a]

Regulatory Strategies (With Size Cutoffs)	Average Unit Cost Increase: Gasoline cents/liter (cents/gallon)	Light Motor Vehicles $/vehicle LDV	LDT[c]	Average National Reduction in Consumption/Production[b] (Percent): Gasoline[d] (Percent)	(10^6 Gal.)	Light Motor Vehicles LDV (%)	LDV (10^3)	LDT (%)	LDT (10^3)
Stage I	0.034 (0.129)			0.055	37.7				
Stage II	0.065 (0.246)			0.104	71.5				
Stage I and Stage II	0.099 (0.375)			0.158	109.2				
Onboard controls		13	22			0.16	17.7	0.18	5.3
Stage I and Onboard	0.034[e] (0.129)[c]	13	22	0.055	37.7	0.16	17.7	0.18	5.3
Stage II and Onboard	0.082[e] (0.311)[e]	13	22	0.131[e]	90.5	0.16	17.7	0.18	5.3
Stage I, Stage II and Onboard	0.116[e] (0.440)[c]	13	22	0.186[e]	128.2	0.16	17.7	0.18	5.3
Benzene reduction in reformate gasoline	0.40 - 0.43 (1.51 - 1.64)			0.64-0.76	439-473				
Benzene reduction in reformate and FCC gasoline	1.01 - 1.17 (3.81 - 4.44)			1.61-1.86	1110-1280				

[a] Based on the declining recovery credit assumption with constant number of facilities.

[b] Reductions attributable to the imposition of new regulations.

[c] Weighted average costs of trucks with single (80 percent) and dual tanks (20 percent) at $18.19/tank.

[d] Percents based on average annual gasoline consumption over the projection period (69×10^9 gallons/year; 261.5×10^9 liters/year).

TABLE 1-10
ECONOMIC CONSIDERATIONS

- The costs of nationwide strategies without facility exemptions are 80 to 100 percent higher than for the comparable strategies with exemptions. For strategies covering only nonattainment areas, costs without facility exemptions are 15 to 35 percent higher than for comparable strategies with exemptions.

- Stage I and Stage II controls will cost 1/2 to 2 1/2 cents more per gallon of throughouput at small gasoline marketing facilities than at large ones. Facility exemptions reduce this cost differential, but do not eliminate it.

- Facility exemptions improve the competitive position of the smallest facilities, but small facilities tend to be less efficient than large facilities.

- This analysis assumes the per vehicle cost for onboard controls is $13 per tank. If, however, the cost really is $25, the net present value of nationwide onboard control costs would increase by more than 50 percent, and would then exceed those of nationwide Stage I and Stage II controls.

- This analysis assumes gasoline consumption will decline in the years ahead. If, however, consumption holds at current levels, then costs for Stage I and Stage II controls would be less because there would be more recovery credits.

- This analysis assumes the number of gasoline marketing facilities remains constant in the years ahead. If, however, the number declines, then costs for Stage I and Stage II controls would be less because there would be less control equipment needed.

In Table 1-11, several of the regulatory strategies are presented with their corresponding emission reductions. The emission reductions are presented as the net present value of all the annual emission reductions over the study period and as an annualized value representing equal emission reductions for each year of the study period. The residual costs were determined assuming several different dollar values for the benefit of reducing each megagram of VOC emissions. For example, in Table 1-11 the annualized emission reduction associated with Stage I is 0.218 million Mg. Multiplying this emission reduction by each of the assumed VOC benefit values yields the annualized VOC benefit in dollars.

Table 1-12 presents annualized cost (control equipment and enforcement costs) and annualized incidence reduction due to benzene exposure associated with several of the regulatory strategies. The cost per cancer incidence avoided, assuming no additional benefits, is calculated by dividing the annualized costs by the annualized incidence reduction. Table 1-13 takes this one step further by incorporating the annualized VOC benefits into the analysis. The values presented represent the residual cost, assuming varying benefits for reducing VOC emissions, of reducing cancer incidences due to benzene exposure.

Table 1-14 contains a similar analysis to that used in Table 1-13, except that Table 1-14 was developed using the sum of the incidences due to benzene and gasoline vapors. It is assumed that the incidences due to benzene exposure and the incidences due to gasoline vapor exposure are additive since the respective exposure results in different types of cancer incidences (leukemia in the case of benzene exposure and liver or kidney tumors in the case of gasoline vapor exposure). Net costs per annual incidence avoided are given using both plausible upper limit and maximum likelihood estimate risk factors for gasoline vapors.

TABLE 1-11. ESTIMATED REGULATORY COSTS AND VOC BENEFITS

Regulatory Strategy (In-use efficiency) (with size cutoffs)	Net Present Value of Emissions (Million Mg)	Annualized Emission Reduction (Million Mg per year)	Annualized VOC Benefits ($Millions) Assuming VOC Benefit Value of:				
			$250/Mg	$500/Mg	$1,000/Mg	$1,500/Mg	$2,000/Mg
Stage I	2.1	0.22	54	109	218	327	436
Stage II-NA(87%)	0.6	0.06	15	30	59	89	118
Stage II-NA(56%)	0.4	0.04	9	19	37	56	75
Stage II-Nation(86%)	1.4	0.15	37	74	147	221	295
Stage II-Nation(56%)	0.9	0.10	24	48	95	143	191
Onboard (92%)							
w/o evaporative	1.3	0.14	34	68	137	205	274
w/ evaporative	2.5	0.26	65	130	259	389	519

TABLE 1-12. BENZENE REGULATORY COSTS AND INCIDENCE REDUCED

Regulatory Strategy (with size cutoffs) (In-use efficiency)	Annualized Costs ($ Millions)[a]	Annualized Benzene Incidence Reduction[b]	Costs ($ Millions per Benzene Cancer Incidence Avoided)
Stage I	91	0.06	1,564
Stage II-NA (87%)	62	0.8	75
Stage II-NA (56%)	52	0.4	126
Stage II-Nation (86%)	183	1.9	95
Stage II-Nation (56%)	146	1.1	128
Onboard (92%):			
w/o evaporative	199	1.4	138
w/ evaporative	199	1.7	120

[a]Includes control equipment and annual enforcement costs.

[b]Incidence reduction after controls. Before-control annualized incidence: Stage I = 0.18, Vehicle Refueling = 4.09.

TABLE 1-13. BENZENE REGULATORY COSTS PER CANCER INCIDENCE AVOIDED (ASSUMING VOC BENEFITS)[a]

Regulatory Strategy (In-use efficiency)	Annualized Incidence Reduction (Benzene)	Costs ($ Millions per Bz Cancer Incidence Avoided)[b] Assuming VOC Benefit Value of:				
		$250/Mg	$500/Mg	$1000/Mg	$1500/Mg	$2000/Mg
Stage I	0.06	629	0[b]	0	0	0
Stage II-NA (87%)	0.8	57	39	4	0	0
Stage II-NA (56%)	0.4	104	81	35	0	0
Stage II-Nation (86%)	1.9	76	57	19	0	0
Stage II-Nation (56%)	1.1	107	86	44	2	0
Onboard (92%):						
w/o evaporative	1.4	120	93	45	0	0
w/ evaporative	1.7	83	43	0	0	0

[a]Cost per cancer incidence avoided =

$$\frac{\text{Annualized Costs (from Table 1-12) - Annualized VOC Benefits (from Table 1-11)}}{\text{Annualized Incidence Reduced}}$$

[b]Zeros indicate that the VOC benefits outweigh the costs.

Table 1-14. BENZENE AND GASOLINE VAPORS COST PER CANCER INCIDENCE AVOIDED[a] (USING RAT DATA UNIT RISK FACTOR FOR GAS VAPORS)

Regulatory Strategy (In-use efficiency)	Annualized Incidence Reduction (Bz+GV)[b] Maximum Likelihood[c] Estimate (M.L.E.)	Annualized Incidence Reduction (Bz+GV)[b] Plausible Upper Limit[c] (P.U.L.)	Costs ($ Million Per Bz + GV[b] Cancer Case Avoided) Assuming VOC Benefit Value of: $250/Mg M.L.E.	$250/Mg P.U.L.	$500/Mg M.L.E.	$500/Mg P.U.L.	1,000/Mg M.L.E.	1,000/Mg P.U.L.	$1,500/Mg M.L.E.	$1,500/Mg P.U.L.	$2,000/Mg M.L.E.	$2,000/Mg P.U.L.
Stage I	1.1	1.9	33	19	0[d]	0	0	0	0	0	0	0
Stage II-NA (87%)	6.1	10	8	5	5	3	1	0	0	0	0	0
Stage II-NA (56%)	3.1	5.1	14	8	11	6	5	3	0	0	0	0
Stage II-Nation (86%)	13	22	11	7	8	5	3	2	0	0	0	0
Stage II-Nation (56%)	7.8	13	16	9	13	8	6	4	0	0	0	0
Onboard (92%)												
w/o evaporative	10	17	16	10	13	8	6	4	0	0	0	0
w/ evaporative	14	23	10	6	5	3	0	0	0	0	0	0

[a] Cost per cancer incidence avoided =

$$\frac{\text{Annualized Costs (from Table 1-12) - Annualized VOC Benefits (from Table 1-11)}}{\text{Annualized Incidence Reduced}}$$

[b] Bz + GV = Benzene plus gas vapors.

[c] Calculated using the maximum likelihood estimate unit risk factor and plausible upper limit unit risk factor

[d] Zeros indicate that the VOC benefits outweigh the costs.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

The gasoline marketing industry (bulk terminals, bulk plants, service station storage tanks, and service station vehicle refueling operations) emit to the atmosphere several organic compounds of concern. These include: volatile organic compounds (VOC), which contribute to ozone formation; benzene, which has been listed as a hazardous air pollutant based on human evidence of carcinogencity; and ethylene dichloride (EDC), ehtylene dibromide (EDB), and gasoline vapors, for which there is animal evidence of carcinogencity. This report contains a summary of the analysis conducted concerning the health, emission, cost, and economic impacts of several regulatory strategies for addressing organic compound emissions from gasoline marketing sources. (The full report is contained in EPA Document EPA-450/3-84-12a.) The regulatory strategies evaluated are: (1) service station controls (Stage II) for vehicle refueling emissions only in areas requiring additional VOC control to attain the national ozone ambient standard; (2) service station controls (Stage II) for vehicle refuleing emissions on a nationwide basis; (3) Onboard vehicle controls for vehicle refuleing emissions on a nationwide basis; (4) bulk terminal, bulk plant, and service station storage tank controls on a nationwide basis; and (5) various combinations of these alternatives.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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